Inflation and Macroeconomic Effects of Inflation Targeting in Asia: Time-Series and Cross-Country Analysis

A thesis

submitted in fulfilment

of the requirements for the degree

of

Doctor of Philosophy in Economics

at

The University of Waikato

by

HAROLD GLENN A. VALERA

THE UNIVERSITY OF
WAIKATO
Te Whare Wānanga o Waikato

2017

Abstract

Controlling inflation is important. The 2008-2009 global financial crisis created new concerns about the macroeconomic effects of inflation targeting. A key issue for many central banks in recent years has been that inflation is uncomfortably too low rather than too high. This thesis examines the impact of inflation targeting on the behaviour of inflation, output growth and real exchange rates for eight Asian countries using time-series and panel data from 1987 to 2013. The econometric methodologies employed include panel GARCH, quantile unit root and Markov regime-switching testing. Panel GARCH results indicate that inflation targeting is more credible in lowering the inflation level rather than its volatility. The quantile unit root testing results indicate that the credibility of inflation targeting and alternative monetary policy frameworks in Asia are imperfect, except for Malaysia and South Korea. Results also suggest that targeting countries have been building up their monetary policy credibility more than non-targeting countries, based on a faster rate of decline in inflation rate changes. Results generally indicate the presence of mean-reversion at the lower quantiles only. Where stationarity is present, results indicate varied speed of adjustment process across quantiles. The regime-switching results indicate that inflation and output growth are generally characterized by partial stationarity, while there is mostly varied stationarity in real exchange rates. Results also indicate that inflation targeting significantly affects the inferred probabilities of remaining in the stationary regime, mainly for output growth and real exchange rates and for inflation in some cases. Results further indicate that the variance of inflation and output growth is lower during the inflation targeting period. Furthermore, results indicate that there is a significant difference between targeting and non-targeting countries in terms of the speed of adjustment

of macroeconomic variables towards the equilibrium level and the behaviour of inferred probabilities of remaining in the stationary regime.

Note on Publications

The following papers from this thesis have been submitted for publication and presented at conferences.

Paper Published from the Thesis

Valera, H. G., Holmes, M. J., & Hassan, G. M. (2017). Is inflation targeting credible in Asia? A panel GARCH approach. *Empirical Economics*, 1-24.

Valera, H. G., Holmes, M. J., & Hassan, G.M. (2017). How credible is inflation targeting in Asia? A quantile unit root perspective. *Economic Modelling, 60*, 194-210.

Papers Submitted to Journals

Valera, H.G.A., Holmes, M.J. & Hassan, G.M. Macroeconomics effects of inflation targeting in Asia: A Regime-switching approach. *Journal of Economic Studies. (Under Review).*

Conferences

Valera, H.G.A., Holmes, M.J. & Hassan, G.M. (2016). Macroeconomics effects of inflation targeting in Asia: A Regime-switching approach. 19th Waikato Management School Student Research Conference, University of Waikato, Hamilton, New Zealand.

Valera, H.G.A., Holmes, M.J. & Hassan, G.M. (2016). How credible is inflation targeting in Asia? A quantile unit root perspective. 57th Annual Conference of the New Zealand Association of Economist 2016 (p. 42). Auckland University of Technology, Auckland, New Zealand.

Valera, H.G.A., Holmes, M.J. & Hassan, G.M. (2015). Is inflation targeting credible in Asia? A panel GARCH approach. Singapore Economic Review Conference 2016 (p. 187). Singapore.

Valera, H.G.A., Holmes, M.J. & Hassan, G.M. (2015). Is inflation targeting credible in Asia? A panel GARCH approach. 18th Waikato Management School Student Research Conference, University of Waikato, Hamilton, New Zealand.

Acknowledgements

First of all, my greatest gratitude to the Lord, without whom I am nothing. I am grateful for all His provision of wisdom and understanding to overcome the challenges encountered during my long, demanding, but very productive and pleasant PhD journey.

I would like to express my deep gratitude to my chief supervisor, Professor Mark J. Holmes, who guided my thinking during confusing moments, patiently read my numerous drafts and helped me improve my writing skills. I am grateful for his excellent direction, valuable comments, encouragement, help in sending out papers for publication and for introducing me to panel GARCH modelling. This in turn led to my greater appreciation of time-series econometrics and applied macroeconomics. Special thank goes to my second supervisor, Dr Gazi M. Hassan, who not only provided helpful comments but whose motivation helped me greatly in this research. I also want to thank Professor Jim Lee of Texas A&M University-Corpus Christi, who provided computational assistance in using the panel GARCH model in RATS and for guiding me in journal article publication. I appreciate the support provided by Dr. Dan Marsh and Professor Anna Strutt during my PhD years in the Department of Economics. I am also grateful to Maria Fitzgerald for providing valuable assistance during the time I have been in the department.

I am thankful to the Ministry of Foreign Affairs and Trade (MFAT) of New Zealand, which granted me the financial means to complete my PhD research. I thank Reina Pelayo, Natalie Christine Jorge, Joseph Imperial and Estrellita Aritao for bringing me to New Zealand and providing assistance with my scholarship. My sincerest thanks to the International Student Office of the University of Waikato, especially Deonne Taylor, Thomas McDonald and Caitriona Gyde who provided invaluable assistance with living and studying in Hamilton. Thanks to Helen Lynch, Clive Wilkinson and Jessica Howie for their excellent guidance in the layout and formatting of my PhD thesis. I am very grateful to Alexandra Benham, Professor Lee Benham and Professor David Bloom for their helpful comments and valuable suggestions concerning my preparations for the Thesis in Three Minutes 2015.

I also wish to convey my utmost thanks to Luisa and Elina Aina, my beloved wife and daughter, who endured this long process with me, always offering unconditional love, prayers and support. To my dear parents, sisters and brothers, thank you for always being there for me. To Tatay, Nanay and Rose, thank you for staying with and taking care of my wife and daughter.

I am also thankful to Professor Gilbert Nartea for his support and to his family – Jema, Abby and Gabi – who have all been very warm and welcoming in their wonderful home. To my friends, Kuya Oscar, Ate Max, Richard, Ate Mayumi, Me-Anne, Edo, Janet, Lakshan, Nisansala, Farnaz, Steve, Nicoloi, Zadok, Ale, Wenefe, Yimei, Yang, Tom and any others whom I have failed to mention, thanks for making Hamilton a wonderful second home. To Father Andrew Paris, thank you for providing spiritual guidance and interesting conversations about economics. To my choir group at St. Matthews Church, thank you for the opportunity to join and enjoy great voices and music talents.

Finally, thanks to my group of friends in Orchard Park, known as the "Food Family," who supported me along the way; most especially Sakiko, Hong, Helena, Banchakarn, Shazre, Summer, Michita, Dianellie-Pearl and Cedar. I also want to thank Dr. Brett McEwan, Thelma and Debbie for their wonderful support during my stay at Orchard Park.

Table of Contents

List of Figures

List of Tables

Abbreviations

ADF: Augmented Dickey Fuller

AIC: Akaike Information Criteria

ARCH: Autoregressive Conditional Heteroscedasticity

BEKK: Baba, Engle, Kraft and Kroner

DF-GLS: Dickey Fuller Generalized Least Squares

DID: Difference-in-Difference

GARCH: Generalized Autoregressive Conditionally Heteroscedasticity

IPS: Im-Pesaran-Chin

IT: Inflation Targeting

KPSS: Kwiatkowski-Phillips-Schmidt- Shin

LB: Ljung-Box

LR: Likelihood Ratio

ML: Maximum Likelihood

MGARCH: Multivariate Generalized Autoregressive Conditionally Heteroscedasticity

MS-ADF: Markov-Switching Augmented Dickey Fuller

NP: Ng and Perron

PP: Phillips Perron

QADF: Quantile Augmented Dickey Fuller

QKS: Quantile Kolmogorov-Smirnov

Q-STARCH: Quadratic Structural ARCH

SIC: Schwarz Information Criterion

SWARCH: Markov-Switching Autoregressive Conditional Heteroscedasticity

VECM: Vector Error Correction Model

Chapter 1: Introduction

1.1 Overview

Controlling inflation is important. Inflation – the overall increase in prices – can expropriate a person's pension, wealth and ability to buy. A quarter of a century has elapsed since New Zealand was the first country to introduce inflation targeting (IT) in 1990 to achieve a low and stable rate of inflation. Now 26 countries engage in IT. In today's global economy, a key issue for many IT central banks has been that inflation is uncomfortably too low rather than too high. Indeed, economies around the world have become more wary of deflation and many central banks hit the zero lower bound after the 2008-2009 global financial crisis.

The depths of the recent crisis have triggered a new debate: do central banks have the credibility needed to perform the standard IT regime? In essence the debate is a revival of the long-standing disputes about the probable effects of IT. Under this approach, a central bank officially announces an inflation target level or target range and adjusts its short-run interest rate instrument to keep inflation on track (Gregoriou & Kontonikas, 2009). As stated by Lee (2010a), IT proponents claim that an explicit target for inflation enhances the credibility, accountability and transparency of a central bank, and that it helps resolve the time inconsistency problem in the conduct of monetary policy. IT in this view is regarded as an effective strategy for reducing the level and variability of inflation.

However, the idea that IT might produce a better performance in terms of macroeconomic fundamentals remains contentious both in theory and practice. At least since Bernanke and Woodford (2005) and Mishkin (2004), strong concerns have been raised about the lack of institutional maturity and consistency of key macroeconomic indicators that could weaken credibility and produce worse results for developing countries (Brito & Bystedt, 2010). In addition, Cordero (2008) explains that IT has negative output effects. In contrast, those in a second group, among them Bernanke et al. (1999), Mishkin (1999) and Svensson (1997), claim that IT leads to a more credible monetary policy and hence better macroeconomic outcomes because the initial credibility of central banks in emerging countries is low. On the neutral side of this debate, there is the so-called conservative window-dressing view expressed by Anna Schwartz (Romer, 2006, p. 532) that pinpoints IT as having contributed very little towards lowering the inflation level and variability because non-IT countries have a similar performance to IT countries in controlling inflation (Capistrán & Ramos-Francia, 2009; McDermott & MacMenamin, 2008).

Motivated by the aforementioned theoretical viewpoints, several studies have focused on examining the performance of IT regimes with respect to key macroeconomic variables such as inflation, output and exchange rate. However, empirical studies do not reach a consensus as to whether IT has caused significant improvement in the behaviour of these macroeconomic variables. A group of studies including those of Batini and Laxton (2007), De Mendonça and De Guimarães e Souza (2012) Gonçalves and Salles (2008), International Monetary Fund (IMF, 2006), Lin and Ye (2009), and Samarina et al. (2014) show empirical evidence that IT lowers the inflation level and volatility for a large sample of developing and emerging countries. In contrast, evidence of a weak decline and/or no impact of IT on inflation level and volatility is reported by Angeriz and Arestis (2006), Ball and Sheridan (2005), Brito and Bystedt (2010), and Gonçalves and Carvalho (2009). In terms of positive impact of IT on output performance, a partial listing of studies includes Amira et al. (2013), Ayres et al. (2014), Mollick et al.

(2011), and Neumann and von Hagen (2002). Other researchers such as Ball and Sheridan (2005), Brito and Bystedt (2010), and Mishkin and Schmidt-Hebbel (2007) report opposite findings. The effects of IT on exchange rates are also controversial. For example, some researchers such as Ouyang and Rajan (2016), Poon and Lee, (2013), and Prasertnukul et al. (2010) find that IT lowers exchange rate volatility, while Edwards (2006), and Berganza and Broto (2012) find conflicting evidence.

To some extent, these contrasting conclusions emanate from differences in methodologies, assumptions and sample of countries. However, nearly all studies share one important premise; that a credible IT regime keeps the absolute difference between actual inflation and its target value to a minimum and that the effect is beneficial to macroeconomic performance as supported by a significant body of empirical literature. This indicates the necessity of undertaking more country-specific and cross-country empirical studies with refined concepts and advanced methodologies to clearly understand the benefits of IT for enhancing macroeconomic performance. In looking broadly at the context of an IT regime, a general question emerges: *Is IT credible for stabilizing inflation? If so, how? Does IT matter for improvement in macroeconomic performance?*

This thesis aims to answer those questions with new insights from Asian IT and non-IT countries, using time-series and panel data analyses. This attempt at such an assessment is highly relevant and timely in light of the renewed attention to the difficulty facing IT central banks in maintaining credibility when they are regularly missing their inflation targets in the relevant horizons. It is also an issue of paramount importance because of the ongoing debate around zero lower bounds on nominal interest rates and the emergence of the so-called negative rate club involving many central banks that aim to address deflation and the risks of slow economic growth. Moreover, there is an ongoing interest in how the attitude of the central banks towards IT might be different now. Specifically, the idea of price level targeting and nominal income targeting as alternatives to IT has been revisited in academic and policy circles alike. For instance, Khan (2009) finds that price level target results in greater near-term volatility of inflation and output, while Du Plessis and Rietveld (2014) conclude that there is a weak case for nominal income targeting as compared with the conduct of IT internationally.

The rest of this chapter is organized as follows. Section 1.2 presents the background and research questions. A brief description of the data and research methods is provided in Section 1.3, followed by a discussion of the significance and contributions of the study in Section 1.4. The specific objectives of the study are outlined in Section 1.5, while the thesis outline is presented in Section 1.6.

1.2 Background and Research Questions

Inspired by the success of New Zealand in stabilizing inflation in the 1990s, IT was formally adopted in South Korea after the Asian financial crisis of 1997-1998, followed respectively by Thailand, the Philippines and Indonesia. Asian IT countries did not primarily emerge from a high inflation background but rather from instability in their previous monetary aggregates targeting regimes, and market pressures to switch from a pegged to a flexible exchange rate regime (Ito, 2010). The IT regime was also fashioned around the pursuit of an alternative nominal anchor for monetary policy following their exit from fixed exchange rate regimes. In the end, Asian IT countries have used the inflation target as a new nominal anchor for monetary policy that can be tied to price levels in the long run and rely on IT policy as a way of achieving and/or maintaining a lower rate of inflation (Freedman

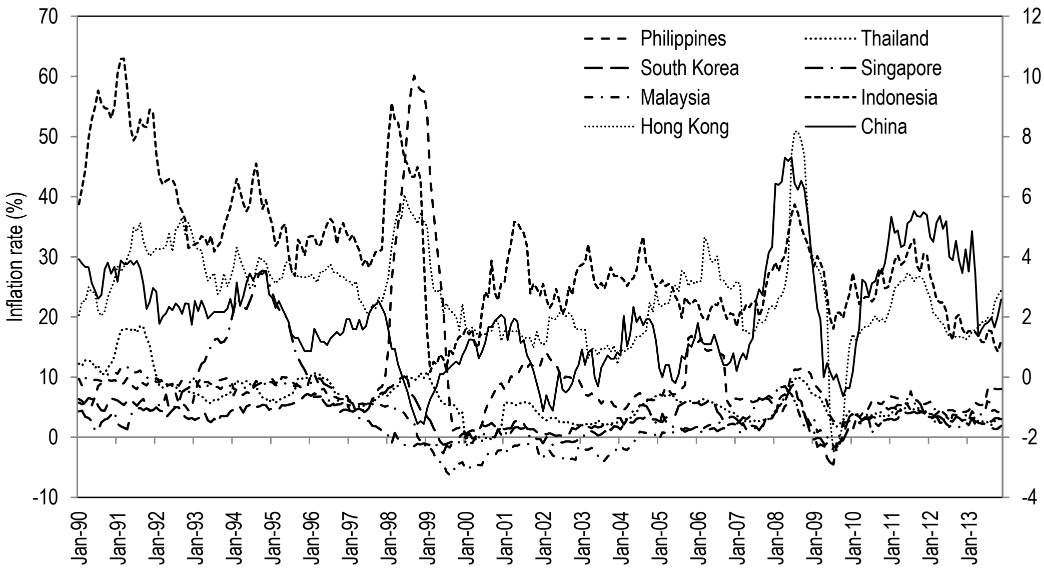
& Laxton, 2009). In other words, the popularity of IT in many countries, including those in Asia, can be explained into two main arguments as stated by Lucotte (2012). Firstly, IT is widely considered as a practical monetary strategy to resolve central banks' difficulties in conducting their monetary policies by means of exchange rate pegs or monetary aggregates as intermediate targets. Secondly, the decision to adopt IT as a monetary policy framework was driven by the observed improvement in the macroeconomic performance of IT industrialized and emerging economies, where a large body of empirical literature has provided evidence of lower levels and variability of inflation.

The introduction of an IT framework in Asian countries helped contribute to the goal of achieving low inflation rates. Figure 1.1 displays the inflationary experience in Asian IT and non-IT countries in recent decades and shows a basic story for IT countries: a drop in inflation after IT adoption and fluctuations in the series over the course of the regime. The fluctuating nature of inflation is unique neither to IT nor non-IT countries like Singapore and Malaysia where, as in the four IT economies, there was an almost continuous drop in inflation during the second half of 2009 and a series of inflation increases during the early part of 2010. Large inflation declines or increases such as those experienced in those two years have direct implications on achieving the target, which varies across Asian IT countries. For example, Inoue et al. (2012) reported that Thailand achieved its inflation target in more than 90% of the total quarters between April 2000 and July 2011, while Indonesia reached its inflation target only twice between 2005 and 2011.

Obviously, there is a problem in terms of credibility when central banks regularly miss their inflation targets. Perrier and Amano (2000) explained that the issue of credibility can arise first when inflation has exceeded a certain target and the central banks decide to reduce it. In this case, the central banks have lost their credibility as they have been unable to prevent the situation from deteriorating. The question of credibility can also arise when inflation has been brought under control and the central banks seek to keep it within the target range. In this case the central bank has already proven its ability to reduce inflation, and the question of credibility relates essentially to whether it can maintain inflation within the target. Many studies have investigated inflation performance as a major criterion for judging the credibility of IT. According to Faust and Henderson (2004), "best-practice monetary policy can be summarized in terms of two goals: first, get mean inflation right; second, get the variance of inflation right" (Tas, 2012). However, there is still no consensus about whether or not IT lowers the level and conditional variance of inflation (that element of inflation volatility that is unexpected). This motivates us to ask the first research question:

Research Question 1: *Is IT credible for lowering the level and volatility of inflation in Asia?*

Figure 1.1: Inflation Rates in Asian Countries, 1990-2013



Source: IMF International Financial Statistics database

The answer to this question is the subject of Chapter 4 of this thesis, where the level and volatility of inflation are investigated using a panel GARCH model that captures interdependence and heterogeneity across countries. The issue of international inflation volatility transfer is tackled first by studying a series of bivariate multivariate generalized autoregressive conditional heteroscedasticity (MGARCH) model for each Asian country with respect to the U.S. or Japan in each case. Inflation spillover could be relatively limited under flexible exchange rates for Asian IT countries. However, the increasing degree of global goods market integration could facilitate foreign inflation volatility transfer, as Asian countries have removed many barriers to world trade. Volatility transfers and co-movements in inflation across countries can also be amplified when central banks respond similarly to common shocks, or even when a macroeconomic shock of domestic country origin is transmitted to foreign countries' inflation through international trade in goods and services and assets (Neely & Rapach, 2011).

Irrespective of the nature of the shocks that influence the transmission of inflation levels and volatility between countries, understanding the speed and pattern of inflation adjustment in response to these shocks has important policy implications. For instance, Tsong and Lee (2011) find that inflation rates among a sample of OECD countries are mean-reverting and display asymmetries in their dynamic adjustments, implying that authorities would need to intervene through monetary policies to keep inflation under control. For Asian targeting countries that are committed to achieve the inflation target, IT adoption may influence asymmetric inflation adjustments to negative (positive) shocks that might come from tightened (loosened) monetary policy or economic recession (boom).

Like many other IT countries, inflation deviations from the target and remedial actions by central banks to contain the gap have characterized the Asian IT regime. For example, the Bank of Korea and the Bank of Indonesia respectively loosened and tightened monetary policy in 2001 to address inflation target misses. Understanding the pattern of inflation misalignments and monetary policy actions over time is important because IT central banks have greater focus on inflation stabilization, so that the announcement of inflation target leads to less persistent and less variable inflation. Moreover, the stationary process of inflation becomes an important consideration in the assessment of successful IT regimes (Çiçek & Akar, 2013; Gerlach & Tillman, 2010). Although the persistence of inflation is a central concern of macroeconomics, there is no consensus regarding whether or not inflation is stationary or has a unit root (Murray et al., 2008). In looking more closely at the relationship between IT credibility and the dynamic behaviour of inflation, this thesis is motivated by asking the question:

Research Question 2: *How credible is IT in terms of stabilizing inflation given different signs and sizes of inflation shocks?*

This thesis addresses this question in Chapter 5 by studying the mean- and trend-reversion of inflation rates in the tails of the distributions using quantile unit root testing. In contrast to least squares estimates, this method allows us to capture not only the average shocks on inflation, but also to distinguish between inflation realizations that are high or low relative to inflation realizations in previous months. In particular, deflation may be viewed in the quantile unit root context as data realizations in the lower conditional quantiles.

It is widely regarded that the primary objective of macroeconomic policies is to achieve high and sustainable output growth combined with low and stable inflation (Omay & Öznur Kan, 2010). Therefore, policymakers find it crucial to examine the dynamic behaviour of output and inflation. However, some scholars question the capacity of IT to stabilize output and inflation simultaneously and to achieve high economic growth. In particular, Brito and Bystedt (2010) show that there is less negative and less significant impacts of IT on the level and volatility of inflation, and output growth volatility in a large sample of developing countries. Some scholars also argue that there is no significant difference in output performance between IT and non-IT countries. For example, De Carvalho Filho (2009) finds that although advanced IT countries had higher GDP growth than non-IT economies, they find no such difference for a sample of emerging countries.

Just as output does not disappear in macroeconomic policy debate under an IT regime, neither does the exchange rate. Policy discussions on exchange rates and IT continue to emerge, largely because of the association of price fluctuations with exchange rate pass-through or volatility (Prasertnukul et al., 2010). For Asian open economies that have adopted IT, there is a strong concern about the difficulty of monetary authorities in controlling inflation and carrying out IT due to the likely impacts of exchange rate pass-through and volatility (Taguchi & Kato, 2011). Another important issue for policymakers is the difficulty of ensuring that the exchange rate remains subordinate to inflation objectives and that dampening exchange rate movement does not undermine the credibility of IT. Given this background and the mixed evidence about the impact of IT on macroeconomic performance, this thesis poses the third research question:

Research Question 3: *Does IT help Asian countries to achieve a significant improvement in macroeconomic performance as measured by the behaviour of inflation, output growth and real exchange rate?*

The final core research in Chapter 6 of this thesis provides an answer to this question by studying the stationarity of the three macroeconomic variables in consideration using a Markov-switching model. Unlike the conventional unit root testing, this method allows modelling the behaviour of macroeconomic series as regime-dependent where periods of stationarity or non-stationarity can be determined and investigated. Specifically, this thesis addresses the above research question by investigating the possibility that the behaviour of macroeconomic variables is influenced by two stationary regimes, or two non-stationary regimes, or one stationary and one non-stationary regime. In addition, the third research question above is addressed by studying the role of IT in influencing the time-varying transition probabilities of switching between two regimes.

1.3 Significance and Contributions of the Study

For monetary authorities to achieve a sustainable environment for price stability and economic growth as well as to enhance credibility, it is important to examine the dynamic behaviour of macroeconomic fundamentals. By providing a better characterization of the inflation, output growth and exchange rate in this thesis, monetary policymakers can be guided in making decisions about what adjustments in interest rate instrument are suitable for achieving a certain inflation target in order to improve macroeconomic performance.

To achieve the first and second goals of 'best-practice monetary policy', the results of this thesis will provide useful insights to monetary authorities in terms of increasing and/or maintaining their credibility by determining whether or not IT is significant in lowering the mean and conditional variance of inflation. At the same time, it will enable policymakers to tackle high inflation uncertainty. As stated by

Kontonikas (2004), higher inflation uncertainty implies more frequent negotiations of nominal contracts, undermines the task of economic agents to distinguish between nominal and relative price changes and may adversely affect real activity. Also, high inflation uncertainty may cause a devaluation of the currency as the cost of exports will increase and thereby raise relative wage costs and decrease price competiveness between countries (Tas & Ertugrul, 2013). Thus, the results of this thesis will enable monetary authorities of implicit targeting countries to consider the extra benefits associated with formal inflation targets (Kontonikas, 2004).

According to Gerlach and Tillmann (2012), the need to adopt IT may not be recognised by countries with a low and stable inflation rate. Considering that the degree of persistence in the inflation process is a key indicator of the changes in monetary policy (Wolters & Tillmann, 2015), the results of this thesis will provide vital information to central banks by uncovering the differences in persistence in more detail. For instance, it will allow policymakers to quantify the tendency to mean-reversion or stationarity based on the size of the shock hitting inflation and in so doing account for possible asymmetric dynamics in a series (Tsong & Lee, 2011). This will then allow central banks to evaluate the extent of IT credibility, determine how to improve their inflation policy approach, and make a comparison with alternative monetary policy strategies in terms of the degree of persistence and stationarity of inflation rather than its level and volatility.

It is well known that all IT central banks “not only aim at stabilizing inflation around the target but also put some weight on stabilizing the real economy” (Svensson, 2007, p. 1). Moreover, some Asian central banks continue to attach great weight to the exchange rate in the formulation of monetary policy despite the adoption of IT (Gerlach & Tillmann, 2012). While various inflation outcomes are being used as major indicators of IT credibility, being able to assess output and exchange rate stability is also critical to understanding the effects of IT in this light. Consequently, central banks can judge the effectiveness of IT based not only in terms of the capacity of IT to stabilize a low inflation rate but also on its capacity to stabilize output and exchange rate.

Aside from the above significance to monetary authorities, the valuable contributions of this thesis to the body of knowledge in the field of IT are:

- The empirical evaluation of IT credibility based on lower inflation levels and volatility poses a major methodological challenge. Most previous studies have used GARCH-type regression on a single country basis and thus neglected possible cross-sectional dependence. If foreign inflation shocks are linked to domestic inflation, then ignoring international volatility transfer could mask the effectiveness of IT. This thesis uses a panel GARCH model developed by Cermeño and Grier (2006) to characterize cross-sectional dependence and heterogeneity across countries. Inflation rates between countries are potentially interrelated and hence it is crucial to account for cross-sectional dependence in panel data. Regional and macroeconomic linkages such as common global and regional financial shocks (the 1997-1998 Asian crisis and the 2008-2009 global financial crisis), trade and economic cooperation (ASEAN and ASEAN+3), and similarities in monetary reaction functions potentially generate common fluctuations in inflation rates. Panel GARCH is also a convenient framework for offering a collective conclusion about the likely impact of IT on the conditional volatility of inflation without the need to estimate pairs of countries separately as in the case of the bivariate MGARCH model.

- A series of bivariate BEKK-MGARCH models for each country is estimated to examine the channel of volatility transmission. Empirical evidence on this issue is scarce, especially from the perspective of Asian IT regimes. However, such issues are vital for assessing the degree of interdependence and the significance of the international economic and financial integration among countries. This allows researchers to view inflation volatility in an open economy context and thus sheds light on the potential spillover effects of monetary policies on other countries and the gains from international policy coordination.
- The evolution of the conditional correlation between the respective inflation volatilities over time is also examined within the MGARCH framework. Previous studies of inflation volatilities have concentrated on using a univariate GARCH model and therefore the time variation in the co-movement between domestic and foreign inflation rates is left unexplored. Indeed, it is also important to pinpoint precisely the timing or the nature of possible changes in the dynamic conditional correlation between unanticipated fluctuations in inflation rates which may depend on the state of the economy.
- The level and volatility of inflation are key indicators of IT credibility and so is inflation persistence. A key missing element, however, is whether inflation is guided by an inertia that follows a deterministic trend process. Unlike past studies that focus on the mean-reversion of inflation rates (Tsong & Lee, 2011; Wolters & Tillmann, 2015), this thesis uses a quantile unit root testing proposed by Koenker and Xiao (2004) to examine trend-reversion as another indicator of IT credibility. If inflation is trend stationary then a credible IT country might be characterized by a faster rate of decline in inflation rate not just at the conditional mean changes but rather over the entire inflation process.

- The potential asymmetric speed of adjustment of inflation towards to its long-run level in terms of negative and positive inflation shocks is also studied using quantile unit root testing. Understanding asymmetric responses can provide valuable insights into theoretical views of IT credibility. A deeper knowledge of asymmetric responses can also be valuable for policy analysis if the inflation dynamics behave differently with smaller or larges changes in inflation.
- In addition to the analysis of local persistence of inflation, this thesis employs the Quantile Kolomogorov-Smirnov (QKS) test to offer a general perspective on the behaviour of inflation rates. That is, the persistence or stationarity of inflation is viewed in a global way. Only a few studies have embarked on such an analysis and all of them have focused on developed countries.
- Drawing insight into inflation stationarity based on quantile unit root testing, this thesis attempts to determine inflation threshold levels by using a method for separating periods of stationary series from non-stationary observations as proposed by Lee et al. (2013). This method represents a significant methodological departure from the few previous studies on developed countries, which relied on threshold unit root testing (Henry & Shields, 2004).
- Most existing empirical studies focus on the level and volatility of inflation, output growth and exchange rate to examine the effects of IT (see Brito & Bystedt, 2010; Gonçalves & Salles, 2008; Lin & Ye, 2009; Prasertnukul et al., 2010). However, studies that consider stationarity of the series as a gauge of IT credibility are quite scarce. Additionally, the limited number of existing studies of stationarity of macroeconomic variables have not substantially explored the effects of IT and have concentrated on developed economies. However, it is also worth studying the stationary properties of macroeconomic variables, which are

crucial to understanding the effects of shocks depending on the initial regime of the variable, and whether or not the shock causes a transition across regimes. This research employs a Markov-switching model to examine the stationary properties of macroeconomic variables, while allowing the series to switch between stationary and non-stationary regimes or between stationary regimes of differing degrees of persistence.

- This thesis also focuses on time-varying transition probabilities rather than the conventional Markov-switching model approach that relies on fixed transition probabilities of switching between regimes. In this case, the probability of switching from one regime to the other can depend on the behaviour of underlying economic fundamentals. In other words, time-varying transition probabilities do not restrict the transition probabilities to being constant over time. Furthermore, this thesis considers the effect of IT on the transition probability. This is an important research direction because no existing studies have addressed this in the literature. The effect of IT on the transition probability is examined as additional measure of IT credibility with respect to the behaviour of inflation, output growth and real exchange rate.
- Aside from important methodological contributions, new insights into the economic interpretation of IT credibility, the dataset and sample of Asian countries analysed in this thesis also contribute in several ways:
  - First, a number of papers have studied IT performance based on credibility index (De Mendonça & Guimarães e Souza, 2012; Kupfer, 2015; Lanzafame & Noguiera, 2011). However, this credibility index is highly reliant on the expected inflation rate, which is not directly observable. Therefore, this research advances the IT credibility literature based on panel

GARCH and MGARCH estimates of inflation level and volatility. That is, this thesis offers an alternative interpretation of IT credibility as a function of low inflation level and volatility around its target.

- Second, this thesis advocates a three-way definition of IT based on *perfect credibility*, *imperfect* or *weak credibility* and *zero credibility*. These concepts are defined with respect to the mean, trend and global stationarity of inflation using quantile unit root testing. Advocating these concepts is important to understand the extent of IT credibility in comparison with alternative monetary policy frameworks.
- Third, this thesis incorporates a fully-fledged adoption date of IT to account for possible structural breaks in investigating inflation stationarity at different quantiles. Hence, this thesis avoids spuriously high estimates of the degree of persistence and therefore provides a more robust interpretation of credibility that fulfills the key preconditions for IT.
- Fourth, the macroeconomic stabilization hypothesis under an IT regime is explored again in this thesis by defining the concepts of *partial* stationarity and *varied* stationarity in inflation, output growth and real exchange rate using the Markov-switching regression model. This allows us to better characterize macroeconomic behaviour by capturing two stationary regimes (*varied* stationarity), or one stationary and one non-stationary regime (*partial* stationarity). To the best of our knowledge, this may be the first time in the academic literature that such an approach has been applied to those variables to examine monetary policy credibility, and to verify the extent to which IT and non-IT central banks are achieving their mandate of macroeconomic stabilization.

- Fifth, previous analysis of inflation dynamics has paid little attention to Asian IT and non-IT samples. Analysing this sample is a major contribution of this thesis because of the complex dynamics of such countries' macroeconomic performance. Indeed, those two groups of countries have marked differences in monetary policy and macroeconomic conditions, while many of them have also experienced periods of pronounced turbulence due to financial crisis and political and economic reform. In other words, this constitutes an interesting scenario for comparison, particularly in light of the no significant difference debate between those two groups of countries in terms of macroeconomic performance.
- Finally, this thesis uses inflation data at monthly frequencies from 1987-2013, which is a relatively long sample period, to allow for a better characterization of the inflation dynamics. Specifically, the span of the dataset covers major economic events such as the shift to a flexible exchange rate regime in most IT countries after the Asian financial crisis, the 2007-2008 food price crisis, and the 2008-2009 global financial crisis.

1.4 Objectives of the Study

In view of the research questions formulated above, the general objective of this thesis is to evaluate IT policy for enhancing macroeconomic performance as measured through inflation, output growth and real exchange rate in order to benefit society. More specifically, this thesis has the following objectives:

1. To assess the credibility of IT in lowering inflation level and volatility;

2. To evaluate the nature of IT credibility in terms of whether or not there is mean- and trend-reversion in inflation rate, and search for time-varying threshold levels for inflation;
3. To assess the effects of IT on macroeconomic performance based on the stationary properties of inflation, output growth and real exchange rate; and
4. To determine whether or not IT makes a significant difference in inflation and macroeconomic performance between Asian IT and non-IT countries.

1.5 Thesis Outline

This section discusses the overall outline of this thesis, which comprises seven chapters. The remaining chapters of this thesis are introduced as follows.

Chapter 2 presents the theoretical framework and existing studies of IT effects on inflation, output growth and real exchange rate. This chapter begins with a definition and description of the characteristics of IT and then discusses different views on the probable effects of IT on macroeconomic performance. The chapter then goes on to describe relevant empirical findings for Asia and other countries based on time-series and panel data studies. This chapter highlights in particular the existing evidence for IT effects on the level and volatility of inflation.

Chapter 3 discusses the data and methodologies used in this thesis. The methodology section outlines the time-series and panel data econometric approaches. The data section describes the sample countries, data frequency, sample period and sources of datasets. The core research discussions are grouped into three topics: IT credibility in Asia (Chapter 4), the nature of IT credibility (Chapter 5), and macroeconomic effects of IT (Chapter 6).

Specifically, Chapter 4 sheds new light on IT credibility hypotheses in terms of lower levels and volatility of inflation. This chapter argues that a single-country GARCH model of inflation could undermine the credibility of an IT regime because of interdependencies between domestic and foreign inflation rates. The bivariate MGARCH is employed first to facilitate the analysis of international volatility transmission. Aside from addressing the issue of country pairing using bivariate MGARCH model, a novel panel GARCH approach is used in this chapter to account for interdependence and heterogeneity across countries.

In a bivariate MGARCH setting, the results indicate that inflation and volatility transmission exist in each of the bivariate pairings of Asian sample countries with the U.S. or Japan. The results also show that IT lowers the inflation in Thailand and the conditional variance in all Asian IT countries. The results using panel GARCH model indicate that IT significantly lowers the level of inflation in the Philippines, South Korea and Thailand. Furthermore, this chapter finds that the adoption of IT helped lower inflation volatility in the Philippines and South Korea. The overall results suggest that Asian IT regime is more credible in terms of reducing the level of inflation. Moreover, the results indicate that the covariance of inflation shocks among IT and non-IT countries tend to increase.

In contrast to the first core research, Chapter 5 examines the dynamic behaviour of inflation using quantile unit root testing. The results show that the credibility of IT and alternative monetary policy frameworks in Asia is *imperfect*, except for Malaysia and South Korea. The results also suggest that Asian IT countries have been building up their monetary policy credibility more than the non-IT countries in terms of a faster rate of decline in inflation rate changes. The results also generally indicate the presence of mean reversion at the lower quantiles only. Chapter 5 also finds that Asian inflation rates generally display stationary behaviour during periods of inflation declining or slowing down.

Chapter 6 examines the macroeconomic effects of IT. In contrast to existing studies, Chapter 6 deals with the extent to which IT influences the stationarity properties of inflation, output growth and real exchange rates, using the Markov-switching model. The results indicate that each country is characterized by at least one stationary regime. There is also evidence that IT in Thailand plays an important role in inflation stationarity, while IT matters for South Korean inflation in terms of reducing the probability of staying in a non-stationary regime. The results also indicate that IT significantly influences the probability of being in a stationary regime for real output in all IT countries, while it reduces the probability of remaining in the non-stationary regime for real exchange rates in most IT countries.

Finally, Chapter 7 provides the summary, implications, and limitations of the thesis. This chapter synthesises the overall findings of the effects of IT on inflation and other macroeconomic variables to consolidate the answers to the research questions and objectives. The implications for researchers and policymakers are discussed, along with the caveats of the study. This thesis concludes by suggesting several avenues for future research.

Chapter 2: Literature Review

2.1 Theoretical Framework

Mishkin (2007) emphasizes that an essential element of a successful monetary policy is the use of nominal anchors or restrictions on the value of domestic money, which help peg inflation expectations and therefore contribute to price stability (Maertens Odria et al., 2012). Another reason for using nominal anchors is that these allow monetary authorities to determine a unique price level, which is a necessary condition for price stability. Prior to IT regimes, central banks used monetary targets as nominal anchors to control inflation. However, many countries eventually shifted to an IT regime because of unsatisfactory performance under the previous regimes, particularly in terms of instability in the demand for money (Gregoriou & Kontonikas, 2009; Sevensson, 1997).

Ever since both industrialized and developing countries have announced a quantitative inflation target as an alternative nominal anchor to tie down price levels in the long run, the practice of IT has proved durable. Samarina and Sturm (2014) explain that the high durability of IT is reflected in the fact that no country thus far has been forced to abandon this regime, possibly due to its endogeneity. They point out that endogeneity of IT can be thought of as having an internal cause of origin, meaning its continuation is internally affected by the institutions and economic conditions that are formed under IT. Furthermore, Lucotte (2012) lists two main reasons for the high popularity of IT in emerging economies. First, the decision to adopt IT is considered as a practical response to central banks' difficulties in the implementation of their monetary policies using exchange rate pegs or monetary aggregates as intermediate targets. Second, the choice of IT is driven by the relative improvement in economic performance after the adoption of IT in industrialized and emerging economies as corroborated by previous studies (see, for example, Lin & Ye, 2009; De Mendonça & De Guimarães e Souza, 2012).

According to Ftiti and Hichri (2014), a relatively precise definition of IT based on Bernanke et al. (1999) is: "IT is a framework for monetary policy characterized by the public announcement of official quantitative targets (or target ranges) for the inflation rate over one or more time horizons, and by explicit acknowledgement that low, stable inflation is monetary policy's primary long-run goal". The central bank under an IT regime explicitly sets the inflation target by controlling the policy rate to close the difference between the announced target and the actual inflation. If inflation deviates above (or below) the target, the central bank will raise (or lower) interest rates to slow down (or boost) the economy and bring inflation back down (or up).

However, authors like Bernanke and Mishkin (1997) highlight some controversies about the precise meaning of IT. They argue that IT is better characterized by a policy framework with some flexibility in policy actions rather than a policy rule, which leads to different ways of practicing IT policy (Dueker & Fisher, 1996; Lee, 1999). In fact, countries that are not classified as targeting countries, such as Germany, Singapore and the U.S., have had inflation-focused monetary policies but they have not made any explicit acknowledgement of them (Ftiti & Hichri, 2014; Gerlach & Tillmann, 2012).

Ayres et al. (2014) highlight the following five main elements of an IT regime as advocated by Mishkin (2004, 2008): (1) public announcement of a medium-term inflation target; (2) institutional commitment to price stability as the primary goal of monetary policy to which other goals are subordinate; (3) an information-inclusive strategy in which many variables are used in the decision to set policy instruments; (4) increased transparency of monetary policy through communication with the public and the markets about the plans, objectives, and decisions of monetary authorities; and (5) increased accountability of the central bank for achieving its inflation objectives.

Bernanke et al. (1999) explain that IT provides a framework of constrained discretion where the official target imposes the constraint, and the discretion is the scope for monetary authorities to address short-term shocks to output or financial stability (Lucotte, 2012). According to Bernanke and Mishkin (1997), an IT framework should also be viewed as combination between a rules scheme and discretionality. Under this scheme of restricted discretionality, the central bank can react to external or internal transitory shocks to stabilize other variables, although the main objective is medium-term price stability (Maertens Odria et al., 2012).

In view of the above considerations, Lucotte (2012) highlights some preconditions that countries should theoretically satisfy before adopting IT. These include an independent, transparent and accountable central bank with a clear price stability mandate; a sound fiscal policy; a well-developed financial market; a flexible exchange rate regime; relatively low inflation rates; and well-developed statistical and econometric models to understand monetary policy transmission mechanisms and to forecast inflation. However, Lucotte (2012) explains that non-fulfilment of those preconditions does not impair the adoption and success of IT policy as shown in the experience of emerging countries. Lucotte (2012) also stresses the fact that practicing IT is a gradual process with economic and institutional reforms before and after its official adoption.

In terms of advantages of IT over alternative nominal anchors, Mishkin (2007) argues that IT allows central banks to counter adverse domestic shocks as compared to monetary or fixed exchange rate targeting regimes. In addition, the effectiveness of IT does not rely on the stability of money velocity and is more easily understood by the general public as compared to monetary targeting. Finally, the announcement of numerical targets under a credible central bank enhances price stability by fixing inflationary expectations to the target. However, Ayres et al. (2014) outline some disadvantages of IT. These include decreased central bank discretion that can result in output growth decline; too much discretion that leads to the inability to influence inflation expectations; higher exchange rate volatility as IT ignores exchange rate levels; and the inability of IT to be successful in countries that do not meet strict preconditions.

2.1.1 Probable Effects of IT

Brito and Bystedt (2010) summarize the conflicting views about the probable effects of IT based on lack of institutional maturity, enhanced credibility, and conservative window-dressing views. In particular, Bernanke and Woodford (2005), and Mishkin (2004) emphasize that the lack of institutional maturity and consistency of key macroeconomic indicators could weaken credibility and give worse results for developing IT countries. Brito and Bystedt (2010) mention five major institutional weaknesses common to emerging countries, as listed by Calvo and Mishkin (2003): (1) weak fiscal institutions; (2) weak financial institutions, including government prudential regulation and supervision; (3) low credibility of monetary institutions; (4) currency substitution and liability dollarization; and (5) vulnerability to sudden stoppages of capital inflows.

In contrast, the enhanced credibility view of IT advocated by Bernanke et al. (1999) and Mishkin (1999) and Svensson (1997) argue that IT leads to a more credible monetary policy and thus better macroeconomic performance since the initial credibility of central banks in emerging countries is low. According to Gonçalves and Salles (2008), some of the alleged gains are lower and less variable inflation and interest rates, more stable growth and an enhanced ability to respond to shocks without losing credibility. Furthermore, Lin and Ye (2007) explain that IT features an explicit target for inflation and greater emphasis on the transparency, credibility, and accountability of the central banks in conducting monetary policies as compared to monetary or exchange rate targeting regimes. Lin and Ye (2007) also point out that the main argument in favour of IT is that an official announcement of an inflation target makes the policy of a central bank more credible. These authors emphasize that IT proponents claim that this monetary policy helps to alleviate the dynamic inconsistency problem, and therefore should result in lower inflation expectations and inflation variability.

Finally, the neutral approach to IT argues that IT is merely a conservative window-dressing view, as expressed by Anna Schwartz (Romer, 2006, p. 532). As noted by Lee (2010a), proponents of this view argue that IT has served as little more than window dressing because many non-IT countries have performed as well as IT countries in controlling inflation. Lin and Ye (2007) note that proponents of this view argue that IT per se contributes very little, if anything, to the lower inflation and inflation variability, and point to evidence that non-targeting countries have also experienced lower inflation and inflation variability since the mid-1980s.

2.1.2 Credibility and Inflation Targeting

This subsection formally defines credibility and discusses its implications for an IT framework. A simple illustrative model is also presented to explain the basic ideas and key theoretical relationships between credibility and inflation rate.

2.1.2.1 Definition of Credibility

Bordo and Siklos (2015) define credibility in broad terms as a commitment to follow well-articulated and transparent rules and policy goals. Likewise, Perrier and Amano (2000) define credibility as the degree of confidence that the public has in the determination and ability of the central bank to meet its announced objectives. According to Lanzafame and Nogueira (2011), the goal of IT is to anchor inflation expectations and boost the credibility of monetary policy. They emphasise that providing an anchor to inflation expectations under an IT regime can help lower the persistence of inflationary shocks and improve the short-run trade-off between inflation and output.

Using a forward-looking Phillips curve, Walsh (2009) argues that anchoring the public's belief about future inflation under IT could improve the short-run trade-off between inflation and output gap volatility. He explains that a larger decline in the output gap is necessary to limit the rise in actual inflation if a positive shock causes the public to conduct incorrect upward adjustments of their estimates of the central bank's target. Inflation expectations will be stabilized further, which should reduce inflation volatility and improve the short-run trade-off between inflation and real activity. This would then lower the volatility of both inflation and output. In line with a simple augmented Phillips curve, Gonçalves and Salles (2008) argue that explicit (firing the central banker) or implicit (damaging personal reputation) costs for missing the target under a credible IT make disinflation less costly and the corresponding mean output losses will thus be smaller.

Vega and Winkelried (2005) offer another definition of credibility, namely the central bank's ability to anchor medium- to long-run expectations and the goal of avoiding expectation traps that may lead to persistently high or low inflation. They argue that under a flexible IT regime, shocks that cause inflation deviations from the target should result in a return to the long-run equilibrium level without causing harm to real activity. That is, the speed of adjustment depends on the degree of flexibility. When the adjustment is very fast, it implies a strict IT whereby the central bank needs to bolster credibility as undue real volatility might emerge due to the fast adjustment. When the adjustment is slow, a more flexible IT is in place, whereby either credibility is strong enough that the central bank can gain some benefits from flexibility or the nominal anchor is lost and inflation expectations fall.

In the credibility definition proposed by Perrier and Amano (2000), the authors explain two distinct situations in which questions of credibility can arise. First, credibility concerns occur when inflation has deviated above a certain target and the central banks decide to reduce it. There is credibility loss in this case because the central banks have missed their target. It is then the task of the central banks to prove that they have both the commitment and ability to control inflation back to the announced target. The second case arises when inflation has been brought under control and the central banks seek to keep it within the target band. A central bank in this case has established its ability to reduce inflation. Here the issue of credibility depends essentially on the central bank's ability to maintain inflation within the announced target range.

Perrier and Amano (2000) also explain the implications of low and high credibility. For example, if credibility is low and if the public expects the central bank to give up before it has attained its goal, price and salary trends will adjust only gradually to the slowdown in aggregate demand caused by the disinflation process. In contrast, a high degree of credibility will speed up the transition to the inflation target, since economic agents will attach greater weight to this rate in wage and price setting. In addition, a high credibility will also keep inflation close to the target when unforeseen events disrupt the behaviour of prices. As a result, credibility will help to anchor inflation expectations to the target. In this case, inflation expectations will not respond strongly to price fluctuations if the public knows that the central bank will do its best to bring inflation back to target.

Grimes and Motu Economic and Public Policy Research (2014), who present a time inconsistency model, also tackle the implications of credibility under IT. In this model, they assume that government has preferences over both real GDP and inflation and agents are forward-looking. They show that if government has perfect credibility, it could set inflation to zero, in which case inflation expectations would be zero and unemployment would equal the natural rate. They added that if the government chooses not to renege, and so sets inflation at zero, while agents continue to believe that government will (optimally) renege, then inflation expectations and the unemployment rate will both be positive, and the government is left with the highest cost outcome of all the alternatives. The high cost of setting inflation at zero when government has the chance to renege but chooses not to, makes it non-credible for governments to stick to a non-inflationary policy.

2.1.2.2 An Interpretive Model of Credibility

This thesis follows the model of Neuenkirch and Tillmann (2014) to interpret central bank credibility. This model incorporates the mechanism for expectation formation to the New Keynesian Phillips curve (NKPC) and the IS curve as follows:

$$\pi_t = \pi^* + \beta E_t(\pi_{t+1} - \pi^*) + \kappa y_t + \varepsilon_t \qquad \beta > 0 \text{ and } \kappa > 0 \qquad (2.1)$$

$$y_t = E_t y_{t+1} - \frac{1}{\sigma}(i_t - E_t \pi_{t+1} - r) \qquad (2.2)$$

where π_t is the inflation rate, π^* is the inflation target, y_t is the output gap, i_t is the short-term nominal interest rate set by the central bank, and r is the natural rate of interest. In addition, E_t is the expectations operator, β is the discount factor, κ is the degree of nominal rigidities, σ is the inverse of the elasticity of intertemporal substitution and ε_t is an i.i.d. supply shock.

The assessment of the degree of a central bank's commitment to a constant inflation target π^* is done by minimizing a quadratic loss function $\mathcal{L}_t$ in terms of the squared fluctuations of inflation and output gap of the form:

$$\mathcal{L}_t = (\pi_t - \pi^*)^2 + \delta y_t^2 \qquad \delta > 0 \qquad (2.3)$$

where δ is a parameter indicating the relative cost of inflation and the output. Neuenkirch and Tillmann (2014) assume that future inflation expectations are determined as a weighted average of the constant inflation target π^* and past inflation described as follows:

$$E_t \pi_{t+1} = \lambda_t \pi^* + (1 - \lambda_t)\tilde{\pi}_{t-1} \qquad (2.4)$$

where $\tilde{\pi}_{t-1}$ is the average of past inflation rates and λ_t is the relative weight attached to the inflation target and reflects the degree of central bank credibility. Under the standard case of rational expectations where $\lambda_t = 1$, the inflation expectation is equal to the inflation target. This means that the higher λ_t, the higher the credibility of the central bank. Considering the average of past inflation, Neuenkirch and Tillmann (2014) define the credibility of a central bank as:

$$\lambda_t = 1 - \alpha|\pi_{t-1} - \pi^*| \qquad \alpha \geq 0. \tag{2.5}$$

Combining Equations 2.4 and 2.5 yields the following function for the evolution of expected inflation:

$$E_t\pi_{t+1} = \pi^* + \alpha(\tilde{\pi}_{t-1} - \pi^*)|\tilde{\pi}_{t-1} - \pi^*| \tag{2.6}$$

where the term $(\tilde{\pi}_{t-1} - \pi^*)|\pi_{t-1} - \pi^*|$ represents the central bank's credibility loss. Neuenkirch and Tillmann (2014) point out that the expectations formation process in Equation 2.6 describes how past deviations from the inflation target affect the current level of credibility and expectations of future inflation.

Neuenkirch and Tillmann also explain two implications of inflation deviations based on the backward-looking Taylor rule augmented by credibility loss term. Firstly, in comparison to a situation where average past inflation meets the target, a central bank sets a higher interest rate if average past inflation is above target. In this case, the central bank attempts to re-establish credibility by actively controlling inflation in response to past inflation deviations. According to Neuenkirch and Tillmann (2014), a central bank's response to past inflation deviations increases non-linearly with the absolute size of the deviation. Secondly, the credibility loss term becomes more important in situations where the central bank puts a larger weight on output fluctuations relative to inflation stabilization. The implication here is that inflation expectations are higher for a positive deviation from target and the real interest rate falls, which is expansionary for output.

Bordo and Siklos (2016) provide another definition of credibility in terms of backward-looking measures as follows:

$$\begin{aligned} \text{CRED}_t^{'} &= (\pi_t - \pi_t^*), \text{if } \pi_t^* - 1 \leq \bar{\pi}_t \leq \pi_t^* + 1 \\ \text{CRED}_t^{'} &= (\pi_t - \pi_t^*)^2, \text{if } \pi_t^* - 1 > \bar{\pi}_t > \pi_t^* + 1 \end{aligned} \tag{2.7}$$

where π_t^* is the proxy for the time-varying inflation objective or target, and $\bar{\pi}_t$ is a moving average (2 to 5 years) of past inflation. According to Bordo and Siklos (2016), Equation 2.7 is a backward-looking credibility indicator in which expected inflation is extrapolated from past inflation performance. In other words, unlike a forward-looking measure of credibility, Bordo and Siklos (2016) used a smoothed inflation rates in terms of observed data rather than using 1-year-ahead inflation forecast. Equation 2.7 states that credibility is determined by how far inflation deviates from the medium-term inflation objective. This definition of credibility implies a greater penalty for missing the inflation target if a moving average of past inflation is outside the $\pm 1\%$ interval when actual inflation misses the target within the target band. In contrast, there is a smaller penalty when the difference between the inflation target and a moving average of past inflation allows small deviations from an IT to have an inconsequential impact on credibility (Bordo & Siklos, 2016). Note that Equation 2.7 also squares the deviations from an inflation target, which is consistent with credibility evolving possibly in a non-linear manner and from assuming a quadratic form for losses in central bank objective functions.

In sum, the simplified relationship between inflation deviations from the target and expectations in Equations 2.6 and 2.7 provides a basic idea for understanding central bank credibility in terms of anchoring future inflation expectations. IT proponents claim that a formal target of inflation raises credibility by anchoring inflation expectations, which should then lower inflation persistence and inflation uncertainty in the face of inflation shocks (Miles, 2008). Accordingly, when credibility concerns occur due to inflation deviation above a target value and the central bank decides to reduce it, the credibility of an IT regime can be assumed to be a function of low inflation and inflation volatility around its target value.

2.2 Empirical Studies of IT

Empirical investigations of the probable effects of IT emphasize whether the adoption of IT improves the performance of inflation and other major macroeconomic variables. The goal of these investigations is to determine whether IT lowers the level and volatility of inflation, as well as the volatility of output and exchange rate. These analyses also aim to explore whether output growth has increased in Asian countries after the adoption of IT.

The majority of the literature on the impact of IT on the performance of inflation and other macroeconomic variables has used panel data. This chapter discusses the relevant studies separately for each of the macroeconomic variables of interest. A separate review of the literature is undertaken in the core research chapters. The purpose is to better highlight the existing studies that focus on stationary properties of inflation, output growth and real exchange rate. More specifically, a separate literature review in the core chapters is important in order to tailor this to the subject or research question being addressed in each chapter. In this chapter, the focus is on discussing more general literature about the impact of IT on the level and volatility of macroeconomic variables.

2.2.1 Inflation Effects

Most of the existing literature on the impact of IT adoption on inflation performance has focused on the analysis of effects on the level and volatility of inflation. Table 2.1 summarizes the mixed evidence on the inflation effects of IT, mainly using a difference-in-difference (DID) approach with panel data. In particular, Abo-Zaid and Tuzemen (2012) used cross-country data for a sample of developed and developing countries over the period 1980-2007 and find that IT is associated with lower and more stable inflation. Likewise, Gonçalves and Salles (2008) find a strong decline in inflation based on a panel dataset of 36 developing countries from 1980 to 2005. In addition, Batini and Laxton (2007) employ a DID estimation and find that IT significantly lowers inflation with no adverse effects to output. Brito and Bystedt (2006) report a similar finding for Latin American countries using the same method. They show that the levels and volatility of inflation in Latin American countries declined after the adoption of IT. IMF (2006), using DID for 13 IT and 22 non-IT developing countries, finds that IT lowers annual inflation rate by 4.8% and inflation volatility by 3.6%.

The above findings are in line with Mishkin and Schmidt-Hebbel (2007) who provide evidence of lower inflation level using OLS and IV estimators for 21 IT countries and 13 non-IT countries, using quarterly data from 1989 to 2004. Moreover, Neumann and von Hagen (2002), using the double differences method and estimate Taylor rules and unrestricted VARs for 6 IT countries and 3 non-IT countries, find that IT lowers the level and volatility of inflation. Levin et al. (2004), employing a univariate autoregressive process for each inflation rate for a sample of 5 IT and 7 non-IT countries, find that IT lowers inflation persistence.

Table 2.1: Summary of Literature on Inflation Effects of IT

Author	Sample countries	Methodology	Sample period	Frequency	Inflation effects
Abo-Zaid and Tuzemen (2012)	23 IT, 27 non-IT	DID	1980-2007	Annual	Strong decrease
Angeriz and Arestis (2006)	10 IT	SURE	1980-2004	Quarterly	No effect
Ball and Sheridan (2005)	7 IT, 13 non-IT	DID	1960-2000	Quarterly	Small decrease
Batini and Laxton (2007)	21 IT, 10 non-IT	DID	1985-2004	Quarterly	Strong decrease
Brito and Bystedt (2006)	5 IT, 8 non-IT	DID	1994-2005	Quarterly	Strong decrease
Brito and Bystedt (2010)	13 IT, 33 non-IT	OLS, fixed effects	1980-2006	Annual	Weak decrease
De Mendonça and De Guimarães e Souza (2012)	180 countries, 23 IT	PSM	1990-2007	Annual	Strong decline
Gonçalves and Salles (2008)	13 IT, 23 non-IT	DID	1980-2005	Annual	Strong decrease
IFM (2006)	13 IT, 22 non-IT	DID		Annual	Strong decrease
Lin and Ye (2007)	22 countries, 7 IT	DID	1985-1999	Annual	No effect
Lin and Ye (2009)	52 countries, 13 IT	PSM	1985-2005	Annual	Strong decrease
Mishkin and Schmidt-Hebbel (2007)	13 non-IT, 21 IT	OLS, IV	1989-2004	Quarterly	Decrease
Levin et al. (2004)	5 IT, 7 non-IT	Impulse responses	1994-2003	Quarterly	Lowers inflation
Neumann and von Hagen (2002)	7 IT, 3 non-IT	VAR, impulse responses	1978-2001	Monthly, Quarterly	Decrease
Vega and Winkelried (2005)	23 IT, 86 non-IT	PSM		Annual	Strong decrease

Using the PSM technique to cross-country data for a treatment sample of 23 IT countries and a control group of 86 non-IT economies, Vega and Winkelried (2005) find that IT adoption lowers the mean inflation and volatility in both industrial and developing countries. Likewise, De Mendonça and De Guimarães e Souza (2012) employ the PSM method on a sample of 183 countries for the period 1990-2007. Splitting their sample into two sets of countries, they find that the adoption of IT lowers both the level and volatility of inflation in the case of developing countries but not in the case of advanced economies.

In contrast, several studies find no evidence of improvement in inflation performance after the adoption of IT. For example, Ball and Sheridan (2005) use the DID approach for a sample of 20 OECD developed economies from 1960 to 2000 and find that the reduction in average inflation and volatility in IT versus non-IT countries disappears after controlling for mean reversion. They argue that the bigger drop in inflation for those economies that moved to IT systems was because these same countries displayed higher initial inflation and there is a tendency for this variable to revert to its mean. A major criticism of their methodology is they did not control for endogeneity and self-selection bias.

Lin and Ye (2007) address the self-selection issue in IT by using the PSM method for 22 industrial countries from 1985 to 1999. They evaluate the treatment effect in 7 IT industrial countries and show that IT has no significant impacts on either the level or variability of inflation. A major drawback of their approach is that the cross-sectional data did not control for time trends and unobservable characteristics of countries. Brito and Bystedt (2010) resolve this problem by using the dynamic panel estimator, which controls for simultaneity and omitted variable biases. They examine the impact of IT on the level and volatility of inflation in 46 emerging countries from 1980 to 2006 and find no evidence that IT lowers the level and volatility of inflation. Furthermore, Angeriz and Arestis (2006) show that IT has no significant effect on the level of inflation for 10 IT countries using seemingly unrelated regression (SURE) over the period 1980-2004.

2.2.2 Output Growth Effects

Table 2.2 summarizes existing empirical studies of the growth effects of IT. In general, there is contrasting empirical evidence on whether or not IT improves output performance. For example, De Guimarães e Souza et al. (2016) employ a pulse dummy analysis to annual panel data for advanced and developing countries from 1990 to 2007. They find that there is a positive constant effect on output after the adoption of IT particularly for developing countries. Amira et al. (2013) also find that IT has a positive and significant effect on output growth, using the two-step system GMM panel estimator for 36 emerging economies. They also show no significant relationship between IT and output growth volatility, which they measured as the standard deviation of real GDP growth.

Ayres et al. (2014) employ OLS and fixed effects estimations to 17 IT and 34 non-IT countries from 1985 to 2010. They find that the impact of IT on real GDP is minimal overall, but there is a significant increase in real GDP among developing countries in certain regions only. Similarly, Abo-Zaid and Tuzemen (2012) use data for 50 developing and developed countries using the DID method from 1980 to 2007. They show that developing IT countries have higher and more stable GDP growth. They also find that there is high GDP growth and a more disciplined fiscal policy in developed IT countries.

Table 2.2: Summary of Literature on Output Growth Effects of IT

Author	Sample countries	Methodology	Sample period	Frequency	Output growth effects
Abo-Zaid and Tuzemen (2012)	23 IT, 27 non-IT	Diff-in-diff	1980-2007	Annual	Strong increase
Amira et al. (2013)	15 IT, 21 non-IT	OLS, fixed effects	1979-2009	Annual	Strong increase
Ayres et al. (2014)	17 IT, 34 non-IT	OLS, fixed effects	1985-2010	Quarterly	Weak increase overall Strong increase among developing countries
Ball and Sheridan (2005)	7 IT, 13 non-IT	Diff-in-diff	1960-2000	Quarterly	Weak increase
Brito and Bystedt (2006)	5 IT, 8 non-IT	Diff-in-diff	1994-2005	Quarterly	Strong decline in volatility
Brito and Bystedt (2010)	13 IT, 33 non-IT	OLS, fixed effects	1980-2006	3 year periods	Weak increase
Chu and Sek (2012)	11 IT	OLS, fixed effects	1980-2010	Annual	Strong increase
De Guimarães e Souza et al. (2016)	128 countries	Pulse dummy analysis	1970-2007	Annual	Strong increase
Mishkin and Schmidt-Hebbel (2007)	13 non-IT, 21 IT	OLS, IV	1989-2004	Quarterly	Strong decline in volatility
Mollick et al. (2011)	23 IT, 32 non-IT	OLS, Arellano and Bond	1986-2004	Annual	Strong increase

Mollick et al. (2011) examine the relationship between IT and real per capita income growth for 55 industrial and emerging economies. They extend the traditional neoclassical growth model to an output growth model that controls for IT and globalization factors such as trade and capital flows. Their overall findings indicate that the adoption of a fully-fledged IT results in higher output income per capita in their sample. In contrast, they also find that the estimated long-run output impact of IT in emerging markets is lower under the dynamic models as compared to the static models. They attributed this finding to the long lags until the full effects of greater credibility are felt in the real economy and the fact that emerging markets adopted the regime much later than industrial economies.

Furthermore, Brito and Bystedt (2006) apply the DID estimation to a sample of Latin American countries and find that IT reduce neither output growth nor output growth volatility. Likewise, Mishkin and Schmidt-Hebbel (2007) find that the reduction in output volatility is much larger for emerging economies after the adoption of IT because they faced smaller supply shocks and they improved their monetary policy efficiency. They also find that in contrast to emerging IT countries, industrial IT countries improved their macroeconomic performance only because they faced smaller supply shocks.

