An Empirical Analysis of the Weak-form Efficiency of Stock Markets

A thesis submitted for the degree of

Doctor of Philosophy

by

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ABSTRACT

The main objective of this thesis is to show that additional insights, beyond the verdict of market efficiency/inefficiency, can be obtained from those existing statistical tests of the weak-form efficient markets hypothesis (EMH). As an introduction, Chapter 1 provides the background and outline of this thesis. Chapter 2 then surveys the relevant literature and discusses the motivations behind the development of the three key research questions addressed in Chapter 3 through 5, respectively.

Chapter 3 examines the association between trade liberalization and the weak-form efficiency of stock market, motivated by the production-based asset pricing model of Basu and Morey [Trade opening and the behavior of emerging stock market prices, *Journal of Economic Integration* 20(1), 2005, 68-92]. Using data from 23 developing countries over the sample period of 1992-2006, we find that a greater level of *de facto* trade openness is associated with a higher degree of informational efficiency in these emerging stock markets, even after controlling for trading volume and market return volatility. Further analyses find no significant association between the extent of financial openness and the degree of informational efficiency. While Chapter 3 provides novel evidence on the association between trade openness and stock market efficiency, our empirical work can also be viewed as addressing the issue of whether the existing theoretical determinants (i.e. trading volume, return volatility, trade liberalization and financial openness) are capable of explaining the variations of index return autocorrelations across countries and over time.

Chapter 4 employs the rolling bicorrelation test to measure the degree of nonlinear departures from a random walk for aggregate stock price indices of 50 countries over the common sample period of 1995-2005. We find that stock markets in economies with low per capita GDP in general experience more frequent price deviations than those in the high income group. Our results consistently show that this clustering effect can largely be attributed to low income economies providing weak protection for private property rights. We conjecture that weak protection deters the participation of informed arbitrageurs, leaving those markets being dominated by sentiment-prone noise traders whose correlated trading cause stock prices in emerging markets to deviate from the random walk benchmarks for persistent periods of time.

Chapter 5 proposes a novel framework to explore the direct relationship between stock return autocorrelations and news events. We first apply the wild bootstrapped automatic variance ratio test to detect significant serial correlations in the 1-minute transaction returns of the Kuala Lumpur Composite Index (KLCI) for each trading day. Our results show that only 141 out of the total 373 trading days during the Asian crisis exhibit significant return autocorrelations at the 1% level. A subsequent event matching procedure reveals that 29 trading days with significant return autocorrelations can be associated with major market-moving media events, which we hypothesize is due to a higher level of information uncertainty. Thirty seven percent of the trading days with significant return autocorrelations cannot be explained by any economic or political news, which we interpret as indicative of investors' herding behavior not driven by information.

Chapter 6 summarizes the key findings of this thesis along with some recommendations for future research. Finally, we conclude this thesis by offering some general guides which might be useful for future empirical research on stock market efficiency.

DECLARATION

I hereby declare that this thesis contains no material which has been accepted for the award of any other degree or diploma at any university or equivalent institution and that, to the best of my knowledge and belief, this thesis contains no material previously published or written by another person, except where due reference is made in the text of the thesis.

This thesis includes one original paper accepted for publication in a peer reviewed journal and four unpublished papers. The core theme of the thesis is on the weak-form efficiency of stock markets. The ideas, development and writing up of all the papers in the thesis were the principal responsibility of myself, the candidate, working within the Department of Econometrics and Business Statistics under the supervision of Robert D. Brooks and Jae H. Kim.

The inclusion of co-authors reflects the fact that the work came from active collaboration between researchers and acknowledges input into team-based research. In the case of Chapters 2, 3, 4 and 5, my contribution to the work is provided in the table overleaf. I have re-numbered sections of submitted or published papers in order to generate a consistent presentation within the thesis.

Signed: [redacted]

Date: June 8, 2009

Thesis Chapter	Publication Title	Publication Status	Nature and Extent of Candidate's Contribution
2 (Sections 2.2 and 2.4)	The evolution of stock market efficiency over time: a survey of empirical literature	Invited for revise and resubmit	The initiation of idea, literature review, and writing up of the first draft.
3	Trade openness and the informational efficiency of emerging stock markets	To be submitted	The initiation of idea, formulation of research questions, development of research framework, literature review, construction of cross-country database, data analysis (except variance ratio estimation) and interpretation, and writing up of the first draft.
4	Why do emerging stock markets experience more persistent price deviations from a random walk over time? A country-level analysis	Accepted	The initiation of idea, formulation of research questions, development of research framework, literature review, construction of cross-country database, data analysis and interpretation, writing up of the first draft, conference presentations, and correspondence with *Macroeconomic Dynamics*.
5	Return autocorrelations and salient news events: an empirical study of the Malaysian stock market during the Asian crisis	To be submitted	The initiation of idea, formulation of research questions, development of research framework, literature review, construction of news database, data analysis (except variance ratio estimation) and interpretation, and writing up of the first draft.
6 (Subsections 6.2.1 through 6.2.3)	The speed of stock price adjustment to market-wide information	Under review	

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Time really flies. My family and I have been in Australia for 3 years and 8 months. As I write this column to wrap up the thesis, it is indeed emotional as this life experience is the most rewarding and memorable. Even though acknowledgements have been given in the thesis chapters and my journal papers, there are many unsung heroes that have played an important part in my PhD journey. I would like to take this opportunity to record my sincere appreciation to them.

First and foremost, I thank my loving God for the countless blessings that I and my family have received. As much as I would like to have greater certainty in life, there are just too many things that are beyond my control. I will always remember those hard times (and hopefully will blog about them in future), and how He gives me peace, hope and joy.

In my journal papers, I gratefully acknowledged the financial support and study leave provided by Universiti Malaysia Sabah. I would like to take this opportunity to thank the unsung hero, my former dean of school, the late Dr. Zainal Abidin Said. He had been instrumental in my academic career, starting with the offer of tutorship, a scholarship for Master degree, various management responsibilities, academic promotion, and finally a PhD scholarship. It saddened me to learn of his death, and this thesis is my dedication to him.

I would like to express my gratitude to Professor Robert Brooks and Associate Professor Jae (Paul) Kim for their dedicated supervision. Rob always encouraged me to write papers based on my PhD ideas for journal submissions and conference presentations. The peer refereeing process has been a rewarding experience, and deserves much credit for shaping the direction of this thesis toward its present form. One precious skill that I learned from Rob is on handling the numerous critical comments from journals' referees, working on the revision, and dealing with rejection. I want to thank Paul for his direct participation in my Chapters 3 and 5, especially giving his full attention and time during the final few months of my thesis write-up.