Considering some Asian countries in their sample, Chu and Sek (2012) find that IT positively and significantly affect output growth based on fixed effects panel data estimates from 1980 to 2010. While they find a positive impact of IT on output growth for the Philippines, South Korea and Thailand, it is only significant in the case of Thailand based on OLS estimates of monthly IPI growth rate. In addition, they show evidence of a significant impact of IT on output gap for three Asian targeting countries.

Empirical evidence of no significant relationship between IT and output growth volatility is found by Brito and Bystedt (2010) based on annual standard deviation and the coefficient of variation as the measure of volatility. After controlling for the dynamic panel bias problem and endogeneity of the IT regime, they show that the impact of IT on output volatility is small and its significance variable due to subtle changes in the instrument set, period of analysis, IT adoption date or non-IT control group. They also find robust evidence of lower output growth during IT adoption. Ball and Sheridan (2005) also find empirical evidence of a weak increase in output growth after the adoption of IT. However, unlike Brito and Bystedt (2010), the methodology employed by Ball and Sheridan (2005) fails to correct for endogeneity and self-selection bias but rather account for country-specific fixed and time effects.

The impact of IT on output has also been studied recently from other perspectives. For example, using a smooth time-varying parameter model and the PSM method, Huang et al. (2016) find evidence that the adoption of IT matters in regard to the extent of trade-off between unemployment and output; the so-called Okun's law. In addition, their full sample results indicate that IT leads to a more negative Okun's coefficient, suggesting that IT is associated with a higher unemployment rate for a given reduction of output. They point out that their findings suggest that IT affects not only macroeconomic variables per se but also the relationship between or among macroeconomic variables.

2.2.3 Exchange Rate Effects

A key concern regarding the relationship between IT and exchange rate is the role of the former in influencing the latter's volatility. Interest in this issue builds on the theoretical justification that a flexible nominal exchange rate constitutes a requirement for a well-functioning, fully-fledged IT regime (Mishkin & Savastano, 2001). Rocha and Curado (2011) and Berganza and Broto (2012) justifies this in accordance with the theory of "Holy Trinity Impossibility", in which, in the presence of free mobility of capital flows, the independence of the monetary policy required for an IT program cannot be fulfilled under fixed or pegged exchange rates through interventions in the foreign exchange markets. The main implication is that IT adoption is pre-conditioned by free floating exchange rate regimes (Rocha & Curado, 2011), which is hypothesized to add to the costs of IT in terms of higher exchange rate volatility in IT countries.

Sek (2009) argues that IT countries might experience higher exchange rate volatility due to two risks that can arise when policymakers intervene in the exchange rate movements. Mishkin (2004) identifies these as the risk of transforming the exchange rate into a nominal anchor that takes precedence over the inflation target and the risk that the impact of exchange rates on inflation and output can differ substantially depending on the nature of the shock that causes exchange rate movements. He argues that pursuing two nominal objectives could result in a situation where one objective will need to be given preference over the second objective. He further points out that the absence of clear guidance for resolving such conflict may make monetary policy less transparent and hinder the attainment of the inflation target. The corollary of this argument was provided by Maertens Odria et al. (2012) who claim that the decision to adopt IT implies a relative increase in the weight that is given to inflation in the policy rule, which leads to a relative decrease in the weight that is given to the other policy rule arguments. They hypothesized that if a monetary authority becomes less responsive to exchange rate variations and more responsive to inflation, then the variance of exchange rate and inflation are expected to rise and fall, respectively.

Table 2.3 presents a summary of existing studies on the effects of IT on exchange rate. Investigations in this area of research are usually based on exchange rate volatility and exchange rate pass-through into domestic inflation. The majority of empirical studies that have employed time-series and panel data for some or all Asian IT countries show that IT lowers exchange rate volatility and pass-through. In terms of exchange rate volatility, Prasertnukul et al. (2010) estimate a GARCH model for each of the four Asian IT countries from 1990 to 2007. They find that IT lowers the conditional exchange rate volatility under a floating exchange rate regime for IT countries. Likewise, Rocha and Curado (2011), who estimate a panel-exponential GARCH for 20 IT countries including South Korea, the Philippines and Thailand, find a reduction in the conditional volatility of real exchange rates for emerging countries. Aside from putting the GARCH model of conditional exchange rate volatility into a panel framework, they include the different exchange rate regimes (e.g., pegged, almost-fixed, free-floating and freely falling exchange regimes) as control variables in explaining volatility. This finding is in line with a study by Edwards (2006), who employs a GARCH model to monthly differences in the log of the nominal effective exchange rate from 1988 to 2005. He finds that the adoption of IT lowers exchange rate volatility for a sample of seven IT countries that include South Korea.

In addition, Rose (2007) investigates the exchange rate volatility for 45 IT and non-IT countries using OLS regressions. He finds that nominal and real exchange rate volatility are lower for IT countries than for non-IT countries. To address the self-selection problem of IT adoption, Lin (2010) employs the PSM

Table 2.3: Summary of Literature on Exchange Rate Effects of IT

Author	Sample countries	Methodology	Sample period	Frequency	Exchange rate effects
Aleem and Lahiani (2014)	6 IT	VARX	1990-2009	Monthly	IT lowers exchange rate pass-through.
Berganza and Broto (2012)	18 IT, 19 non-IT	Pooled OLS	1985-2010	Quarterly	IT increases exchange rate instability.
Catalán-Herrera (2016)	Guatemala	Two-stage IV, GARCH	2008-2012	Daily	Forex intervention lowers exchange rate return's volatility.
Du Plessis and Reid (2015)	11 IT	OLS	1990-2010	Quarterly	Higher IT regimes increase exchange rate volatility.
Edwards (2006)	7 IT	GARCH	1988-2005	Monthly	IT lowers exchange rate volatility.
Lin (2010)	22 industrial 52 developing	PSM	1985-2005	Annual	IT lowers exchange rate volatility.
Maertens Odria et al. (2012)	Peru	VSTAR	1994-2007	Monthly	IT lowers pass-through into import, producer, and consumer prices.
Ouyang and Rajan (2016)	34 developing	Random effect	2007-2012	Monthly	Lower real exchange rate volatility for IT and non-IT regimes.
Pontines (2013)	22 industrial 52 developing	Treatment effect	1990-2005	Annual	Lower exchange rate volatility for IT countries.
Poon and Lee (2014)	4 IT, 6 non-IT	GMM	1990-2010	Annual	Lower exchange rate volatility for IT countries.
Prasertnukul et al. (2010)	4 IT	SUR, GARCH	1990-2007	Monthly	IT lowers pass-through in South Korea and Thailand. IT lowers exchange rate volatility in all sample.
Rocha and Curado (2010)	20 IT	Panel E-GARCH	1971-2001	Monthly	IT lowers exchange rate volatility for emerging economies.
Rose (2007)	45 IT and non-IT	OLS	1990-2005	Monthly	Lower nominal and real exchange rate volatility for IT countries.
Sek et al. (2012)	6 IT	BEKK MGARCH	1960-2010	Monthly	IT increases exchange rate volatility.
Winkelried (2014)	Peru	VAR	1992-2011	Monthly	Strong decline in pass-through.

method. He finds evidence that IT lowers the nominal and real exchange rate volatility in developing countries. On the contrary, he finds that nominal and real exchange rate volatility are higher for developed IT countries.

Pontines (2013) also takes into account the self-selection issue, applying the PSM method to 22 industrial countries and 52 developing countries using annual data from 1990 to 2005. The author estimates a treatment effect regression that allows for the joint estimation of the probability of being an IT country and the IT effect on real and nominal exchange rate volatility. Using treatment group of 10 IT industrial countries and 13 IT developing countries, he finds that nominal and real exchange rate volatility are both lower in IT countries than non-IT countries. He also finds that IT developing countries have lower nominal and real exchange volatility compared with non-IT developing countries.

Most recently, Ouyang and Rajan (2016) use a random effect panel regression with time fixed effect and robust error correction model to investigate the effects of IT on real exchange rate volatility. Using panel datasets for 34 developing countries from 2007 to 2012, they find that real exchange rate volatility is lower in both IT and non- IT regimes. In contrast, Poon and Lee (2014) apply the dynamic GMM approach to ASEAN-10 economies from 1990 to 2010. They find that exchange rate volatility is lower for IT countries than non-IT countries.

From a different perspective, Berganza and Broto (2012) analyse the effects of IT and foreign exchange intervention on real exchange rate volatility for a panel of 37 IT and non-IT emerging countries from 1995 to 2010. Using pooled OLS regression, they find that although IT leads to higher exchange rate instability than alternative regimes, foreign exchange interventions in some IT countries are more effective in reducing volatility than in non-IT countries. Similarly, Catalán-Herrera

(2016) examines the effectiveness of foreign exchange interventions in Guatemala. Applying a GARCH model to daily datasets, he finds that forex intervention lowers exchange rate return volatility. His findings further suggest that forex intervention has no significant effect on the level of real exchange rates.

However, some researchers report contrasting empirical findings for IT effects on exchange rate volatility. For example, Sek et al. (2012) employ the BEKK-MGARCH model for a sample of 6 IT countries including the Philippines, South Korea, Thailand, Norway, Sweden and the U.K. Using monthly data from 1960 to 2010, they find that IT increases exchange rate volatility. Du Plessis and Reid (2015) find a similar result for a sample of 11 IT countries. They differ from the existing study by controlling for the average level of inflation and distinguish between IT countries that target high and low levels of inflation. Using quarterly cross-sectional data from 1990 to 2010, they find that higher IT regimes increases exchange rate volatility.

With respect to IT effects on exchange rate pass-through to domestic inflation, Prasertnukul et al. (2010) estimate a seemingly unrelated regression (SUR) for 4 Asian IT countries from 1990 to 2007. They find that IT lowers exchange rate pass-through in South Korea and Thailand, while the findings are less clear in the cases of Indonesia and the Philippines. Using a semistructural vector autoregressive model, Aleem and Lahiani (2014) also report evidence that the adoption of IT reduces that exchange rate pass-through in the Philippines, South Korea, Thailand, Brazil and Mexico. They also find that that the exchange rate pass-through is higher in Latin American countries than in East Asian countries.

Some researchers have also investigated the exchange rate pass-through effects for single IT countries. For instance, Maertens Ordia et al. (2012) examines whether the exchange rate pass-through into prices change after the adoption of IT in Peru. Using the VSTAR model for monthly data from 1994 to 2007, they find that IT lowers pass-through into import, producer, and consumer prices in Peru. A study by Winkelried (2014) also focuses on Peru, using a VAR approach from 1992 to 2011. He reports evidence of a strong decline in exchange rate pass-through.

As shown above, the existing literature focuses on the impact of IT in reducing exchange rate pass-through and volatility. However, studies investigating the effects of IT on the stationary properties of exchange rate are scarce. Existing empirical studies in this topic are therefore discussed in Chapter 6 to better highlight the theme of the thesis in terms of linking IT credibility to stationarity.

Chapter 3: Methodology and Data

3.1 Introduction

The real thrust of the contribution of this thesis is based on the application of panel GARCH, quantile unit root and Markov regime-switching testing. In general, this particular combination of methodologies was chosen to provide new insights into IT credibility in the context of Asian countries. First, IT credibility is investigated with respect to whether IT lowers the inflation rate and its volatility, using a panel GARCH methodology. This approach accounts for interdependence and heterogeneity across countries and thus its assessment of credibility of IT is more useful than a single-country GARCH model that lacks the ability to incorporate such behaviour. Second, the analysis of IT credibility is complemented by examining whether inflation stationarity is linked to smaller and larger changes in the inflation rate using quantile unit root testing. Quantile unit root regression offers further insights into the extent of IT credibility based on inflation stationarity. Finally, the Markov regime-switching framework is employed to provide a broader perspective of IT credibility in terms of the possibility that inflation, output growth and real exchange rate switch between stationary and non-stationary regimes.

The data requirement is tailored in each of the above empirical steps. It is important to note here that this study is designed so that the relevant methodologies and data to address the research questions are discussed as required in each chapter. In doing so, the research questions are tackled in specific ways to provide a detailed and clear investigation of IT effects on inflation and macroeconomic performance.

The remainder of this chapter is organized as follows. Section 3.2 outlines the details of methodologies. Section 3.3 discusses the data and sample countries. Section 3.4 discusses the procedures for data analysis and the resources used.

3.2 Methodology

3.2.1 GARCH Models for Inflation Uncertainty

According to Payne (2009), one objective of IT is to reduce the degree of inflation uncertainty faced by economic agents. Kontonikas (2004), Berument and Yuksel (2007), Prasertnukul et al. (2010), Tas (2012) and Tas and Ertugrul (2013) employ GARCH-type models and show that IT lowers inflation uncertainty. This section introduces the GARCH models, which will be fully outlined in Chapter 4.

Let $\pi_t = [\pi_{1t}\pi_{2t}]'$ be a 2 x 1 vector containing the inflation rates in a conditional mean equation. As in Lee (2006), the conditional mean equation in a reduced-form VAR can be represented as follows:

$$A(L)\pi_t = \boldsymbol{\varepsilon}_t,\ \boldsymbol{\varepsilon}_t N(0, H_t)\ \forall\ t = 1, \dots, T \qquad (3.1)$$

where $A(L)$ is a polynomial matrix in the lag operator L, and $\boldsymbol{\varepsilon}_t = [\varepsilon_{1t}\varepsilon_{2t}]'$ is a vector of innovations with conditional variance-covariance matrix $H_t = \{h_i\}_t\ \forall_i =$ 1 and 2. To test the IT credibility hypothesis for *N* countries and *T* periods with $\boldsymbol{\varepsilon}_t$, *t* = 1,…, *T*, the conditional mean equation in Equation 3.1 can be re-written as a dynamic model to include the primary exogenous variables as follows:

$$\pi_{it} = \mu_i + \phi_1\pi_{it-1} + \dots + \phi_p\pi_{it-p} + \beta_1\pi_t^f + \beta_2\sigma_{it}$$
$$+ \beta_3 IT_{it} + \beta_3\Delta lnE_{t-1} \times DIT_t + \varepsilon_{it}, \qquad i = 1, \dots, N \qquad (3.2)$$

where μ_i captures possible time-invariant effects associated with inflation rates, and π_{it} is modelled as a stationary $AR(p)$ process, which implies assuming that all the characteristics of the polynomial $(1 - \phi_1 L - \cdots - \phi_p L^p) = 0$ lie outside the unit circle.[1] In Equation 3.2 both μ_i and ϕ_h , $h = 1, \ldots, p$ are parameters. The variable σ_{it} is the conditional standard deviation of inflation rate, π_t^f is the U.S. or Japanese inflation, IT_{it} is the inflation target level, E_{it} is the nominal exchange rate and DIT_{it} is a structural shift dummy variable that takes a value of 1 during the time IT is adopted, and zero otherwise, and ε_{it} is a residual term. The next two subsections outline two alternative approaches to describing the variance processes of the residuals from the conditional mean Equation 3.2.

3.2.1.1 Multivariate GARCH Framework

In the univariate GARCH modelling of inflation, IT credibility can be disguised because of the likely interdependence between the domestic and foreign inflation. To resolve such issues, this thesis uses a multivariate GARCH model, which is useful in studying volatility linkages between countries. This approach can potentially show the existence of inflation linkages between countries that are not always detected in a univariate setting. The estimation of such models requires the imposition of certain restrictions on the conditional variance-covariance matrix to achieve positive definiteness and simplify the optimization process. In this case, Bollerslev et al. (1988) and Bollerslev (1990) respectively proposed a restricted (diagonal) VECH and constant conditional correlation model. The former does not ensure positive definiteness of the conditional variance matrix and makes oversimplifying cross-equation restrictions in not allowing conditional variances

[1] See Cermeño and Sanin (2015) for a similar point.

and covariances to affect each other. The latter model's assumption is unlikely due to the likelihood of stochastic correlation of inflation rates between countries.

To ensure positive definiteness, the parameterization developed by Engle and Kroner (1995), also known as the BEKK model, is used in this thesis.[2] This parameterization uses quadratic forms, assumes constant correlation, and allows for inflation volatility spillover across countries. However, there is a trade-off between its generality and the increasing computational difficulties with higher dimensional systems. For the variance part of the system alone, the simple BEKK model requires the estimation of $\left(\frac{5}{2}N^2 + \frac{1}{2}N\right)$ parameters for a system of *N* variables.

To illustrate the BEKK model, let H_t denote the conditional variance-covariance matrix of the residual term ε_{it}. For a bivariate case, the conditional variance-covariance equation for a GARCH (1,1) process is given by:

$$\mathrm{H}_t = C'C + A'\varepsilon_{t-1}\varepsilon_{t-1}'A + B'\mathrm{H}_{t-1}B + D'\mathrm{F}_t D \qquad (3.3)$$

where ε_t is a 2×1 vector of the residuals ε_{it}, and F_t is a 2 x 2 diagonal matrix of control variables that include a shift IT dummy variable and lagged inflation rates. The terms *A*, *B*, *C* and *D* are unrestricted 2×2 parameter matrices. To ensure the positive definitiveness of H_t, *C* is an upper triangular matrix in the quadratic representation of Equation 3.3. The elements in H_t are given by:

$$\mathrm{H}_{ii,t} = \mathrm{C}_{ii} + A_{ii}\varepsilon_i^2 + B_{ii}\mathrm{H}_{ii}^2 + D_{ii}\mathrm{IT}_t \qquad (3.4)$$

$$\mathrm{H}_{ij,t} = \mathrm{C}_{ij} + A_{ij}\varepsilon_i\varepsilon_j + B_{ii}\mathrm{H}_{ij}^2 + D_{ij}\mathrm{IT}_t, \quad \text{for } i \neq j. \qquad (3.5)$$

[2] The BEKK model has been used, among others, by Holmes and Maghrebi (2005), Holmes and Pentecost (2006), Yong Fu et al. (2011), and Lee and Valera (2016).

The parameter estimate of IT_t in matrix D captures the role of IT in the volatility and covariance of inflation uncertainty across countries. Discussion is provided in Chapter 4 of the full details of a series of bivariate BEKK-MGARCH models for each country relative to the U.S. and Japan. The conditional variance-covariances are estimated together with the conditional mean Equation 3.2 using the maximum likelihood method (ML).

3.2.1.2 Panel GARCH Model

The application of the panel GARCH model is the key contribution of this study. The success of domestic inflation stabilization and keeping inflation around its target under an IT framework is a controversial topic in academic literature. As far as focusing on the time-series of individual IT countries is concerned, many GARCH-type models are already widely used. However, a single country GARCH model lacks the ability to incorporate possible cross-sectional dependence. There is also difficulty, due to country pairing, in the use of the MGARCH approach when providing a general conclusion about IT effects on inflation volatility. Thus, this thesis employs the panel GARCH methodology developed by Cermeño and Grier (2006). This approach offers substantial efficiency gains in estimating the conditional variance and covariance processes by incorporating interdependencies and heterogeneity across economies (Lee, 2010b).

To illustrate the panel GARCH approach, the conditional mean of inflation in Equation 3.2 is estimated with fixed effects in a dynamic panel data model. In line with Cermeño and Sanin (2015), assume that $\boldsymbol{\varepsilon}_t$ follows a multivariate normal distribution with zero mean and covariance matrix $\boldsymbol{\Omega}_t$ with diagonal and off-diagonal elements as detailed in the conditional variance σ_{it}^2 and covariance $\sigma_{ij,t}^2$ equations as follows:

$$\sigma_{it}^2 = \phi_i + \delta\, \sigma_{i,t-1}^2 + \gamma\varepsilon_{i,t-1}^2 + \xi\varepsilon_{i,t-1}^2 I_{i,t-1} + \theta_1\pi_{t-1} + \theta_2 IT_t, \quad i = 1, \dots, N, \qquad (3.6)$$

$$\sigma_{ijt} = \eta_{ij} + \lambda\sigma_{ij,t-1} + \rho\varepsilon_{i,t-1}\varepsilon_{j,t-1} + \vartheta IT_t \qquad i \neq j. \qquad (3.7)$$

Equation 3.6 specifies a GARCH (1,1) process for each inflation rate in the panel. Since shocks are different, the conditional variance across countries is not equal although the model imposes homogeneity. The unconditional variances are also not equal across countries as each variance has a country-specific intercept given by ϕ_i. The IT effect on the conditional volatility and covariance across countries is given by the parameters θ_2 and ϑ. The specifics of the log-likelihood function for the complete panel and its maximization are discussed in Chapter 4.

3.2.2 Quantile ADF Unit Root Testing

The credibility of monetary policy is an important determinant of lag dynamics in inflation (Srinivasan & Kumar, 2012). With this in mind, the second research question, *How credible is IT in terms of stabilizing inflation given different signs and sizes of inflation shocks?* is addressed by employing the quantile unit root testing developed by Koenker and Xiao (2004). An $AR(q)$ process for inflation rate with drift ρ_0 and deterministic trend *t* is given by:

$$\Delta\pi_t = \rho_0 + \rho_1\pi_{t-1} + \beta t + \sum_{i=1}^{q} \gamma_i \Delta\pi_{t-i} + \varepsilon_t, \quad t = q+1, q+2, \dots, n \qquad (3.8)$$

where the AR coefficient ρ_1 measures the persistence of inflation and ε_t is a serially uncorrelated error term. If $\rho_1 = 0$ then inflation has a unit root and, therefore, shocks have permanent effects on inflation. If $-2 < \rho_1 < 0$ then inflation is stationary, meaning shocks have short-lived effects only.

To assess how credible IT is based on the stationarity or non-stationarity of inflation, the τth conditional quantile of $\Delta\pi_t$, conditional on the past information set Γ_{t-1}, can be defined as a linear function of π_{t-1} and lagged values of $\Delta\pi_{t-1}$. The equation below presents the specifics of the inflation model based on Tsong and Lee (2011):

$$\mathrm{Q}_{\Delta\pi_t}(\tau|\Gamma_{t-1}) = x'_t\rho(\tau) \quad (3.9)$$

where $x_t = (1, \pi_{t-1}, t, \Delta\pi_{t-1}, \dots, \Delta\pi_{t-q})'$ and $\rho(\tau) = (\rho_0(\tau), \rho_1(\tau), \dots, \rho_{q+1}(\tau))'$, with $\rho_0(\tau)$ denoting the τth quantile of ε_t. For a given τ, the parameter vector $\rho(\tau)$ in Equation 3.9 is obtained by minimizing the sum of asymmetrically weighted absolute deviations:

$$min\sum_{t=1}^{n}(\tau - I(\pi_t < x'_t\rho(\tau)))|\pi_t - x'_t\rho(\tau)| \quad (3.10)$$

where *I* denotes an indicator function taking the value of 1 (*I* = 1) if $\pi_t < x'_t\rho(\tau)$ and zero otherwise (*I* = 0). With the solution of Equation 3.10, the details of the relevant test statistic are presented in Chapter 5. In particular, the null hypothesis $H_0: \rho(\tau) = 0$ in each quantile is tested using the *t*-ratio statistic suggested by Koenker and Xiao (2004). The null of a constant unit root process over a range of quantiles is also tested using the QKS test proposed by the same authors.

3.2.3 Markov-Switching ADF Unit Root Testing

Credible IT limits not only variability in inflation but also in output and real exchange rate (Mishkin & Schmidt-Hebbel, 2007; Kim, 2014). This is related to the third research question: *Does IT help Asian countries to achieve a significant* *improvement in macroeconomic performance as measured by the behaviour of inflation, output growth and real exchange rate?* This study follows the Markov-switching ADF regression model proposed by Hamilton (1989) and Hall et al. (1999) to investigate stationarity or non-stationarity of inflation rate, output growth and real exchange rate.

Let y_t represent all the three macroeconomic variables of interest, and $S_t \in \{1,2\}$ be an unobservable state variable of two regimes. The state variable S_t is governed by a discrete state Markov chain. The path that S_t follows from period $t-1$ to period t is captured by a probability transition matrix with the following elements:

$$\Delta y_t = \mu(S_t) + \beta(S_t)T + \rho(S_t)y_{t-1} + \sum_{k=1} \delta_k(S_t)\Delta y_{t-k} + \varepsilon_t. \qquad (3.11)$$

All coefficients in Equation 3.11 are allowed to switch according to the state variable, S_t. This Markov-switching framework can also be extended to the variance term (Çevik et al., 2013; Kanas & Genius, 2005). In this case, the residual term is assumed to be $\varepsilon_t \sim N(0, \sigma^2(S_t))$. This means that σ^2 is allowed to switch according to a two-state, first-order Markov process governed by the state of S_t.

Equation 3.11 can be estimated using the two-step EM algorithm suggested by Hall et al. (1999) and Hamilton (1989). This algorithm involves an iterative procedure to obtain ML estimates for the parameters and transition probabilities governing the Markov process. The unit root test with the MS-ADF model of Equation 3.11 can be based on the t_ρ statistic. However, since the distribution of t_ρ under the null hypothesis is unknown, this study adopts the approach of Hall et al. (1999) by generating critical values using bootstrapping with 2,000 replications. In addition, the LR test is used to determine whether the MS-ADF model characterizes the macroeconomic series better than the conventional ADF model.

3.3 Data

3.3.1 Sample of Asian Countries

This thesis considers a sample of eight Asian countries. Four of these countries have announced a quantitative inflation target: South Korea, Thailand, the Philippines and Indonesia. As shown in Table 3.1, South Korea was the first Asian country that adopted an IT policy in April 1998, followed by Thailand in May 2000, the Philippines in January 2002 and Indonesia in July 2005. These four IT countries have employed an IT policy under floating exchange rate arrangement. The remaining four are non-IT countries that include China, Hong Kong, Malaysia and Singapore. China and Hong Kong currently operate with a crawl-like arrangement and a currency board, respectively. The exchange rate regime in Malaysia is classified as a managed arrangement while that of Singapore is a stabilized arrangement.

There are three main reasons for choosing these two groups of countries for this investigation. First, the main focus of the study is to examine the dynamic behaviour of inflation rates, but the choice of sample countries is dictated by the availability of consistent CPI data with respect to the study period. Second, these two groups of countries have marked differences in monetary policies and macroeconomic conditions and therefore represent an interesting scenario for comparisons. Third, the sample countries include the five original members of the Association of Southeast Asian Nations (ASEAN-5): Indonesia, Malaysia, the

Philippines, Thailand and Singapore. According to Dufrenot and Keddad (2014), an initiative for a multilateral negotiating forum for strengthening monetary integration is more likely in these five countries. Moreover, the sample countries belong to the East Asian economic region, where cooperation and integration in trade, investment, finance and money areas are actually perceived as the best strategies for enhancing macroeconomic stability and promoting growth within the region (Dufrenot & Keddad, 2014).

Table 3.1: IT Adoption and Exchange Rate Arrangements in Asia

Country	Official IT adoption	Exchange rate arrangement
IT countries		
Indonesia	July 2005	Floating
Philippines	January 2002	Floating
South Korea	April 1998	Floating
Thailand	January 2000	Floating
Non-IT countries		
China		Crawl-like arrangement
Hong Kong		Currency board
Malaysia		Managed arrangement
Singapore		Stabilised arrangement

Sources: Ito and Hayashi (2004), Prasertnukul et al. (2010), Hammond (2012), and Ouyang and Rajan (2016).

3.3.2 Time-series and Panel Data

The research questions formulated in Chapter 1 are addressed using time-series and panel datasets. Time-series datasets consist of the monthly consumer price index (CPI) and real exchange rate during the period 1987:M1-2013:M11. In addition, quarterly time-series data on real GDP growth were gathered for the period 1987:Q1-2013:Q4. The panel data set is based on CPI inflation data for a balanced panel of eight Asian countries. The datasets for all macroeconomic variables under study were obtained from the IMF's *International Financial*

Statistics using the Datastream database. Data on annual inflation targets were also gathered from statistical databases of Asian IT central banks.

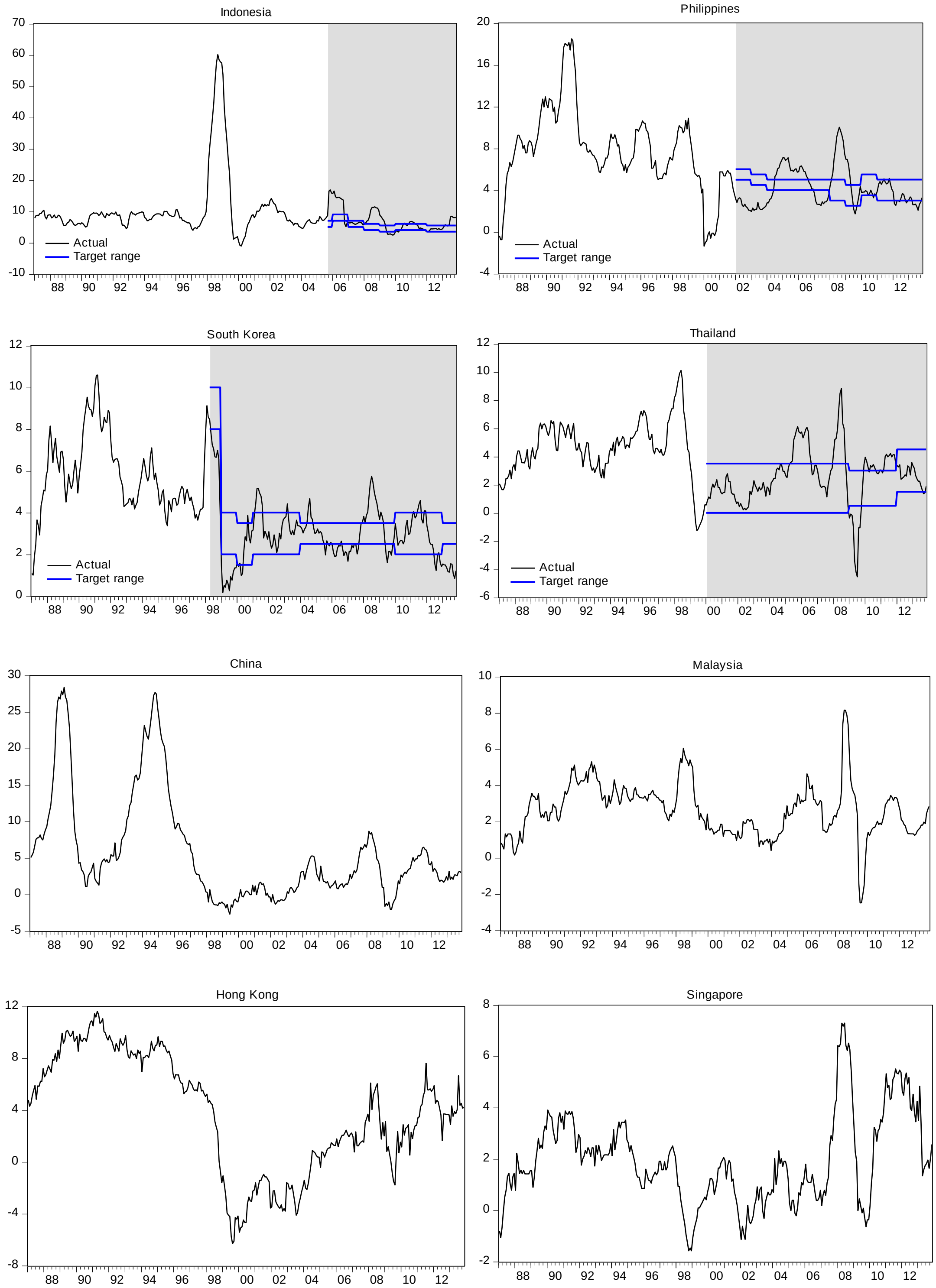
Given that IT regimes typically monitor the behaviour of annual inflation (Gregoriou & Kontonikas, 2009), the inflation rate is calculated as the annual change in the log of the monthly CPI as follows:

$$\pi_{it} = 100 * (lnp_{it} - lnp_{it-12}) \tag{3.12}$$

where p_{it} is the CPI in country i at time t. The monthly CPI data for the U.S. and Japan were also obtained in order to investigate the international inflation volatility transmission using the MGARCH model. In addition, annual inflation targets were obtained to construct an IT dummy variable. Given the monthly inflation measure in Equation 3.12, this thesis constructed a balanced panel of eight Asian countries in order to address the first research question.

Figure 3.1 shows the monthly inflation pattern for Asian countries, as well as the inflation target bands for IT countries, represented by blue lines. Although inflation in Thailand rose after IT adoption, this country has the highest percentage of time (about 65%) of staying within the target bands. Inflation in South Korea and the Philippines declined after the adoption of IT in 2002 and 1998 respectively. South Korea was within the target band about 46% of the time but its absolute deviations from the target in some periods were relatively small compared to Thailand. Actual inflation in Indonesia deviated above the target ranges following IT adoption in 2005. Indonesia and the Philippines spent less time within the target bands. In the case of the Philippines, the central bank was often unable to achieve the target between 2002 and 2008 but following that date, headline inflation has been within the target. In situations where the Philippine central bank misses the inflation target, the governor issues an “Open Letter to the President” along with the steps that will be taken to bring inflation back to the target (Inoue et al., 2012).

Figure 3.1: CPI Inflation (1987-2013) and Inflation Targets (1998-2013)



Notes: The shadowed areas in the figure indicate the inflation targeting periods. The blue lines in the figure indicate the inflation target range.

A similar experience of overshooting the inflation targets is shown for other periods in all Asian IT countries, most notably in 2008. Figure 3.1 also reveals that Asian IT countries' inflation rates have deviated below the target in other periods. Also, all Asian IT countries experienced corresponding inflation surges during the Asian financial crisis and the 2008 price spike, while these rates fell precipitously in 2009 as a result of the global financial crisis. The graph also illustrates that the inflation series display volatility in other periods.

The pattern of a sudden shift in inflation rates in 1997-1998 and 2008-2009 can be also observed in Figure 3.1 in the cases of Asian non-IT countries. In particular, Malaysia and Singapore have experienced inflation surges in 1998 and their inflation series exhibit variability in other periods. In contrast, China and Hong Kong experienced a drop in inflation rates in 1997 and 1998. The abrupt increase in inflation rate in 2008 and sharp decline in 2009 were also evident in the cases of Asian non-IT countries. Overall, the inflation series in Figure 3.1 highlight a sudden shift in the levels of inflation rates in Asia during financial crises as well as varying inflation volatilities in different periods.

3.3.3 Summary Statistics for Inflation Rates

Before embarking on the empirical analysis, the data discussion concludes with an examination of the distributional properties of inflation rates. Table 3.2 displays the first four sample moments of the inflation rates and the Jarque-Bera (JB) normality test statistic. Indonesia and Singapore respectively displayed the largest and smallest mean annual inflation rates of 9.38% and 1.95%. Indonesia had the largest standard deviation (8.99), while Malaysia had the smallest (1.48). The skewness and kurtosis statistics suggest that the inflation rates were not likely to be normally distributed in most cases. In general, the kurtosis statistic is much higher than the value of 3 associated with a normal distribution, meaning the inflation rates exhibit fat tails. Moreover, the JB test shows strong evidence of non-normality in the distribution of inflation rates since the associated *p*-values are statistically significant at the 1% level.

Table 3.2: Summary Statistics for Inflation Rates

Country	Mean	S.D.	Skewness	Kurtosis	JB stat.
Indonesia	9.383	8.996	3.940	19.746	4609.760***(0.000)
Philippines	6.209	3.676	0.860	4.302	62.652***(0.000)
South Korea	4.172	2.138	0.676	3.036	24.600***(0.000)
Thailand	3.555	2.223	-0.089	3.818	9.424***(0.000)
China	5.752	7.246	1.608	4.862	185.823***(0.000)
Hong Kong	3.788	4.520	-0.256	1.997	17.058***(0.000)
Malaysia	2.653	1.482	0.348	5.047	62.928***(0.000)
Singapore	1.953	1.736	0.655	3.360	24.862***(0.000)

Notes: S.D. is denotes the standard deviation. JB stat. denotes the Jarque-Bera normality test, which is χ^2 (2) distributed asymptotically. *** denotes significance at the 1% level.

3.3.4 Univariate Unit Root Testing for Inflation Rates

This thesis is primarily about the analysis of inflation, which is common to all core research chapters. For this purpose, the standard univariate unit root or stationary tests such as the Augmented Dickey-Fuller (ADF), Elliot et al. (1996, DF-GLS), Phillips and Perron (1988, PP), Ng and Perron (2001, NP), and Kwiatkowski-Phillips-Schmidt-Shin (1992, KPSS) tests are examined first in this section. The ADF, DF-GLS, PP and NP tests are of a unit root null hypothesis, while the KPSS test is of a stationary null hypothesis. The results with and without a deterministic trend are reported in Table 3.3. For the ADF and DF-GLS, the optimal lag was determined using the Akaike Information Criterion (AIC). The bandwidth by the Bartlett Kernel, as suggested by the Newey and West (1987) test, was chosen for the KPSS, NP and PP.

Table 3.3 shows that the ADF and DF-GLS reject the unit root null for all countries except Hong Kong. The PP rejects the unit root null for six countries: Indonesia, Malaysia, the Philippines, Singapore, South Korea and Thailand. The NP tests reject the unit root for China and Indonesia at the 1% significance level, and for Malaysia at the 10% significance level with a time trend specification. For the KPSS tests, the null hypothesis of stationarity is rejected for Indonesia, Malaysia, Singapore and Thailand in the case of trend specification.

3.4 Resources Used

Eviews was used to tabulate the necessary statistics and illustrate graphs of the variables. The univariate unit tests were performed using Eviews while panel unit root tests were conducted in STATA. Finally, the estimation of all econometric models applied in this thesis were facilitated by writing the programmes in RATS.

Table 3.3: Results for Univariate Unit Root Tests on Inflation Rates

	ADF		DF-GLS		PP		NP		KPSS	
Country	No trend	With trend	No trend	With trend	No trend	With trend	No trend	With trend	No trend	With trend
Indonesia	-5.903***	-5.938***	-5.834***	-3.787***	-3.625***	-3.652**	-3.581***	-10.217***	0.158	0.223***
Philippines	-3.600***	-4.998***	-1.733*	-1.190***	-3.101**	-4.187***	-1.533	-1.056	0.988***	1.594
South Korea	-2.673*	-2.673***	-1.668*	-1.528***	-2.801*	-4.333***	-1.712*	-1.083	1.240	2.008
Thailand	-4.463***	-4.912***	-3.717***	-1.844*	-3.626***	-3.936**	-3.109***	-1.822	0.483*	0.698**
China	-3.443**	-4.051***	-3.445***	-3.002***	-2.482	-2.933	-2.477**	-3.677***	0.704**	1.252
Hong Kong	-1.570	-1.669	-1.509	-1.185	-1.471	-1.637	-1.430	-1.235	0.930***	1.794
Malaysia	-5.228***	-5.438***	-3.054***	-1.600***	-3.155**	-3.264*	-1.964*	-1.627*	0.261	0.361*
Singapore	-4.216***	-4.337***	-2.278**	-0.794***	-3.560***	-3.564**	-1.876*	-0.875	0.316	0.487**

Notes: Optimal lag for ADF, DF-GLS and LS is determined using the AIC criteria. The bandwidth is chosen using the Bartlett Kernel, as suggested by Newey and West (1987) for KPSS, NP and PP. ***, ** and * denote significance at the 1%, 5% and 10% level, respectively..

Chapter 4: Is Inflation Targeting Credible in Asia? A Panel GARCH Approach

4.1 Introduction

The behaviour of inflation rate is the subject of a large volume of literature on IT, notably among studies of emerging countries. Researchers interested in IT have, for many years, done their best to empirically estimate inflation performance as a major criterion for judging the credibility of central banks. Following the financial crisis of 2008-2009, however, and against a background of a spike in prices in 2008 coupled with an unwarranted depreciation in the exchange rate, this question has taken on renewed importance for emerging IT economies. Some scholars advocate a change in the practice of IT when concerns about high pass-through from the exchange rate to inflation threaten an economy's ability to achieve well-anchored inflationary expectations. Specifically, Céspedes et al. (2014) propose a new configuration of IT for Latin American countries by using non-conventional policy tools to anchor inflationary expectations in crisis times particularly when central banks do not have the credibility required to implement the standard IT paradigm. Lack of credibility also characterizes the recent experience of emerging Asian IT countries during the crisis when there was a delay or hesitancy on the part of central banks to raise interest rates (Tang, 2014).

Open economy monetary models under the purchasing power parity (PPP) condition suggest direct and indirect linkages in the transmission of foreign inflation to domestic price levels with fixed and flexible exchange rate regimes. All existing empirical studies related to this issue have focused on the transmission of foreign inflation shocks to the *level* of domestic inflation and fail to incorporate international *volatility* transfer as well as the impact of IT. Instead, previous studies by Ibrahim (2009), Yang et al. (2006), Cheung and Yuen (2002), Jeong et al. (2002) and Jeong and Lee (2001) only provide evidence of U.S. inflation transmission to domestic price levels in countries with both fixed and flexible exchange rate regimes, with the latter currency system showing less pronounced influences from foreign inflation shocks.

From other perspectives, the link between foreign and domestic inflation rates under an IT regime is widely examined via exchange rate pass-through. For example, researchers including Aleem and Lahiani (2014), Prasertnukul et al. (2010), and Ito and Sato (2008) have tested Taylor's (2000) hypothesis that a low inflationary setting leads to a decline in exchange rate pass-through, and confirm the favourable performance of IT for some Asian IT countries by accepting the aforementioned conjecture. However, most of these studies only consider the influence of foreign inflation on domestic price level indices and neglect international volatility transmission. Prasertnukul et al. (2010) examine the level and volatility of inflation in an open economy setting for Asian IT countries. They find that IT lowers inflation volatility via a reduction in exchange rate pass-through, but they did not capture the foreign volatility spillover.

Recognizing the importance of monetary policy credibility in achieving price stability, this chapter attempts to test the IT credibility hypothesis of a lower level and volatility of inflation for a sample of eight Asian countries. This chapter contributes to the literature in three ways. First, it examines international linkages with respect to inflation rates, looking at the conditional volatilities based on its unpredictable movements. The methodology relies on estimating a series of bivariate MGARCH models, which facilitate the analysis of foreign volatility transfer. Existing studies usually offer findings about interdependencies of inflation rates between the foreign and home countries. However, this chapter provides an alternative insight from which to view world commodity integration and IT credibility in achieving lower and stable inflation. In doing so, MGARCH modelling detects possible changes in the dynamic conditional correlation between foreign and domestic inflation volatilities. This feature was neglected in previous studies, which rely on unconditional variance and covariance measures of inflation.

Second, the main contribution of this paper is the application of the panel GARCH model that incorporates heterogeneity and interdependence across countries. According to Cermeño and Grier (2006) and Lee (2010b), the panel GARCH model can lead to substantial efficiency gains in estimating the conditional variance and covariance processes. Accordingly, this study offers new valuable insights into the correlation between unanticipated inflation shocks. To be specific, panel dynamic conditional correlation analysis allows the researcher to evaluate whether Asian countries are hit by similar (dissimilar) unforeseen inflation shocks irrespective of whether or not their central banks engage in IT. In addition, the panel GARCH model employed in this study explicitly captures the impact of the actual inflation targets. In situations where credibility concerns arise because inflation deviates above a target value and the central bank attempts to reduce it, the panel GARCH model that explicitly captures actual inflation targets allows assessment of the credibility of an IT regime by evaluating the corresponding impact on both the level and volatility of inflation. Explicitly capturing the actual inflation targets is crucial because their values change over a given time horizon and hence convey new information about their past levels and future changes.

Finally, the panel GARCH model employed in this chapter offers a unified method of analysing the impact of IT on the level and volatility of inflation. Past empirical studies, individual and cross-country alike, do not reach a consensus as to whether the adoption of IT lowers inflation and inflation volatility. Studies of individual countries often apply univariate generalized autoregressive conditional heteroscedasticity (GARCH) approaches to estimate the impact of IT on the conditional variance of inflation and they report mixed findings for Asia and outside. For example, IT lowers the inflation variance of the Philippines and South Korea but not Thailand (Taş, 2012). By contrast, IT reduces the inflation variance in Indonesia and the Philippines, but not in South Korea (Taş & Ertugrul, 2013). Meanwhile, inflation variance declines after the adoption of IT in the U.K. (Kontonikas, 2004) while it increases in Canada (Miles, 2008). The conclusions drawn from these studies are from univariate GARCH estimates on a country-by-country basis, which could mask the credibility of an IT regime because of the neglect of possible interdependence of inflation across countries. Consequently, an IT framework in some Asian countries could be credible in reducing the level and volatility of inflation while an IT policy elsewhere might not be.

In terms of related literature that employs cross-country regression, most of these studies rely on an unconditional variance measure. Studies such as those of Gonçalves and Salles (2008), Batini and Laxton (2007) and the International Monetary Fund (IMF) (2006) apply the Differences-in-Differences (DID) method to the change in the standard deviation of inflation in estimating inflation variability, which they find to decrease together with the level of inflation after the adoption of IT in developing countries. Lin and Ye (2009) corroborate those findings for developing countries using a propensity score matching (PSM) estimation of the standard moving average of inflation for a panel dataset. Brito and Bystedt (2010) use the same measure of variability in their panel data estimation and find that IT lowers inflation and inflation volatility in emerging countries, but the effects are less strong and significant as compared to the previous studies.

In addition to these mixed findings, there can be significant differences between unconditional variance and the volatility of innovations in the behaviour of the inflation rate. As Lee (2010b) points out, the volatility of innovations correspond more closely to the notion of uncertainty that plays a key role in the development of macroeconomic theories. Hence, this subtle but important feature of volatility of innovations in the behaviour of inflation rates is addressed in this study by examining an alternative measure of inflation rate uncertainty, which is the conditional variance of inflation rate.

This chapter is organized as follows. The next section presents a review of relevant literature on international transmission of inflation shocks and the role of IT in reducing the level and volatility of inflation rates. Section 4.3 describes the dataset and introduces the MGARCH and panel GARCH procedures. Section 4.4 provides the empirical results. Section 4.5 concludes the chapter.

4.2 Literature Review

4.2.1 Theoretical Framework

The basic ideas and key theoretical links between domestic and foreign inflation rates can be analysed with respect to the literature on IT for an open economy. This subsection follows the framework presented by Rhee and Turdaliev (2012) and Svensson (2000) to motivate the analysis of IT in an open economy context. Following Rhee and Turdaliev (2012), the terms of trade g_t or the price of the foreign country's goods in terms of the home country's goods can be written in log form as:

$$g_t = p_t^f - p_t^d. \tag{4.1}$$

where p_t^f is the log of the foreign price level and p_t^d is the log of the domestic price level. The CPI in log-linear specification is given by:

$$p_t = (1-\alpha)p_t^d + \alpha p_t^f. \tag{4.2}$$

Combining Equations 4.1 and 4.2 yields:

$$p_t = p_t^d + \alpha g_t. \tag{4.3}$$

Thus, the decomposition of inflation is as follows:

$$\pi_t^{CPI} = \pi_t + \alpha \Delta g_t. \tag{4.4}$$

where $\pi_t = p_t^d - p_{t-1}^d$ is the domestic inflation. If $\alpha = 1$, Equation 4.4 means that $\pi_t^{CPI} = \pi_t$, and therefore CPI inflation equals foreign inflation. The log-linear version of the law of one price under the assumption of a large foreign economy can be written as:

$$p_t^f = e_t + p_t^*, \tag{4.5}$$

where e_t is the log nominal exchange rate. Then, using Equations 4.1 and 4.5 gives:

$$g_t = e_t + p_t^* - p_t^d. \tag{4.6}$$

Finally, the log-linear specification of the real exchange rate q_t can be obtained by combining Equations 4.1 and 4.6 as follows:

$$q_t = (1-\alpha)g_t. \tag{4.7}$$

The identities in Equations 4.1 to 4.7 highlight the link between exchange rate and CPI inflation. Svensson (2000) also emphasizes this relationship using a small open-economy model with forward-looking aggregate supply and demand with emphasis on the exchange rate channels in monetary policy. In particular, Svensson (2000) specifies the CPI inflation target of the central bank as follows:

$$\pi_t^{CPI} = \pi_t + \omega(q_t - q_{t-1}), \tag{4.8}$$

where ω represents the share of imported goods in the CPI. The parameter ω also captures the so-called exchange rate pass-through effect. In other words, Equation 4.8 reflects the importance of exchange rate pass-through in explaining the behaviour of CPI inflation. Svensson (2000) notes that this link occurs via three channels: (1) an aggregate demand channel, which shows a real exchange rate effect on domestic and foreign goods' relative price and eventually on local demand for goods from both the home and foreign country; (2) a direct exchange rate channel that affects the domestic currency prices of imported final goods, which comprises CPI inflation; and (3) an additional exchange rate effect on the local currency prices of intermediate inputs that affects nominal wages via the effect of the CPI on wage-setting.

The above framework is relevant to this study because Asian IT countries are open economies, relying heavily on external trade. As noted by Prasertnukul et al. (2010), it is crucial for policymakers to oversee small open economies, like those in Asian countries, to determine whether IT contributes to price stability through external trade channels associated with exchange rate movements. In addition, the framework presented above is important in providing an alternative interpretation of IT credibility. For example, Céspedes and Sotto (2005) argue that one way of gaining credibility is by managing the exchange rate if credibility is affected by deviations of effective inflation from its target. Moreover, Reyes (2007) argues that when the exchange rate increases under an IT regime, central banks increase the interest rate to prevent the exchange rate movements feeding into inflation, thereby affecting exchange rate dynamics and lowering the pass-through to inflation (Maertens Odria et al., 2012).

In line with the aforementioned arguments, IT credibility in this study is interpreted by linking exchange rate pass-through and CPI inflation based on Taylor's (2000) hypothesis that a low inflationary environment leads to a reduction in exchange rate pass-through. Taylor (2000) argues that firms set prices for several periods in advance and respond to cost increases induced by shocks to exchange rate or a rise in inputs price if they perceive more persistent cost changes. Given staggered prices, Taylor (2000) argues that firms are more likely to pass-through cost changes, including those from the exchange rate, when inflation is high. In this chapter, an alternative interpretation of credibility hypothesis is in terms of a lower pass-through from the exchange rate to inflation consistent with Taylor (2000).

However, this study also draws on Carrasco and Ferreiro's (2013) credibility hypothesis that under an IT regime, medium- and long-term inflation expectations follow a normal distribution with the mean of inflation expectations equal to the target and a constant variance. Carrasco and Ferreiro (2013) explain that if agents have complete information on the monetary policy strategy of the central bank, they will expect an inflation level close to the inflation target. Agents will therefore avoid systematic forecast errors and as a result, inflation expectations follow a stationary process that helps make IT credible. Along these lines, this chapter hypothesizes that a credible IT regime keeps the absolute difference between actual inflation and its target to a minimum. When credibility concerns arise due to inflation deviation above a target value and the central bank decides to reduce it, the credibility of an IT regime can be thought of as a function of low inflation and inflation volatility around its target value.

4.2.2 Empirical Research

There is an existing empirical literature that provides evidence of the transmission of inflation rates based on the framework of open economy monetary models with fixed and flexible exchange rate regimes. In particular, Cheung and Yuen (2002) examine how inflation rates in Hong Kong and Singapore interact with the U.S. using a vector error correction model (VECM) for monthly CPI. They find that compared with Singapore, the Hong Kong inflation rate is more responsive to U.S. price shocks because the former country is under a floating exchange regime without IT and the latter country is under a fixed exchange regime with a currency board. Also from an Asian country context, Ibrahim (2009) studies the transmission of U.S. inflationary shocks for Malaysia. Using VECM, he reports evidence of significant spillover of U.S. inflation shocks to Malaysia in the short run.

From a non-Asian country perspective, Jeong and Lee (2001) examine the international transmission of inflation under alternative exchange rate regimes among the G-7 countries, the EU and North American countries. The key findings from their VAR model suggest that the transmission of inflationary disturbances across countries is less pronounced under a flexible exchange rate regime than under a fixed exchange rate regime, and that the main producers of inflationary innovations among G-7 countries and EU countries are the U.S. and the U.K., respectively. Jeong et al. (2002) apply a similar VAR approach in modelling the transmission of inflation in Africa and find that a large fraction of domestic inflation is due to inflation shocks originating from foreign countries, particularly the U.S. They also provide evidence that the influence of foreign inflation innovations tends to be less for African countries that are operating under independently floating exchange rate systems.

Many empirical studies examine inflation performance as a major criterion for judging the credibility of an IT policy. However, the majority of recent empirical works on whether IT lowers the level of inflation and the conditional variance of inflation (that element of inflation volatility that is unexpected) in Asian and other countries rely on a univariate method that offers few contrasting findings. In particular, Taş (2012) examines the impact of IT on inflation volatility by applying asymmetric power GARCH and other GARCH procedures to monthly CPI data for a sample of developed and developing IT countries. A subset of the findings shows that IT adoption significantly lowers inflation variances in the Philippines and South Korea. The author also finds that IT has no significant effect on inflation volatility in Thailand. Focusing the analysis on Thailand, Payne (2009) examines the impact of IT on monthly inflation volatility using an ARIMA-GARCH model. He finds that IT adoption in Thailand slightly reduces the degree of volatility persistence in response to inflation uncertainty. Another study that considers Thailand, the Philippines and South Korea is that of Sek and Har (2012) who employ a bivariate GARCH (1,1) model to monthly CPI and find that the variance of inflation declined during the post IT-period.

Taş and Ertugrul (2013) examine the effects of IT on inflation volatility for 25 IT countries, using the Markov-Switching Autoregressive Conditional Heteroscedastic (SWARCH) method. They find that IT significantly lowers inflation variance in Indonesia and the Philippines, but not in South Korea and Thailand. Moreover, Kontonikas (2004) examines the impact of IT on inflation uncertainty in the U.K using component GARCH-M model and finds that IT lowers the inflation variance. Broto (2011), applying the Quadratic Structural ARCH (Q-STARCH) model to a sample of Latin American IT and non-IT Latin American countries, finds that IT lowers inflation volatility persistence in all IT countries except for Colombia.

By contrast, Miles (2008) finds that IT increases inflation uncertainty in Canada using a univariate GARCH model. Miles (2008) attributes this finding to the less-than-perfect credibility associated with previous policies regarding formal targets and transparency by the Bank of Canada. According to Miles, the monetary (M1) target was a failure, and this would naturally lead to greater uncertainty when future targets were announced. He further highlights that the 1993 policies on IT were in some respects a retreat from previous policies, as they widened the inflation target band. Finally, Miles (2008) points out that this result corroborates evidence that IT has failed to lower expected inflation in Canada as reported by Johnson (1997). On the other hand, Berument and Yuksel (2007) apply a GARCH model to a sample of developed and emerging IT countries and show evidence of lower conditional inflation expectations for Australia, Chile and Sweden, as well as significant decreases in conditional variance for Chile and the U.K.

There are also studies that examine the level and variability of inflation within a panel regression framework. For example, IMF (2006) applies the DID method to a sample of developing countries and finds that the adoption of IT lowers annual long-term inflation rates and long-term inflation variability. Using the same approach for quarterly inflation data, Mishkin and Schmidt-Hebbel (2007) provide evidence of lower inflation for a sample of developing and industrial IT and non-IT countries. Likewise, Gonçalves and Salles (2008) use annual CPI panel data in estimating a DID model for a sample of emerging IT countries and provide evidence of significant declines in inflation after the adoption of IT. Lin and Ye (2007), applying the PSM method to panel datasets for major industrial nations, show that IT has no significant impacts on inflation and variability. In contrast, the PSM estimation results by Lin and Ye (2009) suggest that IT significantly lowers inflation and its variability in developing countries. Moreover, Brito and Bystedt (2010), who apply a panel data estimator to a sample of emerging countries, find that IT lowers the level and volatility of inflation and output growth volatility but the effects are less strong and significant than noted in previous studies.

Empirical studies seeking to understand the transmission of foreign inflation rates to domestic inflation rates under an IT regime have also been conducted in terms of analysing exchange rate pass-through. In particular, Prasertnukul et al. (2010) examine both the level and volatility of inflation in four Asian IT countries using an autoregressive distributed lag model and a GARCH model for each country. They find that IT lowers pass-through in South Korea and Thailand, which provides empirical support for Taylor's (2000) hypothesis. They also report evidence that IT lowers inflation volatility in all Asian IT countries via a reduction in exchange rate pass-through.

Similarly, Ito and Sato (2008) examine the pass-through effects of exchange rate changes on domestic prices in East Asian economies using a VAR analysis. They find that the exchange rate pass-through to the CPI is relatively low compared with pass-through to the producer price index (PPI) in Indonesia, Thailand, Malaysia, Singapore and South Korea. The difference in these results is because IT regimes in these countries are typically implemented based on the CPI rather than the PPI. As noted by Froyen and Guender (2016), IT countries generally define their inflation objectives in terms of the CPI. Aleem and Lahiani (2014) examine the exchange rate pass-through to domestic prices using a semi-structural vector autoregressive model with exogenous variables. Their empirical results suggest that the exchange rate pass-through is higher in Latin American countries than in East Asian countries. They also report evidence that exchange rate pass-through declines after the adoption of an IT policy. Likewise, Winkelried (2014) finds that IT lowers the exchange rate pass-through in Peru, using a structural VAR framework.

4.3 Data and Methodology

4.3.1 Data

The main dataset of this chapter consists of the monthly inflation data for eight Asian countries as introduced in Chapter 3. The empirical analysis in this chapter also involves monthly nominal exchange rate data for this Asian sample. The nominal exchange rate data are expressed with respect to the U.S. dollar and Japanese yen. In addition, monthly inflation data for the U.S. and Japan are used in this chapter. Nominal exchange rate and foreign inflation datasets are employed in the estimation of the BEKK-MGARCH model.

4.3.2 Methodology

4.3.2.1 BEKK-MGARCH Model

To assess how IT might affect the international transmission of inflation shocks, consider a small open domestic economy and a large foreign country that engage in global trade. A standard MGARCH model would characterise the foreign transmission of inflation volatility to domestic economy. Let π_i denote country i's inflation rate, h_{ii} the conditional variance of π_i and ε_i the residual series from the mean equation or innovations associated with the behaviour of π_i. For a two-country model, the conditional mean and variance equations may be respectively written as:

$$\pi_t = k + \beta_1\pi_{t-1} + \beta_2 h_{t-1} + \beta_3 IT_t + \sum_{i=0}^{2}\delta_i \Delta ln\, E_{t-1} + \varepsilon_t$$
$$+ \sum_{l=0}^{2}\gamma_l \Delta ln\, E_{t-1} \times DIT_t + \varepsilon_t \qquad (4.9)$$

$$\mathrm{H_t = C'C + A'(\varepsilon_{t-1}\varepsilon'_{t-1})A + B'H_{t-1}B + D'}DIT_t\mathrm{D} \qquad (4.10)$$

where $\pi_t = \begin{pmatrix}\pi_{1t}\\ \pi_{2t}\end{pmatrix}$, $k = \begin{pmatrix}k_1\\ k_2\end{pmatrix}$, $\beta_1 = \begin{pmatrix}\beta_{11} & \beta_{12}\\ \beta_{21} & \beta_{22}\end{pmatrix}$, $\beta_2 = \begin{pmatrix}\beta_{1h}\\ \beta_{2h}\end{pmatrix}$, $\varepsilon_t = \begin{pmatrix}\varepsilon_{1t}\\ \varepsilon_{2t}\end{pmatrix}$,

$C = \begin{pmatrix}c_{11} & c_{12}\\ 0 & c_{22}\end{pmatrix}$, $A = \begin{pmatrix}a_{11} & a_{12}\\ a_{21} & a_{22}\end{pmatrix}$, $B = \begin{pmatrix}b_{11} & b_{12}\\ b_{21} & b_{22}\end{pmatrix}$, $H_t = \begin{pmatrix}h_{11t} & h_{12t}\\ h_{21t} & h_{22t}\end{pmatrix}$,

$D = \begin{pmatrix}d_{11} & d_{12}\\ 0 & d_{22}\end{pmatrix}$, $h_t = \begin{pmatrix}h_{11t}\\ h_{22t}\end{pmatrix}$,

with $\varepsilon_t | I_{t-1} \sim (0, H_t)$. In Equation 4.9, π_1 is the lagged value of the domestic inflation in each country, π_2 is the lagged value of the U.S. or Japan inflation, IT_t is the inflation target, E_t is the nominal exchange rate, and DIT_t is a shift dummy variable that takes a value of 1 during the time IT is adopted, and 0 otherwise.

The impact of inflation volatility on the level of inflation for each country is captured via the GARCH-in-mean effect by the coefficients β_{1h} and β_{2h}. The β_1 matrix in the conditional mean equation is written so that only single lags with respect to π_1 and π_2 are allowed for but additional lags are included during the estimation of the GARCH models. The coefficient estimates in the conditional mean equation can be interpreted as follows. First, a significant estimate for β_1 for the lagged domestic inflation π_1 indicates evidence of the existence of inflation inertia. The coefficient of lagged domestic inflation allows one to evaluate whether a stronger anti-inflationary policy lowers inflation inertia (Taylor, 2000) and it serves as another channel through which IT may lower long-run exchange rate pass-through (Edwards, 2006). In addition, the estimate for the lagged foreign inflation β_1 captures its linkage to domestic inflation and a significant coefficient estimate may reflect evidence of interdependencies.

Second, the inflation target level variable IT_t is included to study the importance of IT in the transmission of inflation shocks and to test the IT credibility hypothesis in line with Carrasco and Ferreiro (2013) and Taylor (2000). In this case, the β_3 coefficient estimate of IT_t is expected to be negative and statistically significant if an IT regime is credible. Third, the natural log of nominal exchange rate captures its impact on domestic inflation via the pre-IT short run pass-through given by the coefficient δ_i, which is expected to be positive. Finally, the interaction term between $\Delta\ln E_{t-1}$ and DIT_t allows the coefficient γ_l during the post-IT period to be different from the pre-IT coefficient. The estimate for γ_l should be negative and significant according to Taylor's (2000) hypothesis.

The conditional variance is expressed as a function of its own history, past innovations and the *DIT* dummy variable. In this specification, the element a_{21} in matrix A captures the effect of shock from foreign inflation on domestic inflation. The element b_{21} in matrix B captures how much foreign inflation volatility affects domestic inflation volatility. The parameters a_{11} and b_{11} respectively reflect the impact of past innovations and lagged variances on current conditional variances. Specifically, a_{11} shows the extent to which a shock to a home country's inflation affects current variances while b_{11} shows how much levels of persistence in inflation volatility influence current variances. The coefficient estimate for *DIT* reflects the role of IT adoption in the volatility dynamics of domestic and foreign inflation (d_{11} and d_{22}), and their covariances (d_{21}).

To identify the parameters, Engle and Kroner's (1995) standard (general) BEKK specification expresses *C* as a higher triangular matrix. The symmetry and non-negative definiteness of the conditional variance matrix H_t, where the variances are functions of their own histories and past innovations, is assured because of paired matrices. Engle and Kroner (1995) also point out that the condition for covariance stationarity, which ensures that shocks to volatility decay over time, is necessary and sufficient if the sum of the estimated parameters $a_{ii}a_{jj} + b_{ii}b_{jj}$ is less than unity. The estimation method applies the ML technique, which assumes normally distributed errors over the sample and maximises the conditional log-likelihood function:

$$L(\Theta) = \sum_{t=1}^{T} L_t(\Theta) \quad \text{with} \quad L_t(\Theta) = -\frac{N}{2}(2\pi) - \frac{1}{2}(\ln|H_t|) - \frac{1}{2}\ln\varepsilon_t' H_t^{-1}\varepsilon_t \qquad (4.11)$$

where Θ is the vector of unknown parameters in the conditional means and the estimated elements of the *C*, *A* and *B* matrices that specify the conditional variances.

In this thesis, a series of bivariate BEKK-MGARCH models are estimated for each country with respect to the U.S. and Japan. In addition to the parameters included in the mean equations, there are 11 parameters that need to be estimated in the estimation of the variance part of the system, which can be expanded according to the following equations:

$$\begin{aligned} h_{11t} = {} & a_{11}(a_{11}\varepsilon_{1t-1}^2 + a_{21}\varepsilon_{1t-1}\varepsilon_{2t-1}) + a_{21}(a_{11}\varepsilon_{1t-1}\varepsilon_{2t-1} + a_{21}\varepsilon_{2t-1}^2) \\ & + b_{11}(b_{11}h_{11t-1} + b_{21}h_{21t-1}) + b_{21}(b_{11}h_{12t-1} + b_{21}h_{22t-1}) + c_{11}^2 \end{aligned} \qquad (4.12)$$

$$\begin{aligned} h_{22t} = {} & a_{12}(a_{12}\varepsilon_{1t-1}^2 + a_{22}\varepsilon_{1t-1}\varepsilon_{2t-1}) + a_{22}(a_{12}\varepsilon_{1t-1}\varepsilon_{2t-1} + a_{22}\varepsilon_{2t-1}^2) \\ & + b_{12}(b_{12}h_{11t-1} + b_{22}h_{21t-1}) + b_{22}(b_{12}h_{12t-1} + b_{22}h_{22t-1}) + c_{12}^2 + c_{22}^2 \end{aligned} \qquad (4.13)$$

$$\begin{aligned} h_{12t} = {} & a_{12}(a_{11}\varepsilon_{1t-1}^2 + a_{21}\varepsilon_{1t-1}\varepsilon_{2t-1}) + a_{22}(a_{11}\varepsilon_{1t-1}\varepsilon_{2t-1} + a_{21}\varepsilon_{2t-1}^2) \\ & + b_{12}(b_{11}h_{11t-1} + b_{21}h_{21t-1}) + b_{22}(b_{11}h_{12t-1} + b_{21}h_{22t-1}) + c_{11}c_{12} \end{aligned} \qquad (4.14)$$

where $h_{12t} = h_{21t}$. The coefficients a_{12}, a_{21}, b_{11} and b_{21} in the conditional variance-covariance equations capture volatility transmission between π_1 and π_2 in the general BEKK model. Within this multivariate model, the existence of international volatility transfer can be manifested via several channels based on the influence of innovations ε^2_{1t-1} and ε^2_{2t-1} on h_{11t}, h_{22t} and h_{12t}. Following Holmes and Pentecost (2006), Table 4.1 illustrates these multiple channels of international volatility transfers. Channel 1 demonstrates that the effect on h_{11t} of an innovation ε^2_{2t-1} occurring in π_2 in period *t-2* can take place directly through h_{11t-1}.

Table 4.1: International Volatility Transfer, BEKK-MGARCH Model

Channel	Volatility Transmission Mechanism
1	$\varepsilon^2_{2t-2} \xrightarrow{a^2_{21}\neq 0} h_{11t-1}$
2	$\varepsilon^2_{2t-2} \xrightarrow{a^2_{22}\neq 0} h_{22t-1} \xrightarrow{b^2_{21}\neq 0} h_{11t}$
3	$\varepsilon^2_{2t-2} \xrightarrow{a_{21},a_{22}\neq 0} h_{12t-1} \xrightarrow{b_{11},b_{21}\neq 0} h_{11t}$
4	$\varepsilon^2_{2t-2} \xrightarrow{a_{21},a_{22}\neq 0} h_{21t-1} \xrightarrow{b_{11},b_{21}\neq 0} h_{11t}$
5	$\varepsilon^2_{1t-2} \xrightarrow{a^2_{12}\neq 0} h_{22t-1}$
6	$\varepsilon^2_{1t-2} \xrightarrow{a^2_{11}\neq 0} h_{11t-1} \xrightarrow{b^2_{12}\neq 0} h_{22t}$
7	$\varepsilon^2_{1t-2} \xrightarrow{a_{12},a_{11}\neq 0} h_{12t-1} \xrightarrow{b_{22},b_{12}\neq 0} h_{22t}$
8	$\varepsilon^2_{1t-2} \xrightarrow{a_{12},a_{11}\neq 0} h_{21t-1} \xrightarrow{b_{22},b_{12}\neq 0} h_{22t}$

Notes: The transmission channels shown here are based on Equations 4.12, 4.13 and 4.14.

Next, channel 2 shows that an indirect effect might occur either through the variance of h_{22t-1} and later h_{11t}, or via the covariance h_{12t-1}, as the model allows for conditions of contemporaneous interdependency, which are not identified *a priori*. The same reasoning applies for channel 3, which also captures an indirect effect through h_{11t}. Channels 5, 6 and 7 reflect direct and indirect channels through which ε^2_{1t-1} can influence h_{22t}. These channels consider the international volatility transmission towards π_2. The extreme case, under which volatility transfer occurs through each of these channels, is if all *a* and *b* coefficients are statistically significant. In contrast, volatility transmission in both directions is ruled out if $a_{12} = a_{21} = b_{12} = b_{21} = 0$. As for the volatility transmission from π_2, the coefficients a_{12} and b_{22} provide indications of whether ε_{2t-1}^2 ultimately influences h_{11t} through either h_{11t-1}, h_{22t-1} or both h_{11t-1} and h_{22t-1}.

The conditional covariance h_{12t} can be used to estimate the *dynamic correlation coefficient*, which enables evaluation of how the relationship between π_1 and π_2 changes over time depending on the dynamics of conditional covariance and volatility transfer. Using the appropriate elements of the variance-covariance matrix, the conditional correlation can be calculated using the following formula:

$$\rho_{12t} = \frac{h_{12t}}{\sqrt{h_{11t}}\sqrt{h_{22t}}} \tag{4.15}$$

where $|\rho_{12t}| \leq 1$. This measure of conditional correlation is a time-varying parameter that is different from the conventional scalar correlation estimate. There are two interpretations for the values of this conditional correlation. Firstly, when the estimated correlation is close to one, it implies that countries experience similar unanticipated fluctuations in inflation rates that might respond in the same direction to some common shock. Secondly, negative correlation values indicate that countries experience dissimilar unexpected fluctuations in inflation rates that might respond in opposite ways to some common shock.

4.3.2.2 Panel GARCH Model

The goal of this chapter is to investigate whether an IT regime is credible in terms of lowering the level and volatility of inflation over the sample period and across a panel of countries. In addressing this issue, the main contribution of this study is the extension of GARCH methodology, as described in the previous subsection, to panel data. Specifically, this chapter builds on the panel GARCH model suggested by Cermeño and Grier (2006).[3] The empirical specification of the conditional mean inflation rate for cross-sections of N countries and T periods corresponds to the following dynamic panel model with fixed effects:

$$\pi_{it} = \mu_i + \sum_{j=1}^{12} \beta_k \pi_{it-j} + \beta_{13} IT_t^{\mathrm{Id}} + \beta_{14} IT_t^{\mathrm{Ph}} + \beta_{15} IT_t^{\mathrm{Kor}} + \beta_{16} IT_t^{\mathrm{Th}} + \varepsilon_{it}, \quad (4.16)$$

$i = 1, \dots, N;\ t = 1, \dots, T$, where i refers to a specific country and t refers to a given time period. Id, Ph, Kor and Th denote the Asian IT countries included in the sample namely, Indonesia, the Philippines, South Korea and Thailand, respectively. Altogether, 8 countries are included in the panel GARCH analysis. The variable IT_t is an indicator function taking the actual inflation target level if $t \geq s_t$, and zero otherwise, with s_t being a known start date for adopting IT. To construct s_t, this study follows Leyva (2008) in applying the "half-year rule" which states that if IT is adopted in the second half of year t, the adoption year is (t + 1); otherwise the adoption year is t. For this purpose, s_t is 1998M4, 2000M5, 2002M1 and 2005M7 for South Korea, Thailand, the Philippines and Indonesia, respectively.

The term μ_i captures possible time-invariant effects associated with inflation rates, and ε_{it} is a disturbance term with the following conditional moments:

$$E\left[\varepsilon_{it}\varepsilon_{js} | \varepsilon_{it-1}, \varepsilon_{js-1}\right] = 0 \qquad \text{for } i \neq j \text{ and } t \neq s, \quad (4.17)$$

$$E\left[\varepsilon_{it}\varepsilon_{js} | \varepsilon_{it-1}, \varepsilon_{js-1}\right] = 0 \qquad \text{for } i = j \text{ and } t \neq s, \quad (4.18)$$

$$E\left[\varepsilon_{it}\varepsilon_{js} | \varepsilon_{it-1}, \varepsilon_{js-1}\right] = \sigma_{ij,t}^2 \qquad \text{for } i \neq j \text{ and } t = s, \quad (4.19)$$

$$E\left[\varepsilon_{it}\varepsilon_{js} | \varepsilon_{it-1}, \varepsilon_{js-1}\right] = \sigma_{it}^2 \qquad \text{for } i = j \text{ and } t = s. \quad (4.20)$$

[3] The panel-GARCH methodology has been recently used, among others, by Cermeño et al. (2010), Cermeño and Sanin (2015), Drakos and Konstantinou (2013), Escobari and Lee (2014), Goulas and Zervoyianni (2013), Lee (2010b), Lee and Valera (2016), Valera et al. (2016).

The first condition in Equation 4.17 assumes no non-contemporaneous cross-sectional correlation. The second condition in Equation 4.18 assumes no autocorrelation. The general conditions of the conditional variance-covariance process are defined in the third (Equation 4.19) and fourth (Equation 4.20) assumptions. To make the estimation more feasible, those four assumptions follow diagonal VECH parameterization, which reduces the total number of free parameters. The conditional variance and covariance processes of ε_{it} are assumed to follow a GARCH(1,1) process, mainly because of its popularity and parsimony:

$$\sigma_{it}^2 = \alpha_i + \delta\, \sigma_{i,t-1}^2 + \gamma\varepsilon_{i,t-1}^2 + \phi_1 IT_t^{\text{Id}} + \phi_2 IT_t^{\text{Ph}} + \phi_3 IT_t^{\text{Kor}} + \phi_4 IT_t^{\text{Th}},\ i = 1,\ldots, N, \qquad (4.21)$$

$$\sigma_{ijt} = \eta_{ij} + \lambda\sigma_{ij,t-1} + \rho\varepsilon_{i,t-1}\varepsilon_{j,t-1},\ i \neq j. \qquad (4.22)$$

Using matrix notation, Equation 4.16 can be written as:

$$\boldsymbol{\pi}_t = \boldsymbol{\mu} + \mathbf{z}_t\boldsymbol{B} + \boldsymbol{\varepsilon}_t, \qquad (4.23)$$

where $\boldsymbol{\pi}_t$ and $\boldsymbol{\varepsilon}_t$ are $N \times 1$ vectors, $\boldsymbol{\mu}$ is the corresponding $N \times 1$ vector of individual-specific effects, and $\mathbf{z}_t = [\pi_{t-1} \ldots \vdots\ \mathbf{x}_t]$ is a matrix with corresponding coefficients in $\boldsymbol{B} = [\Phi_k \ldots \vdots\ \beta']'$. The disturbance term $\boldsymbol{\varepsilon}_t$ has a multivariate normal distribution, denoted as $\boldsymbol{\varepsilon}_t \sim N(\mathbf{0}, \boldsymbol{\Omega}_t)$. The covariance matrix $\boldsymbol{\Omega}_t$ is time-dependent and Equations 4.21 and 4.22 respectively give its diagonal and off-diagonal elements. Specifically, variance-covariance matrix $\boldsymbol{\Omega}_t$ is an 8×8 symmetric matrix that is positive definite for all periods *t*. The 8 diagonal elements of $\boldsymbol{\Omega}_t$ (i.e. the σ_{it}^2) are given in Equation 4.21 and the 28 unique off-diagonal elements (the σ_{ijt}) are given in Equation 4.22. The covariance specification follows Bollerslev (1990). This allows for country-specific unconditional error variances and time-varying conditional cross-sectional dependence. Because the disturbance term $\boldsymbol{\varepsilon}_t$ is conditionally heteroscedastic and cross-sectionally correlated, the least-squares estimator for this model is no longer efficient but it is still consistent. As in Cermeño and Grier (2006), this problem is resolved by adopting the ML method. The log-likelihood function for the complete panel is given by:

$$L = -\frac{1}{2}\Bigg\{NT\ln(2\Pi) + \sum_{t=1}^{T} \ln|\boldsymbol{\Omega}_t| + \sum_{t=1}^{T}[(\boldsymbol{\pi}_t - \boldsymbol{\mu} - \mathbf{z}_t\boldsymbol{B})' \times \boldsymbol{\Omega}_t^{-1}((\boldsymbol{\pi}_t - \boldsymbol{\mu} - \mathbf{z}_t\boldsymbol{B})]\Bigg\} \qquad (4.24)$$

In this study, numerical methods are used to estimate the panel GARCH model based on direct maximization of this function.[4] The variance-covariance matrix of the estimated parameters is approximated by the negative inverse of the Hessian of *L* evaluated at the ML estimates.

The conditional covariance σ_{ijt}, which is the conditional covariance between country *i* and *j* at time *t*, can be used in estimating the *panel dynamic correlation coefficient*. This enables evaluation of how the relationship between π_{it} and π_{jt} changes over time, depending on the dynamics of conditional covariance and volatility transmission. Using the appropriate elements of the variance-covariance matrix, the conditional correlation for the panel of four IT and four non-IT countries can be calculated using the following formula:

$$\tilde{\rho}_{ijt} = \sum_{i=1}^{4} \rho_{ijt} \qquad (4.25)$$

where $\rho_{ijt} = \frac{\sigma_{ijt}}{\sqrt{\sigma_{iit}}\sqrt{\sigma_{jjt}}}$ and $|\rho_{ijt}| \leq 1$. Estimated values of ρ_{ijt} close to one (zero) imply that countries experience similar (dissimilar) unanticipated fluctuations in inflation rates that might result from some common shocks.

[4] The programs are written in RATS. The Broyden, Fletcher, Goldfarb, Shanno (BFGS) algorithm is used in the estimation process (see Broyden 1965, 1967; Fletcher & Powell, 1963).

4.4 Empirical Evidence

The regressions in this section begin with the bivariate MGARCH model for the eight individual Asian countries. This is followed by regression with balanced panel data for the eight countries. The MGARCH model is estimated first to motivate the application of a panel GARCH framework outlined in Section 4.3. As emphasized by Cermeño and Grier (2006) and Lee (2010b), there is a potential efficiency gain in the estimation of conditional variance and covariances when GARCH estimation also incorporates interdependence across different countries. Moreover, the MGARCH model is estimated at the beginning to provide different perspectives on the investigation of the IT credibility hypothesis. As explained in Section 4.3, for example, the interaction between lagged nominal exchange rate and IT dummy variable is considered in the MGARCH model to interpret IT credibility in line with Taylor's (2000) hypothesis.

4.4.1 Unconditional Distribution of Inflation Rates

Prior to the estimation of the MGARCH modelling of inflation, it is important to note that the distribution of inflation series significantly departs from normality as stated in Chapter 3. To corroborate this finding, Table 4.2 reports the Ljung-Box (LB) *Q* statistics that are computed for each series and each squared series (LB^2) with a fourth and eighth order autoregressive lag. The LB statistics are significant at the 1% level, suggesting that there is evidence of higher moment dependencies that may be attributed to the presence of ARCH effects and volatility clustering in the inflation rate series.

Table 4.2: Ljung-Box Q-statistics for Inflation

Country	LB(4)	LB(8)	$LB^2(4)$	$LB^2(8)$
Indonesia	1058.355(0.000)	1466.905(0.000)	1008.490(0.000)	1308.783(0.000)
Philippines	1102.518(0.000)	1764.396(0.000)	1081.796(0.000)	1677.797(0.000)
South Korea	1043.591(0.000)	1700.815(0.000)	1016.874(0.000)	1672.196(0.000)
Thailand	960.364(0.000)	1327.865(0.000)	871.657(0.000)	1162.790(0.000)
China	1198.772(0.000)	2081.350(0.000)	1123.795(0.000)	1761.896(0.000)
Hong Kong	1240.451(0.000)	2379.407(0.000)	1215.401(0.000)	2314.865(0.000)
Malaysia	868.039(0.000)	1133.893(0.000)	749.867(0.000)	890.000(0.000)
Singapore	1045.217(0.000)	1599.783(0.000)	1001.142(0.000)	1463.396(0.000)

Notes: The values in parentheses are the *p*-values. The diagnostic tests include Ljung-Box Q-statistics, denoted by LB and LB^2, which test for linear and non-linear dependencies in each series and then in each squared series.

4.4.2 Unit Root Tests and ARCH Effects

The first stage of MGARCH modelling is to test for stationarity of the inflation series and determine whether ARCH effects are present in the data. The estimation of the MGARCH model of inflation requires that the series are stationary. As discussed in Chapter 3, the results for univariate unit testing indicate that all the tests are consistent in rejecting the unit root null under the specification with intercept, and conclude that the inflation rate series is $I(0)$ except for Hong Kong. This means that the inflation rates are stationary in levels and therefore these series are employed in the estimation of MGARCH model. In the case of Hong Kong, the inflation rates are stationary after first-differencing and thus these stationary series are used in the MGARCH estimation. The ADF, PP and DFGLS tests are also conducted for nominal exchange rates. The results presented in Table 4.3 show that the unit root null is rejected for all countries, mostly at the 1% significance level. Hence, the nominal exchange rate series are stationary in levels and the MGARCH estimations are performed on these stationary series.

Table 4.3: Unit Root Tests for Nominal Exchange Rate

Country	ADF		PP		DF-GLS	
	No trend	With Trend	No trend	With Trend	No trend	With Trend
Indonesia	-5.575***	-5.572***	-13.667***	-13.648***	-4.887***	-5.329***
Philippines	-7.200***	-7.302***	-11.646***	-11.716***	-6.803***	-6.956***
South Korea	-9.519***	-9.504***	-10.916***	-10.899***	-9.053***	-9.388***
Thailand	-5.770***	-5.799***	-12.136***	-12.129***	-4.427***	-5.145***
China	-11.998***	-12.348***	-16.253***	-16.563***	-11.97***	-12.056***
Hong Kong	-11.319***	-11.302***	-16.018***	-15.992***	-2.510**	-4.768***
Malaysia	-8.132***	-8.168***	-13.792***	-13.793***	-6.688***	-7.474***
Singapore	-9.617***	-9.608***	-13.081***	-13.064***	-4.802**	-7.330***

Notes: The values in parentheses are the *p*-values. *** and ** denote rejection of the non-stationary null at the 1% and 5% level, respectively.

Next, Table 4.4 provides supporting evidence for the use of a GARCH-type modelling of inflation rates. The table shows the *F*-test for ARCH effects and the computation of nR^2 in the regressions of the level of inflation on twelve autoregressive lags. The results show that the null of no ARCH effects is rejected since the *p*-values of *F*-statistic and nR^2 are significant at the 1% level throughout. This means that both test statistics provide strong evidence of conditional heteroscedasticity in the variance of inflation, pointing towards volatility clustering and ARCH effects within the data. Evidence of ARCH effects supports the MGARCH estimation of inflation rates.

Table 4.4: ARCH Effects Test Before MGARCH(1,1) Estimation

Country	F-statistic	Obs*R-squared
Indonesia	1588.202(0.000)	306.212
Philippines	369.677(0.000)	291.423
South Korea	216.789(0.000)	279.036
Thailand	103.466(0.000)	250.804
China	1380.252(0.000)	305.503
Hong Kong	274.803(0.000)	285.225
Malaysia	134.651(0.000)	262.574
Singapore	169.142(0.000)	271.185
Japan	144.574(0.000)	265.411
U.S.	194.806(0.000)	275.837

Note: Figures in parentheses are *p*-values.

4.4.3 BEKK-MGARCH Estimates

An important contribution of this subsection is the investigation of the IT credibility hypothesis following Carrasco and Ferreiro (2013) and Taylor (2000). As mentioned earlier, the interactions between each of the eight Asian countries' inflation data and U.S. or Japanese inflation are modelled using a popular MGARCH(1,1) specification. Table 4.5 reports the MGARCH conditional mean results for IT countries. The results are based on Newey-West HAC standard errors.

The analysis focuses first on the effects of foreign inflation, which provides a perspective of inflation interdependencies. Nearly all estimates for lagged U.S inflation are significant at the 1% level for all IT countries. The estimates for Japan's past inflation are significant up to two lags, mostly at the 5% level or better. This suggests that inflation in IT countries tends to depend on past U.S. or Japanese inflation. In addition, the majority of the estimates for lagged dependent variables are significant at the 1% level for all IT countries. The negative estimates suggest that a stronger anti-inflationary policy lowers inflation inertia (Taylor, 2000).

Next, the results show that the impact of inflation volatility on inflation rate is significant in only two cases. For example, the coefficient estimate for β_{1h} is positive and significant at the 1% level for South Korea relative to the U.S. This indicates that an increase in volatility is likely to drive inflation higher, which is in line with the Cukierman-Meltzer (1986, 1992) hypothesis that inflation volatility increases mean inflation. Moreover, the coefficient estimate for β_{1h} is negative and significant at the 10% level for the Indonesia-Japan country pair. This finding is in line with Holland's (1995) argument that if inflation uncertainty has harmful real effects and if higher average inflation raises uncertainty, then the central bank has a stabilization motive to lower uncertainty by reducing average inflation.

Table 4.5 also reveals that the coefficient estimate for $\Delta\ln E_t$ is positive and significant at the 1% level for South Korean inflation relative to the U.S. In contrast, the estimated value of $\Delta\ln E_t$ is negative and significant at the 1% level for the South Korea-Japan pairing. Likewise, the coefficient estimates for $\Delta\ln E_t$ are negative and significant at the 10% level for Indonesia and Thailand relative to Japan. The deflation phenomenon in Japan may explain the negative influence of nominal exchange rate on inflation that is exerted via the short-run pass-through effect when firms perceive the rise in import prices as temporary. In sum, the results suggest that the effects of contemporaneous nominal exchange rate relative to the Japanese yen are more relevant for most IT countries than is the case for the U.S. dollar.

The main coefficients of interest in Table 4.5 are the estimates for IT and the interaction term $\Delta \ln E_{t-1}$ x DIT. The estimated values of *IT* are negative for all IT countries. However, the impact of *IT* is significant only for Thailand at the 10% level with respect to the U.S. With Japan as the base county, *IT* is significant at the 5% and 10% levels for the Philippines and South Korea, respectively. The negative estimates are consistent with the hypothesis that a credible IT regime keeps the absolute difference between actual inflation and its target to a minimum.

The estimates for the interaction term $\Delta \ln E_{t-1}$ x *DIT* are mostly negative in each of the bivariate country-pair models relative to the U.S. However, the effect is only significant at the 10% level for South Korea, which is supportive of Taylor's (2000) hypothesis that a low inflationary environment leads to a decline in exchange rate pass-through and suggests that IT lowers the inflation rate by means of reduced pass-through during the post-IT period. This empirical finding also corroborates the findings of Prasertnukul et al. (2010) who report evidence of reduced pass-through during the post-IT period for South Korea.

In comparison, Table 4.6 reports the MGARCH conditional mean results for non-IT countries. The lagged values of U.S. inflation are significant at the 5% level or better for most non-IT countries. The lagged values of Japanese inflation are significant for China, Singapore and Malaysia. Those findings are also indicative of interdependencies between the U.S. or Japan and these non-IT countries. The estimates for β_{1h} are insignificant, which suggests that an increase in inflation volatility is not likely to influence the mean inflation for non-IT countries.

Table 4.5: MGARCH Mean Equation, IT Countries

	Indonesia-US	Philippines-US	South Korea-US	Thailand-US	Japan-Indonesia	Japan-Philippines	Japan-South Korea	Japan-Thailand
k_1	0.308**	0.358**	0.048	0.209**	0.540***	0.352**	0.230***	0.187**
β_{11}	1.380***	1.211***	1.165***	1.122***	1.288***	1.198***	1.204***	1.123***
β_{12}	-0.496***	-0.021	-0.411***	-0.200***	-0.379***	0.027	-0.426***	-0.186***
β_{13}	0.183***	-0.231***	0.210***	0.211***	0.023	-0.271***	0.173***	0.187***
β_{1h}	-0.065	-0.115	0.597***	-0.034	-0.041*	0.014	0.116	-0.002
IT	-0.001	-0.053	-0.003	-0.057*	-0.013	-0.039*	-0.028**	-0.034
$\Delta\ln E_t$	0.023	-0.005	0.048***	0.019	-0.025*	0.006	-0.038***	-0.016*
$\Delta\ln E_{t-1}$	0.071***	0.016	0.015	0.013	-0.005	-0.004	-0.016*	-0.001
$\Delta\ln E_{t-2}$	0.025	0.038	0.036***	0.007	-0.029***	-0.014	-0.028**	-0.006
$\Delta\ln E_t$ x DIT	0.008	0.022	-0.027*	0.023	0.013	-0.010	0.029**	0.004
$\Delta\ln E_{t-1}$ x DIT	-0.041	-0.002	-0.006	0.002	-0.004	-0.020	0.009	0.001
$\Delta\ln E_{t-2}$ x DIT	-0.017	-0.087**	-0.018	-0.047	0.020	0.037	0.020	-0.014
k_2	0.095**	0.120***	0.039*	0.047	0.059	0.027	-0.024	0.029
β_{21}	1.240***	1.237***	1.178***	1.301***	1.114***	1.037***	1.137***	1.179***
β_{22}	-0.417***	-0.410***	-0.279***	-0.460***	-0.138**	-0.102*	-0.193**	-0.184***
β_{23}	0.141***	0.258***	0.080	0.135**	-0.020	0.009	0.009	-0.028
β_{2h}	-0.021	-0.127	0.023	0.091	0.140	0.049	0.429	-0.187**

Notes: Lag lengths are determined according to the AIC. ***, ** and * denote significance at the 1, 5 and 10% levels of the BEKK-MGARCH coefficients.

Table 4.6: MGARCH Mean Equation, Non-IT Countries

	China-US	Hong Kong-US	Malaysia-US	Singapore-US	Japan-China	Japan-Hong Kong	Japan-Malaysia	Japan-Singapore
k_1	0.002	0.007	0.215***	0.187**	0.002	0.041	0.267***	0.14***
β_{11}	1.297***	-0.237***	1.053***	0.967***	1.297***	-0.237***	1.04***	1.016***
β_{12}	-0.066	-0.001	-0.022	-0.048	-0.066	-0.019	-0.026	-0.086
β_{13}	-0.248***	-0.058	-0.074	0.174**	-0.248***	-0.042	-0.075	0.165*
β_{1h}	0.123	-0.007	-0.004	-0.613	0.123	-0.029	-0.039	-0.159
$\Delta\ln E_t$	-0.02**	0.134	-0.005	0.01	-0.02**	0.004	0.006	0.003
$\Delta\ln E_{t-1}$	0.026*	0.33	0.01	-0.029**	0.026*	0.004	-0.004	0.021**
$\Delta\ln E_{t-2}$	-0.034***	0.088	-0.009	0.009	-0.034***	0.011	0.002	-0.008
k_2	0.052	-0.014	0.151	0.095	0.052	0.11*	0.162*	-0.042
β_{21}	1.258***	0.219***	1.191***	1.214***	1.258***	0.052	1.028***	1.069***
β_{22}	-0.407***	-0.219***	-0.405***	-0.435***	-0.407***	-0.028	-0.087	-0.131**
β_{23}	0.129**	0.051	0.3***	0.191**	0.129**	-0.082	-0.057	-0.031
β_{2h}	-0.037	0.025	-0.091	-0.04	-0.037	-0.813	-1.134*	0.739

Notes: Lag lengths are determined according to the AIC. ***, ** and * denote significance at the 1, 5 and 10% levels of the BEKK-MGARCH coefficients.

Table 4.6 further shows that the estimates for the first lagged values of inflation are mostly positive and significant at the 1% level relative to U.S. and Japanese inflation. The positive estimates of past inflation may indicate an increase in domestic inflation inertia. Meanwhile, the estimates for $\Delta \ln E_t$ are only significant in the case of China relative to the U.S. and Japan. Clearly, the effect of contemporaneous nominal exchange rate is less evident for non-IT countries.

Tables 4.7 and 4.8 report the results of the variance-covariance estimates for IT and non-IT countries, respectively. Table 4.7 shows that the estimates for a_{11} are positive and significant at the 1% level for the Indonesia-U.S. pair and at the 5% level for the Philippines-Japan pair. The statistical significance of a_{11} implies the presence of strong persistence of inflation volatility. The positive estimate for a_{11} suggests that past innovations will tend to increase the current conditional variance. For the parameter b_{11}, the estimates are positively and negatively significant for the South Korea-U.S and Thailand-U.S./Japan pairs, respectively. The positive estimate for b_{11} indicates that past volatilities lower current conditional variances.

In the case of non-IT countries, Table 4.8 shows that the estimates for a_{11} are positive and significant for the China-U.S./Japan, Hong Kong-U.S./Japan and Singapore-Japan pairs. The estimate for a_{11} for the Malaysia-Japan pairing is negative and significant at the 5% level. Table 4.8 also shows that the estimates for b_{11} are positive and significant at the 10% level or better for Hong Kong, Malaysia and Singapore relative to Japan. Overall, volatility clustering is more evident for non-IT countries, as shown by the statistical significance of the b_{11} estimate.

Evidence of volatility clustering can be also confirmed by the statistical significance of b_{22}. In the case of IT countries, the estimates for b_{22} are significant at the 1% level for South Korea and Thailand relative to the U.S. Additionally, the estimates for b_{22} are significant at the 5% level for Indonesia and South Korea relative to Japan. For non-IT countries, the estimates for b_{22} are mostly significant at the 5% level or better with respect to the U.S. and Japan.

More importantly, Table 4.7 reports the estimates for IT dummy variables. The results show that the estimates for IT are negative and significant at the 5% level or better for most Asian IT countries relative to the U.S. or Japan. The only exception is the insignificant negative effect of IT on the conditional variance for the South Korea-Japan pair. Finding negative impacts of IT on conditional variance is in line with the IT credibility hypothesis. Those findings also concur with the evidence of lower conditional variance of inflation after the adoption of IT (Tas, 2012; Tas & Ertugrul, 2013). These previous studies are based on a univariate GARCH model, which does not explicitly account for the volatility transmission of foreign inflation. Thus, the MGARCH estimation results address the gap in the literature by capturing the impact of IT on the conditional variance of inflation while accounting for inflation volatility transmission from the U.S. or Japan.

Tables 4.7 and 4.8 also provide an overall test statistic for inflation volatility transfers based on the null $a_{12} = a_{21} = b_{12} = b_{21} = 0$. This null is strongly rejected in most cases at the 1% level. This indicates the presence of inflation volatility transfer between the U.S. or Japan and each of the sample countries regardless which of the channels highlighted in Table 4.1 are being considered. The linkage of the Asian sample countries to the U.S. or Japan in terms of inflation volatility transmission is consistent with their economic and financial integration.

Table 4.9 displays the results from the quantification of inflation volatility transmission. The majority of the tests for bi-directional volatility transmission for all the parameters associated with each channel are significantly different from zero at the 1% level, in at least seven alternative channels for all sample countries. This means that inflation volatility transmission is bi-directional where ε_2^2 influences h_{11} directly, while ε_1^2 affects h_{22} indirectly through h_{11}. In short, there is a bi-directional volatility transfer where inflation innovations originating in one country affect volatility in another country.

Given the evidence of inflation volatility transmission from the U.S. and/or Japan, another important issue to examine is the dynamic conditional correlation of unanticipated fluctuations in inflation. Figure 4.1 shows the evolution of the conditional correlation between the corresponding inflation volatilities, ρ_{12}, in the base and home countries. The figure exhibits a fluctuating correlation, which tends to become positive for the Philippines, South Korea and Thailand after the adoption of IT. In the case of the Philippines, the conditional correlation estimates are positive over the study period. The positive conditional correlation estimates imply that the central banks in these countries similarly respond to common macroeconomic shocks that potentially link to U.S. inflation. While the dynamic correlation coefficient for Indonesia generally exhibits higher positive values, there also some negative values following the adoption of IT in 2005.

The dynamic correlation coefficient for Indonesia, South Korea and Thailand also experienced large, positive spikes during the Asian crisis, reflecting common shocks to inflation. Another important pattern that the dynamic correlation coefficient reveals is that it tends to increase most of the time in the Philippines, South Korea and Thailand in 2009 and 2010. This pattern suggests that the conditional correlation of unanticipated fluctuations in inflation is positively associated with the global financial crisis.

Table 4.7: MGARCH Variance-Covariance Equations, IT Countries

	Indonesia-US	Philippines-US	South Korea-US	Thailand-US	Japan-Indonesia	Japan-Philippines	Japan-South Korea	Japan-Thailand
c_{11}	0.710***	0.814***	0.090**	0.398***	0.496***	0.599***	0.342***	0.489***
c_{12}	-0.004	0.008	-0.181***	-0.037	0.066	0.093***	0.228***	-0.023
c_{22}	0.233***	0.186***	0.000	0.182***	0.313***	-0.268***	0.183***	0.342***
a_{11}	0.384***	0.057	-0.106	-0.114	0.373***	0.241**	0.003	-0.052
a_{12}	0.04	0.141***	0.194***	0.084	-0.008	0.329***	0.049	0.258***
a_{21}	-0.118	0.049	0.239***	-0.138	0.723***	0.118	0.222	-0.08
a_{22}	0.404***	0.433***	0.357***	-0.082	0.246**	0.095	0.071	-0.205*
b_{11}	-0.061	-0.048	0.901***	-0.205**	0.088	-0.161	-0.066	-0.097**
b_{12}	0.040*	0.036	0.018	0.172***	-0.014	-0.079	0.096	-0.125*
b_{21}	-0.692**	0.664***	-0.648***	1.02***	-0.848*	-1.114***	0.641***	0.09
b_{22}	0.023	-0.008	-0.281***	0.385***	0.338**	0.197	-0.676***	0.004
IT_{11}	-0.082***	-0.135***	-0.045***	-0.208***	-0.036**	-0.096***	-0.012	-0.044**
IT_{12}	0.035	0.013	-0.057***	-0.001	0.015	-0.015	-0.006	0.017
IT_{22}	0.029**	0.039***	0.000	0.065***	-0.016	0.006	-0.061***	-0.05***
CHI(4)	0.049	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Notes: ***, ** and * denote significance at the 1, 5 and 10% levels of the BEKK-MGARCH coefficients. CHI(4) is the test for bi-directional volatility transmission based on the null $a_{12} = a_{21} = b_{12} = b_{12} = 0$. The figures reported CHI(4) test statistics are *p*-values.

Table 4.8: MGARCH Variance-Covariance Equations, Non-IT Countries

	China-US	Hong Kong-US	Malaysia-US	Singapore-US	Japan-China	Japan-Hong Kong	Japan-Malaysia	Japan-Singapore
c_{11}	0.646***	0.497***	0.281***	0.280***	0.646***	0.369***	-0.107**	0.365***
c_{12}	0.019	-0.007	-0.010	0.028	0.019	-0.130	-0.320***	0.035
c_{22}	-0.106**	0.225***	0.055	0.246***	-0.106**	0.169*	0.000	0.272***
a_{11}	0.257**	0.302***	-0.308	0.224	0.257**	0.330***	-0.225**	0.136*
a_{12}	-0.044**	0.058	0.088	-0.135**	-0.044**	-0.016	-0.039	-0.151***
a_{21}	0.304***	0.487***	0.235*	0.461***	0.304***	0.445	0.438***	-0.016
a_{22}	0.585***	0.268**	0.510*	0.058	0.585***	0.023	-0.124	0.154
b_{11}	0.038	-0.304***	0.227	0.504**	0.038	0.318***	0.266***	0.257*
b_{12}	-0.026	-0.049	-0.159	0.168	-0.026	-0.087***	0.018	-0.040
b_{21}	-0.148	0.167	0.155	-0.145*	-0.148	0.876***	-0.759***	0.023
b_{22}	0.766***	0.382**	0.845**	0.206	0.766***	0.728***	0.275**	-0.472**
CHI(4)	0.001	0.000	0.000	0.003	0.001	0.000	0.000	0.069

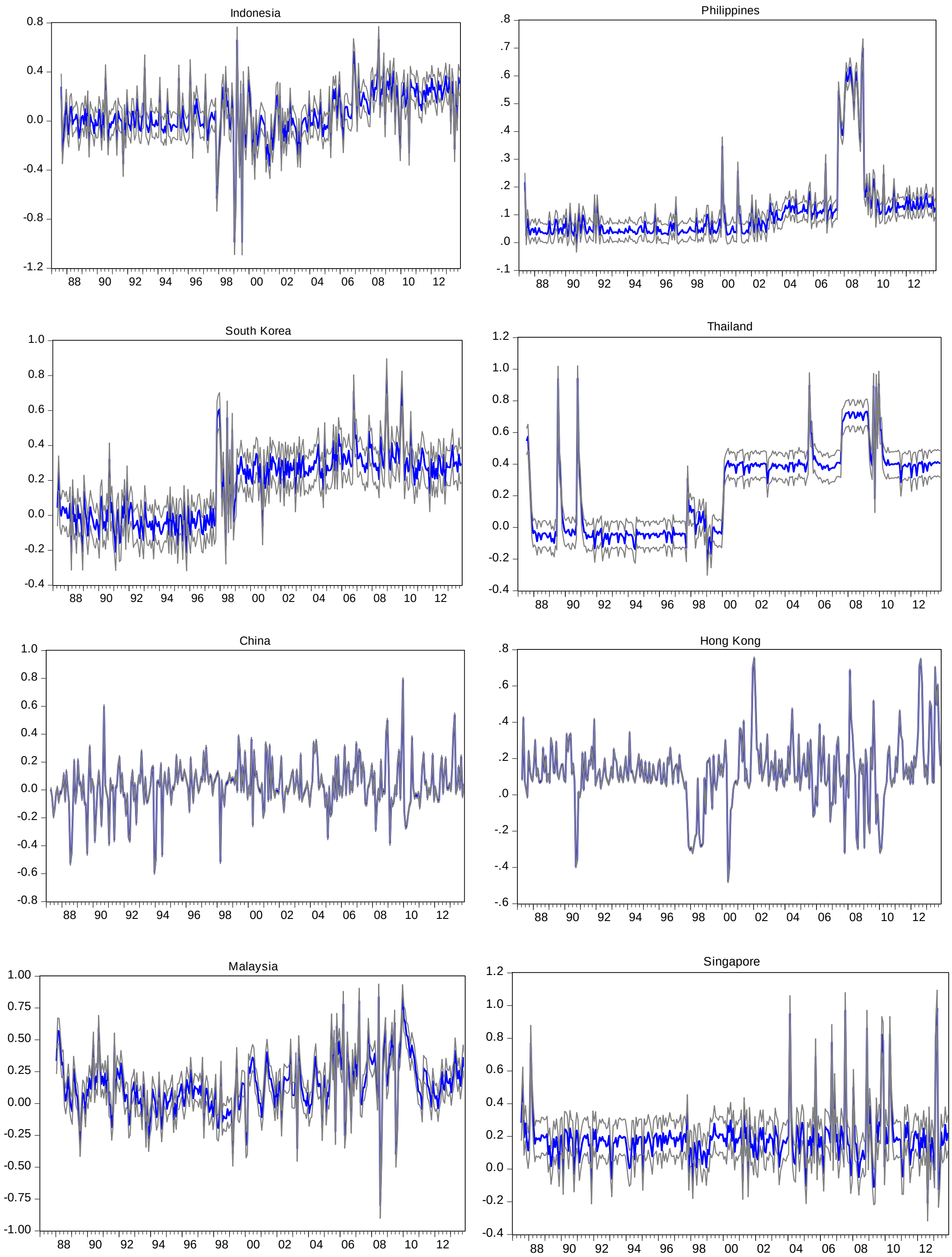
Notes: ***, ** and * denote significance at the 1, 5 and 10% levels of the BEKK-MGARCH coefficients. CHI(4) is the test for bi-directional volatility transmission based on the null $a_{12} = a_{21} = b_{12} = b_{12} = 0$. The figures reported CHI(4) test statistics are *p*-values.

Table 4.9: Quantification of Volatility Transfer

Channel	Indonesia-US	Philippines-US	South Korea-US	Thailand-US	Japan-Indonesia	Japan-Philippines	Japan-South Korea	Japan-Thailand
1	0.704	0.560	0.000***	0.174	0.001***	0.272	0.062*	0.732
2	0.000***	0.000***	0.000***	0.000***	0.000***	0.000***	0.000***	0.060*
3 & 4	0.000***	0.000***	0.000***	0.000***	0.000***	0.000***	0.000***	0.027**
5	0.302	0.002***	0.000***	0.224	0.023**	0.000***	0.412	0.000***
6	0.002***	0.868	0.336	0.002***	0.000***	0.017**	0.000***	0.038**
7 & 8	0.000***	0.000***	0.000***	0.000***	0.000***	0.000***	0.000***	0.000***
	China-US	Hong Kong-US	Malaysia-US	Singapore-US	Japan-China	Japan-Hong Kong	Japan-Malaysia	Japan-Singapore
1	0.001***	0.030**	0.099*	0.004***	0.645	0.053*	0.000***	0.657
2	0.000***	0.000***	0.088*	0.007***	0.215	0.004***	0.003***	0.269
3 & 4	0.000***	0.000***	0.000***	0.022**	0.358	0.001***	0.000***	0.197
5	0.025**	0.120	0.331	0.039**	0.051*	0.587	0.711	0.005***
6	0.019**	0.013**	0.034**	0.326	0.941	0.000***	0.000***	0.199
7 & 8	0.000***	0.000***	0.000***	0.001***	0.000***	0.000***	0.000***	0.021**

Notes: The column headed ‘Channel’ pertains to the volatility transmission mechanism highlighted in Table 4.1. Figures with ***, ** and * indicate that all parameters associated with each channel are significantly different from zero at the 1%, 5% and 10% significance level respectively based on the significance tests reported in Table 4.7 and Table 4.8.

Figure 4.1: BEKK-MGARCH Dynamic Conditional Correlation



Notes: The blue line represents the 95% confidence interval around the point estimates.

Asian non-IT countries also experienced a great deal of fluctuation in their dynamic correlation coefficients, which exhibit more large positive values during most of the sample periods, particularly for Hong Kong and Singapore. However, their conditional correlation series also exhibit some negative values in other years, indicating that inflation rates might respond in opposite ways to some common shocks. Thus, there seems to be no general trend in the dynamic correlation coefficient in the case of non-IT countries.

To see whether the estimates of the dynamic conditional correlation are qualitatively meaningful, Figure 4.1 superimposes the 95 percent confidence intervals around the point estimates. The intervals are computed using the standard bootstrap method with 2000 draws from the estimated distribution of the coefficients in the estimated MGARCH model. The plot suggests that most of the positive correlation estimates for Asian IT countries after the adoption of IT, and the negative estimates in other periods, are statistically significant.

4.4.4 Panel GARCH Estimates

The bivariate BEKK-MGARCH estimates discussed in the preceding section provide equivocal findings that are difficult to generalize when drawing conclusions about volatility transmission between international and Asian sample inflation rates. Addressing this issue is one of the major motivations for the application of panel GARCH model as outlined in Section 4.3. The empirical work on panel GARCH in this section begins with data specification. It was noted in Chapter 3 that the results of the univariate unit root tests clearly indicate that there is no overwhelming evidence in favour of inflation stationarity. Therefore, the corresponding unit root tests for the panel data of inflation are evaluated next. Table 4.10 reports the panel unit root test results. For the Im-Pesaran-Chin (2003, IPS) and Levin et al. (2002) tests, the joint null hypothesis is a unit root across all series. At the panel level, both the IPS *t*-bar and Levin et al. (2002) *t*-star tests reject the null of unit root, which indicates that this panel can be treated as stationary.

Table 4.10: Panel Unit Root Test Results

Panel unit root tests	Test statistic	*p*-value
t-bar test: (Im-Pesaran-Shin, 2003)	-6.793	(0.000)
Pooled *t*-star test: (Levin-Lin-Chu, 2002)	-2.009	(-0.028)
CD test: (Pesaran, 2004)	7.665	(0.000)
CIPS test: (Pesaran, 2007)	-3.129	(0.000)

Notes: Lag lengths are determined by the AIC where the maximum number of lags for each individual country is set to floor $\{4(T/100)^{1/11}\}$. The Pesaran (2004) CD statistic is based on the cross-correlation of the residuals that result from estimating *p*th-order ADF-type regressions (including a constant) for each of the individual inflation rates that conform to the panel. This statistic follows a standard normal distribution under the null hypothesis of cross-sectional independence. Figures in parentheses are *p*-values.

However, the panel unit root tests based on IPS and Levin et al. (2002) are based on a critical assumption of cross-sectional independence among individual time series in the panel. For the IPS test in particular, Pesaran's (2007) Monte Carlo simulations show that it suffers from severe size distortions in the presence of cross-sectional dependence. To account for cross-sectional dependence, this chapter first implements the Pesaran (2004) general diagnostic test for cross-sectional dependence in panels, denoted as the CD statistic in Table 4.10. The CD test rejects the null hypothesis that the series innovations are cross-sectionally independent. With this in mind, this study also implements the Pesaran (2007) test, denoted as the CIPS statistic in Table 4.10. Similar to the IPS test, the CIPS statistic tests the joint null of a unit root against the alternative of at least one stationary series in the panel. The CIPS test, incorporating individual-specific intercepts, rejects the joint null hypothesis of a unit root at the 1% significance level. Hence, this allows us to treat the panel of inflation rate data as stationary and proceed to estimate the panel GARCH model in Equation 4.23. It is important to point out here that the panel test results are very much in agreement with the results of the univariate DF-GLS test, which is partly expected as the DF-GLS test is known to be relatively powerful.

The next step of the empirical work estimates an AR(12) specification for the conditional mean equation. This specification is determined using the Schwarz Information Criterion (SIC) and is in line with central banks' practice of setting inflation target horizon in the medium-term, i.e. including target horizon of two years or more. Then the analysis proceeds to evaluate the poolability of the data, which is important in panel data regression considerations (Lee, 2010b). Specifically, this study employs a Chow-type test for poolability of the data for eight countries. The null hypothesis of a pooled regression is tested against the alternative hypothesis of eight fully separate regressions. An F statistic of 61.24 strongly supports the application of a panel model over individual regression.

Moreover, this study evaluates some diagnostics for testing serial correlation. Table 4.11 reports the Ljung-Box Q-statistics and partial correlations, which are computed for both the residuals and squared residuals for orders up to AR(24) lags. As for the residuals, all partial correlations are not statistically significant. These diagnostic statistics suggest that there is no evidence of serial correlation in the residuals, meaning that the condition in Equation 4.18 is satisfied. This may reflect the efforts of central banks in reducing past inflation deviations from the target. In the case of partial correlations for squared residuals, all lags are significant at the 1% level, which suggests a high-order ARCH process and supports the application of a GARCH-type model.

Table 4.11: Autocorrelation Diagnostics

	Partial correlation	
Lag	Residuals	Squared residuals
1	-0.003	0.169***
2	-0.002	0.008***
3	-0.004	0.039***
4	0.006	0.027***
5	-0.004	0.119***
6	0.017	0.000***
7	0.006	0.027***
8	0.007	0.053***
9	0.006	0.003***
10	0.012	-0.021***
11	-0.009	0.024***
12	-0.045	0.109***
13	-0.010	-0.03***
14	0.002	-0.001***
15	-0.006	-0.001***
16	0.023	-0.006***
17	0.003	0.012***
18	0.025	0.009***
19	0.000	0.006***
20	0.002	0.007***
21	0.017	0.003***
22	0.021	0.011***
23	-0.003	0.026***
24	-0.096	0.086***
Q(24)	31.287	214.910***

Note: *** denotes significance at the 1% level.

Next, an LR test is used for unconditional group-wise heteroscedasticity and cross-sectional correlation. These LR tests are based on the log-likelihood values of the panel model estimated separately with and without individual effects. The unrestricted model is estimated without individual effects on each of the two equations, while the restricted model is estimated with individual effects on each of the two equations. Note that the dependent variables of those regressions are the conditional variance and covariance of inflation. Table 4.12 shows that the corresponding likelihood values are $\chi^2_{(7)} = 324.20$ and $\chi^2_{(28)} = 244.24$, respectively. These test statistics are significant at the 1% level and indicate that there is significant unconditional groupwise heteroscedasticity and cross-sectional correlation. In other words, the second test clearly suggests that the assumption of cross-sectional independence does not hold for this data. This result, in addition to the earlier finding on unconditional groupwise heteroscedasticity, supports the presence of country-specific effects in the conditional variance equation.

Table 4.12: LR tests for Individual Effects

	LR-statistic
Variance equation	324.196***
Covariance equation	244.238***

Note: *** statistical significance at the 1% level.

In addition, the empirical investigation tests the assumption of equal ARCH and GARCH coefficients. The Wald test statistic of 479.831 is statistically significant and hence suggests that the assumption of equal GARCH dynamics holds for this data. Furthermore, the assumption that the IT coefficients are equal across countries is substantiated empirically. The Wald test statistic for the null hypothesis of equal IT coefficients across countries is 9.454, which is statistically significant. Therefore, four IT coefficients are applied to all countries.

It is important to point out that the validity of the panel GARCH estimates depends upon the exogeneity of the regressors that are included in the analysis. Here one could argue that there may be doubts regarding the exogeneity status of the *IT* variable. That is, the empirical model may suffer from endogeneity problems because current inflation rates are highly likely to be correlated with the *IT* variable. Hence, this study applies the Durbin and Wu-Hausman exogeneity tests. Following Lin and Ye (2009), this study uses the lagged inflation rates and broad money growth as instruments. The results reported in Table 4.13 indicate that the exogeneity status of the *IT* variable is not rejected. Therefore, this is not likely to challenge the findings regarding the *IT* dummy variable in the conditional mean and conditional variance equations.

Table 4.13: Durbin-Wu-Hausman Exogeneity Test

Instrument	*F*-statistic	*p*-value
Lagged inflation, broad money supply growth	1.356	0.244

Note: Each *F*-test has one degree of freedom.

The results from the panel GARCH estimation are displayed in Table 4.14. The second and third columns of Table 4.14 disiplay the coefficient estimates for the conditional mean Equation 4.16. The coefficient estimates for lagged π_{it} sum to less than unity, which indicates that the process is stable. The negative estimated coefficients imply a decline in inflation inertia driven by a stronger anti-inflationary policy (Taylor, 2000). This finding is consistent with Prasertnukul et al. (2010), who find that the CPI in all four Asian IT countries is significantly influenced by lagged inflation rates. However, the findings in this study offer new insights into the existence of inflation inertia while capturing the heterogeneity and interdependence across Asian economies.

Looking at the main subject in this chapter, the results show that the estimates for *IT* in the conditional mean equation are negative and significant at the 1% level for the Philippines and South Korea and at the 5% level for Thailand.[5] The coefficient estimate for *IT* for Indonesia is negative but not significant. These results

[5] The coefficient estimate for *IT* is robust for the case of using oil price as an alternative determinant of inflation. In this experiment, this study follows Bhar and Mallik's (2013) approach in constructing a dummy variable for oil price. Here, the oil price is converted first into local currency since an appreciating exchange rate can offset the impact of oil price increases. When the oil price (in local currency) rises more than 4% in three consecutive periods, a dummy equal to (+1) is considered. Likewise, the study uses a dummy of (-1) if the oil price declines more than 4% in three consecutive periods. The dummy is zero otherwise. As a further robustness check, this study uses quarterly GDP deflator as an alternative measure of inflation. In this case, the study confirms the first panel GARCH findings and the earlier experiment.

Table 4.14: Panel GARCH Estimation Results

Conditional Mean			Conditional Variance			Conditional Covariance		
Coefficient	Estimate	t-stat.	Coefficient	Estimate	t-stat.	Coefficient	Estimate	t-stat.
μ	0.279^{***}	8.387	α_1	-0.044^{***}	-5.195	η_{21}	0.006	1.084
$\pi_{i,t-1}$	1.101^{***}	59.594	α_2	0.013^{**}	2.167	η_{31}	0.008^{**}	2.111
$\pi_{i,t-2}$	-0.128^{***}	-8.323	α_3	0.005^{*}	1.677	η_{32}	0.003	1.614
$\pi_{i,t-3}$	0.001^{***}	3.054	α_4	-0.003	-0.765	η_{41}	0.002	0.525
$\pi_{i,t-4}$	0.034^{***}	7.843	α_5	0.004	0.448	η_{42}	0.008^{***}	3.124
$\pi_{i,t-5}$	-0.058^{***}	-5.611	α_6	-0.009^{**}	-1.999	η_{43}	0.004^{*}	1.927
$\pi_{i,t-6}$	0.028^{***}	8.141	α_7	-0.004^{***}	-2.670	η_{51}	-0.008	-1.270
$\pi_{i,t-7}$	0.032^{***}	4.716	α_8	-0.003	-1.404	η_{52}	-0.002	-0.823
$\pi_{i,t-8}$	-0.066^{***}	-7.530	IT^{Id}	0.005	0.695	η_{53}	-0.005^{*}	-1.861
$\pi_{i,t-9}$	0.045^{***}	3.269	IT^{Ph}	-0.013^{***}	-4.360	η_{54}	0.002	0.610
$\pi_{i,t-10}$	0.020^{***}	3.908	IT^{Ko}	-0.005^{***}	-3.386	η_{61}	0.002	0.371
$\pi_{i,t-11}$	-0.068^{***}	-11.132	IT^{Th}	-0.0003	-0.1190	η_{62}	0.006^{*}	1.925
$\pi_{i,t-12}$	-0.005^{***}	-10.765	δ	0.822^{***}	52.932	η_{63}	0.002	0.637
IT^{Id}	-0.024	-1.293	γ	0.095^{***}	7.937	η_{64}	0.004	1.280
IT^{Ph}	-0.031^{***}	-3.054				η_{65}	0.006	1.458
IT^{Ko}	-0.053^{***}	-4.362				η_{71}	0.004	1.332
IT^{Th}	-0.043^{**}	-2.088				η_{72}	0.005^{**}	2.090
						η_{73}	0.003	1.582
						η_{74}	0.004^{**}	1.986
						η_{75}	0.003	1.011
						η_{76}	0.002	0.991
						η_{81}	-0.001	-0.394
						η_{82}	0.003	1.227
						η_{83}	0.000	0.097
						η_{84}	0.002	1.089
						η_{85}	0.004	1.612
						η_{86}	0.003	1.342
						η_{87}	0.001	0.491
						λ	0.922^{***}	27.643
						ρ	0.012^{*}	1.855
Log-likelihood	-2115.76							

Notes: ***, ** and * denote significance at the 1, 5 and 10% levels.

indicate that the inflation target tends to lower the inflation rate. The results provide empirical support for the IT credibility hypothesis in line with Carrasco and Ferreiro (2013). The above findings corroborate the evidence of a lower inflation rate due to the adoption of IT as reported by Gonçalves and Salles (2008) and Lin and Ye (2009), who use the PSM technique applied to annual panel dataset for developed and developing IT and non-IT countries. Cross-country studies such as these deal with an important issue regarding self-selection bias of IT policy. However, these previous studies do not account for international inflation spillovers, which is a major distinction from the panel GARCH estimates in this study that also capture interdependence and heterogeneity across countries.

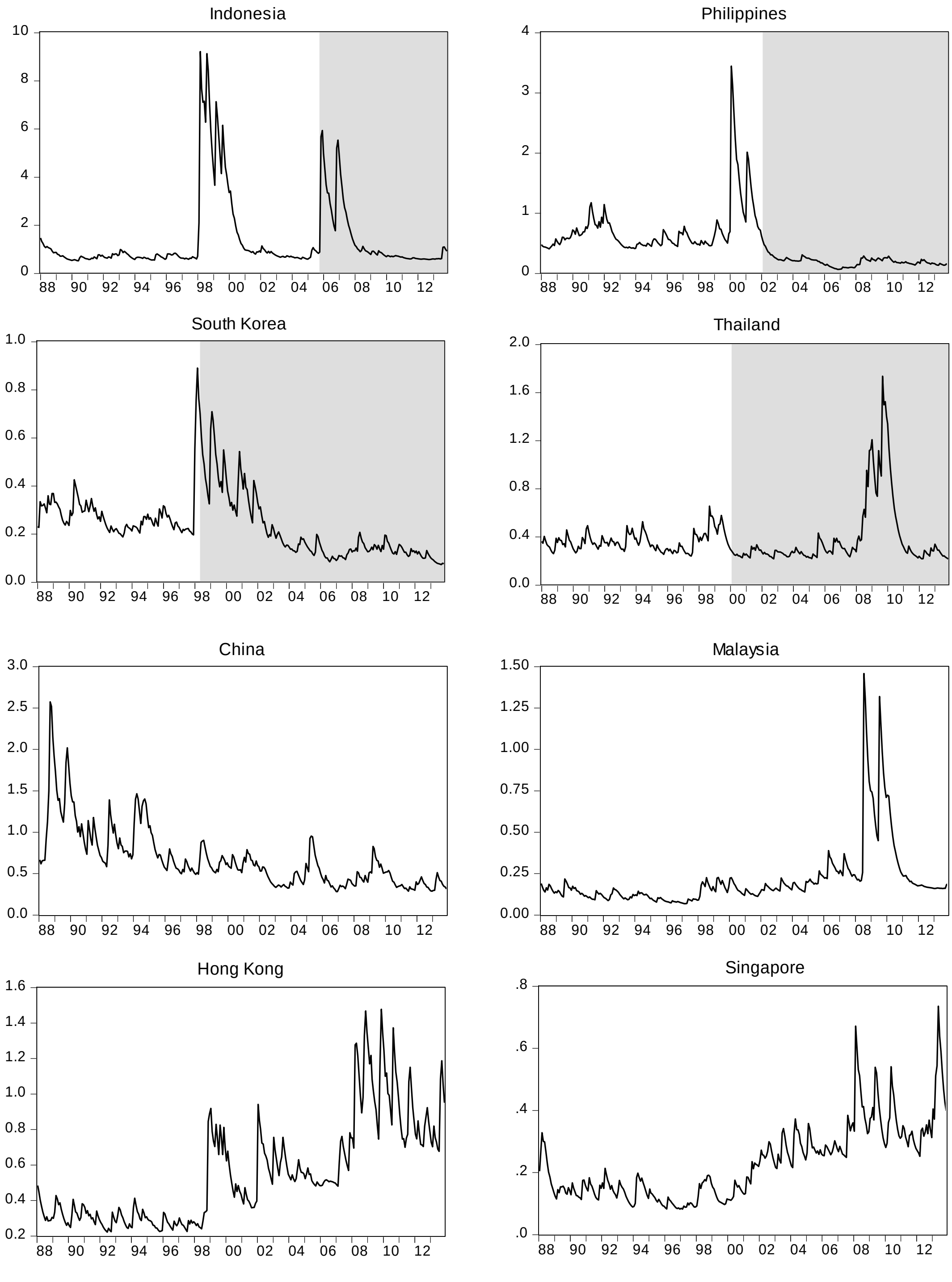
Evidence of a significant negative impact of IT does not concur with Brito and Bystedt (2010) who find a less negative and less significant impact of IT on inflation rate for a panel of developed and developing economies. While Brito and Bystedt (2010) examine both inflation and output growth indicators and their trade-offs using the dynamic panel estimator, thereby controlling for simultaneity and omitted variable biases, they ignore the possible foreign inflation spillovers that is particularly addressed in this study. Moreover, the significant impact of the actual inflation target in most IT countries in this study represents a unique distinction from previous studies that relied on structural shift IT, which is a persistent process (Brito & Bystedt, 2010). Therefore, capturing the evolution of the actual inflation target in this study better characterizes the impact of an IT regime on the dynamic behaviour of inflation rates.

The fifth and sixth columns of Table 4.14 display the results for the conditional variance Equation 4.21. The estimates for the *IT* coefficients are negative and significant at the 1% level for the Philippines and South Korea. This finding confirms the IT credibility hypothesis for these two IT countries. The coefficient estimates for *IT* are respectively negative and positive for Thailand and Indonesia, but these are insignificant. The results also show that the estimate for the parameter δ is significant at the 1% level. The estimated coefficient of 0.82 for δ reflects a relatively high amount of persistence in inflation volatility. By comparison, the estimate for the parameter γ is 0.10, indicating the positive effect of an inflation shock on the volatility of inflation rates.

In relation to the above results, Figure 4.2 plots the estimated conditional variances. It can be seen that the conditional variance decreases after the adoption of IT, particularly in the cases of the Philippines and South Korea. Indonesia shows a drop in the conditional variance in 2005 and a temporary increase in 2006, followed by lower inflation volatility afterwards, which is consistent with the view that the initial credibility of emerging markets' IT central banks is low (Bernanke et al., 1999; Mishkin, 1999). As noted by Leiderman and Bufman (2000), there may be credibility problems at the start of an IT regime because of the discretionary nature of inflation targets. The conditional variance for South Korea and Thailand increased in 2008 and 2009, which highlights the pro-cyclical monetary policy response of central banks during the global financial crisis when there was the fear of a high pass-through from the exchange rate to inflation.

The eight and ninth columns of Table 4.14 display the estimates for the conditional covariance Equation 4.22. Most of the estimates for η_{ij} for $i \neq j$ are positive, which indicate that the variances of the eight inflation rate series vary in the same direction over time. The estimate for λ is significant at the 1% level. The corresponding estimate for λ at 0.92 highlights a rather high persistence among the conditional variances. Similarly, the estimate for ρ is significant at the 10% level,

Figure 4.2: Variances of Inflation Rates



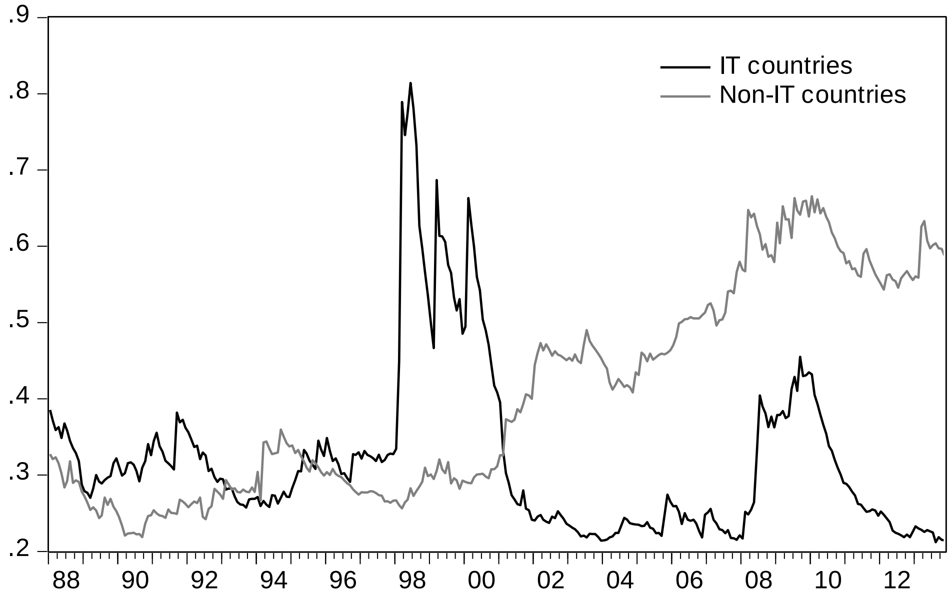
Notes: The shadowed areas in the figure indicate the inflation targeting periods.

supporting the impact of an inflation shock on the conditional variances. The positive estimate indicates that an inflation shock to one country increases its covariance or interdependence with another country. This interdependence can be due to similarities in monetary policy reaction functions across countries (Neely & Rapach, 2011), common shocks (Mumtaz et al. 2011; Ciccarelli & Mojon, 2010) and global factors capturing the correlation of real activity between countries (Ihrig et al. 2011; Borio & Filardo, 2007).