Professor Melvin Hinich has been a good mentor and collaborator for the past 7 years, to whom I am forever grateful. His constant encouragement and guidance always keep me motivated in my research. Special thanks to Chris Brooks, Hiro Ito, James Self, John Griffin, Philip Rothman, Richard Ashley, Yi-Teng Chen for kindly answering many of my questions on their papers. I also acknowledge the generosity of Ignacio Lobato, Jeffrey Racine, Juan Carlos Escanciano, Yi-Teng Chen and Yongmiao Hong for providing their computer codes, though these programs were not used in my PhD research.

I am grateful to my loving wife, Ming Li, for her continuous encouragement, support and many sacrifices. My two major outputs produced during the course of candidature, not reported in the declaration forms, are in fact collaborated with her. Our 3-year old son (Matthias) and 9-month old daughter (Eunice) make our life more beautiful. Matthias, in particular, provided the welcome breaks by keeping me busy with all his endless questions of why and how. I want to thank my mother-in-law for coming over to

Melbourne to help us with the kids during the last three months of my thesis write-up. I also thank my parents, sister and brother for their love and support. My dad deserves special mention here. Coming from a poor family of eight siblings, he knew that education is the key to a comfortable life. Since childhood, dad always reminded us to work hard and aim for a university degree. I also want to thank him for proofreading the preliminary draft of my thesis chapters.

I acknowledge the travel grants provided by the Department of Econometrics and Business Statistics and FIRN for my conference presentations. I greatly appreciate the assistance from many members of the department. Our Faculty Subject Librarian, May Lee Wee, deserves special mention for her kind assistance during my exploration of the Thomson Datastream database. I also appreciate the friendship of my fellow postgraduate students. A special thanks to Javed for sharing his thesis Word template and responding to many of my enquiries on the thesis submission process.

CHAPTER 1

Introduction to the Thesis

1.1 Background

The term 'market efficiency', formalized and operationalized in the seminal review of Fama (1970), is generally referred to as the informational efficiency of financial markets which emphasizes the role of information in setting prices.[1] More specifically, the efficient markets hypothesis (EMH) defines an efficient market as one in which new information is quickly and correctly reflected in its current security price. Other definitions have been proposed by Rubinstein (1975, 2001), Jensen (1978), Beaver (1981), Black (1986), Dacorogna *et al*. (2001), Malkiel (2003), Timmermann and Granger (2004) and Milionis (2007). Given that the literature has not yet produced an agreed-upon standard definition, it is not surprising to learn that the efficiency of financial markets has been examined empirically in many different ways. In terms of empirical findings, Lo (2008) notes that even after thousands of published articles spanning over several decades, there is still no consensus among economists on whether financial markets are efficient.

[1] Another two distinct but interrelated types of financial market efficiency are: (1) operational efficiency which focuses on the level of costs in carrying out transactions on the exchange; (2) allocative efficiency, measuring the extent to which capital is efficiently allocated to the most productive sectors in the economy.

In his first review paper, Fama (1970) outlines the classic taxonomy of information sets available to market participants and further classifies the EMH into the weak-form, semi-strong-form and strong-form. This thesis focuses on the weak-form version, which asserts that security prices fully reflect all information contained in the past price history of the market.[2] Even in this weak-form category, the huge body of literature can be further subdivided into at least two major groups.[3] The first strand of studies tests the predictability of security returns on the basis of past price changes. More specifically, previous studies in this sub-category employ a wide array of statistical tests to detect different types of deviations from a random walk in financial time series, such as linear serial correlations, unit root, low-dimensional chaos, nonlinear serial dependence and long memory (see the literature review in Section 2.2 of this thesis). The second group of studies examines the profitability of trading strategies based on past returns; such as technical trading rules (see the survey paper by Park and Irwin, 2007), momentum and contrarian strategies (see references cited in Chou *et al*., 2007).

Given that there is no consensus on the standard definition of market efficiency, we adopt the version given by Fama (1970) which emphasizes on the speed and accuracy of price adjustment to new information. More specifically, this thesis infers market efficiency from the underlying stock price behavior, where a perfectly efficient stock market is one in which the price changes are completely random and unpredictable. Thus, the existence of significant serial dependence in stock return series, in particularly

[2] The information set is expanded to include publicly available information and privately held information under the semi-strong-form and strong-form EMH, respectively.

[3] Fama (1991) later reclassifies the weak-form EMH as tests for return predictability, and this will include another group of literature that examines return predictability using financial variables such as the dividend-price ratio, earnings-price ratio, book-to-market ratio and various measures of the interest rates (recent studies include Ang and Bekaert, 2007; Boudoukh *et al*., 2008; Campbell and Thompson, 2008; Cochrane, 2008b; Lettau and Nieuwerburgh, 2008; Welch and Goyal, 2008; Hjalmarsson, 2009).

return autocorrelations, would imply investors' mis-reaction (i.e. under- or over-reaction) to the arrival of information. Though its implications on market efficiency are still very much been debated (see Boudoukh *et al*., 1994), the above informational efficiency interpretation of serial dependence in successive price changes has strong theoretical grounds and is widely adopted in existing empirical studies, which are discussed as follows.

First, the well-known behavioral models of Barberis *et al*. (1998), Daniel *et al*. (1998) and Hong and Stein (1999) rationalize how under- or over-reaction to news can give rise to positive return autocorrelations. Barberis *et al*. (1998) hypothesize that investors are subjected to a conservatism bias which causes them not to update their priors sufficiently in the face of new information. Consequently, stock prices initially under-react to public information and stock returns are positively autocorrelated over short horizons. Instead of cognitive biases, the under-reaction and positive return autocorrelations in Hong and Stein's (1999) model arise because of gradual diffusion of information across the investing public, and news watchers and momentum traders are boundedly rational in the sense that they use only partial information in updating their priors. Daniel *et al*. (1998) refute the common presumption that the existence of positive return autocorrelations is due to under-reaction. Instead, these authors argue that it is better characterized as a market over-reaction to news. In their model, investors' overconfidence in extracting information signals would lead stock prices to over-react initially. Subjected to self-attribution bias, investors become more overconfident when public information arrives. Together, both types of psychological biases cause continuing over-reaction and hence positive serial correlations in stock returns at short horizons. The positive feedback trader model of De Long *et al*. (1990b) also characterizes positive return autocorrelations as the result of market over-reaction. Their model shows that when noise traders follow a positive feedback trading strategy, the price pressure causes stock returns to be positively autocorrelated. In another theoretical model, Froot and Perold (1995) show that the slow dissemination of market-wide information results in positive serial correlations in stock index returns, though the authors do not specify whether this is a symptom of under- or over-reaction.