Finally, Figure 4.3 displays the estimates of the panel dynamic conditional correlation for Asian IT and non-IT countries. As stated above, these estimates are calculated by obtaining the sum of the dynamic conditional correlation of all individual countries separately in each of the two groups of countries. Figure 4.3 shows patterns of fluctuating correlation, which tend to remain positive, meaning that inflation rates across countries may respond in the same direction to some common shocks. Figure 4.3 also shows that there is a tendency for the panel conditional correlation coefficient to rise during both the Asian and global financial crises. The positive correlation estimates during the 2008-2009 financial crisis are lower for IT countries than for non-IT countries.

A potential explanation for this pattern is that IT central banks may be much more concerned about preserving their credibility in anchoring inflationary expectations during the global financial crisis when capital flows out and nominal and real exchange rates depreciate sharply (Céspedes et al. 2014). In crisis times, Céspedes et al. (2014) explain that the central banks in emerging market economies used unconventional policy tools that deviate from the textbook IT paradigm. Examples include foreign exchange intervention and capital controls in the form of taxes on short-term inflows in order to prevent unwarranted capital out and global factors capturing the correlation of real activity between countries (Ihrig et al. 2011; Borio & Filardo, 2007) flows and exchange rate depreciation that could pose challenges in anchoring inflationary expectations. Overall, this positive correlation coefficient is consistent with central banks responding to common macroeconomic shocks that potentially link to foreign inflation rates. Countries may be hit by similar unforeseen inflation shocks irrespective of whether or not their central banks engage in IT.

Figure 4.3: Panel Dynamic Conditional Correlation



Notes: The black and gray lines in the figure represent panel dynamic conditional correlation estimates for IT and non-IT countries, respectively.

4.5 Conclusions

The main conceptual contribution of this chapter has been in emphasizing that the behaviour of inflation level and volatility under a credible IT regime hinges upon the nature of the interdependence and heterogeneity of inflation between countries. Specifically, it should be expected that a credible IT regime keeps the absolute difference between actual inflation and its target to a minimum.

Empirically, this chapter tests this hypothesis by applying MGARCH and panel GARCH methods. The MGARCH estimation enables us to look at the conditional volatilities that are based on unpredictable movements and detect possible changes in the dynamic conditional correlation. The use of a panel GARCH method also enables us to achieve substantial efficiency gains in estimating the conditional variance and covariance processes by capturing relevant information about interdependence and heterogeneity in different inflation rates.

This chapter provides evidence of interdependence based on inflation linkages and volatility transfer between the U.S. or Japanese and Asian sample countries in a bivariate MGARCH setting. This study also analyses the impact of IT on the level and volatility of inflation based on MGARCH model, and shows evidence of reduced inflation in Thailand and lower conditional variances in all IT countries. Moreover, this study estimates the conditional correlation coefficient, and shows that it tends to become positive for Asian countries after IT adoption.

By using the panel GARCH estimation, the findings indicate that IT significantly lowers both the level and volatility of inflation in the Philippines and South Korea. The results also indicate that IT has caused a decline in the level of inflation in Thailand. The overall results suggest that an IT regime in Asia is more credible with respect to lowering the level of inflation than in terms of reducing inflation volatility. There is also panel evidence of positive dynamic conditional correlation, which implies that countries may be hit by similar unforeseen inflation shocks irrespective of whether or not their central banks engage in IT. However, the findings also indicate that the covariance of inflation shocks among IT and non-IT countries tends to increase. In contrast to the existing literature, this study sheds new light on foreign inflation spillover by accounting for interdependence and heterogeneity across countries, and capturing the evolution of the actual inflation target in explaining the impact of IT on the dynamics of the inflation rate.

These findings should be useful for improving our understanding of the impact of IT on inflation outcomes in the context of interdependence and heterogeneity among different inflation rates relative to the existing estimates in the literature. When the behaviour of the level and volatility of inflation is best characterized by capturing interdependence and heterogeneity across economies, then an evaluation of the IT policy becomes sharp enough to uncover its distinctive impact over alternative existing monetary policy frameworks in Asian countries.

Chapter 5: How Credible is Inflation Targeting in Asia? A Quantile Unit Root Perspective

5.1 Introduction

To assess IT in developed and emerging countries, the different behaviour of the inflation rate has been a keen area of research in recent years. One important direction of this research has been the examination of the stationarity properties of the inflation rate. A clear understanding of this research is important especially in light of the 2008-2009 financial crisis that brought attention again the concerns about lack of credibility of IT central banks. According to some researchers, the financial crisis has bared the flaws of IT more widely along with the re-emergence of a wider debate on rethinking the suitability of IT as a monetary policy strategy (Drakos & Kouretas, 2015; Volz, 2015; Céspedes et al., 2014). But as Gillitzer and Simon (2015) argued, the conflicting outcomes of the large shocks from the financial crisis in terms of inflation remaining close to target and calling the need to re-engineer IT could be a reflection of the success of IT.

At the root of this debate is the claim by IT proponents that an explicit inflation target increases the credibility, accountability and transparency of a central bank and, as a result, IT is an effective strategy to lowering the inflation level and its variability (Lee, 2010a). As mentioned in Chapter 1, there are three conflicting explanations for the probable effects of IT on the behaviour of macroeconomic variables such as inflation, output and interest rates (Brito & Bystedt, 2010; Kadria & Aissa, 2016). In particular, some authors have pointed to a weak credibility and worse performance that could occur in those developing IT economies that have lacked institutional maturity and consistency of macroeconomic fundamentals

(Bernanke & Woodford, 2005; Mishkin, 2004). Others have emphasized that increased credibility of an IT policy leads to better macroeconomic outcomes in emerging countries because the initial credibility of their central banks is low (Bernanke et al., 1999; Mishkin, 1999; Svensson, 1997). In addition, there is the so-called conservative window-dressing view expressed by Anna Schwartz (Romer, 2006, p. 532) that pinpoints IT of having served very little towards lowering the inflation level and variability because non-IT countries have a similar performance with IT countries in controlling inflation.

Despite extensive research, the empirical evidence about the performance of IT policy is still inconclusive. From an optimistic view, there is evidence that IT lowers the inflation level and volatility for a large sample of developing and emerging countries as illustrated for example in Batini and Laxton (2007), De Mendonça and De Guimarães e Souza (2012) Gonçalves and Salles (2008), IMF (2006), Lin and Ye (2009), Mishkin and Schmidt-Hebbel (2007), Samarina et al. (2014), and Vega and Winkelried (2005). In contrast, a weak decline and/or no impact of IT on the behaviour of inflation is reported by Angeriz and Arestis (2006), Ball and Sheridan (2005), Brito and Bystedt (2010), and Gonçalves and Carvalho (2009).

There are also conflicting evidence that IT has a positive impact on output (see, for example, Abo-Zaid & Tuzemen, 2012; Amira et al., 2013; Ayres et al., 2014; Mollick et al., 2011; Neumann & von Hagen, 2002; Vega & Winkelried, 2005). Other researchers such as Brito and Bystedt (2010), and Mishkin and Schmidt-Hebbel (2007) suggest the opposite empirical evidence. As for the window dressing view of IT, several studies report empirical evidence of no significant difference between IT and non-IT countries in terms of inflation and output performance (see, for example, Angeriz & Arestis, 2007; Capistrán & Ramos-Francia, 2009; Dueker & Fischer, 1996, 2006; Lee, 1999; Lin & Ye, 2007; McDermott & MacMenamin, 2008).

Even the few empirical studies that address the stationarity or persistence of inflation for Asian countries demonstrate contrasting findings. While studies such as Gerlach and Tillmann (2012) find a significant drop in inflation persistence in four Asian IT countries, Siklos (2008) and Filardo and Genberg (2010) report opposite findings for Indonesia, Thailand and the Philippines. Furthermore, Teles and Zaidan (2010), for example, find that the deviation of the expected inflation from its target is stationary in Thailand but not in the Philippines. There are also studies that examine inflation at various quantiles. The motivation is largely driven by the need to improve the performance of monetary policy by accounting for possible asymmetries in the speed of adjustment at different quantiles, and the desire to study local persistence in the inflation series. Yet even studies of the dynamic behaviour of inflation across quantiles do not reach a consensus for developed countries. For example, Tsong and Lee (2011) find stationarity for inflation in the lower quantiles, but the presence of a unit root in the higher quantiles in 12 OECD countries. In contrast, Wolters and Tillmann (2015) find mean reversion in the U.S. inflation across all quantiles after allowing for structural breaks at an unknown date. Meanwhile, Çiçek and Akar (2013) also apply the quantile unit root approach for inflation in Turkey. They find that inflation does not follow a constant unit root process and the corresponding speed of adjustment across different quantiles is asymmetric before and after the start of an IT regime.

Therefore, the aim of this chapter is to examine the different behaviour of the inflation rate data for eight Asian countries. This chapter addresses one major question: how credible is IT in Asia in terms of stabilizing inflation? In other words, this chapter assesses the credibility of IT in terms of whether or not the inflation rate is mean reverting. Specifically, this chapter examines the unit-root hypothesis not only at the conditional mean of inflation, but also in the tails of the distribution using quantile unit root testing.

This chapter contributes to the literature in four ways. First, the unit root hypothesis for inflation in examined in relation to the credibility of monetary policy in Asian countries. Benati (2008) points out that a key driver for the drop in inflation persistence is the conduct of a credible monetary regime such as IT (Baxa et al., 2015). Similarly, Srinivasan and Kumar (2012) emphasized that credibility is an important determinant of lag dynamics in inflation. In line with this context, this chapter offers new insights in terms of advocating a three-way definition of IT based on *perfect credibility*, *imperfect* or *weak credibility* and *zero credibility* based on the quantile regression estimation results.

Second, this chapter searches for an inflation threshold whereby it becomes non-stationary. This is important for policymakers insofar as highly persistent inflation can mean that inflationary expectations become difficult to anchor. Thus far the relevant literature relies on a threshold unit root testing method in explaining the stationary properties of inflation in different regimes. For example, Henry and Shields (2004), who employed the threshold unit root method of Caner and Hansen (2001), find that for Japan and the U.K., shocks to inflation are highly persistent in one regime, but have finite lives in another regime. In contrast, this study employs a method similar with Lee et al. (2013) for separating periods of inflation non-stationarity from stationary ones. That is, the study aims to search for time varying threshold for inflation based on the largest quantile in which the inflation rate exhibits stationary behaviour.

Third, in contrast to past studies that focus on mean reversion for inflation across quantiles, this study captures the trend-reversion to offer new insight on the effects of IT on inflation behaviour. That is, the study aims to verify if an IT country having inflation under control might be characterized by a negative trend coefficient at different quantiles. In doing so, one can see whether inflation is guided by an inertia that follows a deterministic trend process (Gottschalk, 2003). If inflation is trend stationary, then it follows that the level will return to its trend path over time and so it is possible to forecast future movements in inflation based on past behaviour (Lee & Chang, 2008).

And finally, this chapter analyses the inflation dynamics for Asian economies that have hitherto received little attention. Asian countries experienced structural shifts after the 1997 financial crisis. Some Asian countries have shifted to IT and floating exchange regimes while others have also been exposed to periods of pronounced turbulence due to financial crisis, political and economic unrest and reform. Therefore, this implies a potential for complex dynamics of adjustment in the inflation rate.

Given the results of our quantile unit root regression model, this chapter sheds new light on the dynamics of inflation and the imperfect nature of the credibility of IT and alternative monetary policy framework in a sample of Asian countries. The rest of the chapter is organized as follows. Section 5.2 presents the theoretical framework. Section 5.3 reviews relevant empirical studies on inflation stationarity and persistence. Section 5.4 discusses the quantile regression method employed in examining the dynamic behaviour of inflation across quantiles. In

Section 5.5 a description of the data is provided. Section 5.6 presents the quantile ADF unit root results and conclusions are provided in Section 5.7.

5.2 Theoretical Framework

This section presents a simple model for inflation based on that of Gerlach and Tillmann (2012), in order to understand the link between the stochastic process of inflation dynamics and the behaviour of the central bank in terms of controlling inflation. The model is a reduced form that assumes inflation has permanent and temporary shock components. Next, this inflation model is linked to the concept of monetary policy credibility along the lines of Bomfim and Rudebusch (2000), who distinguish between deliberate and opportunistic approaches to disinflation policy.

5.2.1 Inflation Model

According to Chiquiar et al. (2010), when inflation deviations from the target have a positive weight based on a monetary policy loss function, the central bank responds strongly by using the short-run interest rate instrument to ensure that inflation shocks are only temporary; by doing so, the observed inflation will tend to follow a mean-reverting behaviour around the target. For countries where either a credible IT or any disinflationary policy is applied to avoid accommodation of inflation shocks, inflation is expected to follow a stationary process and therefore inflation persistence should decrease (Chiquiar et al., 2010).

The main concern in this chapter is that the stationary process and the persistence of inflation shocks matter at different sizes and signs of shocks to inflation. The initial intuition builds on Gerlach and Tillmann (2012), who argue that deviations of inflation from the target will be temporary if the central bank is effective in stabilizing inflation. However, this chapter goes beyond this intuition by linking instead the stationarity and persistence of inflation to the credibility of monetary policy. Equations 5.1 and 5.2 below represent a model for inflation rate and permanent inflation shock based on the work of Gerlach and Tillmann (2012):

$$\pi_t = \bar{\pi}_t + \upsilon_t \tag{5.1}$$

$$\bar{\pi}_t = \bar{\pi}_{t-1} + \eta_t \tag{5.2}$$

where π_t denotes the inflation rate and $\bar{\pi}_t$ denotes the permanent inflation shock which follows a random walk, $\upsilon_t \sim N(0, \sigma_\upsilon^2)$ and $\eta_t \sim N(0, \sigma_\eta^2)$. For the term η_t in Equation 5.2, the variance σ_η^2 is inversely related to the central bank's control of inflation. This implies that the variance of the innovations to the permanent shocks σ_η^2 decline when a central bank responds strongly to economic shocks in order to control permanent fluctuation in π_t. Thus if $\sigma_\eta^2 = 0$, one can interpret this case as perfect control of inflation.

Assuming the inflation rate as white noise with a persistent component following a first-order autoregressive process, Gerlach and Tillmann (2012) specify the inflation model as:

$$\pi_t = \rho \pi_{t-1} + \varepsilon_t \tag{5.3}$$

with an estimate of inflation persistence parameter $\hat{\rho}$ given by:

$$\hat{\rho} = \frac{(T-1)\sigma_\eta^2}{(T-1)\sigma_\eta^2 + \sigma_\upsilon^2} \tag{5.4}$$

where T denotes the sample length and $0 < \hat{\rho} < 1$. Gerlach and Tillmann (2012) noted that in any finite sample, the estimate of $\hat{\rho}$ in Equation 5.4 can provide a measure of the relative importance of permanent, η_t, to temporary, υ_t, shocks to inflation. If $\hat{\rho} = 1$ and $\sigma_\upsilon^2 = 0$ (i.e., there are no temporary shocks), it means that inflation is non-stationary. On the other hand, σ_η^2 and $\hat{\rho}$ are close to zero when a central bank, whether under an IT regime or any other monetary policy strategy, controls interest rates aggressively to offset shocks to inflation. In such a scenario, one should expect to see temporary effects of shocks on inflation, which in turn suggests a stationary inflation process.

This chapter builds on Zhou's (2013) hypothesis that inflation has stationary behaviour for countries that implement target-zone-type stabilization policies. Zhou (2013) links the mean-reverting behaviour of inflation to non-linear monetary reaction functions in accordance with the inflation zone targeting theory of Orphanides and Wieland (2000). This theory predicts that the optimal monetary policy rule for inflation zone targeting countries is to respond moderately to inflation when it deviates within a target range and increasingly strongly as inflation deviates symmetrically from the target range. Orphanides and Wieland (2000) argue that if the central bank assigns at least some weight to output stabilization, the output stabilization objective will dominate when inflation is within the targeted zone, and inflation stabilization will dominate when inflation deviations from the target become large (Gregouriou & Kontonikas, 2009; Akdogan, 2015). Along this line and following Zhou (2013) and Chiquiar et al. (2010), the main hypothesis to be tested in this chapter is stated as follows:

H1. *To the extent that a credible IT regime or any monetary policy strategy attaches primary importance to stabilising inflation, a central bank ensures that inflation shocks have only temporary effects. As a result, inflation will tend not only to have stationary behaviour but also its degree of persistence will fall at both smaller and larger changes in inflation.*

The theoretical justifications based on Equation 5.3 are important for the empirical analysis in this chapter for three reasons. First, they provide a motivation for understanding the relationship between inflation shocks and the stationary or non-stationary process of inflation. As Fuhrer (2010) points out, the first step in persistence is to find out if inflation contains a unit root; if so, this indicates that its persistence is infinite. Second, it also enables us to distinguish the level of inflation persistence between IT and non-IT countries in Asia. Gerlach and Tillmann (2012) explain that an IT regime is neither a necessary nor a sufficient condition for a decline in inflation persistence. They also explain that countries might claim to target inflation but do not appear to have reduced the persistence of inflation. Accordingly, the theoretical motivation above allows us to assess whether the drop in inflation persistence, if any, is unique to an IT regime. In the empirical analysis of this chapter, the inflation model in Equation 5.3 is used to test the unit root or inflation persistence hypothesis at different quantiles.

Third, Equation 5.3 provides a starting point to motivate possible asymmetry in the persistence of shocks to inflation. Akdogan (2015) provides a rationale for this type of asymmetry in which positive inflation deviations from the target could be larger and more persistent than downward misalignments. The policy action by the central bank would then be asymmetric in the sense that there is a stronger response once inflation increases above the target compared to the response to a negative deviation. In the current climate of zero lower bound and quantitative easing, one could make an argument that central banks are more concerned with the inflation rate being below the inflation target than above the target. Either way, the presence of asymmetries seems plausible.

Furthermore, an important reason for asymmetric inflation adjustment is discussed by Tsong and Lee (2011) and Çiçek and Akar (2013). These authors explain that an asymmetric inflation adjustment exists when higher inflation expectations in the future influence workers to ask for higher nominal wages to make up for the loss of their purchasing power. Firms may then increase their commodity prices, which in turn lead to increase in the overall price level. A similar situation is true for firms that would like to raise their prices due to higher inflation expectations. However, the same might not be valid for low inflation expectations, as workers and firms might not be motivated to seek higher wages or prices, which in turn results in stationary inflation rates.

5.2.2 Disinflation Policy and Credibility

This section links the inflation model above to the model of deliberate and opportunistic disinflation under imperfect credibility by Bomfim and Rudebusch (2000). In this model, the “deliberate” policymaker sets an ultimate inflation target π_t^{**} and consistently attempts to eliminate inflation deviations. The deliberate policymaker then sets the short-term interest rate with respect to the gap between lagged inflation $\tilde{\pi}_{t-1}$ and π_t^{**}.

The “opportunistic” policymaker also assumes an ultimate inflation target similar to the deliberate policymaker. However, except when inflation is too high, the opportunistic policymaker sets the current rate of inflation as the interim inflation target π_t^*. According to Bomfim and Rudebusch (2000), the opportunistic policymaker will take no action to lower inflation insofar as inflation is stable where $\tilde{\pi}_t = \tilde{\pi}_{t-1}$ and attempt to prevent increases in prices. Strictly speaking, prices are increasing if inflation is stable at a positive rate. In addition, the opportunistic policymaker resets the interim inflation target to the newly achieved lower inflation rate if actual inflation drops below the interim target until disinflation is achieved and $\pi_t^* = \pi_t^{**}$.

Bomfim and Rudebusch (2000) measure overall credibility by the extent to which the announcement of an inflation target is believed by the private sector in the formation of their expectations. Accordingly, they discuss the following three cases of credibility:

Case 1: Perfect credibility, where the private sector's long-run inflation expectations are equal to the announced long-run goal of the policymaker. Consequently, inflation expectations adjust fully and instantly to the inflation target.

Case 2: Partial credibility, where inflation expectations adjust slowly.

Case 3: No credibility, where the inflation target is ignored in the formation of expectations.

In the context of this study, countries that explicitly announced an inflation target, such as the four Asian IT countries, are classified under the deliberate approach to disinflation. On the other hand, the Asian non-IT countries in this study can be classified as using the opportunistic approach, in which the policymaker waits for unforeseen shocks to reduce inflation.

5.3 Empirical Studies

Motivated by the pioneering work of Nelson and Plosser (1982), who explored whether or not most macroeconomic time series had a unit root, early literature pertaining to inflation has also focused on this issue using univariate unit root tests. Overall, the early literature has not reached a consensus as to whether or not inflation follows a unit root process. A study by Rose (1988), applying Dickey-Fuller tests to four measures of prices in the U.S. using data from 1892 to 1970 and 1901 to 1950, was one of the first studies that rejects the unit root null in inflation in the case of the U.S. In addition, Edwards (1988) reports evidence of strong persistence in Latin American inflation rates, while Baillie et al. (1996) find fractional integration and mean-reversion in inflation rates in 10 developed countries. However, studies that rely on conventional unit root tests and fail to provide strong evidence in favour of inflation stationarity include Ball and Cecchetti (1990), Crowder and Hoffman (1996) and Evans and Lewis (1995). A study by Ng and Perron (2001) also fails to find strong evidence of stationary inflation, despite using univariate unit root tests with good asymptotic size and power properties.

Recognizing the low power problem of conventional univariate unit root tests, especially for small sample sizes, subsequent strands of the literature addressed this problem by conducting panel-type tests and covariate tests. To increase power, the panel unit root test was used by Culver and Papell (1997) and Basher and Westerlund (2008) for 13 OECD countries and provide evidence in favour of stationarity in inflation rate. By controlling for cross-sectional dependency using the panel unit root test proposed by Im et al. (2003), a study by Lee and Wu (2001) finds that inflation is stationary. To boost power by including valuable information concerning related covariates, the studies by Hansen (1995), Elliott and Jansson (2003), Jansson (2004), and Tsong and Lee (2010b) find mean reversion in inflation rates in 15 OECD countries.

There are also studies that focus on changes in the degree of inflation persistence, such as that of Taylor (2000). Instead of only using unit root tests to distinguish the inflation process as either an I(0) or I(1) process, Taylor (2000) estimates the largest autoregressive root (LAR) and finds a break in U.S. inflation persistence that coincides with Volcker disinflation. Similarly, taking into account structural breaks caused by changes in monetary policy regimes, the studies of

Levin and Piger (2002) and Cecchetti and Debelle (2006) provide strong evidence of much less inflation persistence conditional on a break in the intercept inflation for major industrial economies. A study by Zhang and Clovis (2010) finds that inflation in China over the post-1997 period tends to revert more quickly to its long-run level than during the pre-1997 period. Similar studies that report strong evidence of a reduction in inflation persistence include Cogley et al. (2010) for the US, and Beechey and Österholm (2009) for the Euro area.

Studies by Gerlach and Tillmann (2012), Tillmann (2013), Filardo and Genberg (2010), and Siklos (2008) provide empirical evidence of IT impacts on inflation persistence that include both Asian IT countries and non-Asian IT countries. Measuring inflation persistence by the sum of the coefficients in an autoregressive model for inflation rates, Gerlach and Tillmann (2012) find that IT adoption lowers inflation persistence in Asian IT countries. They also find that the speed with which persistence falls varies across countries, with Asian non-IT economies showing a smaller decline in persistence. These findings are consistent with the evidence provided by Tillmann (2013) for regional inflation persistence in South Korea. He finds that IT adoption in South Korea leads to a fall in regional inflation persistence and a reduction in cross-regional heterogeneity in inflation persistence. Filardo and Genberg (2010), who also measure inflation persistence as the first-autoregressive coefficient for inflation and in terms of an integrated moving average representation, find a drop in persistence for Korea, but increases in Thailand, the Philippines and Indonesia. On the other hand, Siklos (2008) finds that IT has reduced inflation persistence only in some emerging economies based on estimates of a first-order autoregressive process for inflation for a set of emerging market countries.

In contrast to this, a number of studies fail to find strong evidence of a drop in inflation persistence even if rolling window estimation methods are employed. For example, Stock (2001), who applies the LAR with a rolling window estimation method, fails to find evidence of a drop in US inflation persistence. Likewise, studies by O'Reilly and Whelan (2005), Batini (2006), and Pivetta and Reis (2007) provide evidence of a unit root in the inflation process and find that there is no clear reduction in inflation persistence.

More recently, Wolters and Tillmann (2015) examine time-variation in inflation persistence at individual quantiles in the U.S. They apply Oka and Qu’s (2011) approach for estimating structural changes in regression quantiles at unknown dates to detect structural changes in persistence at different quantiles. They report robust evidence for a structural break in persistence at all quantiles of the inflation process in the early 1980s. They also find that while prior to the 1980s inflation was not mean-reverting, their results suggest that the unit root can be rejected at every quantile of the conditional inflation distribution since the end of the Volcker disinflation.

Tsong and Lee (2011) employ quantile unit root tests in studying mean reversion for 12 OECD countries for the period 1957Q1 to 2010Q1. The authors also examine the likely structural break by capturing the mean shift due to the adoption of IT, or to the launching of the Eurozone in 1999Q1. Their findings suggest that the inflation rates are not a constant unit root process across quantiles. They also find that inflation rates exhibit both mean-reverting and asymmetric dynamic adjustment behaviour, in which the bigger the negative shocks, the stronger the mean reversion back toward its long-run equilibrium level, whereas non-stationary behaviour is found with large positive shocks.

Çiçek and Akar (2013) employ a quantile autoregression approach to test for mean reversion of inflation rates in Turkey. In contrast to Tsong and Lee (2011), the authors examine the distributional properties of inflation rates as a whole and by sector and goods disaggregation before and after an IT regime in Turkey. The authors' findings for Turkey lend support both to the evidence that inflation rates do not follow a constant unit root process and that the speed in the inflation adjustment process across different quantiles is asymmetric before and after an inflation-targeting regime. They also find that the persistence still has asymmetry but drops after implicit and explicit IT regimes.

Such results are similar to findings by Henry and Shields (2004), and Teles and Zaidan (2010), who apply the threshold unit root test proposed by Caner and Hansen (2001). Henry and Shields (2004) distinguish between non-stationarity and non-linearity in US, Japanese and UK inflation. They find that for Japan and the UK, inflation rates behave like a unit root process in a higher inflation regime, while they are mean-reverting in a lower inflation regime. For the US, they find that the threshold is not significant and shocks to inflation are infinitely persistent. Meanwhile, Teles and Zaidan (2010) examine whether stationarity of the deviation of the expected inflation from its target in 12 emerging IT countries depends on compliance with the Taylor principle. The authors find that the deviation of the expected inflation from its target is stationary in Thailand upon compliance with Taylor principle. In contrast, they provide evidence of non-stationarity for the Philippines due to non-observation of the Taylor principle.

5.4 Methodology

5.4.1 Lee-Strazicich Unit Root Test

The basic ADF unit root testing procedure employed in the previous chapter is widely known to fail to take into account the effects of structural breaks in the time series. Lumsdaine and Papell (1997) overcome this drawback by proposing an ADF test that allows for two structural breaks. Since Lumsdaine and Papell (1997) assume no breaks under the null hypothesis, Lee and Strazicich (2003) argue that this may lead to the incorrect conclusion that rejection of the null is evidence of trend stationarity, when the true series is difference-stationary with breaks. Accordingly, they propose an LM unit root test that allows for two endogenously determined breaks in both level and trend.

The minimum LM unit root test by Lee and Strazicich (2003) incorporates structural breaks under the null hypothesis, and its rejection gives genuine evidence of stationarity. In this chapter, the minimum LM unit root test is considered to complement the analysis of unit root hypothesis for inflation across quantiles. Specifically, this method is employed to provide a rationale for capturing trend reversion of inflation rates across quantiles. Following a similar application to inflation rate by Lee and Chang (2008), the minimum LM unit root test can be obtained from the following regression:

$$\Delta\pi_t = \delta'\Delta \mathrm{Z}_t + \phi\tilde{S}_{t-i} + \sum_{i=1}^{k}\gamma_i\Delta\tilde{S}_{t-i} + \mu_t \qquad t = 1,\ldots,T \qquad (5.5)$$

where $\tilde{S}_t = \pi_t - \tilde{\psi}_x - \mathrm{z}_t\tilde{\delta}$, $\tilde{\delta}$ are coefficients in the regression of $\Delta\pi_t$ on $\Delta\mathrm{Z}_t$, $\tilde{\psi}_x = \pi_1 - \mathrm{Z}_1\tilde{\delta}$, and π_1 and Z_t denote the first observations of π_1 and Z_t, respectively. Corrections for serial correlation are addressed by including the lagged terms $\Delta\tilde{S}_{t-i}$. The LM unit root test statistics are given by $\tilde{\tau} = t$ statistics testing the unit root null hypothesis $\phi = 0$, implying a unit root with breaks. By using a grid search, the LM unit root test can endogenously determine the breaks $\lambda = T_{Bj}/T$ as follows:

$$LM_{\tau} = \inf_{\lambda} \tilde{\tau}(\lambda) \tag{5.6}$$

5.4.2 Clemente-Montañes-Reyes Unit Root Test

To allow for two structural breaks arising in the inflation series, this chapter applies the Clemente-Montañes-Reyes (1998, CMR) unit root test. CMR unit root test follows an additive outlier (AO) model and an innovational outlier (IO) model to respectively plug out sudden and gradual changes in the mean of a series (Shahbaz et al., 2012). Let a pulse variable $DTB_{it} = 1$ if $t = TB_i + 1$ and 0 otherwise, $DU_{it} = 1$ if $t > TB_i (i = 1,2)$ and 0 otherwise, TB_1 and TB_2 denote time periods when the mean is being modified, and assume that $TB_i = \lambda_i T (i = 1,2)$ where $0 < \lambda_i < 1$ and $\lambda_2 > \lambda_1$ (Clemente et al., 1998). The unit root null in the case of an AO model can be tested by a two-step procedure. First, the deterministic part of the series is eliminated by estimating the model as follows:

$$\pi_t = \mu + d_1 DU_{1t} + d_2 DU_{2t} + \tilde{\pi} \tag{5.7}$$

The second step searches for the minimum *t*-ratio for the hypothesis that $\rho = 1$ in the following model:

$$\tilde{\pi}_t = \sum_{i=0}^{k} \omega_{1i} DTB_{1t-i} + \sum_{i=0}^{k} \omega_{2i} DTB_{2t-i} + \rho\tilde{\pi}_{t-1} + \sum_{i=1}^{k} c_i \Delta\tilde{\pi}_{t-i} + e_t \tag{5.8}$$

The dummy variable DTB_{it} is included in the model to make sure that min $t_{\rho^{\wedge}}^{AO}(\lambda_1, \lambda_2)$ converges to the distribution (Clemente et al., 1998):

$$\min t_{\rho^{\wedge}}^{AO}(\lambda_1, \lambda_2) \rightarrow inf_{\lambda=\Lambda} \frac{H}{[\lambda_1(\lambda_2 - \lambda_1)(1 - \lambda_2)]^{1/2} K^{1/2}} \quad (5.9)$$

In the case of an IO model, the unit root null can be tested by estimating the following model:

$$\pi_t = \mu + \rho\pi_{t-1} + \delta_1 DTB_{1t} + \delta_2 DTB_{2t} + d_1 DU_{1t} + d_2 DU_{2t} \sum_{i=1}^{k} c_j \Delta_{t-i} + e_t \quad (5.10)$$

In Equation 5.10, the minimum value of the simulated *t*-ratio is obtained. This value can be used for testing whether the autoregressive parameter is 1 for all break date combinations. To make it possible to derive the asymptotic distribution of this statistic, assume that $0 < \lambda_0 < \lambda_1, \lambda_2 < 1 - \lambda_0 < 1$. By implementing the largest possible window, λ_1 and λ_2 take values in the $\left((t+2)/T, (T-1)/T\right)$ interval. Furthermore, assume that $\lambda_2 > \lambda_1 + 1$, which implies that cases where the breaks occur in consecutive periods are eliminated (Clemente et al., 1998).

5.4.3 Enders-Granger Threshold Autoregressive Unit Root Test

According to Henry and Shields (2004), the effects of inflation shocks may vary depending on the initial regime of inflation, the sign and size of the shock, and whether or not the shock causes a transition across regimes. In the discussion that follows, the Enders-Granger threshold unit root test method is applied to such issues. The method is also considered here to complement the potential asymmetric inflation adjustment across quantiles. It is also important to note that ADF-type tests have low power in the presence of thresholds as illustrated in Enders and Granger (1998) using Monte-Carlo methods.

Enders and Granger (1998) generalized the Dickey-Fuller unit root test method to allow for asymmetric adjustment. To briefly describe this method, consider the following momentum threshold autoregressive (MTAR) model:

$$\Delta\pi_t = I_t\rho_1\pi_{t-1} + (1 - I)\rho_2\pi_{t-1} + \sum_{i=1}^{k}\gamma_i\Delta\pi_{t-i} + \varepsilon_t \quad (5.11)$$

where $\varepsilon_t \sim i.i.d.(0, \sigma^2)$. The Heaviside indicator function is given by:

$$I_t = \begin{cases} 1 & \text{if } \Delta\pi_{t-1} \geq \tau \\ 0 & \text{if } \Delta\pi_{t-1} < \tau \end{cases} \quad (5.12)$$

The consistent threshold value τ is determined using Chan's (1993) procedure, which sorts the estimated residuals in ascending order, eliminates the smallest and largest 15%, and chooses the parameter that yields the smallest residual sum of squares over the remaining 70%. In the MTAR model, the null hypothesis of a unit root is stated as $\rho_1 = \rho_2 = 0$, while the null hypothesis of symmetric adjustment can be tested by the restriction $\rho_1 = \rho_2$. The MTAR model allows the speed of adjustment to depend on whether the change in inflation is increasing or decreasing. If $|\rho_1| > |\rho_2|$, then increases in inflation tend to persist, whereas decreases revert back to the threshold quickly when $\tau = 0$. On the other hand, the effects of decreases in inflation persist longer than the effects of increases in inflation if τ is not equal to zero.

5.4.4 Quantile ADF Unit Root Test

This chapter employs Koenker and Xiao's (2004) quantile unit root test, which is an extension of the ADF unit root test. The test allows for the possibility that shocks of various sign and size have different impact on inflation, and asymmetric adjustment in different quantiles. Moreover, it allows generally for differences in the transmission of all kinds of different shocks and avoids the estimation of additional regime parameters. In other words, this technique offers a more flexible framework for the purpose of unit-root testing that considers structural changes and reduces estimation uncertainty. Let π_t denote the inflation rate, ρ_0 an intercept term and ε_t a white noise residual. The standard ADF regression with deterministic trend *t* can be written as:

$$\Delta\pi_t = \rho_0 + \rho_1\pi_{t-1} + \beta t + \sum_{i=1}^{q} \gamma_i \Delta\pi_{t-i} + \varepsilon_t \qquad (5.13)$$

where the autoregression (AR) coefficient ρ_1 measures the persistence of inflation. The inflation process contains a unit root if $\rho_1 = 0$. The condition for stationary properties of inflation and for ruling out explosive behavior is where $-2 < \rho_1 < 0$. Following Koenker and Xiao (2004), the τth conditional quantile of $\Delta\pi_t$ can be defined as follows:

$$Q_{\Delta\pi_t}(\tau|\Gamma_{t-1}) = \rho_0(\tau) + \rho_1(\tau)\pi_{t-1} + \beta(\tau)t + \sum_{i=1}^{q} \gamma_i(\tau)\Delta\pi_{t-i} + \varepsilon_t \qquad (5.14)$$

where $Q_{\Delta\pi_t}(\tau|\Gamma_{t-1})$ is τth quantile of $\Delta\pi_t$ conditional on the past information set, Γ_{t-1}. In Equation 5.14, the τth conditional quantile of $\Delta\pi_t$ is denoted by $\rho_0(\tau)$, which measures the average size of inflation shock in each quantile (Tsong & Lee, 2011). The coefficient $\rho_1(\tau)$ measures the speed of mean reversion of $\Delta\pi_t$ within each quantile. The estimates for $\rho_1(\tau)$ can be used in approximating the half-lives (HL) for any monotonic stationary inflation process in each quantile through the formula $\mathrm{HL} = \ln(0.5)/\ln(\hat{\rho}_1(\tau) + 1)$. The HL can be approximated when the null hypothesis of $\rho_1(\tau) = 0$ is rejected; otherwise, half-lives are set to be infinite. The optimal lag length is chosen according to the AIC.

The coefficients $\rho_0(\tau)$, $\rho_1(\tau)$, $\beta(\tau)$ and $\gamma_i(\tau)$ are estimated by minimizing the sum of asymmetrically weighted absolute deviations:

$$min\sum_{t=1}^{n}\left(\tau - I\left(\pi_t < \rho_0(\tau) + \rho_1(\tau)\pi_{t-1} + \beta(\tau)t + \sum_{i=1}^{q}\gamma_i(\tau)\Delta\pi_{t-i}\right)\right)\left|\pi_t - \rho_0(\tau) + \rho_1(\tau)\pi_{t-1} + \beta(\tau)t + \sum_{i=1}^{q}\gamma_i(\tau)\Delta\pi_{t-i}\right| \tag{5.15}$$

where I = 1 if $\pi_t < \left(\rho_0(\tau) + \rho_1(\tau)\pi_{t-1} + \beta(\tau)t + \sum_{i=1}^{q}\gamma_i(\tau)\Delta\pi_{t-i}\right)$ and I = 0, otherwise. Given the solution for $\hat{\rho}(\tau)$ from Equation 5.15, the stochastic properties of $\Delta\pi_t$ within the τth quantile can be tested using the *t*-ratio statistic proposed by Koenker and Xiao (2004) as follows:

$$t_n(\tau) = \frac{f\left(\widehat{F^{-1}(\tau)}\right)}{\sqrt{\tau(1-\tau)}}(\pi'_{-1}M_Z\pi_{-1})^{1/2}(\hat{\rho}(\tau) - 1) \tag{5.16}$$

where π_{-1} is the vector of lagged inflation data and M_Z is the projection matrix onto the space orthogonal to $Z = (1, \Delta\pi_{t-1}, \dots, \Delta\pi_{t-q})$. The consistent estimator of $f(F^{-}(\tau))$ is $f\left(\widehat{F^{-1}(\tau)}\right)$, with f and F denoting the probability and cumulative density functions of ε_t in Equation 5.14. To estimate $f\left(F^{-1}(\tau)\right)$, Koenker and Xiao (2004) proposed the following rule:

$$f\left(\widehat{F^{-1}(\tau)}\right) = \frac{(\tau_i - \tau_{i-1})}{x'(\hat{\rho}(\tau_i) - \hat{\rho}(\tau_{i-1}))} \tag{5.17}$$

with $\tau_i \,\epsilon\, \Gamma$. As shown in the empirical analysis below, this chapter selects $\Gamma = \{0.1, 0.2, \dots, 0.9\}$. The use of the $t_n(\tau)$ statistic allows us to test the unit root hypothesis in each quantile. To be specific, this allows us to examine both the dynamics of inflation and the possibility of different mean reverting behaviour when the series is hit by various sizes and signs of shock at a range of quantiles. The ADF and other unit root tests that only concentrate on the conditional central tendency of the series behaviour do not permit an elaboration of such behaviour.

To obtain a more complete inference of unit root behaviour across quantiles, Koenker and Xiao (2004) proposed the quantile Kolmogorov-Smirnov (QKS) test as follows:

$$\text{QKS} = sup|t_n(\tau)|. \tag{5.18}$$

The QKS statistics are constructed by taking the maximum $|t_n(\tau)|$ statistics at $\tau_i \epsilon \Gamma$. Note that the limiting distributions of $t_n(\tau)$ and QKS test statistics are non-standard. The QKS test provides a general perspective of the behaviour of inflation and insights into global persistence. For example, if the shocks to inflation are short and long-lived in small and large quantiles, respectively, the QKS test means that the stationary behaviour of inflation in the low quantiles facilitates the whole process to revert to inflation's steady-state level (Çiçek & Akar, 2013). The QKS test also indicates that inflation might change apart for a short period of time at various sizes of shocks that hit the inflation but unlikely to deviate from its steady-state level even when a positive shock such as an oil price rise increases inflation.

In this chapter, Koenker and Xiao's (2004) resampling procedure is used to approximate the small-sample distributions of $t_n(\tau)$ and the QKS tests even though their limiting distributions are nonstandard. Following Koenker and Xiao (2004) and Tsong and Lee (2011), this resampling procedure is outlined below:

1. Regress the q-order autoregression $\Delta\pi_t = \sum_{i=1}^{q} \hat{\gamma}_i \Delta\pi_{t-i} + \hat{\varepsilon}_t$ by ordinary least squares (OLS) and obtain estimates $\hat{\gamma}_i$ for $i = 1,2, \ldots, q$, and the residuals $\hat{\varepsilon}_t$.

2. Draw a bootstrap sample of ε_t^* with replacement from the empirical distribution of the centred residuals $\bar{\varepsilon}_t = \hat{\varepsilon}_t - (n-q)^{-1}\sum_{t=q+1}^{n}\hat{\varepsilon}_t$.

3. Generate the bootstrap sample of $\Delta\pi_t^*$ recursively using the fitted autorgression $\Delta\pi_t^* = \sum_{i=1}^{q}\hat{\gamma}_i\,\Delta\pi_{t-i}^* + \hat{\varepsilon}_t^*$, with $\hat{\gamma}$ denoting the OLS estimates in Step (1), and starting values $\Delta\pi_i^* = \Delta\pi_i$ for $i = 1,2,\dots,q$.

4. Obtain the bootstrap sample of π_t^* based on $\pi_t^* = \pi_{t-1}^* + \Delta\pi_t^*$ with $\pi_1^* = \pi_1$.

5. With the resample π_t^*, compute the bootstrap counterparts of $\hat{\rho}_0(\tau)$, $\hat{\rho}_1(\tau)$, the $t_n(\tau)$ and the QKS test, denoted by $\hat{\rho}_0^*(\tau)$, $\hat{\rho}_1^*(\tau)$, $t_n^*(\tau)$ and QKS*, respectively.

6. Repeat Steps 2 to 5 with 5000 bootstrap replications in this study.

7. Calculate the empirical distribution functions of the 5000 bootstrap values of $\hat{\rho}_0^*(\tau)$, $\hat{\rho}_1^*(\tau)$, $t_n^*(\tau)$ and QKS* tests, and use these as an approximation of the cumulative distribution of the respective tests under the null.

8. Use the bootstrap *p*-value to make inferences.

It is important to note that Galvao (2009) has extended the above test by including deterministic components which is important for unit root test of drifting time series. Given that Equation 5.14 includes a deterministic time trend, this means that the non-stationary null is being tested against trend-reversion as opposed to mean-reversion. In this thesis, it is argued that an IT country having inflation under control might be characterized by the trend coefficient $\beta(\tau) < 0$. For example, one might expect a credible IT country to feature a negative and significant $\beta(\tau)$.

In accordance with the quantile unit root regression in Equation 5.14, this section advocates a three-way definition of IT based on perfect, imperfect (weak) and zero credibility based on the estimation results for $\rho_0(\tau)$, $\rho_1(\tau)$ and $\beta(\tau)$. Table 5.1 summarizes this categorization. A *perfectly* credible IT country is defined as one where the non-stationarity of inflation is rejected across all quantiles, $\rho_0(\tau)$

reflects the inflation target when $\beta(\tau) = 0$, and the values of $\rho_1(\tau)$ are close to -1 and therefore there is a fast speed of adjustment or a short half-life. A *perfectly* credible IT country would be expected to have estimates for $\rho_0(\tau)$ that are closer to zero compared to a non-IT country. For perfect credibility, one might also expect the QKS test to support stationarity.

An *imperfect* or *weak* credibility is defined where some of these characteristics are less distinct; for example, non-rejection of non-stationarity in some quantiles. However, in the weaker credibility case, one might expect a negative and significant $\beta(\tau)$ that suggests efforts to stabilize inflation are moving in the right direction. Moreover, one might expect the QKS test to reject non-stationarity for *imperfect* (*weak*) credibility case. *Zero* credibility is defined where most of the above features are absent; for example, there is non-rejection of non-stationarity across all quantiles and the QKS test will not reject non-stationarity.

Table 5.1: Three-way Definition of Inflation Targeting Credibility

IT credibility	Definition
Perfect	$\rho_1(\tau) = 0$ rejected across all τ $\rho_0(\tau)$ reflects inflation target when $\beta(\tau) = 0$ $\rho_1(\tau)$ close to -1 QKS test rejects non-stationarity
Imperfect (weak)	$\rho_1(\tau) = 0$ rejected in some τ $\beta(\tau) < 0$ and significant QKS test rejects non-stationarity
Zero	$\rho_1(\tau) = 0$ rejected in some τ QKS test does not reject non-stationarity

5.5 Data

For empirical analysis, the present chapter uses the inflation rate data for Asian countries introduced in Chapter 3. Before embarking on quantile regression analysis, it is important to mention that the skewness and kurtosis statistics discussed in Chapter 3 indicate that the inflation rates exhibit fat tails and there is strong evidence of non-normality in their distribution. According to Koenker and Xiao (2004), when a series is distributed non-normally, conventional unit root tests might provide weak performance and potentially bias test results in favour of a unit root. Therefore, evidence of fat tails and non-normality in inflation data from the previous chapter lend credence to the application of the quantile unit test for capturing inflation dynamics in Asian countries.

5.6 Empirical Results

5.6.1 Lee-Strazicich Unit Root Test Results

The results obtained from the standard univariate unit root or stationary tests such as ADF, DF-GLS, PP, NP and KPSS presented in Chapter 3 indicate that most inflation rates in the sample of Asian countries are stationary, except for Hong Kong. However, none of these tests allow for structural breaks. Table 5.2 presents the results of the minimum LM unit root tests by Lee and Strazicich (2003) that incorporate structural breaks under the non-stationary null hypothesis. After allowing for two endogenously determined breaks in both the level and trend, Table 5.2 shows that the LS test rejects the unit root null in all cases, suggesting that the inflation rates are trend stationary. Hence, this chapter includes a deterministic trend variable in the quantile unit root regression model.

In terms of the data-driven breaks identified by the LS unit root test, the first break occurs in November 1991 for the Philippines and in December 1991 for South Korea. For Indonesia and Thailand, the first break respectively occurs in November

Table 5.2: Lee-Strazicich Unit Root Test Results

Country	Lag order	TB1, TB2	B1(t)	B2(t)	D1(t)	D2(t)	LM test statistic
Indonesia	12	November 1997, June 2000	-1.858 (-1.536)	0.120 (0.098)	2.791 (5.976)***	-2.569 (-5.898)***	-0.143 (-6.879)***
Philippines	7	November 1991, August 2004	-1.67 (-2.460)**	0.082 (0.125)	-1.081 (-6.302)***	0.447 (4.188)***	-0.147 (-6.258)***
South Korea	6	December 1991, Sept 2000	-1.035 (-2.138)*	-1.841 (-3.726)***	-0.500 (-4.608)***	0.284 (3.638)**	-0.131 (-5.357)***
Thailand	5	January 1999, August 2004	0.236 (0.393)	0.306 (0.520)	-0.630 (-4.867)***	0.300 (2.912)**	-0.165 (-6.690)***
China	12	August 1990, April 1996	-1.211 (-1.491)	-0.215 (-0.271)	-0.159 (-0.889)	-0.575 (-3.733)**	-0.044 (-3.798)***
Hong Kong	6	December 1993, April 1999	-1.904 (-2.635)**	-0.367 (-0.514)	0.071 (0.530)	-0.276 (-1.856)	-0.140 (-4.723)***
Malaysia	7	August 1992, July 2005	0.447 (1.012)	0.988 (2.246)*	-0.298 (-4.073)***	0.146 (2.466)**	-0.183 (-6.927)***
Singapore	12	June 1992, March 2007	0.826 (2.014)*	-0.402 (-0.989)	-0.380 (-4.339)***	0.399 (4.505)***	-0.150 (-5.051)***

Notes: ***, ** and * denote significance at the 1%, 5% and 10% levels, respectively. TB1 and TB2 are the dates of the structural breaks; B1(t) and B2(t) are the dummy variables for the level breaks; D1(t) and D2(t) are the dummy variables for the trend breaks. Figures in parentheses are *t*-values. The 1, 5 and 10% critical values for the minimum LM test with two breaks are -4.545, -3.842 and -3.504, respectively.

1997 and January 1999. In the case of non-IT countries, the first breaks are identified in August 1990 (China), December 1993 (Hong Kong), August 1992 (Malaysia) and June 1992 (Singapore). At the 1% level, the first break point exhibits significant decrease (increase) in the slope of the trend inflation D1(*t*) for Malaysia, Philippines, Singapore, South Korea and Thailand (Indonesia). In addition, for the first break point, the level break B1(*t*) is negative and significant at the 5% level for Hong Kong and the Philippines and at the 10% level for South Korea. In contrast, the level break B1(*t*) is significantly positive at the 10% level for Singapore.

On the other hand, the second breaks for IT countries are identified as follows: June 2000 (Indonesia), August 2004 (Philippines and Thailand) and September 2000 (South Korea). The second breaks occur in April 1996 for China, April 1999 for Hong Kong, July 2005 for Malaysia and March 2007 for Singapore. The findings in Table 5.2 for the second of the two break points suggest significant breaks in the slope of the trend D2(*t*) in all cases except for Hong Kong. In this case, a positive (negative) change in the slope of the trend function occurs for Malaysia, Philippines, Singapore, South Korea and Thailand (China and Indonesia). Table 5.2 also shows that the significant breaks in the level B2(*t*) only occurs for Malaysia and South Korea where the break rises and declines, respectively. In a nutshell, the results show that evidence of a levels break is sparse, while the strongest evidence occurs with respect to the presence of trend breaks except for Hong Kong.

The above-mentioned break dates identified by the LS unit root test have coincided in general with major economic events that might be relevant to inflation dynamics. For example, the first break for the Philippines occurs during a recession and fiscal constraint between 1990 and 1992, while that of South Korea coincides with monetary targeting regime. The first break for Indonesia coincides with the abandonment of crawling band in 1997, while it reflects a crucial transition year for Thailand before the adoption of IT in 2000. The second break for the Philippines marked the period when the inflation target has been set to 4.0-6.0% in 2005. As for Thailand, the second break happened when the Bank of Thailand had raised policy rate three times in 2004. The second break for Malaysia concurs with the period when the country opted for bilateral exchange rate stability against the U.S. dollar, while it reflects the onset of the credit turmoil in mid-2007 for Singapore.

5.6.2 Clemente-Montañes-Reyes Unit Root Test Results

Table 5.3 reports the results for the CMR unit root test. The results show that the unit root null is rejected in all cases for both IO and AO models as the *t*-statistics are negative and significant at the 1% level throughout. As in the LS unit test, the CMR test confirms that the inflation rates are trend stationary. The break dates identified by the CMR test have also coincided with major economic events. Across IT countries, it can be seen that most of the first and second breaks correspond to the periods during and immediately after the Asian financial crisis. An exception to this is the Philippines where the first breaks in July 1991 and April 1992 happened together with a severe energy crisis that can be attributed to a recession and fiscal constraint between 1990 and 1992 (Yap, 1996). In the case of South Korea, the first break in October 1991 coincides with the period when price stability became the government's primary focus (Pahlavani & Harvie, 2008). In addition, the second break in February 2000 concurs with the modification of IT in 2000 when the basis of the inflation target was changed to the core rather than headline CPI inflation rate (Inoue et al., 2012).

Table 5.3: Clemente-Montañes-Reyes Detrended Unit Root Test Results

	Innovative outlier		Additive outlier	
Country	t-statistic	TB1, TB2	t-statistic	TB1, TB2
Indonesia	-13.106***	November 1997, November 1998	-8.016***	April 1998, October 1999
Philippines	-6.703***	July 1991, December 1998	-5.991***	April 1992, November 1999
South Korea	-5.772***	October 1991, September 1999	-4.457***	March 1999, February 2000
Thailand	-6.56***	June 1997, May 1998	-5.326***	March 1999, March 2009
China	-5.271***	January 1989, August 1994	-4.09***	March 1994, February 1996
Hong Kong	-4.847***	April 1998, July 2003	-4.637***	March 1998, January 2004
Malaysia	-5.518***	October 1998, May 2008	-4.917***	May 1999, April 2008
Singapore	-6.315***	October 1994, March 2007	-5.684***	January 1996, November 2007

Notes: ***, ** and * denote significance at the 1%, 5% and 10% levels, respectively. TB1 and TB2 are the dates of the structural breaks.

An examination of the structural breaks in Table 5.3 for the non-IT countries also reveals some important observations. For China, the first breaks occurred in January 1989 and March 1994, while the second breaks happened in August 1994 and February 1996. Some of these breaks are close to the findings of Li and Wei (2015) who identified the break dates for inflation in China at January 1989 and October 1994. In the cases of Hong Kong and Malaysia, the identified break dates occurred around Asian financial and food price crises episodes. To be specific, the first breaks occurred in April 1998 and March 1998 in the case of Hong Kong and in October 1998 and May 1999 for Malaysia. The second breaks for Malaysia occurred in April 2008 and May 2008 which can be driven by the food price crisis in 2007-2008. The same factor can also explain the second breaks in March 2007 and November 2007 in the case of Singapore. The first breaks in October 1994 and January 1996 for Singapore pertains to the decrease in inflation during those periods.

5.6.3 Enders-Granger Threshold Unit Root Test Results

The estimation results of the Enders-Granger threshold unit root test are displayed in Table 5.4. The results for both MTAR and MTAR-consistent models are almost identical in terms of the examination of the null of unit root and the null of symmetric adjustment. Therefore the discussion focuses on the latter model, which pertains to a method of searching for a consistent estimate of the threshold based on the method proposed by Chan (1993). The computed values of ϕ_μ are greater than the 1% critical value of 6.99 for China, Indonesia, Malaysia, Singapore and Thailand, while they exceed the 5% critical value of 4.95 for the Philippines and South Korea. Thus, the null hypothesis of unit root is strongly rejected for all countries except for Hong Kong as reported earlier in Chapter 3.

As for the null hypothesis of symmetry, $\rho_1 = \rho_2$, Table 5.4 shows that it is rejected at the 1% level for China and Indonesia, and at the 5% level for South Korea. This indicates that the adjustments of inflation around the threshold value are asymmetric such that the attractor is stronger for negative changes in the inflation rate. In general, the results also imply that that asymmetry is more likely for IT countries than non-IT countries. With respect to the speed of adjustment, the results show that $|\rho_1| > |\rho_2|$ for all countries. This means that the adjustment towards the threshold tends to persist more when inflation is decreasing than when inflation is increasing. These findings are similar to the results of the previous studies, including those of Henry and Shields (2004) and Teles and Zaidan (2010).

Table 5.4: Results for Enders-Granger TAR Unit Root Test

Model	Indonesia	Philippines	South Korea	Thailand
MTAR				
$\rho_1{}^a$	-0.019	-0.034**	-0.004	-0.057***
	(-1.426)	(-2.279)	(-0.201)	(-2.662)
$\rho_2{}^a$	-0.072***	-0.043***	-0.064***	-0.097***
	(-6.462)	(-2.811)	(-3.487)	(-4.059)
ϕ_μ	22.232	6.548	6.094	10.836
$\rho_1 = \rho_2{}^b$	8.647***	0.159	4.919**	1.661
	(0.000)	(0.691)	(0.027)	(0.198)
$Q(4)^b$	1.554	1.284	1.082	0.052
	(0.817)	(0.864)	(0.897)	(1.000)
MTAR-consistent				
$\rho_1{}^a$	-0.019	-0.035**	-0.004	-0.057***
	(-1.362)	(-2.311)	(-0.198)	(-2.664)
$\rho_2{}^a$	-0.072***	-0.042***	-0.065***	-0.097***
	(-6.464)	(-2.792)	(-3.489)	(-4.058)
ϕ_μ	22.284	6.556	6.104	10.841
$\rho_1 = \rho_2{}^b$	8.820***	0.132	4.945**	1.688
	(0.003)	(0.716)	(0.027)	(0.195)
$Q(4)^b$	1.648	1.284	1.079	0.052
	(0.800)	(0.864)	(0.898)	(1.000)
Threshold	8.953	6.320	4.078	3.509
Lags	4	2	2	5

Notes: ***, **, and * denote significance at the 1%, 5% and 10% levels, respectively. [a] Figures in parentheses are *t*-statistic for the null hypothesis $\rho_j = 0$, $j = 1,2$. [b] Figures in parentheses are *p*-values. The lag lengths are determined by the AIC. The 1, 5 and 10% critical values for ϕ_μ are 6.99, 4.95 and 4.05, respectively. $Q(4)$ is the test for serial correlation.

Table 5.4: (Continued)

	China	Hong Kong	Malaysia	Singapore
MTAR				
ρ_1^a	0.008	-0.033**	-0.098***	-0.068***
	(0.799)	(-2.490)	(-3.567)	(-3.011)
ρ_2^a	-0.051***	0.003	-0.114***	-0.071***
	(-5.558)	(0.210)	(-4.365)	(-3.155)
ϕ_μ	15.656	3.121	13.736	8.892
$\rho_1 = \rho_2^b$	18.737***	3.751*	0.229	0.009
	(0.000)	(0.054)	(0.633)	(0.926)
$Q(4)^b$	0.701	0.169	0.011	0.109
	(0.951)	(0.997)	(1.000)	(0.999)
MTAR-consistent				
ρ_1^a	0.008	-0.033	-0.097***	-0.068***
	(0.806)	(-2.525)**	(-3.568)	(-3.016)
ρ_2^a	-0.050***	0.005	-0.115***	-0.071***
	(-5.572)	(0.372)	(-4.383)	(-3.153)
ϕ_μ	15.822	3.237	13.789	8.895
$\rho_1 = \rho_2^b$	19.345***	4.237	0.264	0.008
	(0.000)	(0.040)	(0.608)	(0.931)
$Q(4)^b$	0.697	0.151	0.011	0.109
	(0.952)	(0.997)	(1.000)	(0.999)
Threshold	6.600	4.858	2.724	1.968
Lags	6	5	7	6

Notes: ***, **, and * denote significance at the 1%, 5% and 10% levels, respectively. [a] Figures in parentheses are *t*-statistic for the null hypothesis $\rho_j = 0$, $j = 1,2$. [b] Figures in parentheses are *p*-values. The lag lengths are determined by the AIC. The 1, 5 and 10% critical values for ϕ_μ are 6.99, 4.95 and 4.05, respectively. $Q(4)$ is the test for serial correlation.

5.6.4 Quantile Regression Results

The estimation results of the quantile ADF unit root tests are reported in Table 5.5. The tests were conducted for the case of a trend and no trend. Since the coefficient estimates for time trend variable *T* are significant in most of the cases, the regression results presents only the case of trend specification. The estimated coefficients of trend variable are also relevant for assessing IT credibility when in to comes to looking at trend-reversion of inflation rates. In addition, omitting the trend variable does not qualitatively alter the quantile regression estimates.

The empirical analysis in this section begins with the QKS test to provide an overall view of the behaviour of inflation rate over a range of quantiles. Table

5.5 shows that he QKS test rejects the unit root null hypothesis at the 5% significance level or better in all cases except for Hong Kong. In a global way, these results support inflation stationarity and therefore provide an indication that both an IT regime as well as alternative monetary policy frameworks on the part of non-IT countries has some degree of credibility. The global mean reversion results also imply that even if the shocks to inflation are respectively short and long-lived in small and large quantiles, the resulting increase in inflation is not anchored in inflationary expectations by workers and firms. This finding is highly relevant for central banks in judging whether the inflationary expectations have been anchored to inflation target, and help them to assess the proper actions for achieving the target.

Table 5.5 shows that for all countries, the estimates for the intercept $\rho_0(\tau)$ increase as the quantiles become larger. The results also show varying sizes of shocks across countries. In particular, looking across the $\rho_0(\tau)$ estimates for each country, China exhibits the most dispersive shocks or monthly change in the inflation rate that from -0.499 to 1.627, while Singapore shows the least dispersion of shocks ranging from -0.341 to 0.473. Overall, the dispersion of average shocks for IT countries (-0.249 to 1.602) is smaller than for non-IT countries (-0.499 to 1.627). This observation is important because it is consistent with Asian IT central banks' greater focus and efforts on inflation control under this regime.

Focusing on the prime coefficient of interest in Table 5.5, the estimates for the autoregressive coefficient $\rho_1(\tau)$ at the 10% to 50% quantiles are negative and significant in most cases thereby rejecting the unit-root null for most countries. Hong Kong is the only exception where the estimates for $\rho_1(\tau)$ are not significantly different from zero across all quantiles. Since Hong Kong has operated under a fixed exchange rate, the results suggest that both negative and positive shocks have

Table 5.5: Quantile ADF Unit Root Results, 1987:M1-2013:M11

Country	τ	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
Indonesia	$\hat{\rho}_0(\tau)$	0.338	0.010	0.238	0.344*	0.263	0.461**	0.697***	0.840***	1.104***
	p-value	0.203	0.961	0.205	0.057	0.141	0.010	0.000	0.000	0.000
	$\hat{\rho}_1(\tau)$	-0.155***	-0.077***	-0.067***	-0.055***	-0.024	-0.027*	-0.025*	-0.009	0.003
	p-value	0.000	0.000	0.000	0.002	0.141	0.067	0.063	0.525	0.876
	$\hat{\beta}(\tau)$	-0.2x10^{-3}	0.2x10^{-3}	-0.2x10^{-3}**	-0.4x10^{-3}**	-0.4x10^{-3}	-0.5x10^{-3}	-1.0x10^{-3}	-1.0x10^{-3}	-1.1x10^{-3}
	p-value	0.135	0.270	0.033	0.016	0.141	0.617	0.414	0.452	0.396
	Half-lives	4.121	8.642	9.999	12.340	∞	25.724	27.866	∞	∞
	QKS/*p*-value	11.732(0.000)***								
Philippines	$\hat{\rho}_0(\tau)$	0.272	0.297*	0.290*	0.567***	0.643***	0.756***	0.723***	0.879***	1.433***
	p-value	0.196	0.093	0.077	0.000	0.000	0.000	0.000	0.000	0.000
	$\hat{\rho}_1(\tau)$	-0.110***	-0.082***	-0.063***	-0.062***	-0.057***	-0.057***	-0.032	-0.032	-0.037
	p-value	0.000	0.000	0.002	0.001	0.000	0.002	0.149	0.190	0.142
	$\hat{\beta}(\tau)$	-1.3x10^{-3}***	-1.1x10^{-3}***	-1.0x10^{-3}***	-1.7x10^{-3}***	-1.7x10^{-3}**	-1.6x10^{-3}**	-1.5x10^{-3}*	-1.6x10^{-3}*	-3.0x10^{-3}***
	p-value	0.004	0.001	0.001	0.001	0.000	0.040	0.076	0.074	0.001
	Half-lives	5.945	8.084	10.616	10.741	11.823	11.883	∞	∞	∞
	QKS/*p*-value	6.100(0.001) ***								
South Korea	$\hat{\rho}_0(\tau)$	-0.210	-0.208	0.142	0.365***	0.491***	0.679***	0.814***	0.791***	1.602***
	p-value	0.303	0.222	0.334	0.007	0.000	0.000	0.000	0.000	0.000
	$\hat{\rho}_1(\tau)$	-0.080**	-0.053*	-0.065**	-0.073***	-0.072***	-0.071***	-0.075***	-0.047	-0.102***
	p-value	0.043	0.087	0.021	0.009	0.000	0.007	0.004	0.144	0.009
	$\hat{\beta}(\tau)$	-0.2x10^{-3}**	0.3x10^{-3}	-0.6x10^{-3}***	-1.1x10^{-3}***	-1.3x10^{-3}***	-1.7x10^{-3}***	-1.6x10^{-3}***	-1.3x10^{-3}*	-3.2x10^{-3}***
	p-value	0.044	0.279	0.002	0.000	0.000	0.004	0.009	0.055	0.000
	Half-lives	8.300	12.720	10.298	9.204	9.285	9.477	8.900	∞	6.461
	QKS/*p*-value	4.001(0.027)**								
Thailand	$\hat{\rho}_0(\tau)$	-0.249	-0.083	-0.040	0.217*	0.205*	0.309***	0.546***	0.706***	1.256***
	p-value	0.168	0.543	0.747	0.063	0.077	0.008	0.000	0.000	0.000
	$\hat{\rho}_1(\tau)$	-0.117**	-0.065**	-0.055*	-0.058**	-0.041*	-0.034	-0.046*	-0.036	-0.107***
	p-value	0.012	0.040	0.053	0.026	0.077	0.175	0.078	0.181	0.003
	$\hat{\beta}(\tau)$	-0.4x10^{-3}**	-0.5x10^{-3}**	-0.2x10^{-3}*	-0.7x10^{-3}**	-0.4x10^{-3}*	-0.5x10^{-3}	-0.9x10^{-3}	-1.1x10^{-3}*	-0.7x10^{-3}
	p-value	0.045	0.018	0.068	0.020	0.077	0.249	0.119	0.084	0.368
	Half-lives	5.549	10.280	12.220	11.638	16.537	∞	14.837	∞	6.115
	QKS/*p*-value	4.072(0.022)**								

Notes: All the *p*-values are calculated with the bootstrap method with 5000 replications. For $\hat{\rho}_0(\tau)$ the null of zero is tested with the student-*t* test, while for $\hat{\rho}_1(\tau)$, the unit-root null is tested with the $t_n(\tau)$ statistic. ***, ** and * denote significance at the 1, 5 and 10% levels.

Table 5.5: (Continued)

Country	τ	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
China	$\hat{\rho}_0(\tau)$	-0.499**	-0.239	0.027	0.143	0.275**	0.474***	0.716***	0.836***	1.627***
	p-value	0.031	0.185	0.862	0.313	0.048	0.001	0.000	0.000	0.000
	$\hat{\rho}_1(\tau)$	-0.071***	-0.052***	-0.048***	-0.036***	-0.028**	-0.023	-0.019	-0.003	-0.024
	p-value	0.000	0.000	0.000	0.005	0.048	0.160	0.297	0.775	0.156
	$\hat{\beta}(\tau)$	-0.8x10^{-3}**	-0.8x10^{-3}**	-0.8x10^{-3}**	-0.6x10^{-3}*	-0.7x10^{-3}**	-1.0x10^{-3}	-1.2x10^{-3}	-1.1x10^{-3}	-2.9x10^{-3}**
	p-value	0.048	0.013	0.013	0.053	0.048	0.590	0.406	0.330	0.024
	Half-lives	9.394	13.079	14.190	19.039	24.023	∞	∞	∞	∞
	QKS/*p*-value	5.343(0.005)***								
Hong Kong	$\hat{\rho}_0(\tau)$	-0.246	-0.288*	-0.144	-0.004	-0.020	0.167	0.382***	0.525***	0.865***
	p-value	0.216	0.055	0.292	0.976	0.874	0.190	0.004	0.001	0.000
	$\hat{\rho}_1(\tau)$	-0.035	-0.006	-0.009	-0.018	-0.004	-0.015	-0.020	-0.022	-0.036
	p-value	0.102	0.654	0.561	0.304	0.874	0.427	0.303	0.350	0.161
	$\hat{\beta}(\tau)$	-3.0x10^{-3}***	-1.0x10^{-3}***	-0.9x10^{-3}***	-0.5x10^{-3}**	0.1x10^{-3}	-0.02x10^{-3}	-0.2x10^{-3}	0.3x10^{-3}	0.4x10^{-3}
	p-value	0.000	0.004	0.005	0.031	0.874	0.797	0.770	0.956	0.935
	Half-lives	∞	∞	∞	∞	∞	∞	∞	∞	∞
	QKS/*p*-value	2.172(0.641)								
Malaysia	$\hat{\rho}_0(\tau)$	-0.076	0.143	0.198**	0.147	0.273***	0.383***	0.537***	0.645***	0.770***
	p-value	0.517	0.150	0.033	0.103	0.002	0.000	0.000	0.000	0.000
	$\hat{\rho}_1(\tau)$	-0.118***	-0.135***	-0.116***	-0.076***	-0.085***	-0.088***	-0.086***	-0.090***	-0.088**
	p-value	0.005	0.000	0.000	0.005	0.002	0.003	0.003	0.008	0.037
	$\hat{\beta}(\tau)$	-0.1x10^{-3}*	-0.1x10^{-3}**	-0.3x10^{-3}**	-0.1x10^{-3}	-0.3x10^{-3}***	-0.5x10^{-3}	-0.8x10^{-3}*	-0.7x10^{-3}	-0.7x10^{-3}
	p-value	0.057	0.025	0.012	0.145	0.002	0.197	0.058	0.209	0.256
	Half-lives	5.537	4.784	5.615	8.751	7.764	7.554	7.665	7.357	7.534
	QKS/*p*-value	5.576(0.000)***								
Singapore	$\hat{\rho}_0(\tau)$	-0.341***	-0.083	-0.012	-0.025	0.058	0.136**	0.184***	0.271***	0.473***
	p-value	0.000	0.268	0.848	0.679	0.329	0.024	0.005	0.000	0.000
	$\hat{\rho}_1(\tau)$	-0.100***	-0.101***	-0.074***	-0.053*	-0.053	-0.065**	-0.055*	-0.037	-0.052
	p-value	0.001	0.000	0.005	0.053	0.329	0.013	0.075	0.366	0.236
	$\hat{\beta}(\tau)$	0.04x10^{-3}	-0.3x10^{-3}**	-0.2x10^{-3}**	0.3x10^{-3}	0.3x10^{-3}	0.4x10^{-3}	0.7x10^{-3}	0.8x10^{-3}	0.9x10^{-3}
	p-value	0.237	0.017	0.022	0.388	0.329	0.968	0.999	1.000	0.998
	Half-lives	6.576	6.535	8.988	12.842	12.665	10.272	12.262	∞	∞
	QKS/*p*-value	4.743(0.011)**								

Notes: All the *p*-values are calculated with the bootstrap method with 5000 replications. For $\hat{\rho}_0(\tau)$ the null of zero is tested with the student-*t* test, while for $\hat{\rho}_1(\tau)$, the unit-root null is tested with the $t_n(\tau)$ statistic. ***, ** and * denote significance at the 1, 5 and 10% levels.

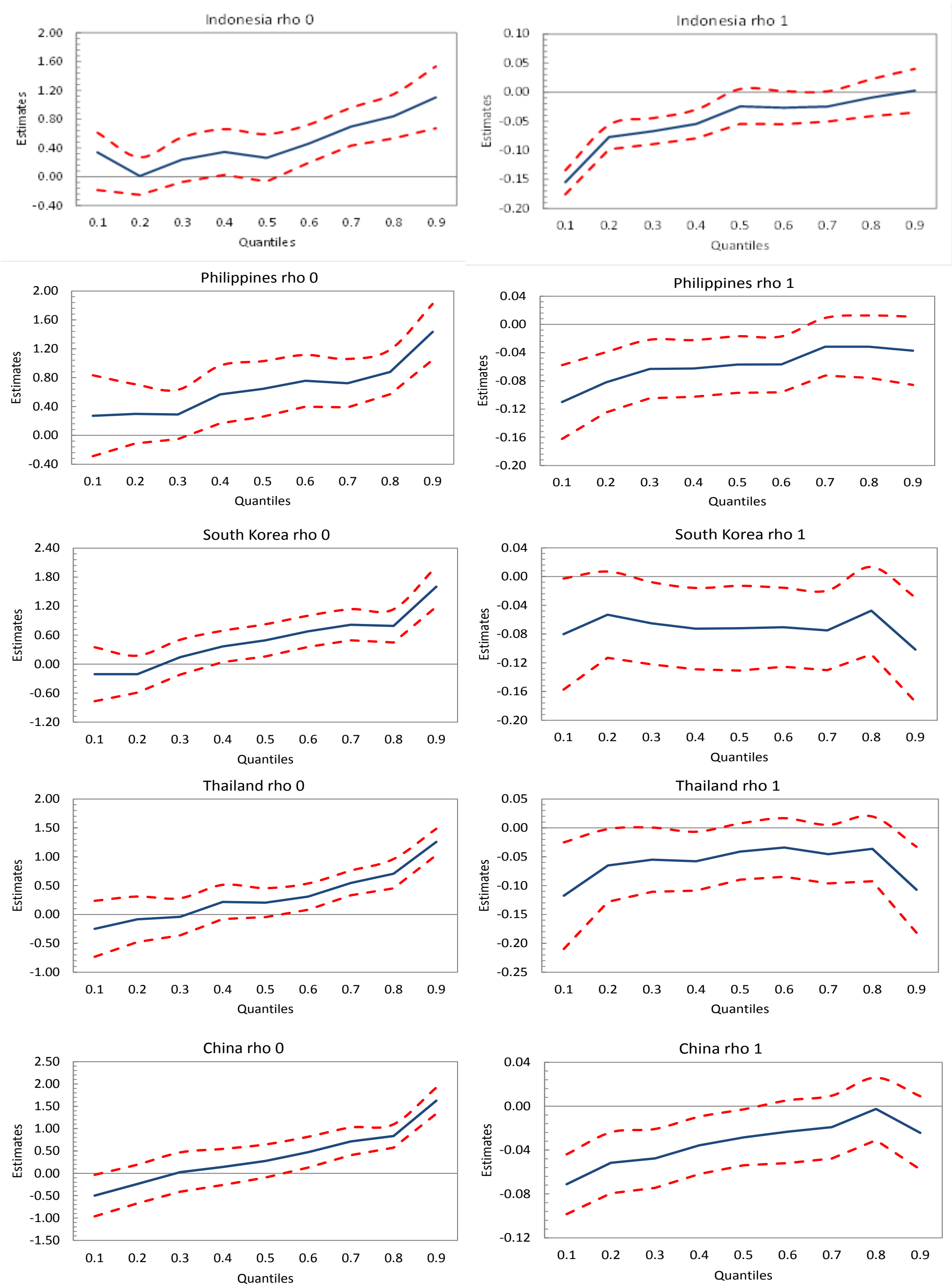
permanent effects on the country's inflation rate. Based on the insignificance of $\rho_1(\tau)$, non-stationarity tends to prevail at the upper quantiles (60% and above) in the case of the IT countries. Similar findings emerge for China and Singapore where a unit root in the inflation process is dominant at the higher quantiles. This implies that the credibility of an IT regime in Asia and the monetary policy in China and Singapore can be described as being *imperfect*.

In contrast, the estimates for $\rho_1(\tau)$ for Malaysia are significantly below zero over the whole conditional distribution which leads us to reject the unit root hypothesis throughout. In other words, the behaviour of inflation in Malaysia exhibits mean reversion across all quantiles. This means that for non-IT economy Malaysia, the country would fit into the description of central bank having *perfect* monetary control and credibility. In countries characterized by monetary policies that are conducive to low and stable inflation but where the target is not public, Capistrán and Ramos-Francia (2010) note that the heterogeneity of inflation expectations will not be large because the expectations will be close to the target. This finding lends support to the view that Malaysia's monetary policy has considerable weight attached to inflation stability without relying on IT (Gerlach & Tillmann, 2012). For non-IT country with sensible monetary policy, Capistrán and Ramos-Francia (2010) explain that economic agents know that their best long-run inflation forecast is the target, but they do not know the actual number. Since in this case the optimal forecast is the simple average of past inflation, expectations may be close to the target even if the target is not public.

Figure 5.1 illustrates the above estimated results for $\rho_0(\tau)$ and $\rho_1(\tau)$ along with their 95% confidence intervals obtained from the bootstrapping procedure. In general, the estimated values of $\rho_0(\tau)$ for all countries tend to increase passing through the zero point at least at the 60% quantile or higher. Also, it can be seen that the estimates for $\rho_0(\tau)$ are generally higher for IT countries, which is not in support of the perfect IT credibility hypothesis. This can be attributed to the fact that an IT country could still experience large unforeseen exogenous inflation shocks that are beyond the (credible) central bank's control. These shocks might push up or down $\rho_0(\tau)$. In terms of the estimates for $\rho_1(\tau)$, we find that $\rho_1(\tau)$ increases with τ in the cases of China, Indonesia and the Philippines. Indeed, the values of $\rho_1(\tau)$ in these countries are more negative in the low quantiles. By contrast, Malaysia, Hong Kong, Singapore, South Korea and Thailand are characterized by $\rho_1(\tau)$ appearing to have no significant variation across the quantiles. Indeed, Hong Kong always exhibits a zero slope inside the confidence interval thereby lending visual support for Hong Kong inflation being non-stationary across all the quantiles.

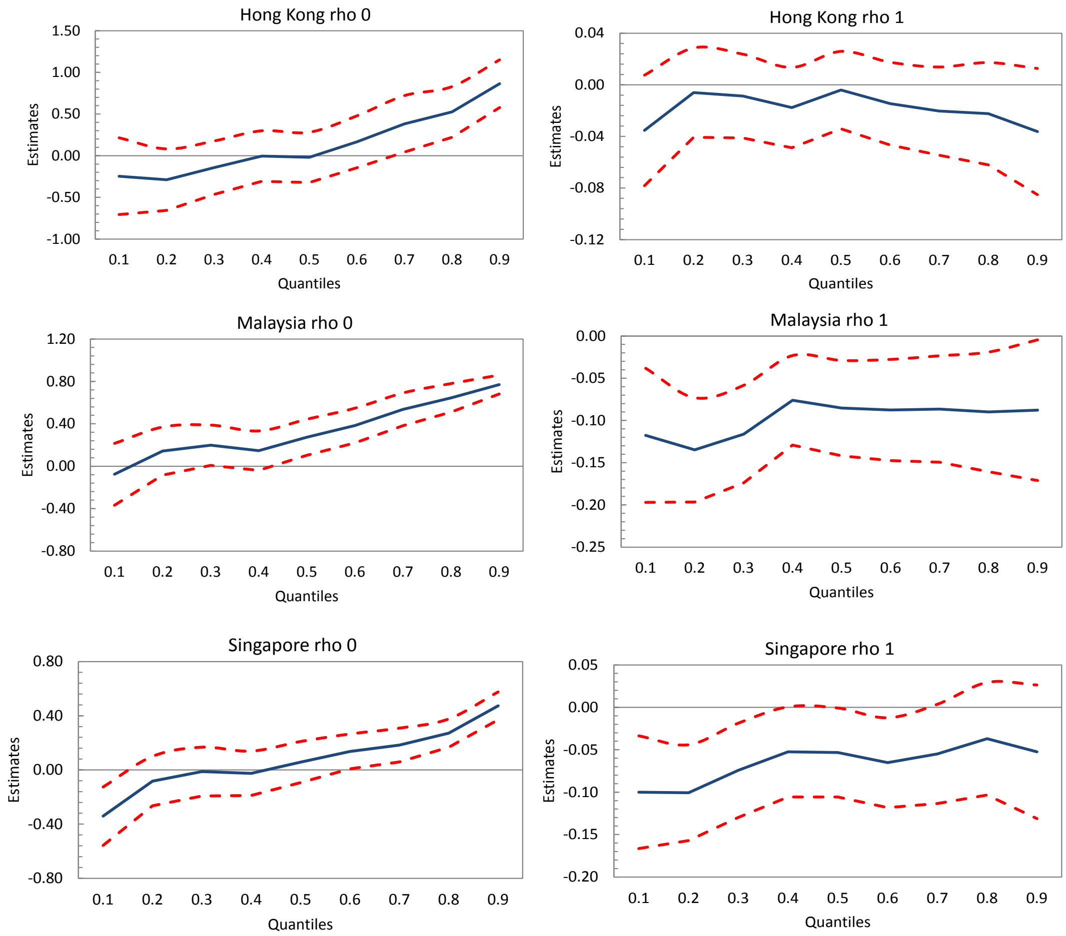
Overall, the results indicate that the presence of negative shocks creates weaker inertia, making inflation revert to its long-run equilibrium level. It confirms the view that under an IT regime, central banks respond strongly to smaller inflation deviations from the target to ensure that inflation shocks are only temporary and by doing so the observed inflation rate would tend to follow a mean-reverting behaviour around the target (Chiquiar et al., 2010). However, extreme positive shocks are not associated with mean-reversion in the cases of China, Hong Kong, Indonesia, the Philippines and Singapore. Such results are similar with the findings in Tsong and Lee (2011) who applied quantile unit root regression to OECD countries, and Henry and Shields (2004) who employed Caner and Hansen's (2001) threshold unit root method to Japan and UK inflation data. Time-series studies such as these address a vital issue about whether the inflation rates contain a unit root in one quantile or regime, while exhibit stationary behaviour in the other quantile or regime. As mentioned earlier, this issue is further enriched in this study by taking into account potential trend-reversion in inflation rate behaviour.

Figure 5.1: Quantile Intercepts (rho 0), Autoregressive Coefficients (rho 1).



Notes: The dashed lines signify the 95% confidence levels.

Figure 5.1: (Continued)



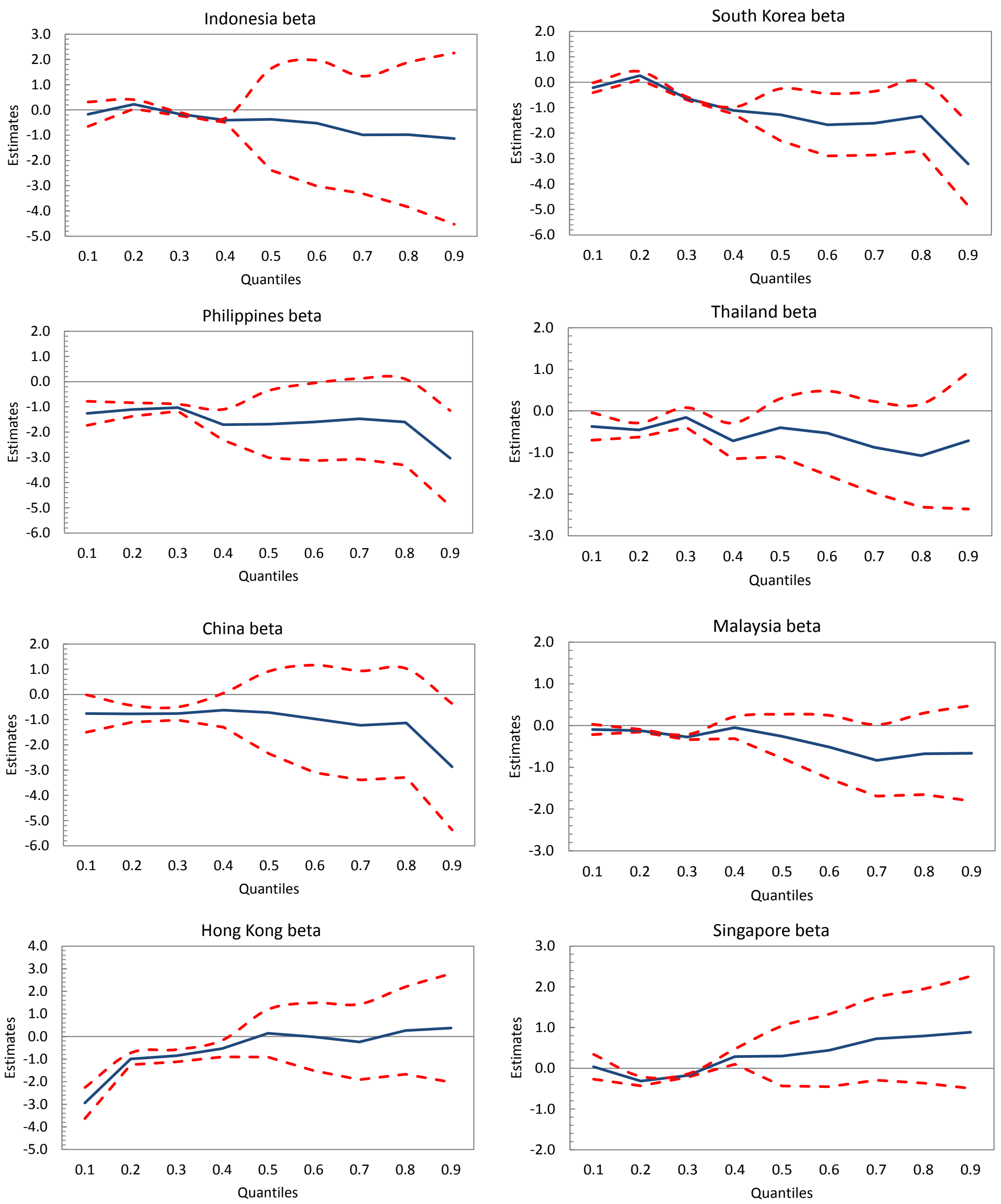
Notes: The dashed lines signify the 95% confidence levels.

Table 5.5 also reports the HLs associated with the quantiles where inflation is stationary. The HLs in the lowest quantile (10%) are relatively small, ranging from 4.12 months in Indonesia to 9.39 months in China. In the highest quantile (90%), the stationary cases of Malaysia, South Korea and Thailand where HLs are characterised by values in the range of 6-7 months. It is noticeable that there is an asymmetry in the speed of inflation adjustment across different quantiles of its distribution for the sample countries except for Malaysia. The results of asymmetry suggest that inflation rates respond differently to various signs and sizes of shocks. For example, at lower quantiles, the speed of inflation adjustment is faster when large negative shocks hit inflation rates. In contrast, at higher quantiles, the inflation rates contain a unit root and are therefore highly persistent. This implies lack of IT credibility regarding large inflation shocks.

Table 5.5 also reports that the estimates for the time trend coefficients are negative and statistically significant for the Philippines across all quantiles. Likewise, the estimates for time trend coefficients are negative and statistically significant to varying degrees across the other IT countries across quantiles. The estimates for the time trend in the case of Asian non-IT countries enter mostly with a negative sign except for Singapore, but these are statistically significant only at the smaller quantiles. Overall, the estimates for the time trend coefficients range from -3.2×10^{-3} to 0.3×10^{-3} for Asian IT countries and from -3.0×10^{-3} to 0.9×10^{-3} for non-IT countries. This evidence is consistent with the Asian IT countries building up their monetary policy credibility more than the non-IT countries in terms of a faster rate of decline in inflation rate changes.

Figure 5.2 plots the trend coefficient across the quantiles. Considering the lower and upper boundaries, the evidence is mixed on whether the trend coefficient is significantly different across the quantiles. For IT countries, the figure shows that the trend coefficient is often below a zero slope that remains outside the 95% confidence intervals for the Philippines and South Korea. In contrast, the 95% confidence intervals often encompass a zero slope, except for some quantiles. In addition to this, the declining trend over the whole conditional distribution is more pronounced for the Philippines and South Korea particularly between the middle and higher quantiles. In the case of non-IT countries, there is evidence that the 95% confidence intervals often contain a zero slope notably from the middle to higher quantiles. For Singapore and Hong Kong, the estimates for time trend exhibit an upward trend and enter with some positive signs.

Figure 5.2: Quantile Trend Coefficients (beta)



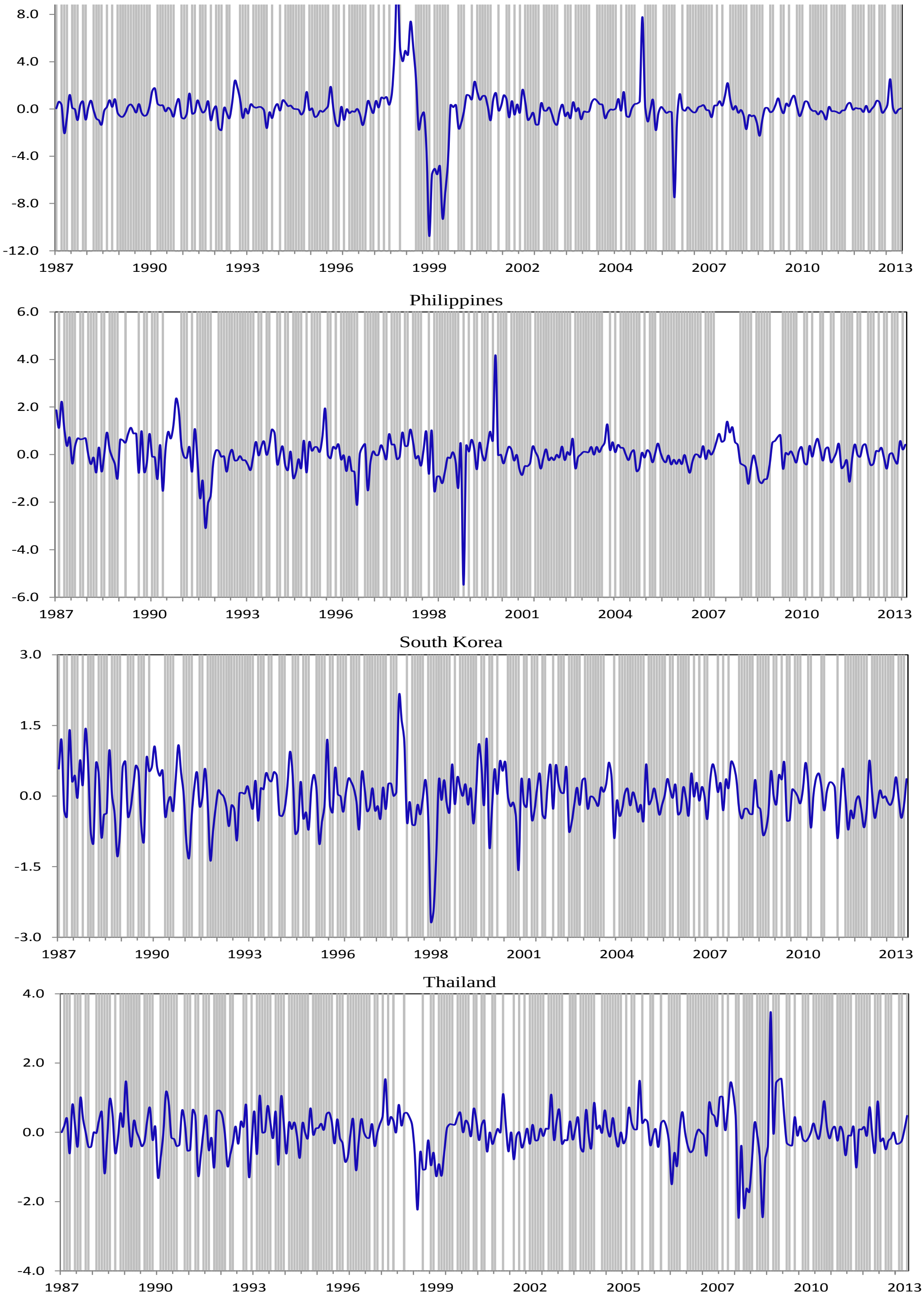
Notes: The dashed lines signify the 95% confidence levels.

Finally, this study offers an interpretation of the quantile regression results in terms of whether there is a threshold level whereby inflation becomes stationary. It has been mentioned in Table 5.5 that the inflation rates exhibit asymmetric adjustment in most of the countries. Based on these asymmetric results, it is shown that Indonesia displays strong stationary behaviour at the quantiles $\tau = 0.1, 0.2, 0.3, 0.4$. This suggests that the threshold level for the case of Indonesia is

$\widehat{Q}_{\Delta\pi_t}(0.4|\Gamma_{t-1}) = x'_t\hat{\rho}(0.4)$. Using the method by Lee et al. (2013), the stationary observations of inflation rates in Indonesia are identified. Based also on the asymmetric results from Table 5.5, the threshold level is different for each country. Specifically, the chosen quantile for the Philippines is $\tau = 0.6$, $\tau = 0.5$ for China and Thailand, $\tau = 0.4$ for South Korea and $\tau = 0.7$ for Singapore. Note that the inflation in Malaysia is stationary across all quantiles based on the results displayed in Table 5.5, and therefore there is no need to determine the threshold level.

Figure 5.3 plots the actual data on the changes in inflation rate and the corresponding stationary observations. The figure demonstrates that the stationary observations of inflation (the shaded areas) seem to frequently occur when inflation is falling from above or slowing down, while those non-stationary observations (unshaded areas) often occur during the periods when inflation is rising from below or increasing. Figure 5.3 also vividly illustrates that that the large positive spikes appear to generally occur in the non-shaded areas, mostly in1997-1998 and 2008. For example, inflation in Indonesia increased sharply in February 1998 on account of a sharp currency depreciation that started from late 1997 (Ito & Hayashi, 2004). Likewise, there was an abrupt increase in inflation in June 2008 in the cases of Indonesia, Malaysia, Philippines, and Thailand and this can be attributed to a food price crisis in 2008 (Dawe & Slayton, 2010). This is consistent with the above quantile results insofar as $\rho_1(\tau)$ is negative and significant at lower quantiles. Since the QKS test is supportive of global stationarity, the overall result in Figure 5.3 indicates that the mean-reverting properties in the low quantiles enable the whole process to return back to a shaded or stationary area. From a policy perspective, this result might imply that central banks in most of the sample countries avoid a high level of inflation and may conduct tightened monetary policy to curb inflation when the level is relatively high.

Figure 5.3: Threshold for Changes in Inflation Rate



Notes: The shaded areas in the figure indicate the stationary months for the inflation rate.

The above results are in line with Tsong and Lee (2011), Çiçek and Akar (2013) and Wolters and Tillmann (2015). However, these studies only focus on the mean-reversion in inflation rates mostly for OECD countries while the present study further enrich this issue by capturing trend-reversion in the series for a sample of Asian countries. This then enables us to confirm that IT countries are building up their monetary policy credibility more than non-IT countries based on a faster rate of decline in inflation rate changes. In addition, the specific sample of Asian countries lends itself more readily to an examination of pronounced turbulence due to financial crisis and shifts in monetary policy.

5.6.5 Robustness Analysis

This section conducts two robustness analyses of the findings with respect to changes in the sample data period and incorporating a structural break.

5.6.5.1 Quantile Regression Results Without Global Financial Crisis

This study considers whether the findings in Table 5.6 have differed before the 2008-2009 global financial crisis. Since economies around the world have become more wary of deflation and a number of central banks have hit the zero lower bound, this may have impacted on the analysis. That is, if deflation has a greater concern, then this has an impact on what happens at the lowest quantile. Consequently, it is difficult to analyse a post-global financial crisis period on account of a limited sub-sample size. For this reason, this study used instead subsample periods of monthly inflation rate data from 1987:M1–2007:M12.

Table 5.6 presents new estimation results of the quantile unit root test. In comparison with the results in Table 5.5, the counterparts in Table 5.6 show the following observations. First, the QKS test results still reject the unit root hypothesis in most cases but at varying levels of significance. To be precise, the QKS test results are statistically significant at the 1% level for Indonesia, Philippines and South Korea, and at the 10% level for China and Malaysia. In contrast to the preceding results, the QKS test exhibits low power performance in favor of a unit root in the inflation rates for Singapore and Thailand. In the cases of China, Malaysia and Thailand, the discrepancies from earlier results could be due to the possibility that central banks might have preferred not to intervene in the inflation dynamics in the absence of large positive inflation shocks before the global financial crisis. Indeed, Table 5.6 shows that large negative (positive) shocks in these three countries are linked to inflation stationarity (non-stationarity) before the global financial crisis. Meanwhile, the QKS test fails to reject the unit root null for Singapore which can be attributed to the change in monetary policy behaviour of its central bank before the global financial crisis. In the case of Hong Kong, the QKS test rejects the unit root null at the 10% significance level. As shown in Table 5.6, the estimated value of $\rho_1(\tau)$ at 90% quantile is far below zero for Hong Kong. Hence, the stationary behaviour of inflation rate in this extreme quantile enables the whole process to revert back to its long-run equilibrium level even though it contains a unit root in the remaining quantiles.

Second, Table 5.6 shows that the values of $\rho_0(\tau)$ for Indonesia and Thailand are slightly less than the preceding results displayed in Table 5.5. The estimates for $\rho_0(\tau)$ in the case of the Philippines and South Korea were marginally higher than the earlier results. Similar findings can also be observed for Singapore. For other Asian non-IT countries, the estimates for $\rho_0(\tau)$ do not vary substantially from the previous results. Overall, the results indicate that the values of $\rho_0(\tau)$ remain to increase as the quantiles get large.

Table 5.6: Quantile ADF Unit Root Results, 1987:M1-2007:M12

Country	τ	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
Indonesia	$\hat{\rho}_0(\tau)$	0.386	-0.060	0.181	0.156	0.170	0.381*	0.631***	0.808***	0.928***
	p-value	0.219	0.802	0.410	0.460	0.417	0.070	0.004	0.001	0.001
	$\hat{\rho}_1(\tau)$	-0.157***	-0.074***	-0.069***	-0.047***	-0.027	-0.029*	-0.022	-0.019	-0.013
	p-value	0.000	0.001	0.002	0.005	0.417	0.096	0.155	0.332	0.483
	$\hat{\beta}(\tau)$	$-0.2\text{x}10^{-3}$	$0.4\text{x}10^{-3}$	$0.5\text{x}10^{-3}$	$0.8\text{x}10^{-3}$	$0.6\text{x}10^{-3}$	$0.2\text{x}10^{-3}$	$-0.6\text{x}10^{-3}$	$0.5\text{x}10^{-3}$	$1.9\text{x}10^{-3}$
	p-value	0.153	0.244	0.302	0.402	0.417	0.841	0.707	0.968	0.981
	Half-lives	4.049	8.993	9.729	14.310	∞	23.214	∞	∞	∞
	QKS/*p*-value	10.334(0.000) ***								
Philippines	$\hat{\rho}_0(\tau)$	0.359	0.130	0.398**	0.694***	0.695***	0.902***	0.947***	1.049***	1.904***
	p-value	0.177	0.550	0.045	0.000	0.000	0.000	0.000	0.000	0.000
	$\hat{\rho}_1(\tau)$	-0.123***	-0.071***	-0.071***	-0.073***	-0.054**	-0.055***	-0.045**	-0.029	-0.063**
	p-value	0.000	0.003	0.001	0.000	0.000	0.005	0.043	0.220	0.033
	$\hat{\beta}(\tau)$	$-1.6\text{x}10^{-3}$**	$-0.4\text{x}10^{-3}$**	$-1.4\text{x}10^{-3}$***	$-2.4\text{x}10^{-3}$***	$-2.3\text{x}10^{-3}$***	$-2.9\text{x}10^{-3}$***	$-2.6\text{x}10^{-3}$**	$-3.2\text{x}10^{-3}$***	$-5.7\text{x}10^{-3}$***
	p-value	0.012	0.046	0.002	0.004	0.000	0.008	0.024	0.005	0.000
	Half-lives	5.270	9.377	9.419	9.087	12.489	12.233	14.999	∞	10.583
	QKS/*p*-value	5.776(0.001) ***								
South Korea	$\hat{\rho}_0(\tau)$	-0.251	-0.120	0.321*	0.449***	0.699***	0.713***	0.827***	1.159***	1.975***
	p-value	0.321	0.568	0.075	0.008	0.000	0.000	0.000	0.000	0.000
	$\hat{\rho}_1(\tau)$	-0.076	-0.056	-0.082**	-0.084**	-0.097***	-0.071**	-0.073**	-0.090***	-0.136***
	p-value	0.108	0.163	0.018	0.012	0.000	0.018	0.018	0.007	0.006
	$\hat{\beta}(\tau)$	$-0.1\text{x}10^{-3}$*	$-0.2\text{x}10^{-3}$*	$-1.2\text{x}10^{-3}$***	$-1.5\text{x}10^{-3}$***	$-2.1\text{x}10^{-3}$***	$-1.9\text{x}10^{-3}$**	$-1.9\ \text{x}10^{-3}$**	$-2.9\text{x}10^{-3}$***	$-5.2\text{x}10^{-3}$***
	p-value	0.070	0.052	0.000	0.003	0.000	0.039	0.044	0.006	0.000
	Half-lives	∞	∞	8.085	7.938	6.821	9.463	9.147	7.375	4.747
	QKS/*p*-value	4.594(0.006) ***								
Thailand	$\hat{\rho}_0(\tau)$	-0.378**	-0.067	0.004	0.191	0.290**	0.366***	0.497***	0.686***	0.873***
	p-value	0.042	0.639	0.973	0.108	0.013	0.002	0.000	0.000	0.000
	$\hat{\rho}_1(\tau)$	-0.088**	-0.062**	-0.050*	-0.054**	-0.050**	-0.029	-0.034	-0.021	-0.030
	p-value	0.018	0.028	0.065	0.034	0.013	0.296	0.182	0.369	0.286
	$\hat{\beta}(\tau)$	$0.6\text{x}10^{-3}$	$-0.5\text{x}10^{-3}$**	$-0.5\text{x}10^{-3}$**	$-0.8\text{x}10^{-3}$**	$-0.8\text{x}10^{-3}$**	$-1.0\text{x}10^{-3}$	$-1.0\text{x}10^{-3}$	$-1.3\text{x}10^{-3}$*	$-1.2\text{x}10^{-3}$
	p-value	0.442	0.020	0.019	0.024	0.013	0.166	0.146	0.067	0.143
	Half-lives	7.541	10.742	13.386	12.502	13.430	∞	∞	∞	∞
	QKS/*p*-value	3.052(0.129)								

Notes: All the *p*-values are calculated with the bootstrap method with 5000 replications. For $\hat{\rho}_0(\tau)$ the null of zero is tested with the student-*t* test, while for $\hat{\rho}_1(\tau)$, the unit-root null is tested with the $t_n(\tau)$ statistic. ***, ** and * denote significance at the 1, 5 and 10% levels.

Table 5.6. (Continued)

Country	τ	0.1	0.2	0.3	0.4	0.5	0.6	0.7.	0.8	0.9
China	$\hat{\rho}_0(\tau)$	-0.547**	-0.188	-0.015	0.128	0.211	0.414**	0.465***	0.970***	1.642***
	p-value	0.038	0.361	0.932	0.441	0.194	0.013	0.009	0.000	0.000
	$\hat{\rho}_1(\tau)$	-0.052***	-0.045***	-0.036**	-0.026	-0.021	-0.011	-0.008	0.003	-0.019
	p-value	0.003	0.004	0.017	0.100	0.194	0.634	0.797	0.947	0.283
	$\hat{\beta}(\tau)$	-1.4x10^{-3}**	-1.4x10^{-3}***	-1.2x10^{-3}***	-1.1x10^{-3}*	-0.7x10^{-3}	-1.0x10^{-3}	-0.4x10^{-3}	-2.0x10^{-3}	-4.1x10^{-3}**
	p-value	0.028	0.005	0.007	0.060	0.194	0.662	0.884	0.411	0.041
	Half-lives	12.865	15.096	19.118	26.788	∞	∞	∞	∞	∞
	QKS/*p*-value	4.277(0.084)*								
Hong Kong	$\hat{\rho}_0(\tau)$	-1.125***	-0.425**	-0.179	-0.027	-0.016	0.188	0.560***	0.803***	1.310***
	p-value	0.000	0.022	0.275	0.863	0.916	0.223	0.001	0.000	0.000
	$\hat{\rho}_1(\tau)$	0.038	0.003	-0.009	-0.015	-0.006	-0.014	-0.029	-0.034	-0.065***
	p-value	1.000	0.956	0.699	0.444	0.916	0.565	0.214	0.110	0.002
	$\hat{\beta}(\tau)$	1.9x10^{-3}	0.1x10^{-3}	-0.3x10^{-3}**	-0.4x10^{-3}*	0.1x10^{-3}	-0.4x10^{-3}	-1.4x10^{-3}	-2.0x10^{-3}	-3.0x10^{-3}*
	p-value	0.822	0.169	0.037	0.059	0.916	0.729	0.424	0.210	0.052
	Half-lives	∞	∞	∞	∞	∞	∞	∞	∞	10.345
	QKS/*p*-value	3.524(0.053) *								
Malaysia	$\hat{\rho}_0(\tau)$	-0.153	0.051	0.053	0.179**	0.229***	0.332***	0.426***	0.490***	0.662***
	p-value	0.258	0.621	0.573	0.046	0.009	0.000	0.000	0.000	0.000
	$\hat{\rho}_1(\tau)$	-0.086*	-0.099***	-0.068**	-0.077***	-0.067**	-0.074**	-0.054	-0.041	-0.046
	p-value	0.067	0.001	0.023	0.008	0.009	0.019	0.200	0.381	0.433
	$\hat{\beta}(\tau)$	-0.3x10^{-3}**	0.0x10^{-3}	0.0x10^{-3}	-0.3x10^{-3}**	-0.5x10^{-3}***	-0.6x10^{-3}	-1.0x10^{-3}	-0.9x10^{-3}	-0.6x10^{-3}
	p-value	0.043	0.157	0.134	0.030	0.009	0.221	0.118	0.249	0.510
	Half-lives	7.706	6.634	9.834	8.683	10.066	8.998	∞	∞	∞
	QKS/*p*-value	3.872(0.055) *								
Singapore	$\hat{\rho}_0(\tau)$	-0.334**	-0.008	0.032	0.073	0.128	0.184**	0.249***	0.463***	0.727***
	p-value	0.021	0.940	0.734	0.404	0.134	0.035	0.008	0.000	0.000
	$\hat{\rho}_1(\tau)$	-0.082	-0.092	-0.085	-0.068	-0.059	-0.063	-0.062	-0.076	-0.076
	p-value	0.309	0.107	0.100	0.233	0.134	0.284	0.302	0.205	0.345
	$\hat{\beta}(\tau)$	-0.4x10^{-3}**	-1.0x10^{-3}***	-0.6x10^{-3}***	-0.4x10^{-3}**	-0.4x10^{-3}	-0.0x10^{-3}	0.3x10^{-3}	-0.3x10^{-3}	-0.9x10^{-3}
	p-value	0.010	0.001	0.002	0.015	0.134	0.886	0.991	0.793	0.545
	Half-lives	∞	∞	∞	∞	∞	∞	∞	∞	∞
	QKS/*p*-value	2.959(0.444)								

Notes: All the *p*-values are calculated with the bootstrap method with 5000 replications. For $\hat{\rho}_0(\tau)$ the null of zero is tested with the student-*t* test, while for $\hat{\rho}_1(\tau)$, the unit-root null is tested with the $t_n(\tau)$ statistic. ***, ** and * denote significance at the 1, 5 and 10% levels.

Third, except for Singapore, the persistence of inflation is still asymmetric depending on the sizes and signs of the shocks. The estimated values of $\rho_1(\tau)$ for Singapore are not significantly different from zero across all quantiles, suggesting that inflation rates follow a unit root process in the subsample period. It is also noticeable that the values of $\rho_1(\tau)$ for Malaysia are far below zero and statistically significant mostly at the 5% level or better but at the 10% up to the 60% quantiles only. Furthermore, the inflation rates in South Korea contain a unit root in the extreme low quantiles (10% and 20% quantiles) but stationary all throughout from the 30% up to the 90% quantiles. This implies that a greater concern on inflation following the global financial crisis has impacted on the inflation adjustment in the lowest quantile. Overall, the results based on sub-period indicate that the rejection of non-stationarity across quantiles depends on whether or not the deterministic trend is included.

5.6.5.2 Quantile Regression Results under Inflation Targeting

Finally, this section takes into account possible structural breaks as Asian economies have experienced important shifts in monetary policy following the financial crisis of 1997/1998. South Korea, Thailand, Philippines and Indonesia have adopted IT, while China, Hong Kong, Malaysia and Singapore adopted alternative policy strategy. Neglecting structural breaks could lead to spuriously high estimates of the degree of persistence (Gerlach & Tillman, 2012). To this end, this study captures the possible mean shift in line with Tsong and Lee (2011) and Çiçek and Akar (2013) by writing Δz_t in Equation 5.19 as follows:

$$\Delta z_t = \rho_0 + \rho_1 z_{t-1} + \beta t + \sum_{i=1}^{q} \gamma_i \Delta z_{t-i} + \varepsilon_t \qquad (5.19)$$

where $z_t = \pi_t - \hat{\mu}_0 - \hat{\mu}_1 D_t$. Here $\hat{\mu}_0$ and $\hat{\mu}_0$ are ordinary least squares (OLS) estimates of μ_0 and μ_1, respectively, obtained from the regression of π_t on $(1, D_t)'$ and D_t is an indicator function taking unity if $t \geq s_t$, and zero otherwise, with s_t being a known start date of adopting IT. For the s_t dummy variable, this study follows Leyva (2008) and applies the "half-year rule" which states that if IT is adopted in the second half of year *t*, the adoption year is (t + 1), otherwise the adoption year is *t*. In this context, Leyva (2008) proposed two classifications of IT adoption dates, namely a partial adoption and a fully-fledged adoption.[6] Since Asian IT countries started implementing both a partial and a fully-fledged IT adoption in the same year as reported in Lucotte (2010, p. 11), the latter adoption date is used for all Asian IT countries to robust the findings reported in Table 5.5. Advancing the analysis in this way is important because a fully-fledged IT is characterized by the fulfilment of key preconditions for IT and the establishment of operational features of IT such as publishing inflation reports that contain inflation projections (Mishkin and Schmidt-Hebbel, 2007; Lucotte, 2010). Note that s_t is 1998M4, 2000M5, 2002M1 and 2005M7 for South Korea, Thailand, Philippines and Indonesia, respectively. As in Lucotte (2010), this study follows the suggestion of Ball and Sheridan (2005) and consider the mean of the adoption dates in IT countries as the "year adoption" for non-IT countries. Therefore in the cases of all Asian non-IT countries, this date corresponds to 2000 considering both a partial and a fully-fledged adoption. On the basis of the new calculation of π_t in Equation 5.19, Table 5.7 presents re-estimated QKS test results, $\rho_0(\tau)$, $\rho_1(\tau)$ and $\beta(\tau)$ coefficients, and HLs obtained using the same methodology as described Section 5.4.

[6] The "half-year rule" is also employed in Samarina and De Haan (2014) and Lucotte (2010).

Table 5.7: Quantile ADF with Structural Breaks, 1987:M1-2013:11

Country	τ	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
Indonesia	$\hat{\rho}_0(\tau)$	-1.452***	-0.907***	-0.536***	-0.284*	-0.059	0.159	0.394**	0.713***	1.096***
	p-value	0.000	0.000	0.001	0.062	0.692	0.291	0.011	0.000	0.000
	$\hat{\rho}_1(\tau)$	-0.136***	-0.080***	-0.069***	-0.053***	-0.027	-0.030**	-0.028*	-0.013	-0.006
	p-value	0.000	0.000	0.000	0.002	0.692	0.042	0.052	0.411	0.633
	$\hat{\beta}(\tau)$	$2.1 x 10^{-3}$	$1.5 x 10^{-3}$	$0.7 x 10^{-3}$	$0.3 x 10^{-3}$	$0.1 x 10^{-3}$	$-0.2 x 10^{-3}$	$-0.5 x 10^{-3}$	$-0.6 x 10^{-3}$	$-1.1 x 10^{-3}$
	p-value	0.973	0.906	0.599	0.304	0.692	0.718	0.676	0.641	0.439
	Half-lives	4.732	8.272	9.687	12.693	25.238	23.133	24.199	∞	∞
	QKS/*p*-value	10.612(0.000)***								
Philippines	$\hat{\rho}_0(\tau)$	-0.743***	-0.492***	-0.279***	-0.021	0.128	0.272***	0.460***	0.638***	1.116***
	p-value	0.000	0.000	0.002	0.796	0.121	0.001	0.000	0.000	0.000
	$\hat{\rho}_1(\tau)$	-0.086***	-0.063***	-0.055***	-0.055***	-0.052	-0.050***	-0.029	-0.036	-0.038
	p-value	0.002	0.004	0.004	0.002	0.121	0.007	0.181	0.113	0.148
	$\hat{\beta}(\tau)$	$0.4 x 10^{-3}$	$0.5 x 10^{-3}$	$0.1 x 10^{-3}$	$-0.4 x 10^{-3}$*	$-0.6 x 10^{-3}$	$-0.7 x 10^{-3}$	$-1.02 x 10^{-3}$	$-1.2 x 10^{-3}$	$-2.4 x 10^{-3}$***
	p-value	0.373	0.472	0.174	0.059	0.121	0.363	0.158	0.113	0.004
	Half-lives	7.664	10.694	12.152	12.269	13.038	13.596	∞	∞	∞
	QKS/*p*-value	10.612(0.000)***								
South Korea	$\hat{\rho}_0(\tau)$	-0.711***	-0.477***	-0.250***	-0.072	0.112*	0.247***	0.345***	0.544***	0.960***
	p-value	0.000	0.000	0.000	0.267	0.076	0.000	0.000	0.000	0.000
	$\hat{\rho}_1(\tau)$	-0.188***	-0.115***	-0.084**	-0.077**	-0.103*	-0.106***	-0.068*	-0.067*	-0.123**
	p-value	0.000	0.003	0.016	0.024	0.076	0.000	0.062	0.084	0.011
	$\hat{\beta}(\tau)$	$0.6 x 10^{-3}$	$0.6 x 10^{-3}$	$0.1 x 10^{-3}$	$-0.3 x 10^{-3}$**	$-0.7 x 10^{-3}$*	$-0.8 x 10^{-3}$	$-0.6 x 10^{-3}$	$-1.1 x 10^{-3}$*	$-1.8 x 10^{-3}$**
	p-value	0.654	0.683	0.170	0.030	0.076	0.129	0.357	0.061	0.010
	Half-lives	3.326	5.693	7.874	8.593	6.386	6.178	9.839	10.019	5.261
	QKS/*p*-value	5.237(0.002)***								
Thailand	$\hat{\rho}_0(\tau)$	-0.642***	-0.411***	-0.280***	-0.071	0.021	0.109	0.325***	0.519***	0.757***
	p-value	0.000	0.000	0.000	0.329	0.772	0.138	0.000	0.000	0.000
	$\hat{\rho}_1(\tau)$	-0.105**	-0.059*	-0.053*	-0.067**	-0.044	-0.040	-0.040	-0.069**	-0.123***
	p-value	0.033	0.093	0.075	0.016	0.772	0.126	0.142	0.026	0.002
	$\hat{\beta}(\tau)$	$-0.2 x 10^{-3}$*	$0.1 x 10^{-3}$	$0.3 x 10^{-3}$	$-0.2 x 10^{-3}$	$-0.2 x 10^{-3}$	$-0.1 x 10^{-3}$	$-0.5 x 10^{-3}$	$-0.8 x 10^{-3}$	$-0.04 x 10^{-3}$
	p-value	0.073	0.208	0.325	0.100	0.772	0.553	0.283	0.187	0.779
	Half-lives	6.243	11.314	12.686	10.044	15.253	∞	∞	9.731	5.268
	QKS/*p*-value	3.972(0.025)**								

Notes: All the *p*-values are calculated with the bootstrap method with 5000 replications. For $\hat{\rho}_0(\tau)$ the null of zero is tested with the student-*t* test, while for $\hat{\rho}_1(\tau)$, the unit-root null is tested with the $t_n(\tau)$ statistic. ***, ** and * denote significance at the 1, 5 and 10% levels.

Table 5.8: (Continued)

Country	τ	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
China	$\hat{\rho}_0(\tau)$	-1.478***	-0.883***	-0.586***	-0.266**	-0.080	0.128	0.457***	0.760***	1.488***
	p-value	0.000	0.000	0.000	0.019	0.471	0.257	0.000	0.000	0.000
	$\hat{\rho}_1(\tau)$	-0.063***	-0.049***	-0.038***	-0.035**	-0.026	-0.020	-0.012	-0.007	-0.039**
	p-value	0.000	0.000	0.006	0.013	0.471	0.230	0.519	0.665	0.027
	$\hat{\beta}(\tau)$	2.4x10^{-3}	1.3x10^{-3}	1.0x10^{-3}	0.5x10^{-3}	0.4x10^{-3}	0.1x10^{-3}	-0.4x10^{-3}	-1.0x10^{-3}	-2.7x10^{-3}**
	p-value	0.986	0.803	0.579	0.360	0.471	0.954	0.783	0.394	0.020
	Half-lives	10.682	13.757	17.754	19.286	26.774	∞	∞	∞	17.212
	QKS/*p*-value	4.426(0.035)**								
Hong Kong	$\hat{\rho}_0(\tau)$	-0.435***	-0.292***	-0.176*	-0.141	-0.066	0.064	0.246**	0.371***	0.727***
	p-value	0.003	0.008	0.078	0.139	0.478	0.499	0.012	0.001	0.000
	$\hat{\rho}_1(\tau)$	-0.019	-0.006	-0.009	-0.009	-0.003	-0.009	-0.013	-0.031	-0.061**
	p-value	0.412	0.703	0.548	0.604	0.478	0.641	0.598	0.179	0.028
	$\hat{\beta}(\tau)$	-2.7x10^{-3}***	-1.02x10^{-3}***	-0.7x10^{-3}***	-0.1x10^{-3}*	0.3x10^{-3}	0.3x10^{-3}	0.1x10^{-3}	0.7x10^{-3}	0.6x10^{-3}
	p-value	0.000	0.001	0.004	0.099	0.478	0.928	0.929	0.994	0.977
	Half-lives	∞	∞	∞	∞	∞	∞	∞	∞	10.953
	QKS/*p*-value	3.488(0.118)								
Malaysia	$\hat{\rho}_0(\tau)$	-0.464***	-0.296***	-0.220***	-0.117**	-0.021	0.107*	0.233***	0.330***	0.504***
	p-value	0.000	0.000	0.000	0.036	0.701	0.053	0.000	0.000	0.000
	$\hat{\rho}_1(\tau)$	-0.128***	-0.142***	-0.109***	-0.094***	-0.093	-0.095***	-0.099***	-0.096***	-0.121***
	p-value	0.005	0.000	0.001	0.000	0.701	0.001	0.002	0.009	0.008
	$\hat{\beta}(\tau)$	0.4x10^{-3}	0.3x10^{-3}	0.4x10^{-3}	0.3x10^{-3}	0.2x10^{-3}	-0.2x10^{-3}	-0.5x10^{-3}	-0.3x10^{-3}	-0.4x10^{-3}
	p-value	0.455	0.468	0.643	0.589	0.701	0.611	0.319	0.659	0.436
	Half-lives	5.046	4.538	5.983	7.016	7.114	6.932	6.671	6.875	5.354
	QKS/*p*-value	5.509(0.000)***								
Singapore	$\hat{\rho}_0(\tau)$	-0.439***	-0.216***	-0.166***	-0.119**	-0.026	0.016	0.077	0.212***	0.428***
	p-value	0.000	0.002	0.005	0.031	0.631	0.772	0.198	0.002	0.000
	$\hat{\rho}_1(\tau)$	-0.099***	-0.107***	-0.067**	-0.052**	-0.048	-0.067***	-0.049*	-0.040	-0.041
	p-value	0.005	0.000	0.020	0.048	0.631	0.007	0.092	0.249	0.343
	$\hat{\beta}(\tau)$	-0.7x10^{-3}***	-0.7x10^{-3}***	-0.1x10^{-3}**	0.2x10^{-3}	0.2x10^{-3}	0.4x10^{-3}	0.8x10^{-3}	0.7x10^{-3}	0.5x10^{-3}
	p-value	0.006	0.001	0.025	0.349	0.631	0.980	0.999	1.000	0.985
	Half-lives	6.683	6.125	9.998	12.960	14.115	9.949	13.717	∞	∞
	QKS/*p*-value	5.156(0.008)***								

Notes: All the *p*-values are calculated with the bootstrap method with 5000 replications. For $\hat{\rho}_0(\tau)$ the null of zero is tested with the student-*t* test, while for $\hat{\rho}_1(\tau)$, the unit-root null is tested with the $t_n(\tau)$ statistic. ***, ** and * denote significance at the 1, 5 and 10% levels.

The findings indicate that incorporating a structural break through a fully-fledged adoption of IT has some important policy implications. With exception of Hong Kong, the QKS test results still exhibit high power performance in favour of global stationarity in inflation rates in most countries. This finding implies that inflation rate follows a stationary process when a fully-fledged IT adoption has been considered. Also, the estimates for $\rho_0(\tau)$ differ slightly from those in Table 5.5 but they remain to indicate that the impact of positive shocks on inflation rate is larger than negative shocks even if a fully-fledged IT adoption has been taken into account.

Furthermore, there is still asymmetry in the persistence of the inflation rates in most countries but its degree is generally reduced at most quantiles, especially in upper ones. This finding is in line with Mishkin (2008) that IT may be helpful in reducing inflation persistence (Tsong & Lee, 2011). Also, Table 5.7 reveals that inflation rates in South Korea exhibit stationarity across all quantiles which is in contrast to the findings in Table 5.5. This result implies that a fully-fledged adoption of IT is *perfectly* credible in South Korea. As in the preceding finding, Malaysia still exhibits a *perfectly* credible monetary policy when a possible mean shift has been incorporated.

Table 5.7 also shows that although the estimated values of $\beta(\tau)$ differ much from those in Table 5.5, Asian IT countries exhibit mostly negative estimates for time trend in the upper quantiles as compared with non-IT countries. This finding still concurs with the results in Table 5.5 and implies that with a fully-fledged IT adoption, countries with inflation target enhance their monetary policy credibility more than non-IT countries with respect to a faster rate of decrease in inflation rate changes. In view of HLs, the findings of asymmetry in the speed of inflation adjustment across different quantiles still hold for all countries. This result suggests that the inflation rates respond differently to various signs and sizes of shocks even after the effects of a possible break on the inflation dynamics have been considered.

5.7 Conclusions

This chapter examines the dynamic behaviour of the inflation rates in eight Asian countries using the quantile unit root test over the period 1987-2013. This method allows for the possibility that shocks of different signs and sizes have a different impact on inflation, and accounts for possible asymmetric adjustment of inflation towards to its long-run equilibrium. This chapter provides new evidence of globally stationary inflation rates for all Asian IT and non-IT countries in our samples except for Hong Kong.

The study also finds that there is asymmetry in the speed of adjustment in the inflation process, in which large negative shocks tend to induce strong mean reversion in the lower quantiles, while inflation follows unit root behaviour in the higher quantiles. These findings corroborate previous studies. However, this study departs substantially by capturing both the mean and trend-reversion in the inflation rates. This has enabled us to offer new insight into the effects of IT on the behaviour of inflation by verifying whether an IT country having inflation under control might be characterized by a negative trend coefficient at different quantiles of inflation. The findings in this chapter also shed new light on whether stationarity is linked to smaller or larger changes in inflation by working with first differenced inflation data, which has clear implications for understanding the behaviour of the level of inflation (i.e. stationary or non-stationary).

The results further indicate that negative estimates for deterministic time trend are mostly significant for Asian IT countries and noticeably lower than non-

IT countries. This indicates that IT central banks have been building up their monetary policy credibility more than the non-IT countries from a faster rate of decline in inflation rate changes. This new insight is of significant value to academics and policymakers alike. With inflation being trend stationary, researchers would then have a more conclusive analysis of monetary theory's assumption of mean-reverting inflation after controlling for structural breaks. In addition, policymakers have the opportunity to forecast future movements in inflation based on past behaviour and to demonstrate the credibility of IT policy in controlling inflation in the presence of large positive shocks.

Finally, the results for determining the threshold levels at which inflation becomes stationary suggest that stationarity seems to occur frequently when inflation is falling from above or slowing down, while non-stationary observations often occur during the periods when inflation is rising from below or increasing. Such results are similar to the findings of Henry and Shields (2004) who employed Caner and Hansen's (2001) threshold unit root method to Japan and UK inflation data. Time-series studies such as this address an important issue about whether the inflation rates contain a unit root in one regime, while exhibit stationary behaviour in another regime. This issue is further enriched in this study by taking into account the trend-reversion in inflation rates.

Since monetary policy strategies in the sample of Asian countries underwent important structural changes after the 1997/1998 financial crisis, this study takes into account a single mean shift in the inflation rates by following the "half-year rule" and focusing on a fully-fledged adoption of IT. In doing so, this study finds that a fully-fledge IT regime in South Korea and the alternative monetary policy in Malaysia are *perfectly* credible insofar as the inflation is stationary across all quantiles. Without considering the break, the overall results suggest that the credibility of Asian IT regime and even the alternative monetary policy frameworks in most non-IT countries can be better described as being *imperfect* or *weak* because the changes in inflation rate are only stable when the level of inflation is low.

These results may have important monetary policy implications. Large negative shocks to inflation in the lower quantiles may have less effect than large positive shocks in the upper quantiles. The evidence in this study suggests lack of IT credibility regarding large inflation shocks. Hence, it seems preferable for central banks to respond strongly when the inflation is hit by large positive shocks in order to prevent inflation expectations by the public to become higher, and therefore the inflation exhibits mean-reverting behaviour. However, central banks should be careful on the possibility of deflation to occur in the short run when negative shock hits inflation. Japan, for example, has established a long track record of tight inflation control (Gerlach & Tillmann, 2012), but faced risk from deflation. With the dangers from deflationary pressures such as depressed revenues and higher real debt burden (Gregouriou & Kontonikas, 2009), central banks should also treat seriously negative inflation shocks and their effects even if only transitory.

Chapter 6: Macroeconomic Effects of Inflation Targeting: A Regime-Switching Approach

6.1 Introduction

Inflation targeting (IT) remains a popular framework for managing monetary policy. Since its launch in New Zealand in 1990, many countries have adopted IT due to its potential gains, including increased credibility, accountability and transparency of the central bank, and alleviation of the time inconsistency problem, which, in turn, reduces the level and variability of inflation (Cornand & M'baye, 2016; Gonçalves & Salles, 2008; Lin & Ye, 2009).