Second, in the empirical literature, the popular interpretation of negative return autocorrelations is that the stock market consistently over-reacts to new information. This in turn implies that a contrarian strategy of buying past losers (stocks that have performed poorly) and selling past winners (stocks that have performed well) will earn positive expected profits (see De Bondt and Thaler, 1985, 1987; Lehmann, 1990). On the other hand, the common empirical implication of price momentum strategies (i.e. buying past winners and selling past losers) based on market under-reaction is that the observed stock returns are positively autocorrelated at some holding periods (see Jegadeesh and Titman, 1993; Chan *et al.*, 1996; Hong *et al.*, 2000). In a parallel development, Amihud and Mendelson (1989a), Damodaran (1993), Brisley and Theobald (1996) and Theobald and Yallup (1998, 2004) develop formal speed of adjustment estimators which are functions of autocorrelations in order to gauge the speed with which new information is reflected in prices of individual stocks or portfolios. In these estimators, the speed of adjustment coefficient will equal one if stock prices fully adjust to new information. The coefficient of less than unity indicates that information is slowly incorporated into prices, while a value of greater than one suggests over-reaction to news.

Third, Malkiel (2003) notes that the definition of market efficiency is associated with the view that stock prices would move unpredictably. The logic behind the random walk idea is that price changes occur only in response to genuinely new information. Since true news is by definition unpredictable, the resulting price changes must be unpredictable and random. On the other hand, if the full impact of an important news announcement is only grasped over a period of time, successive price changes will tend to be positively autocorrelated. There is a good deal of controversy on the random walk behavior of stock prices, even for the developed U.S. stock market, as summarized by the arresting title of three books: "*A random walk down Wall Street*" by Malkiel (1973), Lo and MacKinlay's (1999) "*A non-random walk down Wall Street*", and Singal's (2004) "*Beyond the random walk*". In the extant literature, the weak-form efficiency of stock markets has been widely tested within the framework of the random walk hypothesis (see the literature review in Section 2.2 of this thesis). On the other hand, in the market microstructure literature, the random walk hypothesis is central to the pricing errors measure developed by Hasbrouck (1993). More specifically, the informationally efficient price is assumed to follow a random walk, as it reflects the expected value of the stock conditional on all information available at the transaction time, including public information and private information inferred from order flow. Pricing error then measures the temporary deviation of the actual transaction price from the efficient random walk price that is due to non-information related market frictions. Boehmer *et al*. (2005), Bennett and Wei (2006), Boehmer and Kelley (2009) and Boehmer and Wu (2009) employ the pricing errors to measure the relative informational efficiency of stock prices in their respective empirical investigation.

1.2 Thesis Objectives and Outline

The main objective of this thesis is to show that additional insights, beyond the verdict of market efficiency/inefficiency, can be obtained from those existing statistical tests of weak-form EMH. More specifically, this thesis addresses three key research questions, as follows. (1) What factors are associated with a higher degree of market efficiency? (2) Does market efficiency evolve over time? If so, why? (3) Can the existence of temporal dependence be associated with news events? We highlight here that even if one disagrees on our informational efficiency interpretation of independence of successive price changes, at the very least, this thesis sheds additional light on the factors that give rise to serial dependence in stock return series.

Chapter 2 provides a review of the relevant literature and discusses the motivations behind the development of the three key research questions addressed in Chapter 3 through 5, respectively. Section 2.2 first surveys the mainstream weak-form EMH literature that tests return predictability from past price changes. This is followed by a review of an emerging group of studies that examines market efficiency in the relative rather than absolute sense. We then discuss existing empirical measures of relative market efficiency, and highlight the gap in the extant literature that motivates our investigation on the determinants of index return autocorrelations in Chapter 3. Section 2.4 discusses the adaptive markets hypothesis (AMH) proposed by Lo (2004, 2005) and reviews the empirical findings of evolving market efficiency. We also provide the motivations for our empirical investigation in Chapter 4, which explores the factors that can account for the cross-country variation in the degree of stock price deviations from a random walk over time for 50 stock markets. Section 2.5 surveys the literature that forms the basis of our study on the link between serial correlations and salient news events.

Chapter 3 examines the association between trade liberalization and the weak-form efficiency of stock market, an issue that has been under-researched in the existing literature. Our research is motivated by the production-based asset pricing model of Basu and Morey (2005) which explores the effect of trade openness on the autocorrelation patterns of stock returns. A testable proposition from their model is that the stock return autocorrelations are non-zero in a closed economy, but stock prices should eventually follow a random walk after trade liberalization. These authors further show that financial opening alone, that is, without trade reform, does not lead to an improvement in the informational efficiency of stock market. In the empirical analysis, we employ fixed effects panel regression using data for 23 developing countries over the sample period 1992-2006. In all model specifications, two competing theoretical determinants of index return autocorrelations are included, namely trading volume and market return volatility. While Chapter 3 provides novel evidence on the association between trade openness and stock market efficiency, our empirical work can also be viewed as addressing the issue of whether those existing theoretical determinants are capable of explaining the variations of index return autocorrelations across countries and over time.

Chapter 4 first compares the persistence of deviations from a random walk for aggregate stock price indices of 50 countries over the sample period of 1995-2005 by means of a rolling window. Our research is motivated by the growing empirical evidence of frequent stock price deviations from a random walk benchmark over time. The above market dynamics can be rationalized within the framework of the adaptive markets hypothesis proposed by Lo (2004, 2005). In the empirical analysis, we employ the rolling bicorrelation test to capture nonlinear departures from a random walk since nonlinear tests are more appealing from a statistical perspective than the autocorrelation-based procedures. Apart from its statistical appeal, this line of inquiry sheds additional light on the possible driving forces of widespread nonlinear dynamics in stock data. This chapter then explores the factors that can explain why the degree of stock price deviations varies widely across countries. In the absence of theoretical guide, the search for potential explanations of this country-level phenomenon can be exhaustive. We therefore examine the two explanations considered by Morck *et al*. (2000), namely the structural characteristics and the quality of macro institutions of a country.