The path towards stabilizing economies in the past 25 years is predicated on central banks' goals of achieving a certain inflation target, which is usually 2% in advanced economies. Starting from that premise, policymakers are quite critical in the current context of IT doctrine in the rich world, as recently suggested in the popular press.[7] To be specific, rich-world inflation has been below the target for years, which limits the effectiveness of a low inflation target when central bankers want to cut or adjust short-term interest rates in periods of recession. Indeed, many central banks hit the zero lower bound after the 2008-2009 global financial crisis and many countries have now joined the so-called negative rate club to address deflation and the risks of slow growth (Valera, Holmes & Hassan, 2016). In short, policymakers believe that the usual 2% target is ineffective in the rich world, and that this supposed impotence should be resolved by increasing it.

[7] Economist (2016, August 27). When 2% is not enough.

However, even this alternative solution seems problematic for central bankers when inflation and economic growth move in opposing directions. Since they have undershot their targets for so long, it might be difficult to persuade the public to expect higher inflation. Even a credibly enacted higher target is also seen as a drawback in the sense that advanced IT central bankers might be more effective at boosting very low inflation today. The basis of this claim can be considered based on findings like those shown in Figure 3.1 in Chapter 3, which shows a relatively low inflation rate for most Asian IT economies in recent years. Except for Indonesia, where a higher inflation rate is yet to be tamed, the figure shows that actual inflation has fallen below the target since 2012, most notably for South Korea and the Philippines. That is, if the lower inflation target band shown in Figure 3.1 is the benchmark, the practice of IT in these countries is at least somewhat indicative of deflation. In fact, Tsong and Lee (2011) find that inflation rates are stationary at the lower quantiles only for OECD IT countries based on quantile unit root testing.

The above discussion echoes the debates about the capacity of IT regime to achieve a higher macroeconomic performance. There is an extensive literature that suggests IT lowers the level and volatility of inflation for emerging countries (see, among others, Batini & Laxton, 2007; De Mendonca & De Guimaraes e Souza, 2012; Gonçalves & Salles, 2008; Lin & Ye, 2009). However, some studies such as Ball and Sheridan (2005), Brito and Bystedt (2010), and Gonçalves and Carvalho (2009) find that there is a weak decline and/or no impact of IT on the behaviour of inflation. Some authors like Capistrán and Ramos-Francia (2009), Dueker and Fischer (2006) and Lin and Ye (2007) find no significant difference in inflation performance between targeting and non-targeting countries. The effect of IT on output performance is also inconclusive. For example, Abo-Zaid and Tuzemen

(2012), Amira et al. (2013), Ayres et al. (2014) and Mollick et al. (2011) find that there is evidence that IT has a positive impact on output, while authors like Brito and Bystedt (2010), and Mishkin and Schmidt-Hebbel (2007) suggest the opposite effects. Furthermore, empirical studies of exchange rate effects of IT do not reach consensus. For instance, Prasertnukul et al. (2010), Rocha and Curado (2011) and Edwards (2006) find that IT lowers exchange rate volatility, while Sek et al. (2012) report opposing empirical evidence.

Regarding the relevance of IT to stabilizing inflation, output growth and real exchange rates with respect to regime switches between stationary and non-stationary states, the empirical evidence is scarce. The existing studies have focused on characterizing a two-regime Markov switching unit root process for inflation and output, but the effect of IT is largely unexplored. For example, stationarity in at least one regime is found by Chen et al. (2009), Chen (2010), Cruz and Mapa (2013) and Murray et al. (2008) for studies of inflation, and Camacho (2011), Choi et al. (2003) and Kocaaslan (2016) for studies of output growth. From the perspective of IT policy, a relevant study is that of Villa et al. (2014), who find evidence that the inflation rate in Colombia is stationary in an IT regime that complies with the Taylor principle. As for real exchange rate stationarity, the MS-ADF technique has been employed by Holmes (2008, 2010), Kanas (2006, 2009), and Lee and Yoon (2013) but without consideration of the IT effect.

In contrast with the literature on the impact of IT macroeconomic performance, this chapter investigates the hypothesis that inflation, output growth and real exchange rate switch between stationary and non-stationary regimes for eight Asian countries. This objective is investigated based on ADF unit root testing within a Markov regime-switching framework. This MS-ADF approach, which is in sharp contrast to existing studies of stationarity using a single-regime ADF method, offers valuable new insights into macroeconomic variable behaviour, which is modelled as regime-dependent where periods of stationarity or non-stationarity can be identified and analysed. In other words, the Markov switching model offers a rather general and convenient framework for the purpose of unit root testing in the presence of *a priori* unknown multiple structural breaks due to either abrupt or gradual changes in macroeconomic series behaviour.

This chapter makes three contributions. First, the study offers a reinterpretation of monetary policy credibility in terms of stationary or unit root properties of inflation, output growth and real exchange rate for Asian IT and non-IT economies. Specifically, new insights are provided here by defining the concepts of *partial* stationarity and *varied* stationarity. Advocating these concepts is important because the behaviour of macroeconomic variables may be influenced by two stationary regimes (*varied* stationarity), or one stationary and one non-stationary regime (*partial* stationarity). This then allows us to understand the extent to which central banks are achieving their goal of stabilizing inflation, output growth and real exchange rate independent of whether or not they implement an IT policy or an alternative monetary strategy.

Second, this chapter contributes to the debate about the effects of IT on inflation, output and exchange rate performance by focusing on their stationary properties. That is, this thesis departs from existing studies that have dwelled mainly on the effects of IT on the levels and volatilities of inflation, output growth and exchange rate, and which provide mixed findings (see, for example, Gonçalves & Salles, 2008; Ayres et al., 2014; Brito & Bystedt, 2010; Prasertnukul et al., 2010; Sek et al., 2012). There is no doubt these previous studies provide useful insights for assessing the effects of IT on macroeconomic performance, but there are clearly implications for understanding their stationary or non-stationary properties. More importantly, this study explores the possibility that inflation, output growth and real exchange rate stationarity might coincide with the IT regime and whether this monetary policy strategy has a significant influence on the probability of remaining in the more stationary regime. Therefore, this enables the study to identify whether a country is consistent with *a priori* expectations about IT credibility. In particular, this study looks at the role of IT in potentially driving regime change in terms of stationarity and non-stationarity of key macroeconomic variables.

Finally, the no-difference debate about macroeconomic performance between IT and non-IT countries is articulated anew in this study. As the global economy has recently been reawakened to strong concerns about deflation, the study offers new insight into whether IT may improve macroeconomic performance as compared to the performance of non-IT countries. Aside from assessing the stationarity in each regime, this study compares the speed of adjustments to long-run equilibrium in macroeconomic variables of interest between those two groups of countries. That is, the study provides new perspectives on the view that IT countries might be characterized by a different speed of adjustment and this allows us to contribute further to discussion of the effects of IT.

The rest of the chapter is organised as follows. Section 6.2 presents relevant literature on IT effects on macroeconomic performance. Section 6.3 discusses the MS-ADF unit root test and the data. Section 6.4 discusses the empirical results and Section 6.5 presents the conclusions.

6.2 Literature Review

This section discusses existing studies of IT effects on macroeconomic performance in terms of the stationarity or non-stationarity of inflation rate, output growth and real exchange rate. Note that relevant studies of the effects of IT focusing on the levels and volatilities of inflation, output growth and exchange rate have been discussed in Chapter 2.

6.2.1 The Taylor Rule and Inflation Targeting

According to the monetary policy rule proposed by Taylor (1993), the target short term interest rate i_t is expressed as $i_t = \pi_t + \phi(\pi_t - \pi^*) + \gamma y_t + r^*$, where π_t, π^* and y_t have been defined earlier in Chapter 2, and r^* is the equilibrium level of the real interest rate. As in Murray et al. (2008, 2015), the variables π^* and r^* can be combined into one constant term μ_t. Therefore, the Taylor rule becomes:

$$i_t = \mu_t + (1 + \phi)\pi_t + \gamma y_t. \qquad (6.1)$$

The above equation implies that satisfying the condition $(1 + \phi) > 1$, or the so-called Taylor 'principle', leads to a stationary inflation process provided the central bank responds strongly to inflationary pressures so that inflation returns to its long-run target level. The Taylor principle means that a given increase in inflation leads to a larger increase in the nominal interest rate and therefore a rise in the real interest rate, which is required to bring inflation down. This is the most common interpretation of the hypothesis that inflation switches between stationary and non-stationary regimes in the existing literature. To be specific, Murray et al. (2008, 2015) investigate this hypothesis in line with a textbook macroeconomic model consisting of a Taylor rule plus an IS curve and a Phillips curve given by:

$$y_t = -\sigma(r_t - r^*) \tag{6.2}$$

$$\pi_t = \pi_{t-1} + \lambda y_t + \varepsilon_t \tag{6.3}$$

where r_t is the real interest rate. Murray et al. (2008) show the consistency of stationary and unit root states of inflation with the above macro model if the policy followed by the central switches between compliance and non-compliance with the Taylor principle.

Another approach seen in the literature is to indirectly verify compliance with the Taylor principle based on whether inflation is a stationary time series in the IT regime. Villa et al. (2014) explore this view and argue that IT is beneficial for small countries insofar as it allows central banks to control inflation shocks and steadily maintain low inflation levels in a credible way. In line with these views and considering that the Taylor rule is about controlling inflation, output and real exchange, this study investigates the following three hypotheses:

H1. *Inflation, output growth and real exchange rate switch between stationary and non-stationary regimes.*

H2. *The adoption of IT is more likely to be associated with a greater probability of remaining in the stationary regime consistently if the central bank is credible in following the Taylor rule.*

H3. *If a central bank is credible in controlling inflation, output growth and real exchange rate by following the Taylor rule, the stationary IT period should coincide where variance is lowest for each of these variables.*

The hypotheses stated above are consistent with *a priori* expectations about IT credibility. The first hypothesis builds from previous studies by Murray et al., (2008, 2015) and Villa et al. (2014). The second hypothesis is consistent with theoretical prediction about the alleged benefits of IT adoption. As noted by Kim (2014), for example, IT central banks are more precise in hitting their targets than those in non-IT countries and provide credible forecasts of future inflation rates. The implication is that agents will be more certain about the monetary policy strategy of the central bank so they will expect an inflation level close to the target and hence avoid systematic forecast errors (Carrasco & Ferreiro, 2013). Simon (1996) emphasizes a similar point for the possibility that inflation targets should lower inflation volatility. That is, inflation targets are associated with less uncertainty about the true state. If agents are more certain about the true regime, then the IT period is linked with shorter shock persistence, which implies that the measured probability of being in the stationary regime will be higher in this period.

However, the role of IT adoption in the probability of being in the stationary regime for inflation and output can be explained in two ways. On one hand, under strict IT where stabilizing inflation around the target is the only goal of monetary policy, Svensson (2000) points out that IT may require more activism[8] in monetary policy, with the possibility of more variability in macro variables other than inflation. On the other hand, under flexible IT where output is secondary to the inflation target, there may be less activism and this might prevent excessive volatility in output (Svensson, 2000). In relation to this, Orphanides and Wieland (2000) emphasize that if the central bank assigns at least some weight to output stabilization[9], the goal to stabilize output will dominate when inflation is within the target zone, while the goal to stabilize inflation will dominate when inflation deviations from the target become large (Gregoriou & Kontonikas, 2009).

[8] Svensson (2000) defines activism as the frequent adjustments of the monetary policy instrument.
[9] Bernanke (2015) points out that in principle, the relative weights on the output gap and inflation in the original Taylor rule should depend on, among other things, the extent to which policymakers are willing to accept greater variability in inflation in exchange for greater stability in output.

The third hypothesis that will be investigated in this study is in line with the view that following a monetary policy rule increases a central bank's credibility. As Lin and Ye (2009) point out, a formal target for inflation makes a central bank's monetary policy more credible, which helps to alleviate the dynamic inconsistency problem. This increased credibility will then lower inflation persistence by anchoring expectations in the face of inflation shocks and, as a result, IT should reduce inflation uncertainty (Miles, 2008). Moreover, Walsh (2009) argues that anchoring public belief about future inflation under IT can improve the short-run trade-off between inflation and output gap volatility. He argues that a larger decline in the output gap is necessary to limit the rise in actual inflation if a positive inflation shock causes the public to incorrectly upwardly adjust their estimates of the central bank's target. Inflation expectations will be stabilized further, which should reduce the volatility of inflation and improve the short-run trade-off between inflation and real activity. This would then lower the volatility of both inflation and output. In view of a simple augmented Phillips curve, Gonçalves and Salles (2008) argue that explicit (firing the central banker) or implicit (damaging personal reputation) costs for missing the target under a credible IT make disinflation less costly and the corresponding mean output losses will be smaller.

6.2.2 Empirical Studies

There is a large literature that investigates stationarity of inflation, output growth and real exchange rate. This subsection discusses existing empirical studies that have made use of the Markov regime-switching approach.

6.2.2.1 Inflation Rate Literature

According to Henry and Shields (2004), inflation tends to undergo episodes of marked regime changes. To address this issue, there are existing studies that investigate non-stationarity of inflation rate using a Markov regime-switching methodology. However, not only are empirical studies in this direction scant for Asian countries but also little is known about the effects of IT.

Table 6.1 summarizes existing studies of inflation, the majority of which used a two-regime Markov switching model. Most of these studies have focused on developed economies, particularly the U.S. (see, among others, Davig & Doh, 2014; Evans & Wachtel, 1993; Kang et al. 2009; Murray et al. 2008, 2015; Nikolsko-Rzhevskyy & Papell, 2015). Some of these studies also estimate a Markov switching model for a Taylor rule. For example, Nikolsko-Rzhevskyy and Papell (2012) estimate Taylor rules for the U.S. and find no evidence that monetary policy stabilizes inflation. Murray et al. (2015) estimate a real-time forward-looking Taylor rule using endogenous Markov switching coefficients and variance for the U.S. They find that the estimated Taylor-rule equation switches between regimes where the Fed does and does not try to stabilize inflation by satisfying the Taylor principle. Alba and Wang (2016) advance this analysis by using a k-state Markov regime switching model and find that the Taylor rule regime coincides with periods of lower variability in inflation.

In the case of non-Asian countries, Burger (2014) identifies tranquil and volatile inflation regimes for South Africa and finds that increased market volatility raises inflation in high volatility regimes. Amisano and Fagan (2013) investigate inflation with time-varying transition probabilities for Canada, Germany, the U.S and the U.K. and find that broad money growth has a significant effect on switches between inflation regimes. Pagliaci and Barráes (2010) identify two regimes that switch between forward- and backward-looking regimes for Venezuelan inflation. Chen (2010) and Chen et al. (2009) respectively find at least one stationary regime in most of the sample of 11 OECD and the G-7 countries. Simon (1996) also finds high and low inflation regimes for Australia while capturing output gap effects. Likewise, Ricketts and Rose (1995) find at least two regimes for all G-7 countries except for Germany. Furthermore, Evans and Wachtel (1993) find that U.S. inflation is stationary in one regime but contains a unit root in another regime.

In the context of an IT regime, Villa et al. (2014) find that Colombian inflation is stationary in the IT period upon compliance with the Taylor principle. Similarly, Choi et al. (2003) find that IT significantly lowers inflation volatility in New Zealand. In contrast, Creel and Hubert (2008) find that IT has not constituted a regime switch in favour of inflation. Dueker and Fischer (2006) also find that IT countries generally followed a non-IT neighbour in reducing baseline or trend inflation rates. They also find no significant difference between IT and non-IT countries in terms of inflation performance.

The studies discussed above are similar to existing studies that employed Threshold Autoregression (TAR) methodology. For example, Teles and Zaidan (2010) use the approach of Caner and Hansen (2001) and find that compliance and non-compliance with Taylor principle leads to stationarity and non-stationarity of the deviation of expected inflation from its target for Thailand and the Philippines, respectively. Using the same approach, Henry and Shields (2004) identify a two-regime threshold unit root process for inflation in the U.K. and Japan. Also in the context of Asian countries, Chen et al. (2016) use the TAR and MTAR method and find mean-reversion in inflation for India, Indonesia, Malaysia, the Philippines,

Table 6.1: Summary of Markov Switching Studies of Inflation Rate

Year	Author(s)	MS Framework	Sample countries	Findings about inflation
2016	Alba and Wang	Three-regime	U.S.	Taylor rule coincides with periods of lower inflation variability.
2015	Murray et al.	Two-regime	U.S.	The estimated Taylor-rule equation switches between states where the Fed does and does not try to stabilize inflation by following the Taylor principle.
2014	Burger	Two-regime	South Africa	Two regimes: tranquil and volatile. Increased market volatility increases inflation in the second regime.
2014	Davig and Doh	Two-regime	U.S.	More aggressive monetary policy regime after the Volcker disinflation before 1970 than during the Great Inflation of the 1970s. Low inflation volatility regime after 1984.
2014	Villa et al.	Two-regime	Colombia	Stationary during IT regime; unit root during non-IT period.
2013	Amisano and Fagan	Two-regime	Canada, Germany, U.S, U.K	Broad money growth has significant effect on switches between inflation regimes.
2013	Cruz and Mapa	Two-regime	Philippines	Inflation exceeds upper target band in high inflation state but greater chance of being in low inflation state during IT period.
2012	Nikolsko-Rzhevskyy and Papell	Two-regime	U.S.	No evidence that monetary policy stabilizes inflation, even after allowing for changes in the inflation target.

Note: MS is Markov switching.

Table 6.1: (Continued)

Year	Author(s)	MS Framework	Sample countries	Findings about inflation
2010	Chen	Two-regime	11 OECD countries	At least one stationary regime for most sample countries.
2010	Pagliaci and Barráes	Two-regime	Venezuela	Two regimes: forward- and backward-looking behaviour.
2009	Chen et al.	Two-regime	G-7 countries	At least one stationary regime for most sample countries.
2009	Kang et al.	Two-regime	U.S.	High persistence regime when Bretton Woods system collapsed starting 1970s. Low persistence regime after the Volcker disinflation in early 1980s.
2008	Creel and Hubert	MS VAR	Canada, Sweden, U.K.	IT has not constituted a regime switch in favour of inflation.
2008	Murray et al.	Two-regime	U.S.	Stationary before 1967 and after 1981; unit root 1967-1981.
2006	Dueker and Fischer	Two-regime	Australia, Canada, Germany, New Zealand, U.K., U.S	IT countries generally followed a non-IT neighbour in reducing trend inflation. No significant difference between the two groups in terms of inflation performance.
2003	Choil et al.	Two-regime	New Zealand	IT significantly lowers inflation volatility.
2002	Henry	Two-regime	Hong Kong	Inflationary regime is more persistent than deflationary regime.
1996	Simon	Two-regime	Australia	Two regimes: high and low.
1995	Ricketts and Rose	Three-regime	G-7 countries	At least two regimes are significant for most sample.
1993	Evans and Wachtel	Two-regime	U.S.	Unit root from 1965-1985; stationary otherwise.

Note: MS is Markov switching.

Singapore and Thailand. From a similar perspective outside Asia, the most recent study by Chen and Hsu (2016) use the TAR and MTAR approach and show that the quarterly inflation data for 14 European countries reveal stationary series in the long run with asymmetric adjustment in the short run. Similarly, Giannellis (2013) uses a two-regime TAR unit root test to investigate inflation rate differentials in the Euro area and find unit root regime-switching behaviour in only 6 out of the 16 cases. The author finds that these inflation rate differentials were persistent when they were low in one regime, but transitory when they were high in another regime.

Following a different approach, other existing studies employ the Smooth Transition Autoregressive (STAR) model to allow for the possibility that inflation misalignments may be in some intermediate state between regimes where the nature of adjustment varies with the degree of deviation from the target. For instance, the study by Chen et al. (2016) is relevant to this chapter as it provides empirical evidence of a globally stationary ESTAR process in the quarterly inflation rates of six ASEAN using ESTAR-type unit root tests from 1970 to 2014. Chen et al.'s (2016) findings indicate that the farther the inflation rate deviates from its natural rate, the faster will be the speed of mean reversion. Chen and Hsu (2016) draw the same conclusion for 13 European countries using ESTAR-type unit root tests. Similarly, Akdogan (2015) examines non-linearity in inflation rates for 14 emerging markets and 5 developed countries. Their findings for Asian countries show that inflation displays either ESTAR or AESTAR type non-linearity for Thailand but not for Indonesia and the Philippines.

In terms of earlier studies relevant to other IT countries, Arghyrou et al. (2005) apply STAR-type models to the U.K. and find that inflation adjusts more quickly when prices are farther from the steady state. Likewise, Gregoriou and

Kontonikas (2006), employing LSTAR and ESTAR models, show that inflation deviations from the target in a sample of OECD IT countries are characterized by non-linear stationarity. Applying the same model to inflation deviations from the target for a sample of five OECD countries that adopted IT, Gregoriou and Kontonikas (2009) report strong evidence of non-linearities in the adjustment process in all cases where they classified the inflation misalignments as ESTAR models. They find in particular that while the UK, Australia and New Zealand are characterized by a relatively fast speed of adjustment towards the target, Canada and Sweden exhibit a much smoother transition to the inflation target.

6.2.2.2 Output Growth Literature

Under a flexible IT regime, Samarina and De Haan (2013) note that the stabilization of output is integrated into the objective function of the central bank (Svensson, 1999) without forgoing the inflation target. Along with a highly credible central bank, stable macroeconomic conditions support an IT policy (Leyva, 2008). Thus, economic growth has not disappeared in policy debates under an IT regime. However, only a few studies examine macroeconomic performance under an IT regime in terms of stationarity of output growth.

Earlier empirical contributions that were motivated by the goal of addressing the possibility of structural breaks in real output provide mixed results. For example, Alba and Papell (1995), who examine real aggregate and per capita GDP for 18 newly industrializing and exporting countries in East and Southeast Asia, find trend stationarity with breaks in 15 cases. Allowing for a single structural break in real GDP per capita for 24 Chinese provinces from 1952 to 1998, Smyth and Inder (2004) find non-stationarity in the series but the results are mixed when they consider two structural breaks.

Other existing studies also use panel-type unit root tests. Using the KPSS panel test with multiple structural breaks, Narayan (2008) finds evidence of panel stationarity in per capita real GDP for 15 Asian countries from 1950 to 2002. Romero-Avila (2007), using a panel stationarity test that controls for structural change, finds evidence of regime-wise trend stationarity in annual real GDP data for 13 OECD countries, but not for quarterly data. Mishra et al. (2009) also find regime-wise trend stationarity for a sample of eight Pacific Island countries.

There are also existing studies of output stationarity based on Markov regime-switching framework. Table 6.2 presents a summary of these empirical studies. A study that considers Asian countries include Yang and Hamori (2016) who investigate the link between speculative capital and business cycles in Malaysia, Thailand and Singapore. They use the multivariate Markov-switching intercept autoregressive heteroskedasticity vector autoregressive (MSIAH-VAR) model and find that speculative shocks in tranquil period temporarily increase output growth in Malaysia but lower it in Thailand and Singapore. Moreover, Hooi et al. (2008) find two distinct growth-rate phases that characterized the business cycle for Indonesia, Malaysia, Thailand and the Philippines. They reject the null of symmetry for all samples and find that monetary policy has larger effects during downturns than during upswings. Cerra and Saxena (2005) identify recessions into permanent and transitory components for six Asian countries and find evidence of permanent losses in output levels associated with the Asian crisis.

Other studies include that of Dua and Sharma (2016), who find that recession periods in Germany, India, Japan, U.S. and U.K. are always preceded by low output growth regime, and move in a gradual process from low to negative output growth. Camacho and Perez-Quiroz (2014) examine the dynamic relationship between output growth and commodity prices for seven Latin American countries. They find asymmetric output growth responses when commodity price shocks lead to regime shifts. Kocaaslan (2016) finds that Turkish output is stationary in one regime and non-stationary in another regime. He also finds that the shocks to output are highly persistent and transitory in recession and expansion regimes, respectively. Focusing on the U.S., Camacho (2011) finds that recessions have less transitory effects on the level of output based on Markov-switching trend stationary specification. In addition, Alba and Wang (2016) finds that the Taylor rule coincides with periods of lower output variability based on a three-regime Markov switching model for the U.S. Furthermore, Choi et al. (2003) finds that IT significantly lowers the volatility of output growth in New Zealand.

6.2.2.3 Real Exchange Rate Literature

A key assumption in the standard formulation of the Taylor rule is that the central bank always consider both inflation and economic activity with equal weight (Kurz & Kurz-Kim, 2011). However, Woodford's (2001) version of the Taylor rule for an open economy expresses the policy instrument as a function of the output gap, inflation target, exchange rate and lagged interest rate. This open economy version of the Taylor rule mirrors the policy trade-offs between inflation-output-exchange rate stabilization (Hutchison et al., 2013). Viewed in this way, there is an ongoing debate regarding the challenge by policymakers in ensuring that the exchange rate remains subordinate to the inflation objective and that dampening exchange rate movement does not undermine the credibility of the IT framework. A stationary real exchange rate is therefore indicative of a successful IT policy because, as noted by Kim (2014), IT central banks provide credible forecast of future inflation to help practitioners determine the equilibrium exchange rate.

Table 6.2: Summary of Markov Switching Studies of Output Growth

Year	Author(s)	MS Framework	Sample countries	Findings about output
2016	Alba and Wang	Three-regime	U.S.	Taylor rule coincides with periods of lower output variability.
2016	Kocaaslan	Two-regime	Turkey	Stationary in one regime; non-stationary in another regime.
2016	Yang and Hamori	MSIAH-VAR	Malaysia, Singapore, Thailand	Speculative shocks temporarily increase (Malaysia) and lower (Thailand and Singapore) output growth in tranquil period.
2016	Dua and Sharma	Three-regime	Germany, India, Japan, U.S., U.K.	Recession periods are always preceded by a low growth regime, and move in a gradual process from low to negative growth.
2014	Camacho and Perez-Quiroz	Multivariate MS impulse response	Argentina, Brazil, Chile, Colombia, Mexico, Peru, and Venezuela	Response of output growth to commodity price shocks is time, size and sign dependent. Asymmetric output growth responses when commodity price shocks lead to regime shifts.
2011	Camacho	Two-regime trend-stationary	U.S.	Recessions have less transitory effects on the level of output under the Markov-switching trend stationary specification.
2008	Hooi et al.	Two-regime	Indonesia, Malaysia, Philippines, Thailand	Rejects the null of symmetry for all samples. Monetary policy has larger effects during downturns than during upswings.
2005	Cerra and Saxena	Two-regime	Hong Kong, Indonesia, Malaysia, Philippines, South Korea, Singapore	Permanent losses in output levels associated with Asian crisis for all sample countries.
2003	Choi et al.	Two-regime	New Zealand	IT significantly lowers the volatility of real output growth.

Note: MS is Markov switching.

As a measure of internal and external price competitiveness, the early motivation for modelling real exchange rates is to study the validity of PPP. Nevertheless, existing studies of Asian countries remain very mixed as to whether or not long-run PPP holds, depending on the methodological issues confronted in the analysis. Previous studies by Nusair (2004, 2008) address the issue of structural breaks, while other studies including those of Arize et al. (2015), Choudhry (2005) and Kim et al. (2009) use a cointegration approach. The issue of low test power is also addressed in the literature using panel-type unit root tests (Baharumshah et al., 2007, Baharumshah et al., 2008; Basher & Moshin, 2004; Breitung & Candelon, 2005; Holmes, 2001). Moreover, studies by Hooi and Smyth (2007), Munir and Kok (2015), Narayan (2010) and Soon et al. (2015) apply panel-type unit root tests that account for one and two structural breaks in real exchange rates.

The behaviour of real exchange rates has also been examined in the context of an IT regime. In particular, Ding and Kim (2012) employ panel unit root tests to a sample of 19 OECD countries and find that IT matters for PPP. They also find that stronger mean reversion is present as more IT countries are involved. Another important study by Kim (2014) examines the effects of IT on PPP using a bias correction approach under cross-sectional dependence. He finds that IT lowers the variability of real exchange rates and plays an important role in providing favourable evidence for long-run PPP for a sample of 19 OECD countries. Furthermore, other studies have explored the possibility that real exchange rate misalignments may occur in some intermediate state between regimes. For example, Bec and Zeng (2014), Holmes (2004), Liew et al. (2004), Nusair (2012) and Zhou (2008) apply STAR-type models to a sample of Asian countries.

In terms of using the Markov regime-switching approach, Table 6.3 summarizes some existing studies that investigate the stationarity of real exchange rate. The study by Holmes (2010) is most relevant to the present study with respect to using MS-ADF unit root testing. Specifically, he employs this approach for a sample of nine Asia-Pacific countries and finds that each country is characterised by at least one stationary regime, with five countries being characterised by two regimes. He also reports evidence that the 1997 Asian crisis facilitates the achievement of long-run PPP. Similarly, Holmes (2008) use the MS-ADF unit root testing for a sample of six Latin American countries and finds that most of the sample is characterised by the existence of two distinct stationary regimes. In addition, Holmes (2008) finds that the high inflation and exchange rate volatility experienced in Latin American countries facilitate long-run PPP.

Similarly, Kanas (2009) employs the MS-ADF unit root testing to a sample of 43 developing countries and finds that the real exchange rate is stationary in one regime and non-stationary in another regime (i.e., regime-dependent stationarity). Kanas (2006) applies a two-state Markov regime-switching model to a sample of 16 countries and finds that the stationarity of the real exchange rates is regime-dependent. He also reports evidence for non-stationary real exchange rates during the Bretton Woods period for most countries. Kanas and Genius (2005) examine the stationarity of the UK:US real exchange rate using the same approach and finds evidence of switching between regimes of stationarity and non-stationarity. Kruse et al. (2012) also find evidence of regime changes in the real exchange rates for a sample of four currencies. In addition, Lee and Yoon (2013) apply the MS-ADF approach to the real exchange rates of 5 European countries and find evidence of stationary regimes in all samples. Using a multivariate Markov-switching vector error correction approach, Beckmann and Czudaj (2014) show that the Canada:US exchange rate adjustment is characterised by regime shifts. Overall, the aforementioned studies of real exchange rate stationarity using MS-ADF procedure did not consider the effect of IT.

Walid et al. (2011) employ a Markov-switching EGARCH model for Mexico and three Asian countries. They find that the link between stock and foreign exchange markets is regime-dependent and that stock price volatility responds asymmetrically to events in the foreign exchange market. Moreover, Wilfling (2009) applies a Markov-switching GARCH model to a sample of 11 EMU countries and finds that four currencies exhibit longer-lasting transitional periods of gradual adjustment from high to low volatility. He also finds that four other currencies switch more or less abruptly between the volatility regimes. Employing the same approach to a sample of four Asian countries, Brunetti et al. (2008) find that real effective exchange rates, money supply relative to reserves, stock index returns, and bank stock index returns and volatility play a significant role in identifying turbulent and ordinary regimes. Furthermore, Abul Basher et al. (2014) use a Markov switching model to study the impact of oil shocks on real exchange rates for a sample of oil-exporting and oil-importing countries. They report evidence of significant exchange rate appreciation pressures in oil exporting economies after oil demand shocks. Although the above existing studies offer interesting insights about real exchange rate stationarity, the effect of IT remains unexplored in the literature which is the subject of this chapter.

Table 6.3: Summary of Markov Switching Studies of Real Exchange Rate

Year	Author(s)	MS Framework	Sample countries	Findings about real exchange rate
2016	Abul Basher et al.	Two-regime MS model	6 oil exporting countries 3 oil importing countries	Significant effect of oil demand shocks on exchange rate appreciation in oil exporting economies.
2014	Beckmann and Czudaj	Multivariate MSVEC	Canada, U.S.	Exchange rate adjustment is regime-dependent.
2013	Lee and Yoon	Two-regime MSADF	5 European countries	Stationary regimes in all five real exchange rates.
2012	Kruse et al.	MSAR	Denmark, France, Japan, U.K.	Real exchange rate stationarity is regime-dependent.
2011	Walid et al.	MS EGARCH	Hong Kong, Malaysia, Singapore, Mexico	The link between stock and foreign exchange markets is regime-dependent and the stock price volatility responds asymmetrically to events in the foreign exchange market.
2010	Holmes	Two-regime MSADF	9 Asia Pacific countries	At least one regime for all samples. Two regimes for 5 countries. Asian crisis facilitates long-run PPP.
2009	Kanas	Two-regime MSADF	43 developing countries	Sub-periods of stationarity and non-stationarity for 36 countries.
2009	Wilfling	MS GARCH	11 EMU countries	Four currencies exhibit longer-lasting transitional periods of gradual adjustment from high to low volatility. Four other currencies switch more or less abruptly between the volatility regimes.
2008	Brunetti	MS GARCH	Malaysia, Philippines, Singapore, Thailand	Real effective exchange rates, money supply relative to reserves, stock index returns, and bank stock index returns and volatility play a significant role in identifying turbulent and ordinary regimes.
2008	Holmes	Two-regime MSADF	6 Latin American countries	Two regimes for most samples. High rates of inflation and exchange rate volatility facilitate long-run PPP.
2006	Kanas	Two-regime MSADF	16 countries	Real exchange rate stationarity is regime-dependent.
2005	Kanas and Genius	Two-regime MSADF	U.S., U.K.	US/UK real exchange rate is stationary and nonstationary in low and high volatility regimes, respectively.

Note: MS is Markov switching.

6.3 Methodology and Data

6.3.1 Markov-Switching ADF Model

This chapter employs Hamilton's (1989) Markov regime-switching framework[10] to provide answers to the third research question: *Does IT help Asian countries to achieve a significant improvement in macroeconomic performance as measured by the behaviour of inflation, output growth and real exchange rate?* This study specifically applies the MS-ADF test, which has a major advantage in identifying regime-dependent periods of stationarity and non-stationarity based on different speed of adjustments towards long-run equilibrium (Kanas, 2006). This approach is in sharp contrast to the single-regime ADF test, which gives only a single test statistic for the entire study period (Shen & Holmes, 2014).

Let y_t represent the three macroeconomic variables: inflation, output growth and real exchange rate. Consider an AR process for y_t with drift μ and deterministic trend *t* given by $y_t = \mu + \phi y_{t-1} + \beta t + \varepsilon_t$. To assess the unit root properties of y_t, the usual test for linear adjustment towards long-run equilibrium can be done through the OLS estimation of a single-regime ADF regression:

$$\Delta y_t = \mu + \rho y_{t-1} + \beta t + \sum_{i=1}^{q} \gamma_i \Delta y_{t-i} + \varepsilon_t \qquad (6.4)$$

where ε_t is an i.i.d. residual term distributed as $N(0, \sigma^2)$. In Equation 6.4, the condition for stationary properties of macroeconomic time series and for ruling out explosive behaviour is where $-2 < \rho_1 < 0$, which is consistent with $|\phi| < 1$.

[10] The Markov regime-switching methodology has been recently used, among others, by Çevik and Dibooglu (2013), Çevik et al. (2013), Dutu et al. (2016), and Valera and Lee (2016).

The above testing procedure is widely known for failing to take into account the possibility that this form of non-stationarity test for y_t is too restrictive. In addition to this, the dynamic behavior of y_t might be subject to regime shifts and if so, it is inappropriate to use a linear ADF regression based on Equation 6.4 that makes no allowance for modelling regime-switches. Following Hamilton (1989) and Hall et al. (1999), this chapter considers nonlinear dynamics by incorporating a Markov-switching process in the ADF regression model. Let S_t be a discrete random variable that takes two possible values$[S_t = (0,1)]$. The state variable S_t is governed by a discrete state Markov chain and serves as an indicator for the state of the world economy at time *t*.

The expected component of Δy_t, conditional on the value of S_t, is given by:

$$E(\Delta y_t | S_t) = [(1 - S_t)\alpha_0 + S_t\alpha_1] + (1 - S_t)\lambda_0 y_{t-1} + S_t\lambda_1 y_{t-1} \qquad (6.5)$$
$$+(1 - S_t)\sum_{i=1}^{l}\xi_i\Delta y_{t-i} + S_t\sum_{i=1}^{l}\tau_i\Delta y_{t-i} + \varepsilon_t$$

where $\varepsilon_t \sim \text{i.i.d.} N\left(0, \sigma_\varepsilon^2(S_t)\right)$, which allows for the variance to change across regimes. This means that σ^2 is allowed to switch based on a two-state, first-order Markov process governed by the state of S_t as described in Hamilton (1989):

$$P[S_t = 0 | S_{t-1} = 0] = p = \Phi(\delta_0)$$
$$P[S_t = 1 | S_{t-1} = 0] = 1 - p \qquad (6.6)$$
$$P[S_t = 1 | S_{t-1} = 1] = q = \Phi(\delta_1)$$
$$P[S_t = 0 | S_{t-1} = 1] = 1 - q$$

where p and q are fixed transition probabilities of being in Regime 0 or Regime 1, respectively, with $0 < p, q < 1$, and $\Phi()$ is the cumulative normal distribution function ensuring that the transition probabilities lie in the open interval (0,1). The model defined by Equations 6.5 and 6.6 can be denoted as MS-ADF Model I. Stationarity in both regimes is confirmed if $-2 < \lambda_0, \lambda_1 < 0$. If $-1 < \lambda_0, \lambda_1 < 0$, and the half-life associated with a deviation from long-run equilibrium may be approximated as $\mathrm{HL}_0 = (\ln 0.5)/(1 + \lambda_0)$ and $\mathrm{HL}_1 = (\ln 0.5)/(1 + \lambda_1)$ for Regimes 0 and 1, respectively.

On the basis of the autoregressive coefficients and speeds of adjustment towards long-run equilibrium in Regime 0 and Regime 1, this chapter defines the concept of *varied* stationarity and *partial* stationarity by building on the concepts introduced by Holmes (2008, 2010) in relation to exchange rate stationarity. Table 6.4 summarizes the definitions of these two concepts. Firstly, *varied* stationarity is defined if $\lambda_0 \neq \lambda_1$, which means that stationarity is confirmed across both regimes, but the autoregressive coefficients and speeds of adjustment towards long-run equilibrium are different. Secondly, the concept of *partial* stationarity is defined if we are only able to confirm that either λ_0 or λ_1 is negative and significantly different from zero. This means that the three macroeconomic variables of interest are switching between regimes of stationarity and non-stationarity (or one stationary and one non-stationary regime).

Note that the MS-ADF Model I features transition probabilities that are fixed. In this study, the extent to which the adoption of IT is responsible for pushing the economy into Regime 0 or Regime 1 is also investigated. Therefore, extending the fixed two-state Markov-switching chain to allow for the possibility of time-varying transition probabilities enables us to specify:

$$P[S_t = 0|S_{t-1} = 0, \Omega_{t-1}, \Omega_{t-2}, ...] = p_t = \Phi\left(\delta_0 + \sum_{i=1}^{m} \vartheta_i \Omega_{t-i}\right)$$

$$P[S_t = 1|S_{t-1} = 1, \Omega_{t-1}, \Omega_{t-2}, ...] = q_t = \Phi\left(\delta_1 + \sum_{i=1}^{n} \kappa_i \Omega_{t-i}\right) \quad (6.7)$$

where Ω denotes the IT dummy variable driving the transition probabilities. This gives rise to MS-ADF Model II, which employs the IT dummy variable as Ω in Equation 6.7. As a measure of policy, the IT dummy takes the value of 1 in the year which an IT regime is adopted; 0 otherwise. Thus, ϑ_i and κ_i measure the impact of IT on the transition probabilities in a specific country. To determine which model specification better characterizes the three macroeconomic series, this chapter employs LR tests. The LR statistic can be expressed as: $LR = 2[L_1 - L_2]$, where L_i is the log-likelihood value of a particular model *i*. LR tests have a χ^2 distribution with the number of degrees of freedom equal to the number of restrictions.

Table 6.4: Definition of Partial and Varied Stationarity

Stationarity	**Definition**
Varied	$\lambda_0 \neq \lambda_1$ Two stationary regimes
Partial	Either λ_0 or λ_1 is negative and statistically significant One stationary and one non-stationary regime

As mentioned earlier, if the central bank is successful in controlling inflation, output growth and real exchange rate by following a Taylor rule, the stationary IT period should be characterized by lower variance of each of these variables and is more likely associated with a higher probability of staying in the more stationary regime. This is because IT central banks are expected to be more precise in hitting their targets than non-IT countries and to provide credible forecast of future inflation rate to help policymakers determine equilibrium output growth and real exchange rate (Kim, 2014). This eventually stabilizes the three macroeconomic variables under review to a significant degree in the long run.

6.3.2 Data

The empirical work in this chapter involves monthly inflation rates as mentioned in the earlier chapters and real exchange rates over the period 1987:M1 to 2013:M11. The chapter also uses quarterly data for real output growth rates from 1987:Q1 to 2013:Q4. Real exchange rates are calculated based on the consumer price index and nominal exchange rates with respect to the U.S. dollar. For a given country *i*, the real exchange rate q_t is defined as follows:

$$q_t = e_t + p_t^f - p_t^d \tag{6.8}$$

where p_t^d is the natural logarithm of the domestic price level, p_t^f is the natural logarithm of the foreign or U.S. price level and e_t is the nominal exchange rate, i.e. the domestic price of a U.S. dollar. Real exchange rate measures domestic prices relative to U.S. prices as converted in domestic currency. All real exchange rate data are expressed in natural logarithm form. The real output growth rates are calculated as the annual log difference of the quarterly real GDP growth rates.

Figure 6.1 displays the pattern of output growth. Except for China, output growth in all countries declined significantly during the Asian crisis. Output growth also dropped during the 2008-2009 global financial crisis except in Indonesia. Overall, output growth suddenly declined during times of crisis, while the extent of its volatility differed across countries and between different time periods. This pattern is also described in Table 6.5, which presents summary statistics of output growth in three time periods. Specifically, these periods are labelled as pre-Asian financial crisis or pre-AFC (1987:Q1-1996:Q4), post-AFC and pre-global financial crisis or pre-GFC (1997:Q1-2007:Q4) and post-GFC (2008:Q1-2013:Q4). The particular dates for AFC and GFC are chosen based on their years of occurrence and the pattern shown in Figure 6.1.

Figure 6.1: Quarterly Real Output Growth in Asian Countries, 1987-2013

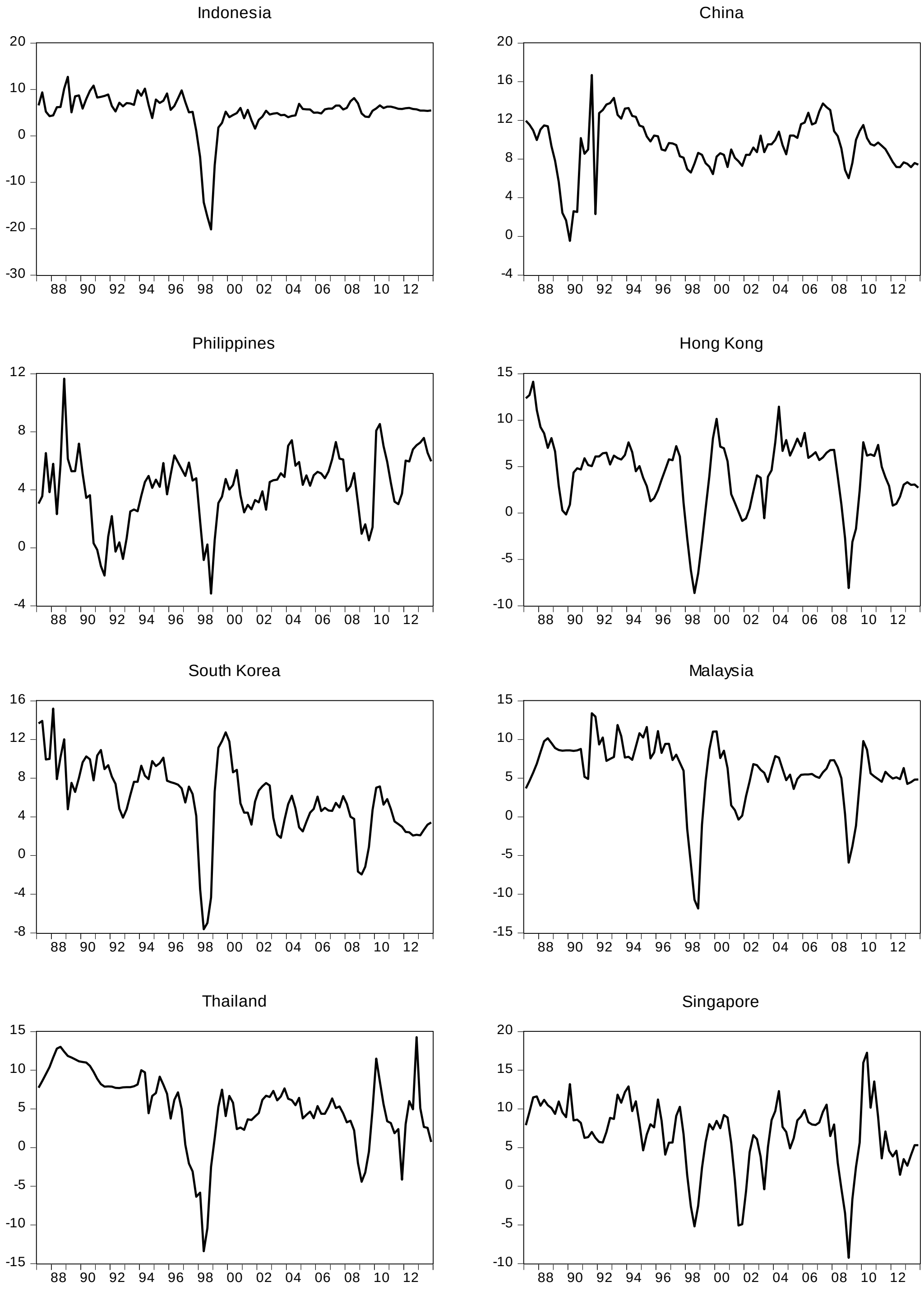


Table 6.5: Summary Statistics of Output Growth

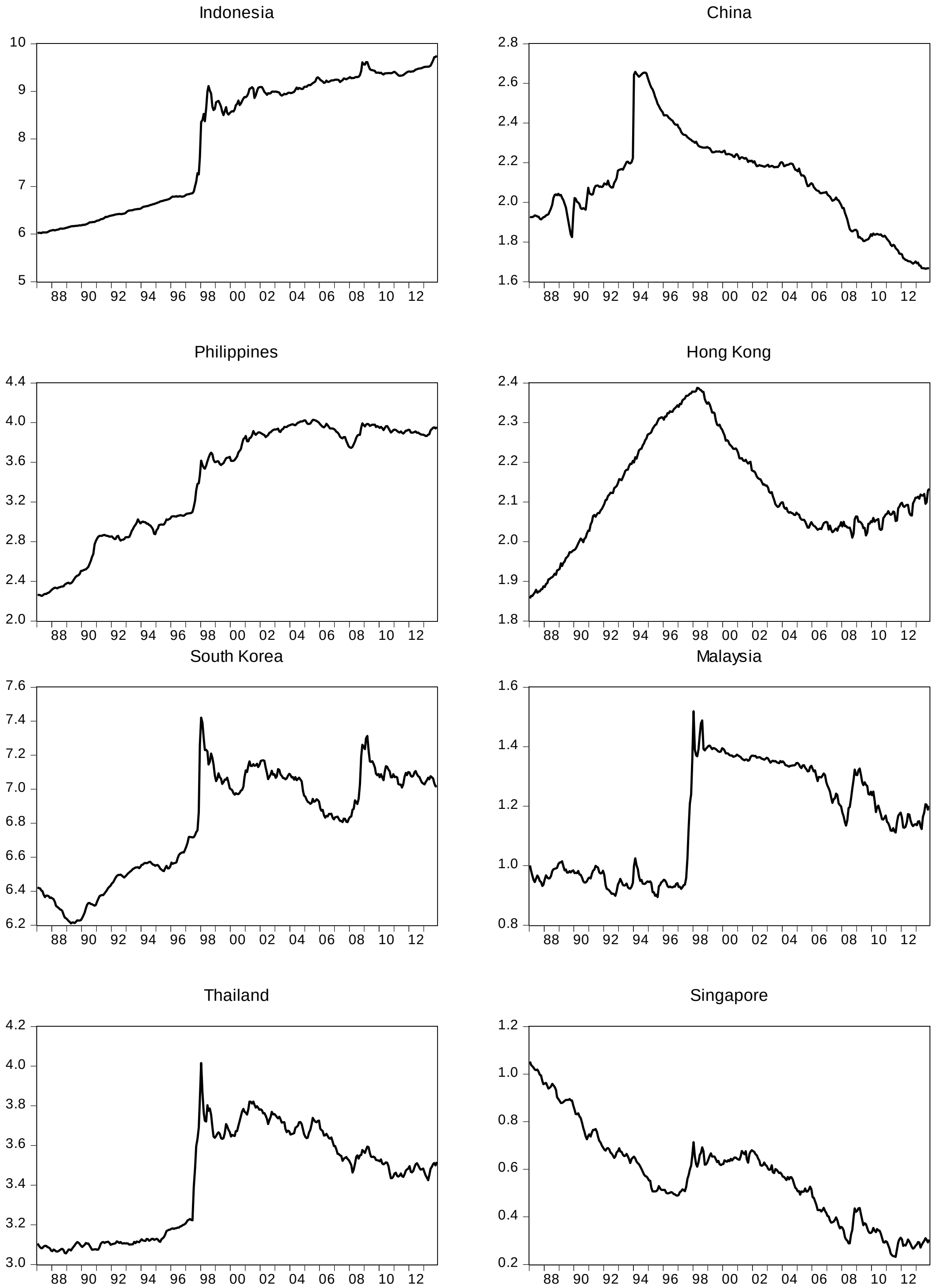
	Pre-AFC		Post-AFC/Pre-GFC		Post-GFC	
Country	Mean	S.D.	Mean	S.D.	Mean	S.D.
Indonesia	7.560	1.952	2.803	6.081	5.870	0.894
Philippines	3.613	2.704	4.162	2.070	4.918	2.345
South Korea	8.716	2.397	4.809	4.179	3.094	2.390
Thailand	8.861	2.235	3.155	4.700	3.143	4.411
China	9.787	3.933	9.428	1.917	8.674	1.509
Hong Kong	5.695	3.181	3.861	4.518	2.606	3.717
Malaysia	8.688	2.107	4.372	4.743	4.256	3.562
Singapore	8.872	2.314	5.563	4.495	4.851	5.830

Notes: Pre-AFC is 1987:Q1-1996:Q4, post-AFC and pre-GFC is 1997:Q1-2007:Q4, and post-GFC is 2008:Q1-2013:Q4.

A few notable characteristics of Table 6.5 are as follows. First, output growth exhibits substantial variation both across countries and time periods. Second, the levels and variability in output growth experienced sharp declines and increases during the post-AFC and pre-global financial crisis in most countries except for China and the Philippines. During this period it can be seen that Indonesian output growth was relatively stable. However, the downward spike drove the large standard deviation for Indonesia's real exchange rate at the time of the Asian financial crisis. Third, the levels and variability of output growth declined for most of the countries during the post-GFC period.

Figure 6.2 shows the behaviour of the real exchange rate, which is a measure of internal and external price competiveness. Note that a rise in e_t in Equation 6.8 is a nominal exchange rate depreciation. Thus, real exchange rate q_t will increase if e_t and the U.S. CPI and/or the domestic CPI falls. That is, a rise in q_t means increased competitiveness. In Figure 6.2, this corresponds to the Philippines becoming more competitive relative to the U.S. from 1987 to 2000. For Singapore and China, real exchange rate exhibits a declining trend for most of the study period. Hong Kong shows a similar decreasing pattern after 1998 and up to 2006. The real exchange rates for Malaysia, South Korea and Thailand display a see-saw pattern across the entire study period. Figure 6.2 also shows the sudden rise in real exchange rate in 1997 in all cases except for China and Hong Kong. The abrupt increase in real exchange rate was also noticeable in 2008 in the majority of cases.

Figure 6.2: Monthly Real Exchange Rates in Asian Countries, 1987-2013



6.4 Empirical Results

This section describes the results of characterizing the behaviour of the inflation rate, output growth and real exchange rate series using the MS-ADF model outlined in Section 6.3.

6.4.1 Standard Unit Root Test

The first stage of the empirical investigation is to examine the unit root properties of the macroeconomic variables. Note that with the exception of Hong Kong, inflation stationarity has been confirmed in Chapter 3. Aside from the more familiar ADF test, the univariate unit root tests advocated by Elliott et al. (1996, DF-GLS) and Ng and Perron (2001, NP) are employed. The DF-GLS unit root test is regarded as the more powerful of these tests. The rejection rate of non-stationarity using the DF-GLS test is likely to be higher than for the ADF and NP tests. The optimal lag length is selected using the AIC. Table 6.6 reports the results for output growth and real exchange rate, while the results for inflation are presented in the earlier chapter. For output growth, the ADF test with and without a trend rejects the null of unit root in the cases of China, Indonesia and the Philippines at the 5% significance level or better. The ADF test without a trend rejects the null of non-stationarity at the 5% and 10% significance levels for Hong Kong and Singapore, respectively, while the null with trend is rejected for South Korea at the 5% significance level.

Table 6.6: Univariate Unit Root Tests, Output and Real Exchange Rate

Country	ADF		DF-GLS		NP	
	No trend	With trend	No trend	With trend	No trend	With trend
Output growth						
China	-3.630***	-3.609**	-2.896***	-3.385**	-2.188**	-2.530
Hong Kong	-3.197**	-3.131	-0.591	-1.629	-1.392	-2.703*
Indonesia	-3.874***	-3.849**	-3.776***	-3.876***	-3.636***	-3.733***
Malaysia	-2.260	-2.754	-2.036**	-2.234	-4.442***	-4.698**
Philippines	-3.087**	-3.951**	-2.937***	-3.986***	-3.361***	-3.628***
Singapore	-2.747*	-3.013	-2.355**	-3.066**	-14.012***	-30.720***
South Korea	-2.007	-3.951**	-0.282	-2.489	-1.121	-4.244***
Thailand	-2.297	-2.301	-1.812*	-2.376	-2.558**	-3.023**
Real exchange rate						
China	-0.664	-1.648	-0.799	-0.773	-0.804	-0.770
Hong Kong	-3.187**	-3.221*	-1.136	-2.305	-1.616	-2.788*
Indonesia	-0.950	-1.611	0.964	-1.682	1.163	-1.674
Malaysia	-1.662	-1.669	-1.026	-1.745	-1.006	-1.672
Philippines	-2.105	-1.156	1.064	-0.855	1.284	-0.703
Singapore	-2.035	-2.356	1.335	-1.088	1.029	-1.435
South Korea	-1.555	-1.917	-0.444	-2.016	-0.395	-1.903
Thailand	-1.475	-1.374	-0.462	-1.467	-0.640	-1.608

Notes: The values in parentheses are the *p*-values. In all cases, the lag length is selected according to the AIC. ***, ** and * denote rejection of the non-stationary null at the 1, 5 and 10% significance levels. The respective critical values are -3.496, -2.890 and -2.582 for output growth, and -3.451, -2.871 and -2.572 for real exchange rate.

Using alternative univariate unit root tests, the DF-GLS test with and without trend rejects the null of non-stationarity at the 5% significance level or better for China, Indonesia, the Philippines and Singapore. Also, the DF-GLS test without a trend rejects the null of non-stationarity for Malaysia and Thailand respectively at the 5% and 10% significance levels. Based on the NP test, the null of non-stationarity with trend specification is rejected for all sample countries except China. Excluding a trend, the unit root null is rejected at the 5% level or better for all sample countries except for Hong Kong and South Korea. As a whole, the results of the univariate unit root tests indicate that stationarity in real output growth does exist in some form in all eight Asian countries. This finding is consistent with existing literature and the traditional view of business cycles; real GDP fluctuates around a stable trend path so that current shocks have only temporary effects (Alba & Papell, 1995).

The results of the univariate unit root tests for real exchange rate reject the null of non-stationarity for all countries. The ADF and NP tests with trend specification marginally reject the null of non-stationarity at the 10% level for Hong Kong, while the null is accepted based on the DF-GLS test. Hong Kong has operated under a currency board before and after the Asian crisis. In addition, its currency has been nominally pegged to the U.S. dollar since 1984. Kim et al. (2009) noted that this kind of managed exchange rate system causes a violation of PPP.

6.4.2 Tests for Regime-Switching

The possibility that the failure to reject the null of non-stationarity based on the single-regime ADF test findings discussed above may be attributed to previous unacknowledged regime switches, which can be examined using Markov regime-switching ADF tests. For this purpose, the analysis in this section compares the single-regime ADF model described by Equation 6.4 and the MS-ADF Model I as represented by Equations 6.5 and 6.6. Table 6.7 reports a comparison of estimates of the log likelihood values associated with these two models. Note that different maximum lags of Δy are selected for each country based on the AIC. For each country and for each macroeconomic variable of interest, the application of the LR test proposed by Davies (1987) leads to the strong rejection of the single-regime ADF model in favour of the regime-switching MS-ADF Model I that is characterized by constant transition probabilities.

6.4.3 Tests for Time-Varying Transition Probabilities

Considering the evidence of regime-switching for each macroeconomic series for IT countries, this chapter next examines whether the data indicate constant or time-varying transition probabilities. Accordingly, this subsection compares the single-regime ADF model described by Equation 6.4 and the time-varying transition probabilities or MS-ADF Model II as represented by Equations 6.5 and 6.7. In this case, different lagged values of Δy_t in Equation 6.5 and with one lagged Ω in the state transition probability process are included in the MS-ADF Model II. Table 6.7 reports the log likelihood values for the MS-ADF Model II that captures an IT regime as the driver of the transition probabilities. Table 6.7 also reports the corresponding LR test statistics comparing the single-regime ADF model and MS-ADF Model II. These LR tests are exclusion tests on Ω_{t-1} in both the transition probabilities equations.

At the 1% significance level, the model involving time-varying transition probabilities provides a significant improvement in log likelihood function for all macroeconomic variables in each IT country. For example, the LR statistics for comparing the single-ADF model and MS-ADF Modell II with respect to inflation rate are 288.032 and 127.706 for Indonesia and the Philippines, respectively. In terms of output growth, Indonesia is characterized by an LR statistics of 106.274 and the value is 105.830 in the case of the Philippines. Similarly, with respect to real exchange rate, the time-varying transition probabilities model gives a significant improvement in log likelihood function for Indonesia and the Philippines, with LR statistics of 640.488 and 144.059 respectively.

6.4.4 Markov-Switching Regression Results

The estimation results of the MS-ADF test for inflation, output growth and real exchange rate are respectively reported in Tables 6.8, 6.9 and 6.10. It should be noted that the main focus of this thesis is on inflation. However, the behaviour of output growth and real exchange is also examined to provide a broader perspective on assessing the impact of IT on macroeconomic performance. In addition, investigating output growth is important to enable better understanding of the extent to which IT central banks attach weight to output stabilization. It is also crucial to study the behaviour of real exchange rate because the capacity of central banks to stabilize this key macroeconomic indicator is an important factor in the effectiveness of controlling inflation (Carrasco & Ferreiro, 2014).

The analysis focuses first on investigating the first hypothesis; that *the three macroeconomic variables of interest switch regimes between stationarity and non-stationarity*. The empirical findings under this perspective are twofold. Firstly, *partial* stationarity is noticeable for both inflation and output growth. In cases where inflation is stationary in Regime 0 only, it can be seen from Panel A of Table 6.8 that the coefficient estimates for λ_0 are negative and statistically significant in varying degrees for China, Singapore and all IT countries. This finding of *partial* stationarity in inflation supports the evidence of global stationarity and stationarity at lower quantiles reported in Chapter 5. As in Chapter 5, *partial* stationarity in inflation also implies weak IT credibility regarding highly persistent shocks in the non-stationary Regime 0.

Table 6.7: Regime-Switching, Time-Varying Transition Probabilities Tests

	Log likelihood values			Likelihood ratio (LR) statistic	
Variable/ country	ADF	MSADF Model I	MSADF Model II	ADF vs MSADF Model I[a]	ADF vs MSADF Model II[b]
Inflation rate					
Indonesia	-519.922	-376.163	-375.906	287.517(0.000)	288.032(0.000)
Philippines	-325.884	-262.416	-262.031	126.935(0.000)	127.706(0.000)
South Korea	-230.864	-207.484	-212.521	46.759(0.000)	36.686(0.000)
Thailand	-290.688	-261.207	-259.87	58.961(0.000)	61.636(0.000)
China	-390.511	-366.528		47.966(0.000)	
Hong Kong	-356.443	-322.375		68.137(0.000)	
Malaysia	-202.076	-126.763		150.627(0.000)	
Singapore	-201.947	-177.42		49.054(0.000)	
Output growth					
Indonesia	-242.008	-204.296	-188.871	75.425(0.000)	106.274(0.000)
Philippines	-202.185	-188.801	-149.27	26.769(0.000)	105.830(0.000)
South Korea	-202.789	-168.651	-149.27	68.275(0.000)	107.038(0.000)
Thailand	-248.298	-202.7	-201.954	91.195(0.000)	92.688(0.000)
China	-213.119	-149.529		127.179(0.000)	
Hong Kong	-201.331	-184.45		33.762(0.000)	
Malaysia	-231.572	-200.28		62.583(0.000)	
Singapore	-233.415	-208.64		49.550(0.000)	
Real exchange rate					
Indonesia	444.922	764.614	765.166	639.385(0.000)	640.488(0.000)
Philippines	816.238	885.474	888.267	138.470(0.000)	144.059(0.000)
South Korea	683.401	844.074	846.173	321.345(0.000)	325.544(0.000)
Thailand	749.741	924.732	927.19	349.981(0.000)	354.898(0.000)
China	708.833	1032.338		647.010(0.000)	
Hong Kong	1113.427	1151.112		75.371(0.000)	
Malaysia	802.611	956.889		308.556(0.000)	
Singapore	940.893	980.317		78.848(0.000)	

Notes: [a]LR is based on testing the null hypothesis of no regime switching against the alternative of regime switching. [b]LR is the likelihood ratio exclusion test statistic based on the null hypothesis of constant transition probabilities (MSADF Model I with $\vartheta_1 = \tau_i = 0$) against the alternative of time-varying transition probabilities (using MSADF Model II). Model II is based on the estimation of Equation 6.7 with transition probabilities that are influenced by the nature of an IT regime. Each LR statistic is distributed as $\chi^2(m)$ on the null, where m is the number of restrictions. The values reported in parentheses are Davies (1987) upper bound p-values.

The results for output growth offer stronger evidence of *partial* stationarity than is the case for inflation. To be specific, Panel A of Table 6.9 shows that the coefficient estimates for λ_0 are negative and statistically significant at the 5% level in most of the sample. This finding implies that central banks, whether or not they practice an IT policy, put greater weight on stabilizing output. Particularly for Asian IT central banks, the results further imply that their IT regime is flexible where output is secondary to the inflation target. As noted by Svensson (2000), a flexible IT regime may allow less activism or infrequent adjustment of monetary policy instruments to possibly prevent excessive volatility in output. As a whole, the findings of *partial* stationarity in inflation and output growth are consistent with the unit root test results displayed in Table 6.6 that found in favour of stationarity. In addition, the unit root finding for Hong Kong inflation based on a single-regime unit root test concurs with the MS-ADF results, which are unable to identify stationarity in both regimes. This finding accords with the accelerationist hypothesis that inflation is either in the high- or low-volatility regime.