Chapter 5 proposes a novel framework to explore the direct relationship between news events and stock return autocorrelations. Our contention is that, if significant serial correlations in the return series reflect under- or over-reaction to information, it would be interesting to examine whether their presence coincides with days in which market-moving public news is announced. Given that news events database is generally constructed at a daily frequency, we advocate the use of high-frequency minute-by-minute stock data to detect significant serial correlations for each trading day. On the grounds of data availability, this chapter limits the investigation to the Malaysian stock market during the 1997 Asian financial crisis. The proposed framework not only sheds light on the efficiency of stock market at an intraday level, but also permits us to identify the possible explanations of significant return autocorrelations.

Chapter 6 first summarizes the key findings of this thesis by directly answering the three research questions addressed in Chapters 3 through 5, respectively. Apart from the extensions suggested in each of the three empirical chapters, we also highlight some issues that have been under-researched in the existing literature, indicating that stock market informational efficiency will continue to be an exciting avenue of research in financial economics for many years to come. Chapter 6 finally concludes this thesis by offering some general guides which might be useful for future empirical research on stock market efficiency.

DECLARATION FOR THESIS CHAPTER 2

Declaration by Candidate

In the case of Chapter 2 (Sections 2.2 and 2.4), the nature and extent of my contribution to the work was the following:

Nature of contribution	**Extent of contribution (%)**
The initiation of idea, literature review, and writing up of the first draft.	80%

The following co-author contributed to the work:

Name	**Nature of contribution**
Robert D. Brooks	Participated in the development of idea, refining the draft paper, and correspondence with *Journal of Economic Survey*.

Candidate's Signature		**Date** June 8, 2009

Declaration by Co-author

The undersigned hereby certify that:

(1) the above declaration correctly reflects the nature and extent of the candidate's contribution to this work, and the nature of the contribution of each of the co-authors;

(2) they meet the criteria for authorship in that they have participated in the conception, execution, or interpretation, of at least that part of the publication in their field of expertise;

(3) they take public responsibility for their part of the publication, except for the responsible author who accepts overall responsibility for the publication;

(4) there are no other authors of the publication according to these criteria;

(5) potential conflicts of interest have been disclosed to (a) granting bodies, (b) the editor or publisher of journals or other publications, and (c) the head of the responsible academic unit; and

(6) the original data are stored at the following location(s) and will be held for at least five years from the date indicated below:

Location	**Department of Econometrics and Business Statistics,** **Monash University**

Co-author's Signature:

Robert D. Brooks		**Date** **June 8, 2009**

CHAPTER 2

Empirical Issues in the Stock Market Weak-form Efficiency Literature[★]

2.1 Introduction

In his seminal review, Fama (1970) surveys the empirical evidence for the weak-form, semi-strong-form and strong-form efficient markets hypothesis (EMH). The author gives relatively wider coverage to the weak-form EMH. Empirical studies prior to 1970 generally employ serial correlation tests and technical trading rules, and their findings strongly suggest that stock markets are weak-form efficient. Two decades later, Fama (1991) conducts a second review of the market efficiency literature. Instead of focusing on past returns, the author expands the coverage of weak-form EMH to tests of return predictability using other variables such as the dividend-price ratio, earnings-price ratio, book-to-market ratio and various measures of the interest rates. The tests for the semi-strong-form and strong-form EMH are renamed as event studies and tests for private information, respectively. His review shows mounting evidence of return predictability from past returns, dividend yields and a number of term-structure variables, but the author argues that these findings might be spurious and should be met with skepticism.

[★] Sections 2.2 and 2.4 of this chapter have been expanded and prepared in a manuscript entitled "The evolution of stock market efficiency over time: a survey of empirical literature" (co-author with Robert D. Brooks). The paper received an invitation from the editor of *Journal of Economic Survey* to revise and resubmit. We thank two anonymous referees of the journal for their constructive comments and suggestions that have greatly improved not only the submitted manuscript but also the presentation of Chapter 2.

More recently, Yen and Lee (2008) provide a chronological review of empirical evidence on the EMH over the last five decades. Their survey clearly demonstrates that the EMH no longer enjoys the level of strong support it received during the golden era of the 1960s, but instead has come under relentless attack from the school of behavioral finance in the 1990s. Besides the above broad review, there are other survey papers with a specific theme, for instance, (1) Fama (1998) surveys the empirical work on event studies, with a focus on those papers reporting long-term return anomalies of under- and over-reactions to information; (2) Malkiel (2003) and Schwert (2003) scrutinize those studies reporting evidence of statistically significant predictable patterns in stock returns; (3) Park and Irwin (2007) review the evidence on the profitability of technical trading rules in a variety of speculative markets, including 66 stock market papers published over the period from 1960 to 2004.

In Section 2.2, we survey the mainstream weak-form EMH literature that examines return predictability from past price changes.[1] It is worth noting that the number of empirical studies has grown tremendously, but survey papers after Fama (1970) have largely neglected this strand of literature. The main objective of this thesis is to show that additional insights, beyond the verdict of market efficiency/inefficiency, can be obtained from those statistical tests of weak-form EMH discussed in Section 2.2. Sidestepping the ongoing debate between proponents of EMH and champions of behavioral finance, a developing literature has shifted its focus to examining market efficiency in the relative rather than absolute sense. Section 2.3 highlights this group of

[1] Since this thesis focuses on the informational efficiency interpretation of independence of successive price changes, our survey does not include the return predictability literature using other financial variables which is still a subject of considerable debate in recent years (see Ang and Bekaert, 2007; Boudoukh *et al*., 2008; Campbell and Thompson, 2008; Cochrane, 2008b; Lettau and Nieuwerburgh, 2008; Welch and Goyal, 2008; Hjalmarsson, 2009).

studies, discusses existing empirical measures of relative market efficiency, and finally outlines the issue addressed in Chapter 3 of this thesis. Briefly, guided by existing theoretical models, Chapter 3 explores the factors that give rise to index return autocorrelations in 23 emerging stock markets using fixed effects panel regression.

In another parallel development, Lo (2004, 2005) offers a reconciliation to the opposing camps of EMH and behavioral finance, calling for an evolutionary perspective to market efficiency. Section 2.4 discusses the adaptive markets hypothesis (AMH) proposed by Lo (2004, 2005) and reviews the empirical findings of evolving market efficiency. We also provide the motivations behind the empirical investigation in Chapter 4, which examines the persistence of stock price deviations from a random walk over time for 50 stock markets by means of the rolling bicorrelation test statistic. Cross-sectional regression is then employed to identify those factors that can account for the documented cross-country variation. Using the Malaysian stock market as a case study, Chapter 5 investigates whether the presence of significant autocorrelations in intraday return series can be associated with major news stories in the media. Section 2.5 discusses the related literature that motivates this line of inquiry. Section 2.6 then concludes our survey of the empirical issues in the weak-form EMH literature.

2.2 The Mainstream Weak-form EMH Literature

This section surveys the weak-form EMH literature that examines the predictability of stock returns from past price changes. The empirical studies are organized based on the nature of temporal dependence their statistical tests are designed to detect. It is worth mentioning that in an earlier review paper, Andreou *et al*. (2001) trace the development of various statistical models for speculative price data since the early 20th century, and these authors also cover the temporal dependence discussed here. As a whole, our survey reveals overwhelming evidence of predictable patterns from past returns, especially for emerging stock markets. While most of these studies claim that the existence of temporal dependence contradicts the weak-form EMH because there are profitable investment opportunities (for technical trading rules or past-return based investment strategies), we emphasize that the evidence implies information is not reflected fully and instantaneously into current stock price.

2.2.1 Linear serial correlations

Serial correlation tests and spectral analysis are the earlier tools employed in the weak-form EMH literature, pioneered by Fama (1965) and Granger and Morgenstern (1963), respectively. These statistical procedures are testing the least restrictive version of the random walk hypothesis, which is the Random Walk 3 model of Campbell *et al*. (1997) that only requires uncorrelatedness of price changes. Since the seminal work of Lo and MacKinlay (1988), the variance ratio (VR) test has emerged as the primary tool for testing whether stock return series are serially uncorrelated. Charles and Darné (2009b) provide an exclusive and extensive survey on its recent developments. The VR test is based on the statistical property that if the stock price follows a random walk, then the variance of k-period return is equal to k times the variance of one-period return. Hence, the VR, defined as the ratio of the variance of k-period return to k times the variance of one-period return, should be equal to one for any holding period k, under the null hypothesis of serially uncorrelated stock returns. A notable recent innovation of the VR test includes non-parametric tests proposed by Wright (2000) based on signs and ranks of returns that follow exact distributions.

In empirical applications, it is customary to examine the variance ratios for several holding periods, and the verdict of non-random walk is proclaimed when one of the estimated variance ratio statistics is significantly different from unity. However, this multiple comparison across all pre-selected holding periods can lead to over-rejection of the null hypothesis. To control for the overall test size, joint testing procedures have been proposed in the literature, among others, by Richardson and Smith (1991), Chow and Denning (1993), Whang and Kim (2003), Chen and Deo (2006), Kim (2006), and Kim and Shamsuddin (2008). These multiple variance ratio tests remain the firm favorites in the extant weak-form EMH literature. In contrast, despite numerous methodological refinements to existing serial correlation tests (Lobato *et al*., 2002; Horowitz *et al*., 2006) and spectral-based tests (Durlauf, 1991; Deo, 2000), we do not find any applications of these improved statistical tools on stock market data, with McPherson *et al*. (2005) and McPherson and Palardy (2007) being the only two studies identified.

The empirical studies in this group experience a phenomenal growth over the past five decades and it is impossible to give a full review here. Since Lim and Brooks (2006) provide a list of those papers published over the 1965-2005 period, our survey hence focuses on recent stock market efficiency studies that examine the uncorrelatedness of stock return series. Based on the non-exhaustive list in Lim and Brooks (2006), 57 of the total 92 papers conduct their efficiency tests on one single country, covering the stock markets of 25 countries. The remaining 35 articles perform comparative analysis, either on a regional basis or based on the classification of market status. In terms of empirical evidence, the findings are contradictory even for the same stock market under study, due to differences in methodologies employed or sample periods selected.

To provide a glimpse of this controversy, we use China as a case study, since the weak-form efficiency of her two stock exchanges in Shanghai and Shenzhen has been subjected to strict scrutiny, including the books by Groenewold *et al*. (2004) and Ma (2004). On one hand, Laurence *et al*. (1997), Liu *et al*. (1997), Long *et al*. (1999) and Lima and Tabak (2004) conclude that the Chinese stock markets are weak-form efficient as their stock returns do not exhibit linear serial correlations. These efficiency findings are quite surprising given the widely-shared perception that the Chinese stock markets are highly speculative, driven mainly by market rumors and individual investor sentiments. On the other end of the spectrum, Mookerjee and Yu (1999) and Ma (2004) arrive at the conclusion that the same market is inefficient since their autocorrelation-based tests reject the random walk hypothesis. In between are those studies that find evidence of return predictability, yet avoid making inference on market inefficiency as these authors are mindful that the apparent predictability could be spurious autocorrelations induced by thin trading (see Darrat and Zhong, 2000; Lee *et al*., 2001; Groenewold *et al*., 2003, 2004; Seddighi and Nian, 2004). Fifield and Jetty (2008), Zhang and Li (2008) and Charles and Darné (2009a) add to this growing list of Chinese efficiency papers, but their applications of a battery of variance ratio tests yield mixed findings.

The literature continues to grow in the past three years albeit at a slower pace, with greater emphasis on emerging stock markets. Squalli (2006) examines the weak-form efficiency of two exchanges in the United Arab Emirates, the Dubai Financial Market (DFM) and the Abu Dhabi Securities Market (ADSM). Both exchanges are relatively young in age with their inauguration in year 2000. The results from variance ratio tests consistently show that most of the economic sectors in DFM and ADSM are inefficient.