Secondly, *varied* stationarity seems to be more pronounced for real exchange rates as compared to inflation and output growth. As shown in Panel A of Table 6.10, the case where real exchange rate stationarity is present in two regimes involves three IT countries: Indonesia, South Korea and Thailand. The coefficient estimates for λ_0 and λ_1 in these countries are negative and statistically significant at varying degrees. The empirical evidence of *varied* stationarity in real exchange rate for IT countries implies that their central banks are also assigning at least some weight to real exchange rate stabilization. This finding also lends support to the view that under an IT regime, the high degree of transparency and accountability of monetary policy limits not only the variability in inflation but also

Table 6.8: MS-ADF Unit Root Testing, Inflation Rate

Panel A

	Indonesia	Philippines	South Korea	Thailand	China	Hong Kong	Malaysia	Singapore
α_0	0.503***(0.000)	0.475***(0.000)	0.480***(0.000)	0.075**(0.011)	0.110**(0.014)	-0.035(0.716)	0.496***(0.000)	0.148***(0.000)
α_1	3.155***(0.000)	1.277(0.213)	0.547***(0.000)	-0.149***(0.000)	0.096(0.207)	0.149***(0.000)	0.301***(0.000)	0.011(0.475)
λ_0	-0.062**(0.020)	-0.047**(0.048)	-0.067*(0.054)	-0.184**(0.042)	-0.052***(0.009)	-0.009(0.826)	-0.156*(0.096)	-0.081*(0.052)
λ_1	-0.106(0.170)	-0.081(0.643)	-0.114(0.120)	0.635(0.136)	-0.010(0.428)	-0.016(0.417)	-0.083***(0.008)	-0.016(0.162)
σ_0	0.416(0.775)	0.166(0.376)	0.471**(0.023)	0.141***(0.003)	0.112***(0.000)	1.124(0.619)	0.387(0.569)	0.253(0.930)
σ_1	10.259(0.300)	1.462***(0.005)	0.144**(0.036)	-2.206(0.996)	0.944(0.143)	0.126(0.417)	0.045(0.165)	0.008(0.892)
ξ_1	0.396***(0.000)	0.429***(0.000)	0.443***(0.000)	0.236***(0.000)	-0.004(0.945)	-0.315***(0.001)	0.170**(0.046)	0.007(0.887)
τ_1	0.584***(0.000)	0.062(0.708)	0.188***(0.008)	0.353**(0.025)	0.423***(0.000)	-0.073(0.315)	0.085*(0.075)	0.170***(0.008)
δ_0	4.266(0.710)	2.904(0.995)	3.226(0.992)	0.783***(0.001)	0.583(0.941)	0.770(0.572)	-0.094***(0.002)	2.234(0.868)
δ_1	1.706(0.625)	0.954(1.000)	4.059(0.999)	0.383(0.998)	1.210(1.000)	1.297(0.866)	1.566(0.992)	0.488(1.000)
ϑ_1	-0.076(0.341)	0.012(0.780)	-0.042(0.100)	0.336**(0.022)				
κ_1	-2.039(0.105)	0.880(0.371)	-0.078**(0.025)	-0.119***(0.004)				

Panel B

	Indonesia	Philippines	South Korea	Thailand	China	Hong Kong	Malaysia	Singapore
$\sigma_0= \sigma_1$	0.000	0.000	0.000	0.000	0.019	0.778	0.004	0.000
$\lambda_0=\lambda_1$	0.059	0.566	0.102	0.000	0.036	0.000	0.000	0.000
HL_0	10.762	14.405	9.954	3.408	12.890	N/A	4.094	8.231
HL_1	N/A	N/A	N/A	N/A	N/A	N/A	7.973	N/A
p	1.000	0.998	0.999	0.783	0.887	0.779	0.941	0.987
q	0.956	0.830	1.000	0.014	0.720	0.903	0.463	0.687

Notes: The *p*-values for MS-ADF autoregressive coefficients in parentheses are calculated using a parametric bootstrap method with 2000 replications. p and q denote the probability of remaining in Regime 0 and Regime 1, respectively. HL denotes half-life and *p*-values are reported for the hypothesis test. ***, ** and * denote significance at the 1, 5 and 10% levels.

Table 6.9: MS-ADF Unit Root Testing, Output Growth

Panel A

	Indonesia	Philippines	South Korea	Thailand	China	Hong Kong	Malaysia	Singapore
α_0	2.390***(0.000)	1.856***(0.000)	6.967***(0.000)	3.747***(0.000)	1.256***(0.000)	1.466***(0.000)	4.973***(0.000)	2.531*** (0.000)
α_1	-0.509(0.118)	0.208(0.636)	5.387***(0.000)	-0.159(0.784)	3.846***(0.002)	0.737***(0.000)	2.534***(0.000)	2.744*** (0.000)
λ_0	-0.531***(0.001)	-0.414***(0.009)	-0.776**(0.021)	-0.297**(0.015)	-0.135**(0.018)	-0.411***(0.000)	-0.557**(0.036)	-0.346*(0.067)
λ_1	0.044(0.755)	-0.252(0.498)	-0.535***(0.005)	-0.265(0.218)	-0.651(0.123)	-0.148(0.207)	-0.252(0.377)	-0.120*(0.053)
σ_0	0.071***(0.002)	0.781(0.120)	0.175(0.949)	0.521**(0.016)	0.822(0.256)	3.829(0.486)	0.536(0.311)	6.145(0.880)
σ_1	5.898(0.976)	5.617(0.654)	1.159*(0.070)	13.915(0.992)	16.184(0.348)	0.344*(0.050)	8.627***(0.001)	0.103**(0.014)
δ_0	1.094(0.671)	2.733(0.832)	0.267(0.991)	2.803(0.934)	4.435(0.922)	0.810(0.953)	2.141(1.000)	1.870(0.988)
δ_1	1.440(1.000)	1.959(0.994)	3.046(0.977)	2.434(0.999)	2.400(0.968)	0.400(0.999)	1.790(0.897)	0.504(0.998)
ξ_1	0.186***(0.000)	0.050(0.586)	1.575***(0.000)	0.021(0.817)	0.134*(0.076)	0.300***(0.001)	0.158***(0.001)	0.355*** (0.000)
τ_1	0.080(0.382)	-0.026(0.872)	0.239***(0.000)	0.116(0.404)	-0.242(0.426)	0.374***(0.000)	0.522***(0.000)	-0.154*** (0.000)
ϑ_1	0.647***(0.000)	0.340**(0.024)	9.756***(0.000)	1.590***(0.000)				
κ_1	0.022(0.990)	0.941(0.298)	0.179(0.667)	-0.437(0.564)				

Panel B

	Indonesia	Philippines	South Korea	Thailand	China	Hong Kong	Malaysia	Singapore
$\sigma_0 = \sigma_1$	0.000	0.000	0.000	0.000	0.003	0.000	0.000	0.000
$\lambda_0 = \lambda_1$	0.000	0.113	0.000	0.729	0.000	0.000	0.000	0.000
HL_0	0.916	1.297	0.464	1.971	4.773	1.309	0.852	1.634
HL_1	N/A	N/A	0.906	N/A	N/A	N/A	N/A	5.410
p	0.925	0.997	0.999	0.997	1.000	0.791	0.984	0.969
q	0.863	0.975	0.605	0.993	0.992	0.655	0.963	0.693

Notes: The *p*-values for MS-ADF autoregressive coefficients in parentheses are calculated using a parametric bootstrap method with 2000 replications. *p* and *q* denote the probability of remaining in Regime 0 and Regime 1, respectively. HL denotes half-life and *p*-values are reported for the hypothesis test. ***, ** and * denote significance at the 1, 5 and 10% levels.

Table 6.10: MS-ADF Unit Root Testing, Real Exchange Rate

Panel A

	Indonesia	Philippines	South Korea	Thailand	China	Hong Kong	Malaysia	Singapore
α_0	0.944***(0.000)	0.328***(0.000)	2.199***(0.000)	1.509***(0.000)	0.787***(0.000)	0.074***(0.000)	0.148***(0.000)	0.166***(0.000)
α_1	0.019***(0.000)	-0.006***(0.000)	0.041***(0.000)	0.016***(0.000)	0.017***(0.000)	0.008***(0.000)	-0.001**(0.020)	0.005***(0.000)
λ_0	-0.120**(0.016)	-0.130**(0.012)	-0.300**(0.019)	-0.243***(0.001)	-0.648***(0.002)	-0.036***(0.009)	-0.102*(0.053)	-0.178*(0.070)
λ_1	-0.002*(0.058)	0.004(1.000)	-0.006***(0.004)	-0.005*(0.075)	-0.007***(0.002)	-0.002**(0.034)	0.002(0.997)	-0.009(0.155)
σ_0	0.011(0.983)	0.001(0.977)	0.003(0.610)	0.004***(0.006)	0.002***(0.004)	0.000(0.947)	0.002(0.386)	0.000(0.960)
σ_1	0.000(0.153)	0.000***(0.005)	0.000(0.167)	0.000(0.995)	0.000(1.000)	0.000***(0.004)	0.000(0.624)	0.000**(0.047)
ξ_1	0.293***(0.000)	0.647***(0.000)	0.430***(0.000)	0.207*(0.079)	-0.145(0.381)	0.018(0.955)	0.193***(0.003)	0.218**(0.025)
τ_1	0.305***(0.000)	0.454***(0.000)	0.272***(0.000)	0.406***(0.000)	0.374***(0.000)	0.170***(0.005)	0.291***(0.000)	0.304***(0.000)
δ_0	1.945(1.000)	-0.288***(0.003)	2.018(0.959)	2.703(0.811)	1.125(0.870)	0.356(0.974)	1.276(0.992)	1.603(1.000)
δ_1	2.921(0.745)	2.562(0.980)	3.941(0.888)	5.646(0.991)	4.555(0.984)	2.226(1.000)	3.409(0.882)	3.645(0.936)
ϑ_1	0.003(0.946)	-0.003(0.886)	-0.054(0.190)	0.438(0.224)				
κ_1	-0.006***(0.000)	-0.009***(0.000)	-0.006*(0.074)	0.001(0.200)				

Panel B

	Indonesia	Philippines	South Korea	Thailand	China	Hong Kong	Malaysia	Singapore
$\sigma_0 = \sigma_1$	0.000	0.004	0.000	0.000	0.168	0.000	0.000	0.000
$\lambda_0 = \lambda_1$	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
HL_0	5.434	4.959	1.941	2.488	0.664	18.948	6.474	3.535
HL_1	281.561	N/A	109.606	147.098	96.262	308.021	N/A	N/A
p	0.998	0.995	1.000	1.000	0.870	0.639	0.899	0.946
q	0.974	0.387	0.978	0.997	1.000	0.987	1.000	1.000

Notes: The *p*-values for MS-ADF autoregressive coefficients in parentheses are calculated using a parametric bootstrap method with 2000 replications. p and q denote the probability of remaining in Regime 0 and Regime 1, respectively. HL denotes half-life and *p*-values are reported for the hypothesis test. ***, ** and * denote significance at the 1, 5 and 10% levels.

variability in the real exchange rate at a long horizon, which, in turn, stabilizes the real exchange rate more significantly relative to non-IT countries (Kim, 2014). Indeed, the case of two stationary regimes for real exchange rate involves only China and Hong Kong, where the coefficient estimates for λ_0 and λ_1 are negative and statistically significant at the 5% level or better.

Furthermore, the cases where stationarity is present in two regimes only include Malaysia for inflation, and South Korea and Singapore for output growth. As Table 6.8 reveals, the coefficient estimates for λ_0 and λ_1 are negative and statistically significant respectively at the 10% and 1% levels in the case of Malaysia. This evidence of *varied* stationarity in inflation corroborates the findings of global stationarity and stationarity across all quantiles presented in Chapter 5. Again, this is indicative of perfect credibility of Malaysia's monetary policy. In the case of South Korea, Panel A of Table 6.9 reveals that the estimated values of λ_0 and λ_1 are negative and statistically significant at the 5% and 1% levels, respectively. The *varied* stationarity finding for South Korea's output growth implies some degree of success by the Bank of Korea in controlling output volatility under an IT regime. Similar implications apply to Singapore, where the estimates for λ_0 and λ_1 are negative and significant at the 10% level.

Regarding the real exchange rate, it can been seen from Panel A of Table 6.10 that the coefficient estimates for λ_0 are negative and statistically significant at the 5% level for the Philippines, and at the 10% level for Malaysia and Singapore. In the case of the Philippines, this indicates that the Bangko Sentral ng Pilipinas (BSP) implements a flexible IT framework in which it allows less activism in adjusting the monetary policy instruments to prevent unwarranted volatility inflation, output and real exchange rate. Overall, the findings of *partial* stationarity are consistent with the evidence of inflation and output growth stationarity reported in Table 6.6 but not for real exchange rate, which shows evidence of non-stationarity in terms of single-regime standard unit root tests.

Based on the estimated values of λ_0, the half-lives are approximated for each country and each macroeconomic variable with *partial* stationarity. Note that the half-life associated with each λ_0 is approximated as $\mathrm{HL}_0 = (\ln 0.5)/(1 + \lambda_0)$. By and large, the empirical findings suggest that inflation in IT countries is characterized by a much slower speed of adjustment in Regime 0 as compared with non-IT countries. To be specific, Panel B of Table 6.8 reveals that the half-lives of inflation in Regime 0 range from 10.0 to 14.4 months for IT countries of Indonesia, the Philippines and South Korea, and from 8.2 to 12.9 months for non-IT countries of China and Singapore. Clearly, the half-lives is relatively large for most IT countries. This indicates that when hit by large unforeseen exogenous shocks that are within a credible central bank's control, inflation can revert to its steady-state level relatively slowly. IT central banks can obtain useful insights from this information, especially for monitoring the behaviour of annual inflation under IT, and for setting the inflation target horizon in the medium-term, i.e. including target horizons of two years or more (Hammond, 2012).

Panel B of Table 6.9 shows that the half-lives of output growth in Regime 0 range between 0.9 and 2.0 quarters in the case of IT countries, and between 0.9 and 4.8 quarters in the case of non-IT countries. That is, output growth in Regime 0 adjusts to shocks relatively fast for IT countries. Similarly, those two groups of countries are characterized by marked differences in half-lives in the cases of *varied* stationarity in output growth. For example, Panel B of Table 6.9 shows that the half-lives of output growth across regimes range from 0.5 to 0.9 quarter for South Korea, and from 1.6 to 5.4 quarters for Singapore.

The half-lives of real exchange rate under the case of *partial* stationarity are also comparable for some IT and non-IT countries. For instance, Panel B of Table 6.10 shows that the Philippines and Malaysia feature half-lives of 5.0 and 6.5 months, respectively. In the case of Singapore, the approximated half-life in Regime 0 is 3.5 months. These half-life approximations are markedly different from the general PPP literature that argues for a half-life of 3 to 5 years where long-run PPP holds (Rogoff, 1996). On the other hand, the case of *varied* stationarity in real exchange rate reveals that IT countries are characterized by a relatively fast speed of adjustment. In particular, the half-lives of real exchange rate across regimes range between 1.9 and 281.6 months in the case of IT countries, and between 0.7 and 308 months in the case of non-IT countries. As a whole, the findings highlighted above imply that IT central banks behave much differently from those in non-IT countries in stabilizing inflation, output and real exchange rate.

The present study also considers the impact of IT on the stationarity of the three macroeconomic variables of interest. The context of the analysis here focuses on whether IT significantly influences the transition probabilities of switching between regimes. In other words, this study investigates the second hypothesis that *the adoption of IT is more likely associated with a greater probability of remaining in the stationary regime*.

Closer scrutiny delivers further indication that the second hypothesis holds strongly in the case of Thailand only. To be specific, the last two rows of Panel A of Table 6.8 show that the estimate for ϑ_1 is positive and significant at the 5% level for Thailand. The positive estimate indicates that IT increases the probability of remaining in the more stationary Regime 0. In addition to this, IT reduces the probability of being in the non-stationary Regime 0 in the cases of Thailand and South Korea, where the estimates for κ_1 are negative and statistically significant at the 1% and 5% levels, respectively. Note that the estimate for κ_1 is negative but marginally significant at the 10.5% significance level in the case of Indonesia. In general, the results suggest that Thailand and South Korea are consistent with *a priori* expectations concerning IT credibility.

Looking at IT effects on output growth, Panel A of Table 6.9 offers further insight that the second hypothesis stated above is confirmed for all IT countries. The results show that the estimates for ϑ_1 are positive and mostly significant at the 5% level throughout. This means that IT plays an important role in the stationary Regime 0, which conforms to the view that this monetary policy has the capacity to stabilize output. However, IT has no effect on the non-stationary Regime 1 as the estimates for κ_1 are not significant. One possible explanation for this finding is that the Asian and 2009 financial crises are associated with the non-stationary Regime 1 in all IT countries, as will be shown later in Figure 6.4. This implies that output stabilization under IT lacks credibility for large recession shocks.

For real exchange rates, Panel A of Table 6.10 shows that the second hypothesis is rejected since the estimates for ϑ_1 are not significant for all IT countries. Note that IT countries are characterized by *varied* stationarity in real exchange rates. Thus, the no IT effect finding for the stationary Regime 0 implies that central banks possibly put less weight on stabilizing the exchange rate relative to inflation and output. This is because the real exchange rate series will revert anyway to its equilibrium level. On the other hand, Panel A of Table 6.10 reveals that the estimates for κ_1 are negative and significant at the 1% level for Indonesia and the Philippines, and at the 10% level for South Korea. This finding provides further insight that IT adoption lowers the probability of remaining in Regime 1.

To further interpret the above results, the next stage of the analysis looks at the inferred probabilities of being in the stationary Regime 0 during each month of the study period. Figures 6.3, 6.4 and 6.5 illustrate these in sequence for inflation, output growth and real exchange rate. In general, the inferred probabilities suggest that all IT countries display a high probability of being in the stationary Regime 0 for each macroeconomic variable both during the whole study period and following the adoption of IT. For the whole study period, the high inferred probabilities of being in the stationary Regime 0, denoted by *p*, are supported by the results reported in Panel B of Tables 6.8, 6.9 and 6.10. Specifically, the computed probabilities are particularly high for staying in Regime 0 for IT countries in many cases.

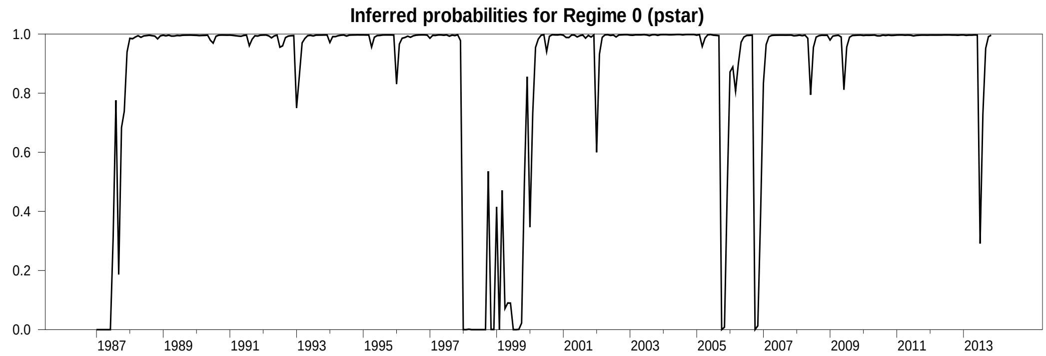
During the periods in which countries implemented IT, Figure 6.3 shows that there is only a very short-lived increase in the inferred probability of being in the non-stationary Regime 1 in the cases of Indonesia, South Korea and the Philippines. Figure 6.4 also exhibits the same pattern for output growth in the cases of the Philippines and South Korea. This pattern provides an indication that an IT regime in these countries has some degree of credibility in stabilizing both inflation and output. Moreover, it is noticeable from Figure 6.5 that there is only a very modest and transitory rise in the inferred probability of being in the non-stationary real exchange rate Regime 1 during the IT period in Thailand. This is supportive of the above evidence that IT increases (decreases) the probability of being in the stationary (non-stationary) regime. These results imply that the Bank of Thailand's IT regime has the capacity to stabilize both inflation and real exchange rate.

Non-targeting countries also display a high probability of remaining in the stationary Regime 0 for most of the three macroeconomic variables under consideration. The only exceptions are China and Hong Kong, where much of the study period portrayed in Figure 6.3 is characterized by a low probability of being in the stationary inflation Regime 0. This is consistent with the earlier evidence of weak and zero credibility of monetary policy in China and Hong Kong, respectively. Furthermore, it can be seen that the inferred probabilities over the study period are generally less variable for IT countries than for non-IT countries. Indeed, the inferred probabilities remained highly volatile over the study period for most non-IT countries in each macroeconomic variable. In contrast, the inferred probabilities only remained highly volatile in the cases of Thai inflation (Figure 6.3), and Indonesian output growth (Figure 6.4) and real exchange rate (Figure 6.5).

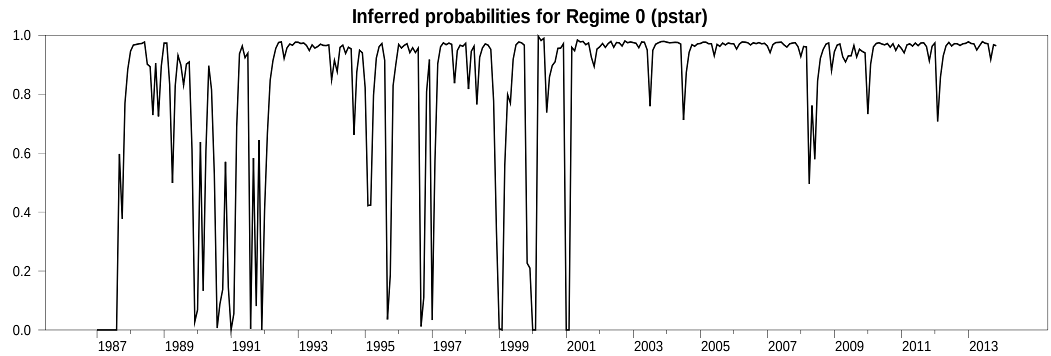
Moreover, Figure 6.5 shows that the inferred probabilities remained relatively volatile during the adoption of IT in the Philippines and South Korea. As noted by Holmes (2010), the transitory components of real exchange rates are expected to be highly volatile when nominal exchange rates are flexible or controlled by managed floating. Since IT adoption in Asian countries coexists with a flexible exchange rate regime, it might be expected that their real exchange rate would be highly volatile during an IT regime. Despite the highly volatile pattern discussed above for some IT countries, they are generally characterized by a high probability of remaining in the stationary Regime 0, implying that central banks have the capacity to stabilize inflation, output and real exchange rate.

Figure 6.3: Filtered Inferred Probabilities of Regime 0, Inflation Rate

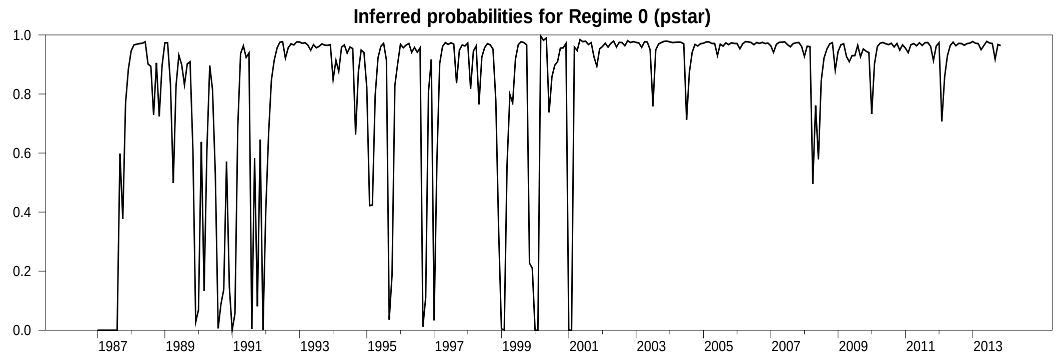
(a) Indonesia



(b) Philippines



(c) South Korea



(d) Thailand

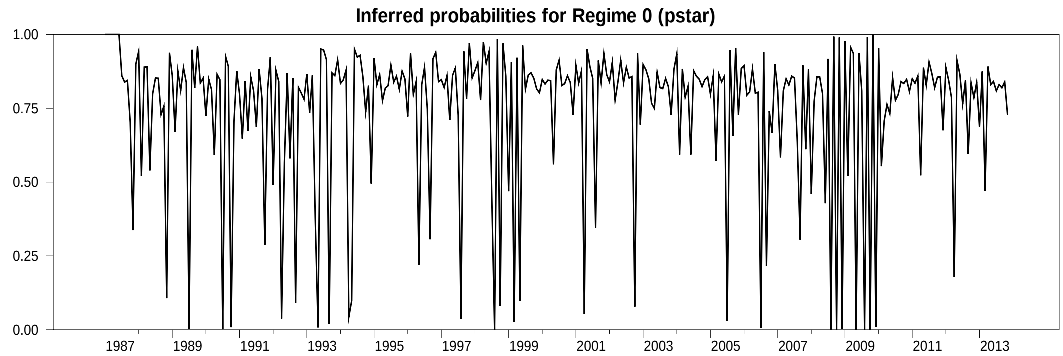
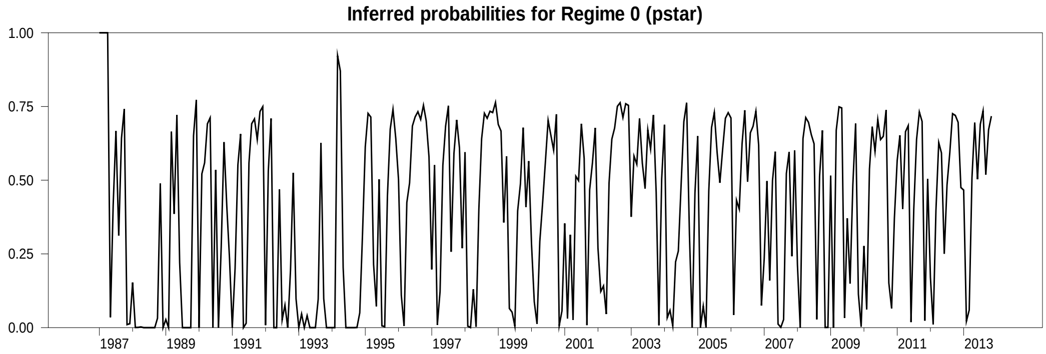
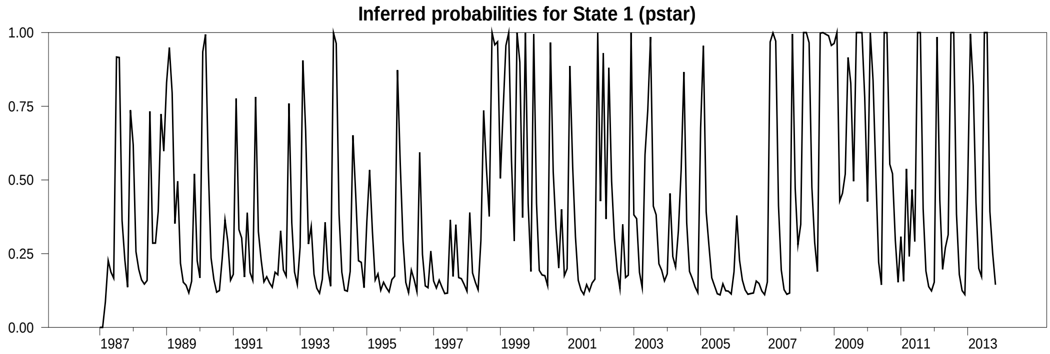


Figure 6.3: (Continued)

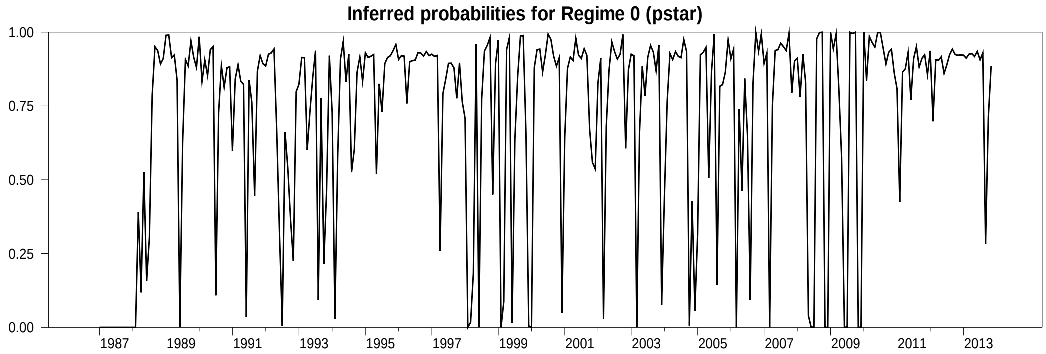
(e) China



(f) Hong Kong



(g) Malaysia



(h) Singapore

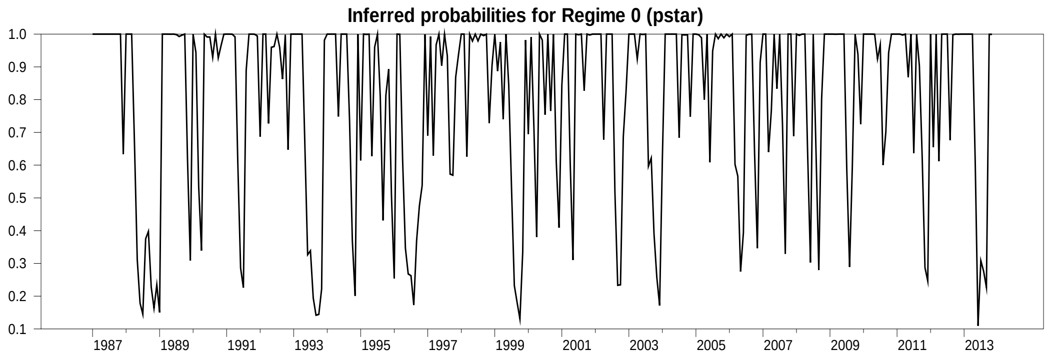
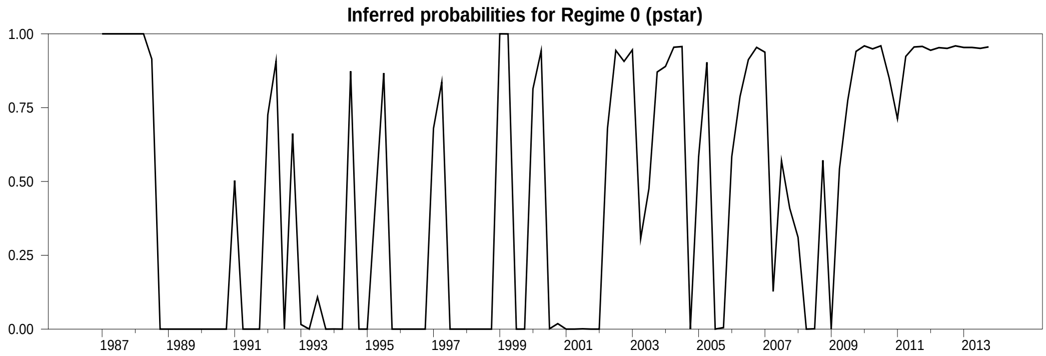
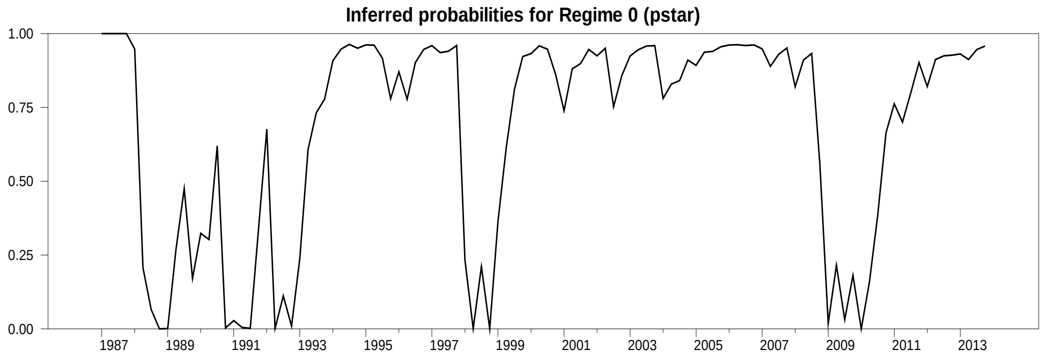


Figure 6.4: Filtered Inferred Probabilities of Regime 0, Output Growth

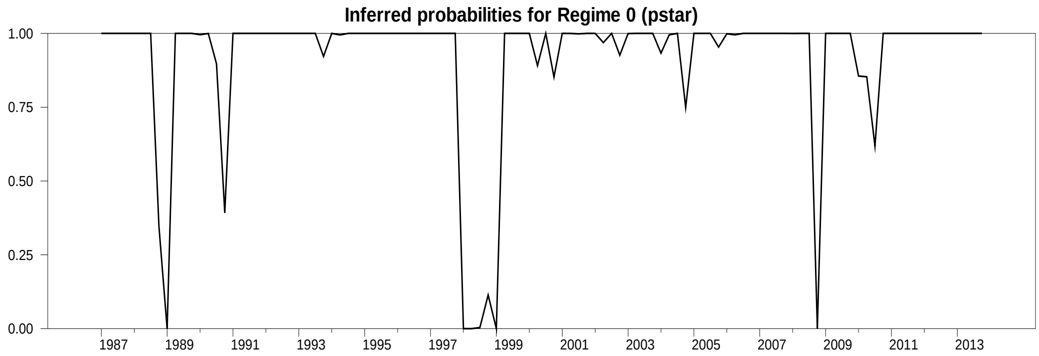
(a) Indonesia



(b) Philippines



(c) South Korea



(d) Thailand

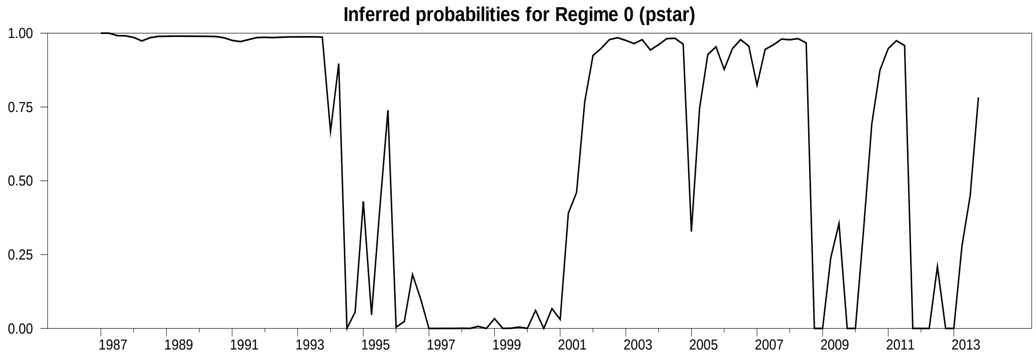
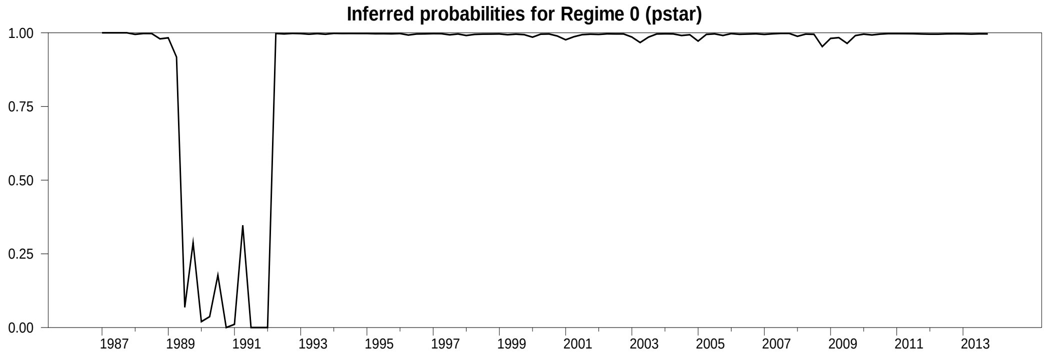
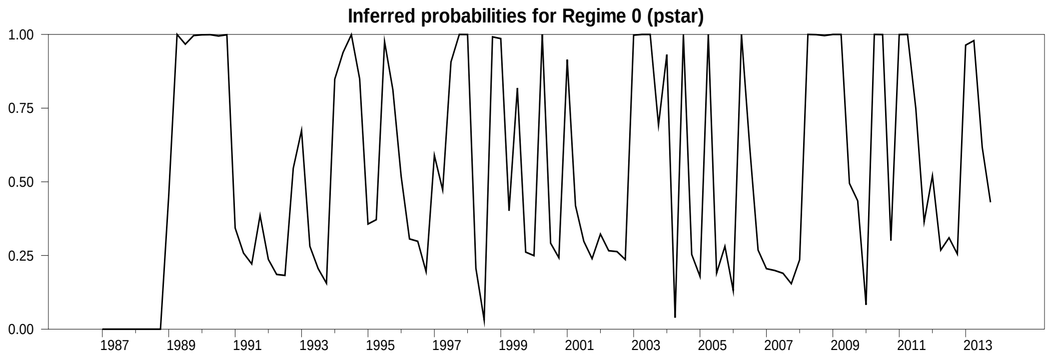


Figure 6.4: (Continued)

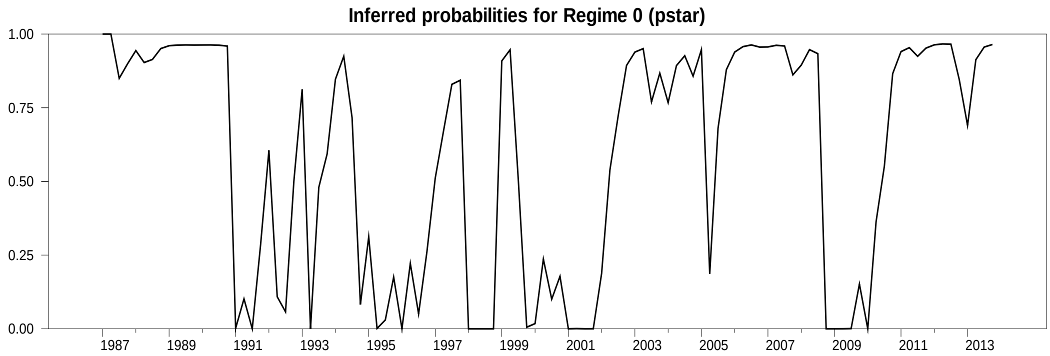
(e) China



(f) Hong Kong



(g) Malaysia



(h) Singapore

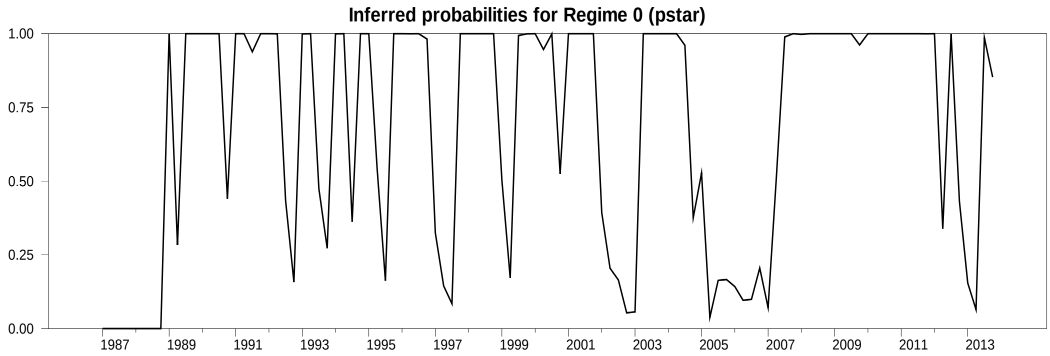
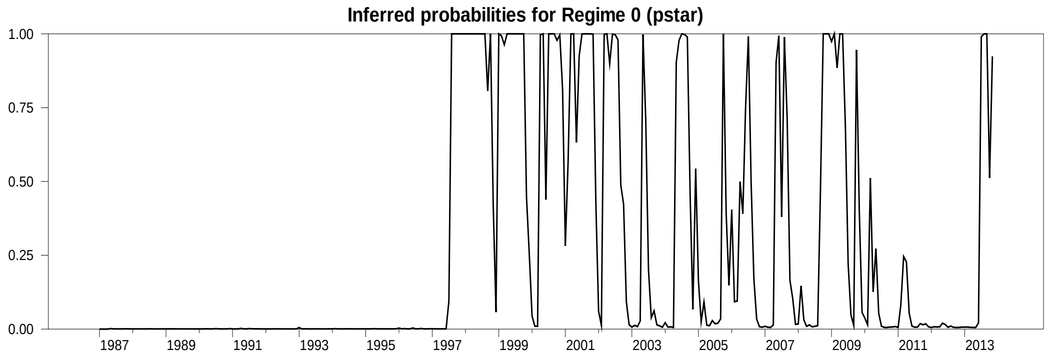
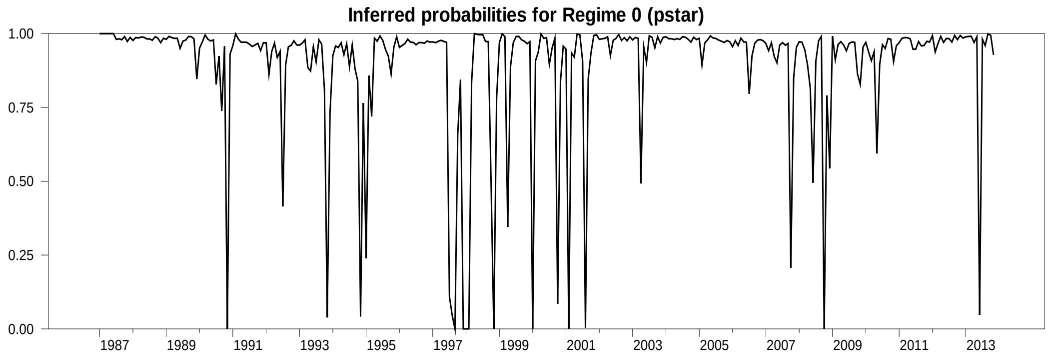


Figure 6.5: Filtered Inferred Probabilities of Regime 0, Real Exchange Rate

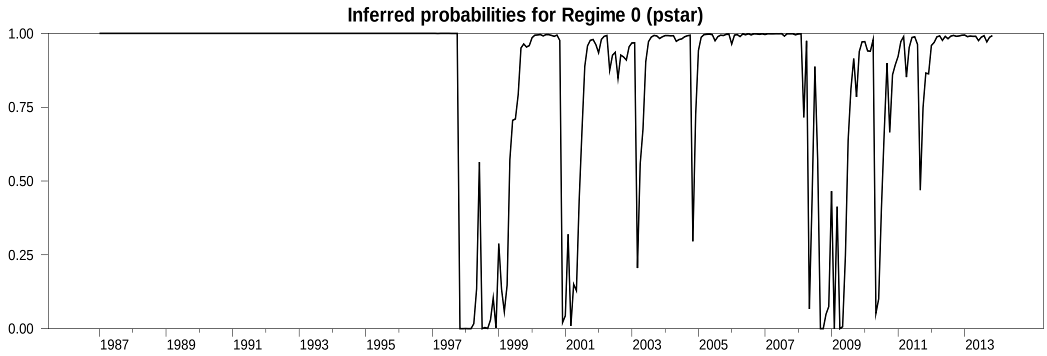
(a) Indonesia



(b) Philippines



(c) South Korea



(d) Thailand

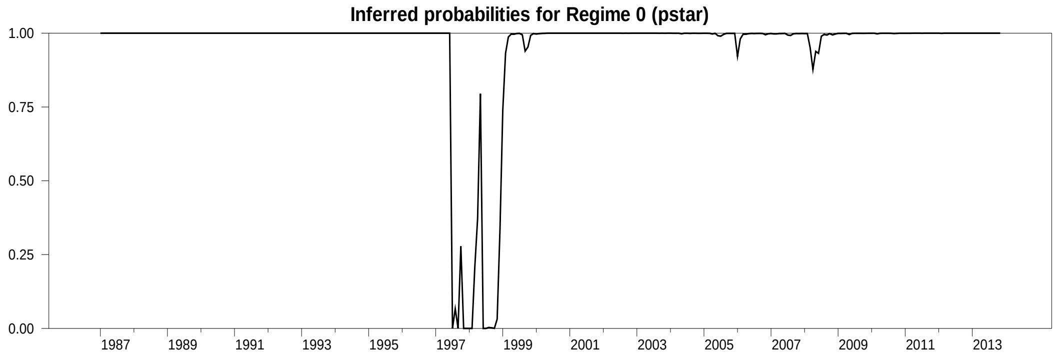
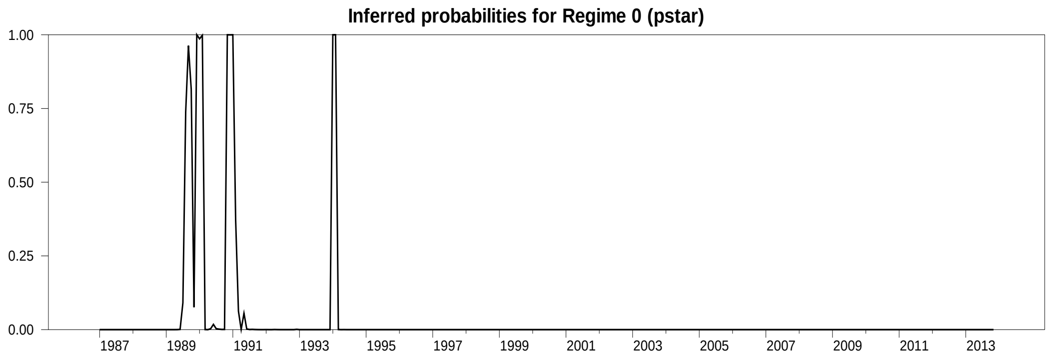
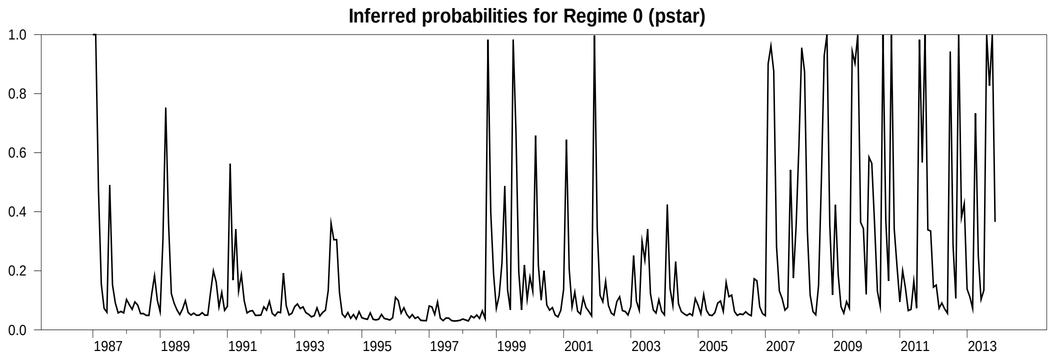


Figure 6.5: (Continued)

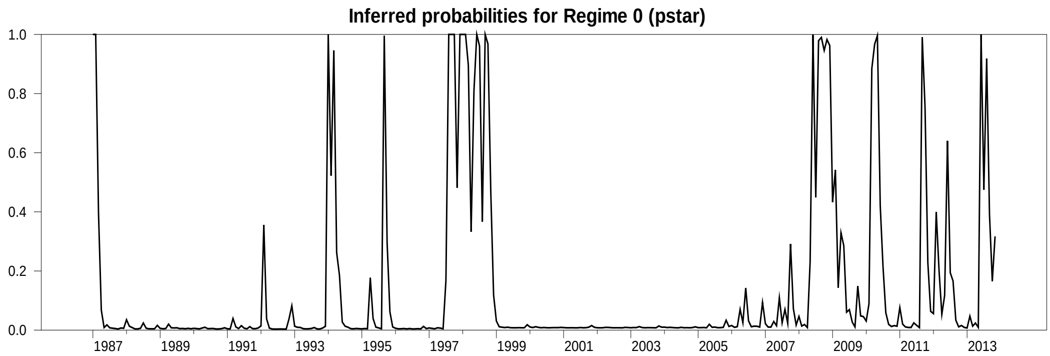
(e) China



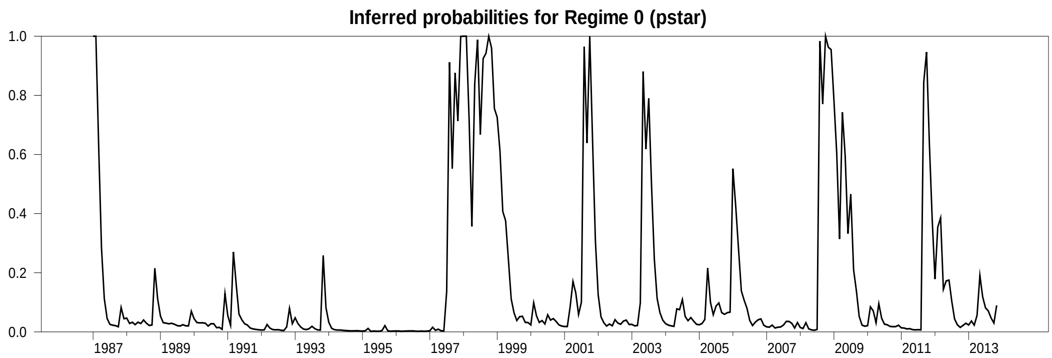
(f) Hong Kong



(g) Malaysia



(h) Singapore



Finally, this section investigates the third hypothesis that *if a central bank is credible in controlling inflation, output growth and real exchange rate by following a Taylor 'rule', the stationary IT period should coincide where variance is lowest for each of these variables.* Before embarking on the analysis, this section examines first the null $\sigma_0 = \sigma_1$. Panel B of Tables 6.8, 6.9 and 6.10 reveals that the null $\sigma_0 = \sigma_1$ is strongly rejected in the majority of cases, meaning the two regimes are characterized by different volatilities. Note that in testing the restriction $\sigma_0=\sigma_1$, a credible IT should lead to a smaller σ because the high degree of transparency and accountability of monetary policy under IT limits not only the variability in inflation but also the variability in output and real exchange rate in the long run (Kim, 2014).

In testing the third hypothesis stated above, Panel A of Tables 6.8 shows that it is not always the case that inflation variance is lower in the stationary Regime 0 than in the non-stationary Regime 1. It is only in the cases of Indonesia and the Philippines that the IT period seems to coincide with the variance of inflation being lower in the stationary Regime 0 only. Specifically, the coefficient estimates for σ_0 and σ_1 are respectively 0.416 and 10.259 in the case of Indonesia, and 0.166 and 1.462 in the case of the Philippines. In terms of output growth variance, Panel A of Table 6.9 reveals that this is lower in the stationary Regime 0 for all IT countries. One may read this finding as implying that IT central banks also attach a greater weight to stabilizing output.

On the other hand, Panel A of Table 6.10 shows that the variance of real exchange rate in the stationary Regime 0 is greater than in the non-stationary Regime 1 in all IT countries. This finding concurs with the evidence above that IT has no significant effect on the inferred probabilities of remaining in the stationary

Regime 0 for real exchange rate. In addition, this is consistent with the view that the transitory components of real exchange rates are expected to be highly volatile when nominal exchange rates are flexible, as in the case of IT countries.

In qualitative terms, Tables 6.11, 6.12 and 6.13 present a summary of the MS-ADF results for inflation, output growth and real exchange, respectively. The overall results suggest *partial* stationarity is generally apparent for inflation and output growth, while *varied* stationarity is more evident for real exchange rate. The findings in this study are in line with previous MS-ADF studies of inflation (Cruz & Mapa, 2013; Murray et al., 2015; Villa et al. (2014), output (Camacho, 2011; Kocaaslan, 2016), and real exchange rate (Holmes, 2010; Kanas, 2009; Lee & Yoon, 2013). The similarity between the present investigation and these existing studies is in terms of characterizing regime-switches in macroeconomic variables under review. However, the main contribution of this study is the analysis of the effects of IT on a relatively broader set of macroeconomic variables. Accordingly, this study offers a more comprehensive assessment of IT effects on macroeconomic performance with new insights on the relationship between IT credibility and stationarity of the series. Additionally, this study compares the nature of stationarity of inflation among a sample of IT and non-IT countries, which is important in light of the ongoing concern about deflation in many economies around world.

Another important highlight of the results explained above is the role played by IT in influencing the inferred probabilities in the case of inflation in some targeting countries, and in the cases of output growth and real exchange rate in most targeting countries. The results also indicate that the variance of inflation and output growth is lower during the stationary regime period in most IT countries. Therefore, these aforementioned findings further extend the literature on MS-ADF modelling

Table 6.11: Summary of MS-ADF Unit Root Testing, Inflation Rate

	Stationary:		Variance of inflation:	Probability of remaining in Regime 0:		Role of IT dummy on the probability of remaining in:	
	Regime 0[a]	Regime 1	Regime 0 < Regime 1	Whole study period	Following IT adoption[b]	Regime 0	Regime 1
Indonesia	Yes	No	Yes	High	High	No effect	No effect
Philippines	Yes	No	Yes	High	High	No effect	No effect
South Korea	Yes	No	No	High	High	No effect	Negative effect
Thailand	Yes	No	No	High	High	Positive effect	Negative effect
China	Yes	No	Yes	Low			
Hong Kong	No	No	No	Low			
Malaysia	Yes	Yes	No	High			
Singapore	Yes	No	No	High			

Notes: [a]Where possible, Regime 0 is the stationary regime or the regime characterized by the shorter half-life.
[b]High means the probability is greater than 0.5 for the time period following the adoption of IT.

Table 6.12: Summary of MS-ADF Unit Root Testing, Output Growth

	Stationary:		Variance of output growth:	Probability of remaining in Regime 0:		Role of IT dummy on the probability of remaining in:	
	Regime 0[a]	Regime 1	Regime 0 < Regime 1	Whole study period[b]	Following IT adoption[b]	Regime 0	Regime 1
Indonesia	Yes	No	Yes	Low	High	Positive effect	No effect
Philippines	Yes	No	Yes	High	High	Positive effect	No effect
South Korea	Yes	Yes	Yes	High	High	Positive effect	No effect
Thailand	Yes	No	Yes	High	High	Positive effect	No effect
China	Yes	No	Yes	High			
Hong Kong	Yes	No	No	High			
Malaysia	Yes	No	Yes	High			
Singapore	Yes	Yes	No	High			

Notes: [a]Where possible, Regime 0 is the stationary regime or the regime characterized by the shorter half-life.
[b]High means the probability is greater than 0.5 for the time period following the adoption of IT.

Table 6.13: Summary of MS-ADF Unit Root Testing, Exchange Rate

	Stationary:		Variance of real exchange rate:	Probability of remaining in Regime 0:		Role of IT dummy on the probability of remaining in:	
	Regime 0[a]	Regime 1	Regime 0 < Regime 1	Whole study period[b]	Following IT adoption[b]	Regime 0	Regime 1
Indonesia	Yes	Yes	No	High	High	No effect	Negative effect
Philippines	Yes	No	No	High	High	No effect	Negative effect
South Korea	Yes	Yes	No	High	High	No effect	Negative effect
Thailand	Yes	Yes	No	High	High	No effect	No effect
China	Yes	Yes	No	High			
Hong Kong	Yes	Yes	No	High			
Malaysia	Yes	No	No	High			
Singapore	Yes	No	Yes	High			

Notes: [a]Where possible, Regime 0 is the stationary regime or the regime characterized by the shorter half-life.
[b]High means the probability is greater than 0.5 for the time period following the adoption of IT.

of macroeconomic variables and shed new light on the role of IT in driving time-varying transition probabilities. The aforementioned findings are consistent with the optimistic view that IT should lead to better macroeconomic outcomes (Bernanke et al., 1999; Mishkin, 1999; Svensson, 1997). Moreover, those findings lend support to the existence of a positive impact of IT on macroeconomic performance as reported, for example, by Ayres et al. (2014), Mollick et al. (2011), Amira et al. (2013), Ding and Kim (2012) and Kim (2014).

The role of IT as emphasised in this study has been largely unexplored in previous literature. In fact, existing studies concentrate instead on integrating the role of certain economic factors in regime switches between stationarity and non-stationarity. For example, Burger (2014) considers stock market volatility while Amisano and Fagan (2013) take into account broad money in influencing two inflation regimes. Likewise, Yang and Hamori (2016) examine the role of speculative shocks in influencing output growth regimes in a sample of three Asian countries. Moreover, Abul Basher et al. (2016) and Holmes (2010) capture the role of oil shocks and Asian crisis, respectively, in modelling the regime-switch in real exchange rates.

Furthermore, the results suggest that inflation in IT countries is characterized by a much slower speed of adjustment in the stationary regime as compared with non-IT countries. IT countries are also characterized by a much faster speed of adjustment than non-IT countries in the case of *varied* stationarity in output growth and real exchange rate. In addition, the results suggest that the inferred probabilities over the study period are generally less variable for IT countries than for non-IT countries. In short, there is a significant difference between these two groups of countries in terms of the speed of adjustment of macroeconomic variables and the behaviour of inferred probabilities. Therefore, those findings throw new light on the no-difference debate about macroeconomic performance in IT and non-IT countries. Clearly, the findings in this study depart substantially from existing studies that report no difference between IT and non-IT countries in terms of inflation and output performance (Angeriz & Arestis, 2007; Capistrán & Ramos-Francia, 2009; Dueker & Fischer, 2006; Lin & Ye, 2007; McDermott & MacMenamin, 2008).

6.5 Conclusions

This chapter investigates the extent to which IT influences the stationarity properties of inflation, output growth and real exchange rate, using a Markov-switching procedure. This is an important new contribution to the existing studies insofar as the role of IT is considered in examining the issue of stationarity. Aside from advocating the concepts of *partial* and *varied* stationarity, this study offers a comparison of the performance between Asian IT and non-IT countries in terms of stationarity of macroeconomic variables.

Based on Markov-switching ADF unit root testing, the salient findings that can be drawn from this study are as follows. First, the stationarity of macroeconomic variables under study is present for each country in at least one regime except for inflation rate in the case of Hong Kong. Instead of assessing stationarity based on a single test statistic across the entire study period, these results suggest that Asian IT and non-IT economies are characterized by *partial* stationarity where the macroeconomic outcomes shift between a stationary and non-stationary regime, or *varied* stationarity where the macroeconomic outcomes shift between two stationary regimes with very different dynamics of adjustment. In this case, the identification of one or two stationary regimes of macroeconomic variables is country-specific.

Second, the results suggest that Thailand represents the strongest case in which IT plays an important role in stabilizing inflation rate. However, IT matters for South Korean inflation rates in terms of reducing the probability of remaining in the non-stationary regime. Third, IT significantly influences the probability of being in the stationary regime for output growth in all IT countries, while it reduces the probability of remaining in the non-stationary regime for real exchange rates in most IT countries. Fourth, a lower variance in the stationary regime is found in most cases for output growth, but only in some cases for inflation rate and in a single case for real exchange rate. Finally, the results suggest that there is a significant difference between IT and non-IT countries with respect to the speed of adjustment of macroeconomic variables and the behaviour of inferred probabilities. Therefore, those findings refute the no-difference debate between IT and non-IT countries as previously found in the literature.

The above findings have important implications for monetary policy. First, the *partial* stationarity in inflation implies that monetary policy intervention should become contractionary-sensitive only for periods during which inflation is highly persistent. In terms of the changes in output growth, policy makers should respond more to output shocks that are highly persistent during recession periods to avoid greater volatility of future GDP growth, and pay less attention to output shocks during expansionary periods. In addition, *varied* stationarity in real exchange rates implies that central banks should not over-implement exchange rate intervention policies because the series will revert anyway to its equilibrium level.

Finally, since the effect of IT seems to be stronger for output growth than for inflation in terms of driving higher probabilities of being in the stationary regime, IT central banks should respond more to output stabilization in situations where inflation and economic growth move apart because of large supply shocks. However, another key lesson for policymakers is that IT central banks should stabilize both inflation and output more actively in light of the significant negative effect of IT on the probability of remaining in the non-stationary regime for real exchange rates.

Chapter 7: Conclusion

A key feature of an IT regime as a monetary policy strategy is predicated on the view that it enhances credibility by anchoring inflationary expectations. However, such a view has become questionable in the aftermath of the global financial crisis in 2008-2009 and ongoing concerns about deflation in many economies around the world. Doubts about low inflation targets, as well as recognition of other drawbacks with present IT policy, have left many central banks, particularly in rich economies, with little room to hit their targets and facing dilemmas when inflation and economic growth move apart. Despite renewed attention being paid to the relevance of IT in recent years, its impact on key macroeconomic variables in Asian countries and elsewhere remains controversial. Indeed, the crisis has raised a more general question about the current regime: Is IT really credible?

An affirmative answer to this question is the basis of the following hypothesis, referred to as the *IT credibility hypothesis*. Under an IT regime, the high degree of transparency and accountability of monetary policy enables central banks to hit their targets more precisely than non-IT countries. As a result, agents will avoid systematic forecast errors in future inflation rates and so inflation expectations follow a stationary process that makes IT credible. In this case, a credible IT regime keeps the absolute difference between actual inflation and the inflation target to a minimum. Therefore, the main theme of this thesis is IT credibility, which can be assessed in terms of the level, volatility and stationarity of inflation, real output growth and real exchange rate. By using both time-series and panel data, the empirical findings reported in this thesis challenge the existing empirical findings as summarized in the following three main conclusions drawn from the analysis.

First, Chapter 4 concludes that a panel GARCH model is better suited to assessing the impact of IT on the conditional mean and conditional variance of inflation than a single country GARCH model because the latter ignores cross-sectional dependence. Specifically, the relationship between the inflation target and inflation outcomes is more appropriately explained within a panel setting where information about interdependence and heterogeneity across countries is incorporated. After capturing these two features in the model and confirming the exogeneity status of the IT variable, this study finds that IT significantly lowers the level of inflation in most IT countries, and helps to reduce inflation volatility in the Philippines and South Korea. Therefore, this thesis concludes that IT is more credible in achieving lower inflation rate than lower inflation variance. A tendency to increase the interdependence of inflation shocks in a sample of Asian countries is also revealed. In addition, the panel dynamic conditional correlation to remain positive, indicating that the Asian sample countries in this study may experience similar unforeseen inflation shocks regardless of whether or not their central banks implement IT policy.

Chapter 4 also provides empirical support for employing a panel GARCH model by estimating eight separate bivariate BEKK-MGARCH models using the U.S. and Japan as reference countries. Indeed, the results indicate a significant drop in inflation in Thailand relative to U.S. inflation, and in the Philippines and South Korea relative to Japan. This suggests that IT has some degree of credibility but it depends on country pairing of inflation linkages. However, the results also suggest that the conditional variances of inflation in all Asian IT countries decline after the adoption of IT, regardless of the reference country. An IT regime is therefore credible with respect to lowering conditional volatility of inflation within a bivariate MGARCH framework. Overall, the results indicate that there is interdependence between Asian countries and the U.S. or Japan based on inflation linkages and volatility transmission. In a bivariate framework, the results further suggest a tendency for the conditional correlation coefficient to become positive for IT countries after the adoption of this regime.