Similar findings of serially correlated stock returns are also reported by Chakraborty (2006) and Hassan and Chowdhury (2008) for stock markets in Bangladesh and Pakistan. The recent methodological refinements to variance ratio tests have prompted a number of studies to conduct a re-examination of the stock market data in Asia (Hoque *et al*., 2007; Kim and Shamsuddin, 2008), Europe (Smith, 2009), Middle East and Africa (Al-Khazali *et al*., 2007; Ntim *et al*., 2007; Smith, 2007, 2008; Lagoarde-Segot and Lucey, 2008). These recent studies do report evidence of weak-form efficiency for emerging stock markets, for instance, Al-Khazali *et al*. (2007) for Bahrain, Egypt, Jordan, Kuwait, Morocco, Oman, Saudi Arabia and Tunisia; Smith (2007) for Israel, Jordan and Lebanon; Kim and Shamsuddin (2008) for Korea, Taiwan and Thailand; Smith (2008) for Egypt, Nigeria, South Africa and Tunisia; Smith (2009) for Poland and Turkey. To conclude our survey, two observations are worth mentioning here: (1) though the variance ratio tests have been widely accepted as the standard tool, there are still some recent papers which rely solely on the conventional autocorrelation tests (see Mollah, 2007; Mobarek *et al*., 2008); (2) the efficiency of developed markets receives relatively less attention, with DePenya and Gil-Alana (2007), Lovatt *et al*. (2007), Jirasakuldech *et al*. (2008) and Hung *et al*. (2009) among the few recent additions to the literature.

2.2.2 Unit root

The unit root test is another type of statistical test favored by researchers in the weak-form EMH literature. Earlier studies generally employ conventional unit root tests in particular the popular augmented Dickey-Fuller (ADF) test, and find that the log-levels of stock prices are non-stationary. They then conclude the markets under study are weak-form efficient. Since a review of previous findings has been provided by Lean and

Smyth (2007), we limit our survey to recent empirical papers that adopt structural-break or panel unit root tests. The argument given in favor of the former is that if a structural break is present in the data, there is a possibility the break is interpreted as the existence of a unit root and hence will lead to under-rejection of the null hypothesis. The methodology has been further refined to allow for multiple structural breaks. On the other hand, panel unit root tests are justified on the grounds that univariate unit root tests have low power when the sample size is small, measured in terms of time span of the data rather than the frequency of observations.

Narayan and Smyth (2007) find that the price indices for stock markets in G7 countries contain a unit root, even after taking into account the presence of structural breaks in the trend. These G7 stock price indices only attain stationarity when Narayan (2008) employs the panel Lagrange multiplier (LM) unit root test with two structural breaks. Using univariate LM unit root tests with both one and two structural breaks, Lean and Smyth (2007) find that stock price indices in eight Asian countries follow a random walk process. This verdict is further supported by the panel LM unit root test with one break. However, when allowing for two structural breaks, the panel result instead suggests stock prices are mean reverting. Even the emerging Istanbul Stock Exchange is proclaimed as weak-form efficient by Ozdemir (2008) because its major price index is characterized by a unit root with two structural breaks. Narayan and Prasad (2007) apply three different panel unit root testing approaches on seventeen European countries' stock price indices, and the null hypothesis of a unit root cannot be rejected in all cases. Using similar methodologies but with two more panel unit root tests, Narayan and Narayan (2007) also cannot reject the null of unit root in their sampled countries. To sum up, the consensus from the aforementioned studies is that there is a unit root in the logarithmic price level. This is not surprising as Campbell *et al*. (1997) note that stock returns have more attractive statistical properties than prices such as stationarity and ergodicity. Evidence of stationarity in stock prices only emerges when panel LM unit root test with two structural breaks is employed (Lean and Smyth, 2007; Narayan, 2008).

Due to the lower power of the ADF unit root test in identifying stationarity when the underlying data generating process is characterized by a nonlinear process, Caner and Hansen (2001) propose a unit root test built on an unrestricted two-regime threshold autoregressive (TAR) model. This newly developed threshold unit root test has been adopted by Narayan (2005, 2006) and Qian *et al*. (2008). The consensus from the above three studies is that the stock price indices under study exhibit threshold nonlinearity, with Narayan (2005) and Qian *et al*. (2008) reporting unit roots in both regimes, while Narayan (2006) documents a partial unit root regime in the U.S. stock price index. Koustas *et al*. (2008) re-examine the U.S. stock market data using a statistical framework in which the null hypothesis of a unit root is tested against the alternative of globally stationary three-regime self-exciting threshold autoregressive (SETAR) process. Their results show the inner regime is characterized by a unit root while the two outer regimes are well captured by a stationary autoregressive process. This body of literature also employs unit root tests that allow the alternative hypothesis to incorporate nonlinear dynamics in the form of exponential smooth transition autoregressive process (Lim and Liew, 2007; Hasanov, 2009a, b) and transitional autoregressive process (Kim *et al*., 2009). The applications of these nonlinear unit root tests consistently show strong evidence of mean reversion in stock prices. Despite all the methodological advances, Rahman and Saadi (2008) highlight that a unit root is a necessary pre-requisite for the random walk hypothesis but not a sufficient condition. More specifically, the presence of a unit root per se is not sufficient to imply a random walk since the return series must also be serially uncorrelated or serially independent.

2.2.3 Nonlinear serial dependence

Given that the assumption of normality is rather restrictive for financial time series, several authors criticize the use of autocorrelation-based procedures in testing the weak-form EMH. This is because all pure white noise series (i.e. a random walk with independent and identically distributed (i.i.d.) increments) are white noise (i.e. serially uncorrelated), but the converse is not true unless the series is normally distributed. Hinich and Patterson (1985) blame Jenkins and Watts (1968) and Box and Jenkins (1970) for blurring the definitions of whiteness and independence. According to Hinich and Patterson (1985), many early investigators implicitly assume the observed time series is generated from a Gaussian process and test for white noise using the correlation structure, hence ignoring possible nonlinear relationships between consecutive price changes. From a statistical perspective, the distinction between white noise and pure white noise is nontrivial when nonlinear dependence is present. It has been pointed out three decades ago by Granger and Andersen (1978) that autocorrelation-based tests have no power against nonlinear processes with zero autocorrelation, such as the bilinear autoregressive, nonlinear moving average and threshold autoregressive processes. A misleading conclusion in favor of market efficiency could be delivered when the variance ratio test statistics are insignificant. Motivated by this concern, the literature during 1980s witnesses the development of new statistical tools capable of uncovering hidden nonlinear structures in previously observed serially uncorrelated stock market data (for early empirical evidence, see Hinich and Patterson, 1985; Brockett *et al*., 1988; De Gooijer, 1989; Scheinkman and LeBaron, 1989).

It is worth mentioning our literature survey reveals it is in fact the chaos theory, originated from the physical sciences, that has caught the fancy of economists in the early 1980s. The issue of whether chaos exists in stock markets has generated much excitement because its presence suggests the potential of short-term return predictability and hence contradicts the weak-form EMH (for details, see the survey papers by LeBaron, 1994 and Barnett and Serletis, 2000). On the other hand, Brock and Hommes (1998) show that chaos in stock prices can arise if heterogeneous expectations among traders are introduced into a standard asset pricing equilibrium model (for subsequent modifications and extensions to this type of heterogeneous beliefs model, consult the survey paper by Hommes and Wagener, 2009). Most of the early empirical papers employ the correlation dimension estimate proposed by Grassberger and Procaccia (1983) to detect low-dimensional chaotic dynamics in stock returns (see Scheinkman and LeBaron, 1989; Kohers *et al*., 1997; Barkoulas and Travlos, 1998; Yadav *et al*., 1999).[2] Other complementary approaches adopted in the empirical literature are the dominant Lyapunov exponent (Yadav *et al*., 1999) and the close returns test (Gilmore, 1993, 1996; McKenzie, 2001).

[2] One of the limitations of correlation dimension is the lack of statistical theory for hypothesis testing, and this gap has been filled by Brock *et al*. (1996) who develop asymptotic distribution theory for statistics based on the correlation dimension. However, the null hypothesis for the BDS test is i.i.d. and hence does not provide a direct test for chaos. Even though the test is designed to have high power against deterministic chaos, various simulations show that it also has good power to detect linear dependence and nonlinear stochastic processes (see Brock *et al*., 1991, 1996; Hsieh, 1991).

The consensus that emerges from the aforementioned studies is the absence of low-dimensional chaos in stock return series. Instead, their further analysis on the same dataset reveals the existence of nonlinear serial dependence. This negative evidence on chaos still holds even when larger sample size is used or a more advanced chaos test is employed. For instance, Abhyankar *et al*. (1995, 1997) utilize high-frequency intraday data as a means to increase the number of observations, but still their Lyapunov exponent point estimates indicate no conclusive evidence of chaos. On the other hand, significant methodological advancements have been made by Whang and Linton (1999) and Shintani and Linton (2004), who construct the standard error for the neural network Lyapunov exponent estimator, and hence provide a formal statistical test for chaos. Empirical studies applying the above refined framework to daily stock returns also reject the null hypothesis of chaos (see Serletis and Shintani, 2003; Shintani and Linton, 2004).

Given that the search for chaotic dynamics in stock market data remains an elusive goal, the initial enthusiasm among researchers has faded and their attention has since turned to nonlinear stochastic dependence. This has contributed to an explosive growth of nonlinearity tests to the extent that a full review is impossible (for a limited survey, see Granger and Teräsvirta, 1993; Patterson and Ashley, 2000; Tsay, 2005). Generally, the existing tests can be divided into two broad categories. The first group contains all the tests derived without a specific nonlinear alternative. Those widely adopted in extant stock market studies are the bispectrum test (Hinich, 1982), McLeod and Li's (1983) test, Tsay's (1986) test, the third-order moment test (Hsieh, 1989), the neural network test (Lee *et al*., 1993), the BDS test (Brock *et al*., 1996) and the bicorrelation test

(Hinich, 1996).[3] Despite their usefulness as general tests for nonlinearity, a rejection of the null hypothesis gives little clue on the actual type of nonlinear dynamics. The usual method for assessing their power properties is by means of Monte Carlo simulations (see, for example, Ashley *et al*., 1986; Brock *et al*., 1991, 1996; Hsieh, 1991; Lee *et al*., 1993; Barnett *et al*., 1997; Patterson and Ashley, 2000). The second category involves testing linearity against a well-specified nonlinear model, employing the Lagrange multiplier, likelihood ratio or Wald test. The popular nonlinear alternatives considered in the literature are the self-exciting threshold autoregressive (SETAR)-type nonlinearity (Petruccelli and Davies, 1986; Tsay, 1989; Chan and Tong, 1990; Hansen, 1999; Petruccelli *et al*., 2009), smooth transition autoregressive (STAR)-type nonlinearity (Luukkonen *et al*., 1988; van Dijk *et al*., 1999; González and Teräsvirta, 2006) and ARCH process (Engle, 1982; Lumsdaine and Ng, 1999; Blake and Kapetanios, 2007).

The rich and expanding theoretical literature continues to supply empiricists with advanced nonlinear statistical tools for testing the random walk hypothesis. A list of those empirical studies published over the 1985-2005 period is provided by Lim *et al*. (2006). All their listed 42 papers report overwhelming evidence of nonlinear serial dependence across international stock markets with different market structure mechanisms, indicating that the observed feature is a stylized fact of stock data. More recently, Patterson and Ashley (2000) introduce a 'nonlinearity toolkit' that provides convenient access to a selection of the best tools available for statistically detecting

[3] Some of these tests are continually being refined over the years, which include the BDS test (Kočenda and Briatka, 2005; Genest *et al*., 2007), the bispectrum test (Hinich *et al*., 2005; Hinich, 2009; Rusticelli *et al*., 2009) and the bicorrelation test (Wild *et al*., 2008).

nonlinearity in the generating mechanism of a given time series.[4] The battery of nonlinearity tests included in the toolkit are the Engle LM test (Engle, 1982), Hinich bispectrum test, McLeod and Li's (1983) test, Tsay's (1986) test, Hinich bicorrelation test and the BDS test. Due to its convenience, this 'nonlinearity toolkit' has been adopted by recent studies to re-examine the weak-form efficiency of stock markets.[5] For instance, Panagiotidis (2005) finds strong evidence of nonlinear dependence in the returns of major stock indices traded in the Athens Stock Exchange. Subsequent applications in other stock markets by Lim *et al*. (2008a), Lim (2009) and Lim and Brooks (2009a) consistently show that nonlinearity is a stylized fact of stock return series.

2.2.4 Long memory

Long memory is characterized by an autocorrelation function that decays at a hyperbolic rate or, equivalently, an infinite spectrum at zero frequency. Mandelbrot (1971) argues that the presence of long memory implies less than perfect arbitraging and the resulting prices do not follow a random walk process. Empirically, Greene and Fielitz (1977) are perhaps the first to investigate whether stock returns exhibit such persistent statistical dependence. Using the classical rescaled range (R/S) analysis proposed by Hurst (1951), these authors find strong evidence of long memory in the daily returns of their sampled 200 U.S. common stocks. Though subsequent studies using the same methodology lend further support to the findings of Greene and Fielitz (1977), Lo (1991) argues that the distribution of the classical R/S statistic is not well defined and is sensitive to higher

[4] The toolkit can be downloaded from Richard Ashley's website at http://ashleymac.econ.vt.edu/. Ashley and Patterson (2006) further illustrate the usefulness of this toolkit in nonlinear model identification using the *p*-values of those included statistical tests.