Secondly, the nature of IT credibility is examined in Chapter 5 from the perspective of potential link of inflation stationarity to smaller or larger changes in inflation rate. In others words, this study departs from most existing studies that focus on examining the unit root hypothesis at the conditional mean of inflation, and focuses attention on the tails of the distribution using quantile ADF unit root testing. More importantly, the core research in this chapter incorporates the trend-reversion within the QADF model instead of concentrating on mean reversion for inflation as previous studies have done. By integrating this crucial information and details about mean-reversion and global stationarity, this study sheds light on the credibility of IT in Asia based on a three-way definition of IT with respect to *perfect*, *imperfect* or *weak*, and *zero* credibility, and offers a comparison between Asian IT countries and non-IT countries.

The results indicate that there is mean reversion in inflation rates, but at the lower quantiles only, except for Malaysia where inflation is stationary across all quantiles. When a fully-fledged adoption of IT is captured, there is evidence that inflation is stationary across all quantiles except for Malaysia and South Korea. The results also suggest an asymmetry in the speed of inflation adjustment across quantiles for all countries except for Malaysia. Based on trend-reversion, there is evidence of more significant decline in inflation rate changes for IT countries than for non-IT countries, which suggests that the former group has enhanced their monetary policy credibility and therefore IT is heading in the right direction.

Chapter 5 also finds that with the exception of Hong Kong, the inflation rate is globally stationary and hence both IT and non-IT central banks in Asia have some degree of credibility. By approximating the threshold level whereby inflation becomes stationary based on QADF model estimation, the results suggest that stationary behaviour of inflation rates tends to occur in periods when inflation is declining or slowing down. This study concludes in general that the credibility of IT and alternative monetary policy in most of the Asian samples can be characterized as being *imperfect*, because inflation is stationary only when inflation is low. South Korea and Malaysia are perhaps the strongest cases of labelling as *perfectly* credible because inflation is stationary even when these two countries are hit by small or large unforeseen inflation shocks.

Finally, Chapter 6 looks at a much broader picture of IT credibility with insights from stationarity of inflation, real output growth and real exchange rate. Based on time-series of these key macroeconomic variables from each country, this study finds that a Markov-switching ADF framework is preferable to a single-regime ADF model. Thus, the dynamic behaviour of macroeconomic variables is better explained in regime-specific terms. In doing so, Chapter 6 attempts to reinterpret the macroeconomic stabilization hypothesis based on the possibility that the series might be influenced by two stationary regimes (*varied* stationarity), or one stationary and one non-stationary regime (*partial* stationarity). This study further explores the role of IT in influencing the time-varying transition probabilities of switching between two regimes.

Based on the use of the regime-switching methodology, this study finds that inflation in China, Singapore and all IT countries is characterized by one stationary regime (*partial* stationarity), while there is evidence of two stationary regimes (*varied* stationarity) for Malaysia. The results also indicate that one stationary regime (*partial* stationarity) in output growth exists for most of the sample countries, except for South Korea and Singapore, which are characterized by two stationary regimes (*varied* stationarity). Whereas a range of standard unit root tests involving eight Asian real exchange rates is inconclusive in terms of supporting stationarity, the application of a Markov-switching unit root in Chapter 6 indicates that stationarity of the real exchange rate is present for each country in at least one regime. For five out of the eight members of the sample, this study finds that real exchange rate is characterized by two stationary regimes (*varied* stationarity), though this is not the case for Malaysia, the Philippines and Singapore, where evidence of only one stationary regime (*partial* stationarity) is found.

The results further suggest that based on the inferred probabilities of being in the stationary period, IT has a significant effect on inflation for Thailand and on output growth for all IT countries. There is also evidence of a negative effect on the probability of being in the non-stationary regime for inflation in South Korea and Thailand, and for the real exchange rate in most IT countries. The results also suggest that inflation in IT countries is characterized by a much slower speed of adjustment in the stationary regime as compared with non-IT countries. In addition, IT countries are characterized by a much faster speed of adjustment than non-IT countries in the case of *varied* stationarity in output growth and real exchange rate. Furthermore, there is evidence that the IT period coincides with a lower variance of output growth in the stationary regime in all IT countries, while this is not always the case in terms of inflation and real exchange rate. In sum, this study concludes that the effect of IT on the stationary behaviour of key macroeconomic variables is country-specific. The study further concludes that there is a significant difference between these two groups of countries in terms of the speed of adjustment of macroeconomic variables and the behaviour of inferred probabilities.

With these findings, the key lessons for monetary policy and academics are the following. First, panel data analysis suggests significant reduction in the level of inflation for all IT countries and for most of them in terms of lower inflation volatility. Therefore, monetary authorities in IT countries where inflation levels are relatively high, such as Indonesia and the Philippines, should acknowledge that they will gain more from IT policy. In particular, central banks in these countries should perform IT as a way to reduce high levels of inflation uncertainty. Such policy advice is also applicable to monetary authorities in non-IT countries with relatively high levels of inflation like China and Hong Kong. In other words, central banks in non-IT countries should also recognize the long-run benefits from explicit inflation targets to achieve the goals of best-practice monetary policy.

However, the effectiveness of the above policy advice should be consistent with how IT central banks are hitting their inflation targets. For example, IT central banks should leave enough room to control inflation both when it is high and when it is below the target. More importantly for IT countries with a relatively low inflation target such as South Korea and Thailand, a credible IT should be in line with achieving low inflation while at the same time avoiding the risk of deflation such as central banks in many advanced economies have been experiencing in recent years. In addition, the evidence of international transmission of inflation volatility has an important bearing on the debate about the benefits of international policy coordination, which is likely to increase with larger monetary and inflationary shocks and increasing inflation volatility.

Secondly, asymmetric monetary policies may be responsible for the lack of IT credibility regarding large inflation shocks. To be specific, mean-reversion of inflation associated only with large negative shocks to inflation implies that tight monetary intervention policy may not be over-implemented because the inflation itself will eventually return to its equilibrium level. That is, even if the effects of negative shocks to inflation are only short-lived, central banks should still pay more attention to avoiding short-run deflation, which can reduce revenues and increase real debt burden. However, policy implications are more crucial with respect to large positive shocks to inflation such as a rise in oil prices. This positive shock can send inflation to higher levels and become highly persistent, which in turn, leads to higher inflation expectations by the public. While increased monetary tightening could be a way to curb inflation, central banks should ensure they conduct a more active monitoring of inflation in the early stages in order to achieve well-anchored inflation expectations and less persistent inflation.

Thirdly, partial stationarity in inflation for most of the sample implies that monetary policy intervention should become contractionary-sensitive only for periods during which inflation is highly persistent. This is important to avert higher inflation expectations that will influence workers and firms to seek higher wages or prices, which might result in a rise in the overall price level. Likewise, in response to changes in output growth, policy makers should respond more to output shocks that are highly persistent during recession periods to avoid greater volatility of future GDP growth, and pay less attention to output shocks during expansionary periods. Furthermore, varied stationarity in real exchange rates for most of the sample suggests that central banks should not over-implement exchange rate intervention policies as the series will revert anyway to its equilibrium level. In other words, when shocks to real exchange rates are less likely to manifest themselves as permanent shifts in exchange rate market prices, central banks may shift some of their attention from exchange rate-oriented policy measures towards macroeconomic stabilization policies for inflation and output.

Fourthly, the regime-switching results show that IT has caused higher probabilities for output growth than for inflation to stay in stationary regimes. Since a Taylor rule is about controlling inflation and output and IT attaches significant weight to these two variables, a clear prescription for IT policy is that when inflation and economic growth move apart due to large supply shocks, central banks should respond more in favour of output stabilization. The main reason for this is to allow central bankers to avoid tricky decisions about which to respond to in the face of large supply shocks. This is particularly relevant if IT central banks have no leeway to keep inflation on track for periods during which inflation has been too high or too low. Moreover, the significant negative effect of IT on the probability of being in a non-stationary regime for real exchange rates suggests that central banks should focus their policy actions more on stabilizing inflation and output.

It is important to note that this thesis has some limitations. These limitations could form the basis for further avenues of future research insofar as other scholars can build from where this study has left off. For instance, a primary objective of IT is to anchor inflationary expectations with credibly enacted inflation targets. Since the focus of this thesis is on monetary and relevant macroeconomic policies, only macro data-based methods were employed to investigate IT credibility, for which inflation expectations are embedded in principle in the relationship between actual inflation and inflation targets. One advantage of an aggregate data-based approach is the availability of long time series for many countries. In addition, macro data allows us to distinguish between stationary and non-stationary properties of inflation and other macro variables, and determine the speed of adjustment to restore the long-run equilibrium level following a shock, as well as estimate the time taken for the adjustment process. However, macro data is not able to model the possibility that inflation targets are part of households' inflation expectation formation. The anchoring behaviour of households with regard to inflation expectations and awareness of inflation targets depends on their demographic characteristics. This requires micro level data or some household survey measures of inflation expectations, which are beyond the scope of this thesis.

There are also other important limitations regarding the panel dataset on inflation and frequency of output growth data employed in this research. First, the study considers four countries with a target and four countries without a target, driven mainly by the need for a consistent balanced panel dataset on inflation across this range of countries based on monthly frequency data. Second, the panel data focused on headline CPI inflation instead of core inflation for cross-country analysis because a consistent balanced dataset on core inflation was not available for most of the studied countries. Therefore, to be consistent with earlier studies and to be more easily comparable, this research also used headline CPI inflation data. Third, consistent measures of output growth based on the Industrial Production Index were not available at the desired monthly frequency for the sample of 8 Asian countries, so quarterly real GDP data were used to generate measures of output growth. In fact, most of the previous studies of the impact of IT on economic growth have used either quarterly or annual real GDP data.

The study can be extended in several avenues for future research. Firstly, from Chapter 4, the panel dataset can be expanded by adding emerging IT countries outside Asia; for example, those in Latin America. Extending the empirical work in this way may still be seen as worthwhile research as concerns about high inflation and lack of IT credibility in those countries have also been raised in recent years. This was not attempted in this study as the main focus was on Asian countries. In addition, India has recently adopted IT and hence it should be included in future panel data analysis of inflation. However, the availability of consistent data across a panel of other emerging IT and non-IT countries could be a potential problem.

Further research may be developed from Chapter 5 by examining how the ongoing concern about deflation and the debate around zero lower bounds on nominal interest rates, especially for Euro and other advanced countries, are potentially reflected in the conditional distribution of inflation. These ongoing issues can be realized later on and thus cannot be studied at this stage. One might, for example, use econometric methodology that identifies structural breaks at conditional quantiles (Oka & Qu, 2011) to study the changing nature of inflation persistence. Once this is known, proceeding with a quantile ADF test could provide new insights about the credibility of IT and alternative monetary policy frameworks.

Thirdly, from Chapter 6, future research could apply a three-regime Markov switching model to provide a deeper understanding of the impact of IT on key macroeconomic variables in expansionary, steady-state and recession regimes. Finally, the role of fiscal policy could be investigated to assess whether fiscal authority dominates the monetary authority in controlling inflation. However, finding consistent fiscal deficit data across a panel of Asian IT and non-IT countries for this task will be a huge challenge.

References

Abo-Zaid, S., & Tuzemen, D. (2012). Inflation targeting: A three-decade perspective. *Journal of Policy Modeling*, *34*(5), 621-645.

Abul Basher, S., Haug, A., & Sadorsky, P. (2016). The impact of oil shocks on exchange rates: A Markov-switching approach. *Energy Economics, 54*, 11-23.

Akdoğan, K. (2015). Asymmetric behaviour of inflation around the target in inflation-targeting countries. *Scottish Journal of Political Economy, 62*(5), 486-504.

Alba, J. D., & Papell, D. H. (1995). Trend breaks and the unit-root hypothesis for newly industrializing and newly exporting countries. *Review of International Economics*, *3*(3), 264-274.

Alba, J. D., & Wang, P. (2016). Taylor rule and discretionary regimes in the United States: Evidence from a k-state Markov regime-switching model. *Macroeconomic Dynamics*, 1-17. doi: 10.1017/S1365100515000693

Aleem, A., & Lahiani, A. (2014). Monetary policy credibility and exchange rate pass-through: Some evidence from emerging countries. *Economic Modelling*, *43*, 21-29.

Amira, B., Mouldi, D., & Feridun, M. (2013). Growth effects of inflation targeting revisited: Empirical evidence from emerging markets. *Applied Economics Letters*, *20*(6), 587-591.

Amisano, G., & Fagan, G. (2013). Money growth and inflation: A regime switching approach. *Journal of International Money and Finance, 33*, 118-145.

Angeriz, A., & Arestis, P. (2006). Has inflation targeting had any impact on inflation? *Journal of Post Keynesian Economics, 28*(4), 559-571.

Angeriz, A., & Arestis, P. (2007). Assessing the performance of 'inflation targeting lite' countries. *The World Economy, 30*(11), 1621-1645.

Arghyrou, M., Martin, C., & Milas, C. (2005). Non-linear inflationary dynamics: Evidence from the UK. *Oxford Economic Papers, 57*(1), 51-69.

Arize, A., Malindretos, J., & Ghosh, D. (2015). Purchasing power parity-symmetry and proportionality: Evidence from 116 countries. *International Review of Economics & Finance, 37*, 69-85.

Ayres, K., Belasen, A. R., & Kutan, A. M. (2014). Does inflation targeting lower inflation and spur growth? *Journal of Policy Modeling*, *36*(2), 373-388.

Baharumshah, A. Z., Aggarwal, R., & Haw, C. T. (2007). East Asian real exchange rates and PPP: New evidence from panel-data tests. *Global Economic Review, 36*(2), 103-119.

Baharumshah, A. Z., Tze-Haw, C., & Fountas, S. (2008). Re-examining purchasing power parity for East-Asian currencies: 1976-2002. *Applied Financial Economics*, *18*(1), 75-85.

Baillie, R.T., Chung, C.F., & Tieslau, M.A. (1996). Analysing inflation by the fractionally integrated ARFIMA-GARCH model. *Journal of Applied Econometrics 11*, 23-40.

Ball, L., & Cecchetti, S.G. (1990). Inflation and uncertainty at short and long horizons. *Brookings Papers on Economic Activity*, *21*(1), 215-254.

Ball, L., & Sheridan, N. (2005). Does inflation targeting matter? In B. Bernanke, & M. Woodford (Eds.), *The inflation targeting debate* (pp. 249-276). Chicago, IL: The University of Chicago Press.

Basher, S. A., & Mohsin, M. (2004). PPP tests in cointegrated panels: Evidence from Asian developing countries. *Applied Economics Letters, 11*(3), 163-166.

Basher, S. A., & Westerlund, J. (2008). Is there really a unit root in the inflation rate? More evidence from panel data models. *Applied Economics Letters, 15*(3), 161-164.

Batini, N. (2006). Euro area inflation persistence. *Empirical Economics 31*(4), 977- 1002.

Batini, N., & Laxton, D. (2007). Under what conditions can inflation targeting be adopted? The experience of emerging markets. In F.S. Mishkin, & K. Schmidt-Hebbel (Eds.), *Monetary policy under inflation targeting* (pp. 1-38). Santiago, Chile: Central Bank of Chile.

Baxa, J., Plasil, M., & Vasicek, B. (2015). Changes in inflation dynamics under inflation targeting? Evidence from Central European countries. *Economic Modelling, 44*, 116-130.

Bec, F., & Zeng, S. (2013). Are Southeast Asian real exchange rates mean reverting? *Journal of International Financial Markets, Institutions and Money, 23*(1), 265-282.

Beckmann, J., & Czudaj, R. (2014). Regime shifts and the Canada/US exchange rate in a multivariate framework. *Economics Letters*, *123*(2), 206-211.

Beechey, M., & Österholm, P. (2009). Time-varying inflation persistence in the Euro area. *Economic Modelling, 26*, 532-535.

Benati, L. (2008). Investigating inflation persistence across monetary regimes. *The Quarterly Journal of Economics*, *123*(3), 1005-1060.

Berganza, J. C., & Broto, C. (2012). Flexible inflation targets, forex interventions and exchange rate volatility in emerging countries. *Journal of International Money and Finance, 31*(2), 428-444.

Bernanke, B.S., Laubach, T., Mishkin, F.S. & Posen, A.S. (1999). *Inflation targeting: Lessons from the international experience*. Retrieved from http://press.princeton.edu/chapters/s02_6380.pdf

Bernanke, B. S., & Mishkin, F. S. (1997). Inflation targeting: A new framework for monetary policy? *The Journal of Economic Perspectives, 11*(2), 97-116.

Bernanke, B., & Woodford, M. (2005). Introduction. In B. Bernanke & M. Woodford (Eds.), *The inflation targeting debate* (pp. 1-10). Chicago, IL: The University of Chicago Press.

Bernanke, B. (2015). *The Taylor Rule: A benchmark for monetary policy?* Brookings Institution. Retrieved from http://www.brookings.edu/blogs/ben-bernanke/posts/2015/04/28-taylor-rule-monetary-policy.

Berument, H., & Yuksel, E. (2007). Effects of adopting inflation targeting regimes on inflation variability. *Physica A: Statistical Mechanics and its Applications*, *375*(1), 265-273.

Bhar, R., & Mallik, G. (2013). Inflation uncertainty, growth uncertainty, oil prices, and output growth in the UK. *Empirical Economics, 45*(3), 1333-1350.

Bollerslev, T., Engle, R. F., & Wooldridge, J. M. (1988). A capital asset pricing model with time-varying covariances. *Journal of Political Economy, 96*(1), 116-131.

Bollerslev, T. (1990). Modelling the coherence in short-run nominal exchange rates: A multivariate generalized ARCH model. *The Review of Economics and Statistics*, *72*(3), 498-505.

Bomfim, A. N., & Rudebusch, G. D. (2000). Opportunistic and deliberate disinflation under imperfect credibility. *Journal of Money, Credit and Banking, 32*(4), 707-721.

Bordo, M. D., & Siklos, P. L. (2015). *Central bank credibility: An historical and quantitative exploration* (NBER Working Paper No. 20824). Retrieved from http://www.nber.org/papers/w20824

Bordo, M. D., & Siklos, P. L. (2016). Central bank credibility before and after the crisis. *Open Economies Review,* 1-27. doi: 10.1007/s11079-016-9411-2

Borio, C. & Filardo, A. (2007). *Globalisation and inflation: New cross-country evidence on the global determinants of domestic inflation* (BIS Working Paper No. 227). Basel, Switzerland: Bank for International Settlements. Retrieved from http://www.bis.org/publ/work227.pdf

Breitung, J., & Candelon, B. (2005). Purchasing power parity during currency crises: A panel unit root test under structural breaks. *Review of World Economics, 141*(1), 124-140.

Brito, R., & Bystedt, B. (2006). *The macroeconomic effects of inflation targeting in Latin America* (Ibmec Sao Paulo Working Paper). Retrieved from http://professores.ibmecrj.br/erg/wkshops/2006/papers/20060929.pdf

Brito, R. D., & Bystedt, B. (2010). Inflation targeting in emerging economies: Panel evidence. *Journal of Development Economics*, *91*(2), 198-210.

Broto, C. (2011). Inflation targeting in Latin America: Empirical analysis using GARCH models. *Economic Modelling, 28*(3), 1424-1434.

Broyden, C. G. (1965). A class of methods for solving nonlinear simultaneous equations. *Mathematics of Computation, 19*(92), 577-593.

Broyden, C. G. (1967). Quasi-newton methods and their application to function minimisation. *Mathematics of Computation*, *21*(99), 368-381.

Brunetti, C., Scotti, C., Mariano, R. S., & Tan, A. H. H. (2008). Markov switching GARCH models of currency turmoil in Southeast Asia. *Emerging Markets Review*, *9*(2), 104-128.

Burger, P. (2014). Inflation and market uncertainty in South Africa. *South African Journal of Economics*, *82*(4), 583-602.

Calvo, G. A., & Mishkin, F. S. (2003). The mirage of exchange rate regimes for emerging market countries. *The Journal of Economic Perspectives*, *17*(4), 99-118.

Camacho, M. (2011). Markov-switching models and the unit root hypothesis in real US GDP. *Economics Letters*, *112*(2), 161-164.

Camacho, M., & Perez-Quiros, G. (2014). Commodity prices and the business cycle in Latin America: Living and dying by commodities? *Emerging Markets Finance and Trade*, *50*(2), 110-137.

Caner, M., & Hansen, B. E. (2001). Threshold autoregression with a unit root. *Econometrica*, *69*(6), 1555-1596.

Capistrán, C., & Ramos-Francia, M. (2009). Inflation dynamics in Latin America. *Contemporary Economic Policy*, *27*(3), 349-362.

Capistrán, C., & Ramos-Francia, M. (2010). Does inflation targeting affect the dispersion of inflation expectations? *Journal of Money, Credit and Banking*, *42*(1), 113-134.

Carrasco, C. A., & Ferreiro, J. (2013). Inflation targeting and inflation expectations in Mexico. *Applied Economics*, *45*(23), 3295-3304.

Carrasco, C., & Ferreiro, J. (2014). Latin American inflation differentials with USA inflation: Does inflation targeting make a difference? *Journal of Economic Policy Reform, 17*(1), 13-32.

Catalán-Herrera, J. (2016). Foreign exchange market interventions under inflation targeting: The case of Guatemala. *Journal of International Financial Markets, Institutions and Money*, *42*, 101-114.

Cecchetti, S. G., & Debelle, G. (2006). Has the inflation process changed? *Economic Policy, 21*(46), 311-352.

Cermeño, R., & Grier, K. B. (2006). Conditional heteroskedasticity and cross-sectional dependence in panel data: An empirical study of inflation uncertainty in the G7 countries. In B. H. Baltagi (Eds.), *Panel Data Econometrics: Theoretical Contributions and Empirical Applications* (Vol. 274, pp. 259-277). Amsterdam, Netherlands: Emerald Group Publishing Limited.

Cermeño, R., Grier, K., & Grier, R. (2010). Elections, exchange rates and reform in Latin America. *Journal of Development Economics, 92*(2), 166-174.

Cermeño, R., & Sanin, M. E. (2015). Are flexible exchange rate regimes more volatile? Panel GARCH evidence for the G7 and Latin America. *Review of Development Economics, 19*(2), 297-308.

Cerra, V., & Saxena, S. C. (2005). Did output recover from the Asian crisis? *IMF Staff Papers, 52*(1), 1-23.

Céspedes, L. and C. Soto (2005). *Credibility and inflation targeting in an emerging market: The case of Chile*. (Central Bank of Chile Working Paper No. 312). Retrieved from http://si2.bcentral.cl/public/pdf/documentos-trabajo/pdf/dtbc312.pdf

Céspedes, L. F., Chang, R., & Velasco, A. (2014). Is inflation targeting still on target? The recent experience of Latin America. *International Finance, 17*(2), 185-208.

Çevik, E. İ., Atukeren, E., & Korkmaz, T. (2013). Nonlinearity and nonstationarity in international art market prices: Evidence from Markov-switching ADF unit root tests. *Empirical Economics, 45*(2), 675-695.

Çevik, E. İ.., & Dibooglu, S. (2013). Persistence and non-linearity in US unemployment: A regime-switching approach. *Economic Systems, 37*(1), 61-68.

Chan, K. S. (1993). Consistency and limiting distribution of the least squares estimator of a threshold autoregressive model. *The Annals of Statistics*, *21*(1), 520-533.

Chen, S. W. (2010). Regime non-stationarity and non-linearity in inflation rates: Evidence from OECD countries. *International Research Journal of Finance and Economics*, *463*, 47-57.

Chen, S. W., Hsu, C. S., & Pen, C. J. (2016). Are inflation rates mean-reverting processes? Evidence from six Asian countries. *Journal of Economics and Management*, *12*(1), 119-155.

Chen, S., & Hsu, C. (2016). Threshold, smooth transition and mean reversion in inflation: New evidence from European countries. *Economic Modelling, 53*, 23-36.

Chen, S. W., & Shen, C. H. (2009). Testing regime non-stationarity of the G-7 inflation rates: Evidence from the Markov switching unit root test. *Journal of the Chinese Statistical Association*, *47*, 1-18.

Cheung, Y. W., & Yuen, J. (2002). Effects of U.S. inflation on Hong Kong and Singapore. *Journal of Comparative Economics, 30*(3), 603-619.

Chiquiar, D., Ramos-Francia, M., & Noriega, A. E. (2010). A time-series approach to test a change in inflation persistence: The Mexican experience. *Applied Economics, 42*(24), 3067-3075.

Choi, K., Jung, C., & Shambora, W. (2003). Macroeconomic effects of inflation targeting policy in New Zealand. *Economic Bulletin*, *5*(17), 1-6.

Choudhry, T. (2005). Asian currency crisis and the generalized PPP: Evidence from the Far East. *Asian Economic Journal*, *19*(2), 137-157.

Chu, J. F., & Sek, S. K. (2012). Evaluating the performance of inflation targeting. *International Journal of Economics and Finance, 4*(9), 69-86.

Ciccarelli, M., & Mojon, B. (2010). Global inflation. *The Review of Economics and Statistics, 92*(3), 524-535.

Çiçek, S., & Akar, C. (2013). The asymmetry of inflation adjustment in Turkey. *Economic Modelling, 31*(1), 104-118.

Clemente, J., Montañés, A., & Reyes, M. (1998). Testing for a unit root in variables with a double change in the mean. *Economics Letters*, *59*(2), 175-182.

Cogley, T., Primiceri, G. E., & Sargent, T. J. (2008). *Inflation-gap persistence in the US* (NBER Working Paper No. 3749). Retrieved from http://www.nber.org/papers/w13749

Cordero, J. A. (2008). Economic growth under alternative monetary regimes: Inflation targeting vs real exchange rate targeting. *International Review of Applied Economics*, *22*(2), 145-160.

Cornand, C., & M'baye, C. K. (2016). Does inflation targeting matter? An experimental investigation. *Macroeconomic Dynamics*, 1-40.

Creel, J., & Hubert, P. (2008). *Has the adoption of inflation targeting represented a regime switch? Empirical evidence from Canada, Sweden and the UK*. Retrieved from http://ssrn.com/abstract=1302866

Crowder, W. J., & Hoffman, D. L. (1996). The long-run relationship between nominal interest rates and inflation: The Fisher equation revisited. *Journal of Money, Credit and Banking*, *28*(1), 102-118.

Cruz, C. J. F., & Mapa, D. (2013). An early warning system for inflation in the Philippines using Markov-switching and logistic regression models. *Theoretical and Practical Research in Economic Fields, 4*(2), 137-152.

Cukierman, A., & Meltzer, A. H. (1986). A theory of ambiguity, credibility, and inflation under discretion and asymmetric information. *Econometrica, 54*(5), 1099-1128.

Cukierman, A. (1992). *Central bank strategy, credibility, and independence: Theory and evidence*. Cambridge, MA: MIT Press.

Culver, S. E., & Papell, D. H. (1997). Is there a unit root in the inflation rate? Evidence from sequential break and panel data models. *Journal of Applied Econometrics*, *12*(4), 435-444.

Davies, R. B. (1987). Hypothesis testing when a nuisance parameter is present only under the alternative. *Biometrika*, *74*(1), 33-43.

Davig, T., & Doh, T. (2014). Monetary policy regime shifts and inflation persistence. *Review of Economics and Statistics*, *96*(5), 862-875.

Dawe, D., & Slayton, T. (2010). The world rice market crisis of 2007-2008. In D. Dawe (Eds.), *The rice crisis: Markets, policies and food security* (pp. 15-28). London, UK: The Food and Agriculture Organization of the United Nations and Earthscan.

De Carvalho Filho, I. (2009). *Inflation targeting at the crisis: An empirical assessment* (IMF Working Paper WP/10/45). Retrieved from https://www.imf.org/external/pubs/ft/wp/2010/wp1045.pdf

De Guimarães e Souza, G.J., De Mendonça, H. F., & De Andrade, J. P. (2016). Inflation targeting on output growth: A pulse dummy analysis of dynamic macroeconomic panel data. *Economic Systems, 40*(1), 145-169.

De Mendonça, H. F., & De Guimarães e Souza, G. J. (2012). Is inflation targeting a good remedy to control inflation? *Journal of Development Economics, 98*(2), 178-191.

Ding, H., & Kim, J. (2012). Does inflation targeting matter for PPP? An empirical investigation. *Applied Economics Letters, 19*(18), 1777-1780.

Drakos, A., & Kouretas, G. (2015). The conduct of monetary policy in the Eurozone before and after the financial crisis. *Economic Modelling, 48*, 83-92.

Dua, P., & Sharma, V. (2016). A comparison of economic indicator analysis and Markov switching methods concerning the cycle phase dynamics. *OECD Journal: Journal of Business Cycle Measurement and Analysis*, 1-27.

Dueker, M., & Fischer, A. M. (1996). Inflation targeting in a small open economy: Empirical results for Switzerland. *Journal of Monetary Economics, 37*(1), 89-103.

Dueker, M. J., & Fischer, A. M. (2006). Do inflation targeters outperform non-targeters? *Federal Reserve Bank of St. Louis Review, 88*(5), 431-450.

Dufrenot, G., & Keddad, B. (2014). Business cycles synchronization in East Asia: A Markov switching approach. *Economic Modelling, 42*, 186-197.

Du Plessis, S., & Reid, M. B. (2015). The exchange rate dimension of inflation targeting: Target levels and currency volatility. *South African Journal of Economics, 83*(2), 174-179.

Du Plessis, S., & Rietveld, M. (2014). Should inflation targeting be abandoned in favour of nominal income targeting? *Journal for Studies in Economics and Econometrics*, *38*(2), 1-18.

Dutu, R., Holmes, M. J., & Silverstone, B. (2016). Modelling a regime-shifting Beveridge curve. *Bulletin of Economic Research, 68*(1), 90-104.

Economist. (2016, August 27). *When 2% is not enough*. Retrieved from http://www.economist.com/news/leaders/21705826-rich-worlds-central-banks-need-new-target-when-2-not-enough

Edwards, S. (1998). Two crises: Inflationary inertia and credibility. *The Economic Journal*, *108*(448), 680-702.

Edwards, S. (2006). *The relationship between exchange rates and inflation targeting revisited* (NBER Working Paper Series 12163). Cambridge, MA: NBER. Retrieved from http://www.nber.org/papers/w12163.pdf

Elliott, G., & Jansson, M. (2003). Testing for unit roots with stationary covariates. *Journal of Econometrics*, *115*(1), 75-89.

Elliott, G., Rothenberg, T. J., & Stock, J. H. (1996). Efficient tests for an autoregressive unit root. *Econometrica 64* (4): 813-836.

Enders, W., & Granger, C. W. J. (1998). Unit-root tests and asymmetric adjustment with an example using the term structure of interest rates. *Journal of Business & Economic Statistics*, *16*(3), 304-311.

Engle, R. F., & Kroner, K. F. (1995). Multivariate simultaneous generalized ARCH. *Econometric Theory, 11*(1), 122-150.

Escobari, D., & Lee, J. (2014). Demand uncertainty and capacity utilization in airlines. *Empirical Economics, 47*(1), 1-19.

Evans, M. D., & Lewis, K. K. (1995). Do expected shifts in inflation affect estimates of the long-run Fisher relation? *The Journal of Finance*, *50*(1), 225-253.

Evans, M., & Wachtel, P. (1993). Inflation regimes and the sources of inflation uncertainty. *Journal of Money, Credit and Banking, 25*(3), 475-511.

Faust, J., & Henderson, D. (2004). Is inflation targeting best-practice monetary policy? *Federal Reserve Bank of St Louis Review, 86*(4), 117-143.

Filardo, A., & Genberg, H. (2010). *Monetary policy strategies in the Asia and Pacific region: What way forward?* (ADBI Working Paper No. 195). Retrieved from https://asianbondsonline.adb.org/publications/adb/2010/monetary_policy_strategies_asia_pacific.pdf

Fletcher, R., & Powell, M. J. (1963). A rapidly convergent descent method for minimization. *The Computer Journal*, *6*(2), 163-168.

Freedman, C., & Laxton, D. (2009). *Why inflation targeting?* (IMF Working Paper WP/09/86). Retrieved from https://www.imf.org/external/pubs/ft/wp/2009/wp0986.pdf

Froyen, R. T., & Guender, A. V. (2016). What to aim for? The choice of an inflation objective when openness matters. *Open Economies Review*, 1-24. doi: 10.1007/s11079-016-9409-9

Ftiti, Z., & Hichri, W. (2014). The price stability under inflation targeting regime: An analysis with a new intermediate approach. *Economic Modelling, 38*, 23-32.

Fuhrer, J. C. (2010). Inflation persistence. In B. M. Friedman & M. Woodford (Eds.), *Handbook of Monetary Economics*, (p. 423-486). San Diego, CA: North-Holland.

Galvao, A. F. (2009). Unit root quantile autoregression testing using covariates. *Journal of Econometrics, 152*(2), 165-178.

Gerlach, S., & Tillmann, P. (2012). Inflation targeting and inflation persistence in Asia-Pacific. *Journal of Asian Economics, 23*(4), 360-373.

Giannellis, N. (2013). Asymmetric behavior of inflation differentials in the euro area: Evidence from a threshold unit root test. *Research in Economics, 67*(2), 133-144.

Gillitzer, C., & Simon, J. (2015). Inflation targeting: A victim of its own success? *International Journal of Central Banking*, *11*(4), 259-287.

Gonçalves, C. E. S., & Carvalho, A. (2009). Inflation targeting matters: Evidence from OECD economies' sacrifice ratios. *Journal of Money, Credit and Banking*, *41*(1), 233-243.

Gonçalves, C. E. S., & Salles, J. M. (2008). Inflation targeting in emerging economies: What do the data say? *Journal of Development Economics, 85*(1), 312-318.

Gottschalk, R. (2003). Testing for breaks in inertia: An alternative approach. *Applied Economics Letters*, *10*(3), 161-163.

Goulas, E., & Zervoyianni, A. (2013). Economic growth and crime: Does uncertainty matter? *Applied Economics Letters, 20*(5), 420-427.

Gregoriou, A., & Kontonikas, A. (2006). Inflation targeting and the stationarity of inflation: New results from an ESTAR unit root test. *Bulletin of Economic Research, 58*(4), 309-322.

Gregoriou, A., & Kontonikas, A. (2009). Modeling the behaviour of inflation deviations from the target. *Economic Modelling, 26*(1), 90-95.

Grimes, A. & Motu Economic and Public Policy Research Trust (2014). *Four lectures on central banking* (Motu Working Paper No. 14-02). Retrieved from http://motu-www.motu.org.nz/wpapers/14_02.pdf

Hall, S. G., Psaradakis, Z., & Sola, M. (1999). Detecting periodically collapsing bubbles: A Markov-switching unit root test. *Journal of Applied Econometrics, 14*(2), 143-154.

Hamilton, J. D. (1989). A new approach to the economic analysis of nonstationary time series and the business cycle. *Econometrica, 57*(2), 357-384.

Hammond, G. (2012). *State of the art of inflation targeting – 2012*. (Centre for Banking Studies Handbook No. 29.) London, UK: Bank of England.

Hansen, B. E. (1995). Rethinking the univariate approach to unit root testing: Using covariates to increase power. *Econometric Theory*, *11*(05), 1148-1171.

Henry, O.T., & Shields, K. (2004). Is there a unit root in inflation? *Journal of Macroeconomics 26*, 481-500.

Holland, A. S. (1995). Inflation and uncertainty: Tests for temporal ordering. *Journal of Money, Credit and Banking, 27*(3), 827-837.

Holmes, M. J. (2001). New evidence on real exchange rate stationarity and purchasing power parity in less developed countries. *Journal of Macroeconomics, 23*(4), 601-614.

Holmes, M. J. (2004). Is there non-linear real exchange rate adjustment for the Asian economies? *ASEAN Economic Bulletin, 21*(2), 198-212.

Holmes, M.J. & Maghrebi, N. (2005). *Volatility transmission and dynamic covariance modelling of real interest rates: How integrated are the G7 economics?* New Zealand Econometric Study Group (NZESG) 14th Meeting. University of Canterbury, New Zealand. Retrieved from http://www.econ.canterbury.ac.nz/downloads/holmes_nzesg.pdf

Holmes, M. J., & Pentecost, E. J. (2006). Volatility transmission and growth: An international perspective. *International Journal of Applied Economics, 3*(1), 15-33.

Holmes, M. J. (2008). Real exchange rate stationarity in Latin America and relative purchasing power parity: A regime switching approach. *Open Economies Review, 19*(2), 261-275.

Holmes, M. J. (2010). Are Asia-Pacific real exchange rates stationary? A regime-switching perspective. *Pacific Economic Review, 15*(2), 189-203.

Hooi, L. H., & Smyth, R. (2007). Are Asian real exchange rates mean reverting? Evidence from univariate and panel LM unit root tests with one and two structural breaks. *Applied Economics, 39*(16), 2109-2120.

Hooi, T. S., Habibullah, M. S., & Smith, P. (2008). The asymmetric effects of monetary policy in four Asian economies. *International Applied Economics and Management Letters, 1*(1), 1-7.

Hosseinkouchack, M., & Wolters, M. (2013). Do large recessions reduce output permanently? *Economics Letters, 121*(3), 516-519.

Huang, H., Yeh, C., Ku, K., & Lin, S. (2016). The effects of inflation targeting on Okun's law. *Applied Economics Letters, 23*(12), 868-874.

Hutchison, M. M., Sengupta, R., & Singh, N. (2013). Dove or Hawk? Characterizing monetary policy regime switches in India. *Emerging Markets Review, 16*, 183-202.

Ibrahim, M. H. (2009). A rolling regression analysis of international transmission of inflation in Malaysia. *Margin: The Journal of Applied Economic Research, 3*(1), 21-39.

Ihrig, J., Kamin, S. B., Lindner, D., & Marquez, J. (2010). Some simple tests of the globalization and inflation hypothesis. *International Finance*, *13*(3), 343-375.

Im, K. S., Pesaran, M. H., & Shin, Y. (2003). Testing for unit roots in heterogeneous panels. *Journal of Econometrics, 115*(1), 53-74.

Inoue, T., Toyoshima, Y., & Hamori, S. (2012). *Inflation targeting in Korea, Indonesia, Thailand, and the Philippines: The impact on business cycle synchronization between each country and the world* (IDE Discussion Paper No. 328). Retrieved from http://www.ide.go.jp/English/Publish/Download/Dp/pdf/328.pdf

International Monetary Fund (2006). *Inflation targeting and the IMF*. Retrieved from https://www.imf.org/external/np/pp/eng/2006/031606.pdf

Ito, T. (2010). *Monetary policy and financial stability: Is inflation targeting passé?* (ADB Economics Working Paper Series No. 206). Retrieved from https://www.adb.org/publications/monetary-policy-and-financial-stability-inflation-targeting-passe

Ito, T., & Hayashi, T. (2004). *Inflation targeting in Asia* (HKIMR Occasional Paper No.1). Retrieved from http://www.hkimr.org/uploads/publication/33/ub_full_0_1_78_op-no-1_4cc-4ct.pdf

Ito, T., & Sato, K. (2008). Exchange rate changes and inflation in post-crisis Asian economies: Vector Autoregression analysis of the exchange rate pass-through. *Journal of Money, Credit and Banking, 40*(7), 1407-1438.

Jansson, M. (2004). Stationarity testing with covariates. *Econometric Theory*, *20*(01), 56-94.

Jeong, J., Fanara, P., & Mahone, C. E. (2002). Intra- and inter-continental transmission of inflation in Africa. *Applied Financial Economics, 12*(10), 731-741.

Jeong, J., & Lee, Y. (2001). International transmission of inflation under alternative exchange rate regimes. *Global Finance Journal*, *12*(1), 121-137.

Johnson, D. R. (1997). Expected inflation in Canada 1988-1995: An evaluation of Bank of Canada credibility and the effect of inflation targets. *Canadian Public Policy*, *23*(3), 233-258.

Kadria, M., & Aissa, M. S. B. (2016). Inflation targeting and public deficit in emerging countries: A time varying treatment effect approach. *Economic Modelling*, *52*, 108-114.

Kahn, G. A. (2009). Beyond inflation targeting: Should central banks target the price level? *Economic Review (Kansas City), 94*(3), 37.

Kanas, A. (2006). Purchasing power parity and Markov regime switching. *Journal of Money, Credit and Banking, 38*(6), 1669-1687.

Kanas, A. (2009). Real exchange rates and developing countries. *International Journal of Finance and Economics*, *14*(3), 280-299.

Kanas, A., & Genius, M. (2005). Regime (non)stationarity in the US/UK real exchange rate. *Economics Letters, 87*(3), 407-413.

Kang, K. H., Kim, C. J., & Morley, J. (2009). Changes in US inflation persistence. *Studies in Nonlinear Dynamics & Econometrics*, *13*(4), 1-23.

Kapetanios, G., Shin, Y., & Snell, A. (2003). Testing for a unit root in the nonlinear STAR framework. *Journal of Econometrics, 112*(2), 359-379.

Kim, B., Kim, H., & Oh, K. (2009). The purchasing power parity of Southeast Asian currencies: A time-varying coefficient approach. *Economic Modelling, 26*(1), 96-106.

Kim, J. (2014). Inflation targeting and real exchange rates: A bias correction approach. *Economics Letters*, *125*(2), 253-256.

Kocaaslan, O. K. (2016). Regime nonstationarity and nonlinearity in the Turkish output level. *International Journal of Economics and Financial Issues*, *6*(2), 503-507.

Koenker, R., & Xiao, Z. (2004). Unit root quantile autoregression inference. *Journal of the American Statistical Association, 99*(467), 775-787.

Kontonikas, A. (2004). Inflation and inflation uncertainty in the United Kingdom: Evidence from GARCH modelling. *Economic Modelling, 21*(3), 525-543.

Kruse, R., Frömmel, M., Menkhoff, L., & Sibbertsen, P. (2012). What do we know about real exchange rate nonlinearities? *Empirical Economics, 43*(2), 457-474.

Kupfer, A. (2015). Revisiting Svensson's test of inflation target credibility. *Applied Economics Letters, 22*(5), 343-348.

Kurz, C., & Kurz-Kim, J. R. (2011). Taylor rule revisited: From an econometric point of view. *Review of Economics & Finance, 1*(3), 46-51.

Kwiatkowski, D., Phillips, P. C. B., Schmidt, P., & Shin, Y. (1992). Testing the null hypothesis of stationarity against the alternative of a unit root: How sure are we that economic time series have a unit root? *Journal of Econometrics, 54*(1-3), 159-178.

Lanzafame, M. & Nogueira Jr, R. P. (2011). Credibility in emerging economies: Does inflation targeting matter? *The Manchester School*, *79*(6), 1080-1098.

Lee, C., & Chang, C. (2008). Trend stationary of inflation rates: Evidence from LM unit root testing with a long span of historical data. *Applied Economics*, *40*(19), 2523-2536.

Lee, C., Hu, T., Li, P., & Tsong, C. (2013). Asymmetric behavior of unemployment rates: Evidence from the quantile covariate unit root test. *Japan and the World Economy*, *28*, 72-84.

Lee, J. (1999). Inflation targeting in practice: further evidence. *Contemporary Economic Policy*, *17*(3), 332-347.

Lee, J. (2006). The comovement between output and prices: Evidence from a dynamic conditional correlation GARCH model. *Economics Letters, 91*(1), 110-116.

Lee, J. (2010a). Does inflation targeting matter for monetary policy? Further evidence. *Journal of International Finance and Economics*, *10*(4), 102-106.

Lee, J. (2010b). The link between output growth and volatility: Evidence from a GARCH model with panel data. *Economics Letters*, *106*(2), 143-145.

Lee, J., & Strazicich, M. (2003). Minimum Lagrange multiplier unit root test with two structural breaks. *Review of Economics and Statistics 85*(4), 1082-1089.

Lee, J., & Valera, H. G. A. (2016). Price transmission and volatility spillovers in Asian rice markets: Evidence from MGARCH and panel GARCH models. *The International Trade Journal, 30*(1), 14-32.

Lee, H. Y., & Wu, J. L. (2001). Mean reversion of inflation rates: Evidence from 13 OECD countries. *Journal of Macroeconomics*, *23*(3), 477-487.

Lee, H., & Yoon, G. (2013). Does purchasing power parity hold sometimes? Regime switching in real exchange rates. *Applied Economics, 45*(16), 2279-2294.

Leiderman, L., & Bufman, G. (2000). Inflation targeting under a crawling band exchange rate regime: Lessons from Israel. In M. I. Blejer, A. Ize, A. M. Leone & S. Werland (Eds.), *Inflation targeting in practice: strategic and operational issues and application to emerging market economies*. Washington, DC: International Monetary Fund. Retrieved from https://www.imf.org/external/pubs/ft/seminar/2000/targets/strach9.pdf

Levin, A., Lin, C. F., & Chu, C. S. J. (2002). Unit root tests in panel data: Asymptotic and finite-sample properties. *Journal of Econometrics, 108*(1), 1-24.

Levin, A., Natalucci, F. M., & Piger, J. (2004). The macroeconomic effects of inflation targeting. *Federal Reserve Bank of St. Louis Review*, *86*(4), 51-80.

Levin, A. T., & J. M. Piger. (2002). *Is inflation persistence intrinsic in industrial economies?* (Working Paper 2002-023). Retrieved from https://research.stlouisfed.org/wp/more/2002-023/

Leyva, G. (2008). *The choice of inflation targeting* (Central Bank of Chile Working Paper No. 475). Retrieved from https://core.ac.uk/download/pdf/6642479.pdf

Li, T., & Wei, J. (2015). Multiple structural breaks and inflation persistence: Evidence from China. *Asian Economic Journal*, *29*(1), 1-20.

Liew, V. K., Baharumshah, A. Z., & Chong, T. T. (2004). Are Asian real exchange rates stationary? *Economics Letters, 83*(3), 313-316.

Lin, S., & Ye, H. (2007). Does inflation targeting really make a difference? Evaluating the treatment effect of inflation targeting in seven industrial countries. *Journal of Monetary Economics 54*(8), 2521-2533.

Lin, S., & Ye, H. (2009). Does inflation targeting make a difference in developing countries? *Journal of Development Economics, 89*(1), 118-123.

Lin, S. (2010). On the international effects of inflation targeting. *The Review of Economics and Statistics, 92*(1), 195-199.

Lucotte, Y. (2010). *The choice of adopting inflation targeting in emerging economies: Do domestic institutions matter?* Retrieved from https://hal.archives-ouvertes.fr/hal-00539713

Lucotte, Y. (2012). Adoption of inflation targeting and tax revenue performance in emerging market economies: An empirical investigation. *Economic Systems*, *36*(4), 609-628.

Lumsdaine, R.L., & Papell, D.H. (1997). Multiple trend breaks and the unit root hypothesis. *Review of Economics and Statistics*, *79*(2), 212-218.

Maertens Odria, L. R., Castillo, P., & Rodriguez, G. (2012). Does the exchange rate pass-through into prices change when inflation targeting is adopted? The Peruvian case study between 1994 and 2007. *Journal of Macroeconomics, 34*(4), 1154-1166.

McDermott, J. F., & McMenamin, P. (2008). *Assessing inflation targeting in Latin America with a DSGE model* (Central Bank of Chile Working Paper No. 469). Retrieved from http://si2.bcentral.cl/public/pdf/documentos-trabajo/pdf/dtbc469.pdf

Miles, W. (2008). Inflation targeting and monetary policy in Canada: What is the impact on inflation uncertainty? *The North American Journal of Economics and Finance, 19*(2), 235-248.

Mishkin, F. S. (1999). International experiences with different monetary policy regimes. *Journal of Monetary Economics*, *43*(3), 579-605.

Mishkin, F. S., & Savastano, M. A. (2001). Monetary policy strategies for Latin America. *Journal of Development Economics, 66*(2), 415-444.

Mishkin, F.S. (2004). *Can inflation targeting work in emerging market countries?* (NBER Working Paper Series No. 10646). Retrieved from http://www.nber.org/papers/w10646

Mishkin, F.S. (2007). International experiences with different monetary policy regimes. In: F.S. Mishkin (Eds.), *Monetary policy strategy*, (1st ed., pp. 227-252). Cambridge, MA: MIT Press.

Mishkin, F. S. (2008). Challenges for inflation targeting in emerging market countries. *Emerging Markets Finance and Trade*, *44*(6), 5-16.

Mishkin, F. S., & Schmidt-Hebbel, K. (2007). *Does inflation targeting make a difference?* (NBER Working Paper No. 12876). Retrieved from http://www.nber.org/papers/w12876

Mishra, V., Sharma, S., & Smyth, R. (2009). Are shocks to real output permanent or transitory? Evidence from a panel of Pacific Island countries. *Pacific Economic Bulletin, 24*(1), 65-82.

Mollick, A. V., Cabral, R., & Carneiro, F. G. (2011). Does inflation targeting matter for output growth? Evidence from industrial and emerging economies. *Journal of Policy Modeling*, *33*(4), 537-551.

Mumtaz, H., Simonelli, S., & Surico, P. (2011). International comovements, business cycle and inflation: A historical perspective. *Review of Economic Dynamics*, *14*(1), 176-198.

Munir, Q., & Kok, S. C. (2015). Purchasing power parity of ASEAN-5 countries revisited: Heterogeneity, structural breaks and cross-sectional dependence. *Global Economic Review, 44*(1), 116-149.

Murray, C. J., Nikolsko-Rzhevskyy, A., & Papell, D. H. (2008). *Inflation persistence and the Taylor principle* (MPRA Working Paper No. 11353). Retrieved from https://mpra.ub.uni-muenchen.de/11353

Murray, C. J., Nikolsko-Rzhevskyy, A., & Papell, D. H. (2015). Markov switching and the Taylor Principle. *Macroeconomic Dynamics*, *19*(04), 913-930.

Narayan, P. K. (2008). Is Asian per capita GDP panel stationary? *Empirical Economics, 34*(3), 439-449.

Narayan, P. K. (2010). Evidence on PPP for selected Asian countries from a panel cointegration test with structural breaks. *Applied Economics, 42*(3), 325-332.

Neely, C. J., & Rapach, D. E. (2011). International comovements in inflation rates and country characteristics. *Journal of International Money and Finance, 30*(7), 1471-1490.

Nelson, C. R., & Plosser, C. R. (1982). Trends and random walks in macroeconomic time series: Some evidence and implications. *Journal of Monetary Economics*, *10*(2), 139-162.

Neuenkirch, M., & Tillmann, P. (2014). Inflation targeting, credibility, and non-linear Taylor rules. *Journal of International Money and Finance*, *41*, 30-45.

Neumann, M. & von Hagen, J. (2002). Does inflation targeting matter? *Federal Reserve Bank of St. Louis Review, 84*(4), 127-46.

Newey, W. K., & West, K. D. (1987). A simple, positive semi-definite, heteroskedasticity and autocorrelation consistent covariance matrix. *Econometrica, 55*(3), 703-708.

Ng, S., & Perron, P. (2001). Lag length selection and the construction of unit root tests with good size and power. *Econometrica, 69*(6), 1519-1554.

Nikolsko-Rzhevskyy, A., & Papell, D. H. (2012). Taylor rules and the Great Inflation. *Journal of Macroeconomics, 34*(4), 903-918.

Nusair, S. A. (2004). Testing for PPP in developing countries using confirmatory analysis and different base countries: An application to Asian countries. *International Economic Journal, 18*(4), 467-489.

Nusair, S. A. (2008). Purchasing power parity under regime shifts: An application to Asian countries. *Asian Economic Journal, 22*(3), 241-266.

Nusair, S. A. (2012). Nonlinear adjustment of Asian real exchange rates. *Economic Change and Restructuring, 45*(3), 221-246.

Oka, T., & Qu, Z. (2011). Estimating structural changes in regression quantiles. *Journal of Econometrics, 162*(2), 248-267.

Omay, T., & Öznur Kan, E. (2010). Re-examining the threshold effects in the inflation-growth nexus with cross-sectionally dependent non-linear panel: Evidence from six industrialized economies. *Economic Modelling, 27*(5), 996-1005.

O'Reilly, G., & Whelan, K. (2005). Has Euro-area inflation persistence changed over time? *The Review of Economics and Statistics, 87*(4), 709-720.

Orphanides, A., & Wieland, V. (2000). Inflation zone targeting. *European Economic Review, 44*(7), 1351-1387.

Ouyang, A. Y., & Rajan, R. S. (2016). Does inflation targeting in Asia reduce exchange rate volatility? *International Economic Journal, 30*(2), 294-311.

Pagliacci, C., & Barráez, D. (2010). A Markov-switching model of inflation: Looking at the future during uncertain times. *Análisis Económico, 25*(59), 25-46.

Pahlavani, M., & Harvie, C. (2008). Multiple structural breaks in Korea's macroeconomic data: An application of the Lumsdaine and Papell test. *The Journal of the Korean Economy*, *9*(3), 425-441.

Payne, J. E. (2009). Inflation targeting and the inflation-inflation uncertainty relationship: Evidence from Thailand. *Applied Economics Letters, 16*(3), 233-238.

Perrier, P., & Amano, R. (2000). Credibility and monetary policy. *Bank of Canada Review, Spring 2000, 11-17.* Retrieved from http://www.bankofcanada.ca/wp-content/uploads/2010/06/r002b-e.pdf

Pesaran, M. H. (2004). *General diagnostic tests for cross section dependence in panels* (CESifo Working Paper Series No. 1229; IZA Discussion Paper No. 1240). Retrieved from http://ssrn.com/abstract=572504

Pesaran, M. H. (2007). A simple panel unit root test in the presence of cross-section dependence. *Journal of Applied Econometrics*, *22*(2), 265-312.

Phillips, P. C. B., & Peron, P. (1988). Testing for unit roots in time series. *Biometrika 75*(2), 335-346.

Pivetta, F., & Reis, R. (2007). The persistence of inflation in the United States. *Journal of Economic Dynamics and Control*, *31*(4), 1326-1358.

Pontines, V. (2013). Inflation targeting and exchange rate volatility: A treatment effect regression approach. *International Economic Journal, 27*(1), 25-39.

Poon, W. C., & Lee, Y. S. (2014). Inflation targeting in ASEAN-10. *South African Journal of Economics, 82*(1), 141-157.

Prasertnukul, W., Kim, D., & Kakinaka, M. (2010). Exchange rates, price levels, and inflation targeting: Evidence from Asian countries. *Japan and the World Economy, 22*(3), 173-182.

Reyes, J. (2007). Exchange rate passthrough effects and inflation targeting in emerging economies: What is the relationship? *Review of International Economics*, *15*(3), 538-559.

Rhee, H. J., & Turdaliev, N. (2012). Targeting rules for an open economy. *Open Economies Review*, *23*(3), 447-471.

Ricketts, N., & Rose, D. (1995). *Inflation, learning and monetary policy regimes in the G-7 economies* (Bank of Canada Working Paper 95-6). Retrieved from http://www.bankofcanada.ca/wp-content/uploads/2010/05/wp95-6.pdf

Rocha, M., & Curado, M. (2011). Inflation targeting and exchange rate volatility: an analysis of international experience with panel GARCH. *Revista de Economia Contemporânea*, *15*(2), 342-368.

Rogoff, K. (1996). The purchasing power parity puzzle. *Journal of Economic Literature, 34*(2), 647-668.

Romer, D. (2006). *Advanced macroeconomics* (3rd ed.). New York, NY: McGraw-Hill/Irwin.

Romero-Ávila, D. (2007). The unit root hypothesis for aggregate output may not hold after all: New evidence from a panel stationarity test with multiple breaks. *Southern Economic Journal*, *73*(3), 642-658.

Rose, A. K. (2007). A stable international monetary system emerges: Inflation targeting is Bretton Woods, reversed. *Journal of International Money and Finance, 26*(5), 663-681.

Rose, A. K. (1988). Is the real interest rate stable? *The Journal of Finance, 43*(5), 1095-1112.

Samarina, A., & De Haan, J. (2014). Right on target: Exploring the factors leading to inflation targeting adoption. *Contemporary Economic Policy, 32*(2), 372-389.

Samarina, A., & Sturm, J. (2014). Factors leading to inflation targeting - the impact of adoption. *Applied Economics Letters, 21*(13), 918-923.

Samarina, A., Terpstra, M., & De Haan, J. (2014). Inflation targeting and inflation performance: A comparative analysis. *Applied Economics*, *46*(1), 41-56.

Sek, S. K. (2009). Interactions between monetary policy and exchange rate in inflation targeting emerging countries: The case of three East Asian countries. *International Journal of Economics and Finance, 1*(2), 27-44.

Sek, S. K., & Har, W. M. (2012). Does inflation targeting work in emerging East-Asian economies? *Panoeconomicus, 5*, 599-608.

Sek, S. K., Ooi, C. P., & Ismail, M. T. (2012). Investigating the relationship between exchange rate and inflation targeting. *Applied Mathematical Sciences*, *6*(32), 1571-1583.

Shahbaz, M., Zeshan, M., & Afza, T. (2012). Is energy consumption effective to spur economic growth in Pakistan? New evidence from bounds test to level relationships and Granger causality tests. *Economic Modelling*, *29*(6), 2310-2319.

Shen, X., & Holmes, M. J. (2014). Do Asia-Pacific stock prices follow a random walk? A regime-switching perspective. *Applied Economics Letters*, *21*(3), 189-195.

Siklos, P. L. (2008). Inflation targeting around the world. *Emerging Markets Finance and Trade*, *44*(6), 17-37.

Simon, J. (1996). *A Markov-switching model of inflation in Australia* (Reserve Bank of Australia Discussion Paper No. 9611). Retrieved from http://www.rba.gov.au/publications/rdp/1996/pdf/rdp9611.pdf

Smyth, R., & Inder, B. (2004). Is Chinese provincial real GDP per capita nonstationary? Evidence from multiple trend break unit root tests. *China Economic Review, 15*(1), 1-24.

Soon, S., Baharumshah, A. Z., & Ahn, S. K. (2015). Real exchange rate dynamics in the Asian economies: Can regime shifts explain purchasing power parity puzzles? *Global Economic Review, 44*(2), 219-236.

Srinivasan, N., & Kumar, P. (2012). Inflation persistence: Does credibility of the monetary regime matter? *Economics Bulletin*, *32*(4), 2944-2954.

Stock, J. H. (2001). Evolving post-World War II US inflation dynamics: Comment. *NBER Macroeconomics Annual*, *16*, 379-387.

Svensson, L. E. O. (1997). Inflation forecast targeting: Implementing and monitoring inflation targets. *European Economic Review*, *41*(6), 1111-1146.

Svensson, L. E. O. (1999). Inflation targeting as a monetary policy rule. *Journal of Monetary Economics*, *43*(3), 607-654.

Svensson, L. E. O. (2000). Open-economy inflation targeting. *Journal of International Economics*, *50*(1), 155-183.

Svensson, L. E. O. (2007). *Inflation targeting* (CEPS Working Paper No. 144). Princeton, NJ: Princeton University. Retrieved from https://www.princeton.edu/ceps/workingpapers/144svensson.pdf

Taguchi, H., & Kato, C. (2011). Assessing the performance of inflation targeting in East Asian Economies. *Asian-Pacific Economic Literature, 25*(1), 93-102.

Tang, H. C. (2014). Commodity prices and monetary policy in emerging East Asia during the global financial crisis. *Asian-Pacific Economic Literature, 28*(1), 137-160.

Taş, B. K. O. (2012). Inflation targeting and inflation uncertainty. *Scottish Journal of Political Economy, 59*(3), 283-297.

Taş, B. K. O., & Ertugrul, H. M. (2013). Effect of inflation targeting on inflation uncertainty: A SWARCH analysis. *Australian Economic Review, 46*(4), 1-16.

Taylor, J. B. (2000). Low inflation, pass-through, and the pricing power of firms. *European Economic Review, 44*(7), 1389-1408.

Teles, V. K., & Zaidan, M. (2010). Taylor principle and inflation stability in emerging market countries. *Journal of Development Economics, 91*(1), 180-183.

Tillmann, P. (2013). Inflation targeting and regional inflation persistence: Evidence from Korea. *Pacific Economic Review*, *18*(2), 147-161.

Tsong, C. C., & Lee, C. F. (2010). Testing for stationarity of inflation rates with covariates. *South African Journal of Economics*, *78*(4), 344-362.

Tsong, C. C., & Lee, C. F. (2011). Asymmetric inflation dynamics: Evidence from quantile regression analysis. *Journal of Macroeconomics, 33*(4), 668-680.

Valera, H. G. A., Holmes, M.J., & Hassan, G.M. (2016). Stock market uncertainty and interest rate behaviour: A panel GARCH approach. *Applied Economics Letters*, 1-4. doi: 10.1080/13504851.2016.1223817

Valera, H. G. A., & Lee, J. (2016). Do rice prices follow a random walk? Evidence from Markov switching unit root tests for Asian markets. *Agricultural Economics,* doi:10.1111/agec.12265

Vega, M., & Winkelried, D. (2005). Inflation targeting and inflation behavior: A successful story? *International Journal of Central Banking, 1*(3), 153-175.

Villa, E., Misas, M. A., & Giraldo, A. F. (2014). Inflation targeting and an optimal Taylor Rule for an open economy: Evidence for Colombia 1990-2011. *Latin American Journal of Economics, 51*(1), 41-83.

Volz, U. (2015). On the future of inflation targeting in East Asia. *Review of Development Economics, 19*(3), 638-652.

Walid, C., Chaker, A., Masood, O., & Fry, J. (2011). Stock market volatility and exchange rates in emerging countries: A Markov-state switching approach. *Emerging Markets Review, 12*(3), 272-292.

Walsh, C. E. (2009). Inflation targeting: What have we learned? *International Finance, 12*(2), 195-233.

Wilfling, B. (2009). Volatility regime-switching in European exchange rates prior to monetary unification. *Journal of International Money and Finance, 28*(2), 240-270.

Winkelried, D. (2014). Exchange rate pass-through and inflation targeting in Peru. *Empirical Economics, 46*(4), 1181-1196.

Wolters, M. H., & Tillmann, P. (2015). The changing dynamics of US inflation persistence: A quantile regression approach. *Studies in Nonlinear Dynamics & Econometrics,* 19(2), 161-182.

Woodford, M. (2001). The Taylor rule and optimal monetary policy. *The American Economic Review, 91*(2), 232-237.

Yang, J., Guo, H., & Wang, Z. (2006). International transmission of inflation among G-7 countries: A data-determined VAR analysis. *Journal of Banking and Finance, 30*(10), 2681-2700.

Yang, L., & Hamori, S. (2016). Hot money and business cycle volatility: Evidence from selected ASEAN countries. *Emerging Markets Finance and Trade*, *52*(2), 351-363.

Yap, J. T. (1996). *Inflation and Economic Growth in the Philippines* (Philippine Institute for Development Studies Discussion Paper No. 96-11). Makati, Philippines: PIDS. Retrieved from http://dirp4.pids.gov.ph/ris/dps/pidsdps9611.pdf

Yong Fu, T., Holmes, M. J., & Choi, D. F. S. (2011). Volatility transmission and asymmetric linkages between the stock and foreign exchange markets: A sectoral analysis. *Studies in Economics and Finance*, *28*(1), 36-50.

Zhang, C., & Clovis, J. (2010). China inflation dynamics: Persistence and policy regimes. *Journal of Policy Modeling*, *32*(3), 373-388.

Zhou, S. (2008). Stationarity of Asia-Pacific real exchange rates. *Economics Letters, 98*(1), 16-22.

Zhou, S. (2013). Nonlinearity and stationarity of inflation rates: Evidence from the Euro-zone countries. *Applied Economics, 45*(7), 849-856.