[5] This toolkit has also been used to test for nonlinearity in economic time series (see Panagiotidis, 2002; Panagiotidis and Pelloni, 2003, 2007; Ashley and Patterson, 2006; Reboredo, 2008; Tang, 2009).

frequency serial correlation. With these shortcomings in mind, Lo (1991) constructs a new test called the modified R/S test that accounts for the presence of short-term dependence, and re-examines the earlier claim of widespread evidence of long memory. In contrast with prior findings, none of the modified R/S statistics in his study are statistically significant at the five percent level in any sample period or sub-period for daily and monthly U.S. stock index return series. In recent years, the rescaled variance (V/S) statistic developed by Giraitis *et al*. (2003) has emerged as a competing statistical test for detecting long memory (for applications, see Cajueiro and Tabak, 2005e; Assaf, 2006, 2008).

An alternative approach to detect long memory in the financial economics literature is the direct estimation of an autoregressive fractionally integrated moving average model, denoted as ARFIMA (p, d, q), where d is the fractional differencing parameter (for details on fractionally integrated processes, consult the survey paper by Baillie, 1996). Under this approach, a process exhibits long memory when $d \neq 0$, and the sign of d will determine the nature of the process. More specifically, for $d \in (0, 0.5)$, the sum of the autocorrelations diverges to infinity and the ARFIMA process is said to exhibit persistent behavior. On the other hand, the sum of the autocorrelations converges to zero for $d \in (-0.5, 0)$ and the long memory is called anti-persistent. Various procedures have been proposed to estimate this fractional differencing parameter, but the semi-parametric GPH test (Geweke and Porter-Hudak, 1983) and the local Whittle estimator developed by Robinson (1995) remain popular in empirical applications. In another development, the now rapidly expanding interdisciplinary field of *econophysics* has witnessed a resurgence of interest in long memory, but its focus is on the Hurst exponent (H), which is related to the fractional differencing parameter by the equality d

= H – 0.5.[6] Our review of recent stock market studies shows that various methods have been used to extract the Hurst exponent, such as the R/S analysis (Cajueiro and Tabak, 2005c; Batten *et al*., 2008), V/S analysis (Cajueiro and Tabak, 2005e), detrended fluctuation analysis (Oh *et al*., 2008; Serletis *et al*., 2008), detrending moving average (Serletis and Rosenberg, 2009), wavelet analysis (Kyaw *et al*., 2006; Brooks *et al*., 2008) and the generalized Hurst exponent approach (Di Matteo *et al*., 2005).

Unlike the overwhelming support for nonlinear serial dependence, the evidence of significant long memory in stock return series is far from pervasive. Cheung and Lai (1995) and Hiemstra and Jones (1997) extend the analysis of Lo (1991) to 1,952 U.S. common stocks and 18 major stock market indices, respectively. In most cases, however, the modified rescaled range statistic cannot reject the null hypothesis of no long memory at the conventional significance level. Their conclusion is further reinforced by the GPH spectral regression. Other studies with negative evidence include Barkoulas and Baum (1996), Jacobsen (1996), Kilic (2004), Ma *et al*. (2006), Elder and Serletis (2007), Batten *et al*. (2008), Granero *et al*. (2008), Oh *et al*. (2008) and Serletis *et al*. (2008). Using a battery of four different statistical tests, Sadique and Silvapulle (2001) find evidence of long memory in the weekly stock returns for four of their seven sampled markets. Such mixed findings are also reported for stock markets in the Middle East and North Africa region (Assaf, 2006; Maghyereh, 2007), Central Europe (Kasman *et al*., 2008) and major developed countries (Gil-Alana, 2006; Assaf, 2008). Nevertheless, this voluminous literature does contain papers with significant evidence of

[6] Similarly, there is no evidence of temporal dependence between observations widely separated in time if $H = 0.5$. On the other hand, $0.5 < H < 1$ indicates that the series is somewhat persistent, while there is evidence of long memory with anti-persistent behavior if $0 < H < 0.5$. Different tools from statistical physics have been adopted to shed new light on the scaling properties of stock returns (see the survey paper by Di Matteo, 2007).

long memory (see Barkoulas *et al*., 2000; Limam, 2003; Cajueiro and Tabak, 2005e; Christodoulou-Volos and Siokis, 2006; Kyaw *et al*., 2006; Serletis and Rosenberg, 2009). Although not of direct concern to our study, it is worth noting that the long memory effects are more pronounced in stock return volatility, measured by squared and absolute returns (see, for example, Ding *et al*., 1993; Kilic, 2004; Cajueiro and Tabak, 2005e; Assaf, 2006, 2008; Ma *et al*., 2006; Maghyereh, 2007; DiSario *et al*., 2008; Oh *et al*., 2008).

2.2.5 Other statistical contributions

The development of new statistical tests in the econometrics literature has been advancing rapidly, along with their empirical applications. We highlight in this subsection two groups of time series analytic tools yet to be adopted in the extant stock market studies, except by the developers of the tests themselves. First, several test statistics have been proposed for testing whether stock returns are martingale difference sequence (m.d.s.), or equivalently, whether stock prices follow a martingale process (Hinich and Patterson, 1992; Domínguez and Lobato, 2003; Kuan and Lee, 2004; Hong and Lee, 2005; Escanciano and Velasco, 2006a, b). Statistical tests of m.d.s. are designed to capture linear and nonlinear serial dependence in mean, but they do not impose any restrictions on the dynamics in conditional variance and other higher-order conditional moments.[7,8] Second, given that an independently and identically distributed process is time reversible, testing for time reversibility (TR) provides an alternative

[7] A white noise process is not necessarily a martingale difference sequence because it may have a non-zero conditional mean. Examples are the bilinear autoregressive and nonlinear moving average processes which have zero autocorrelation, yet they are not m.d.s. because both processes can be predicted nonlinearly using its own past history.

[8] On the other hand, a random walk with i.i.d. increments (i.e. a pure white noise process) is a martingale process, but a martingale process may not be a random walk. For instance, though the volatility of an ARCH process is time-varying and predictable, it is a martingale difference sequence because the conditional mean is zero.

means to examine the random walk behavior of stock prices.[9] Though suggestion on how to test for time reversibility has been alluded to as early as Brillinger and Rosenblatt (1967), a formal statistical test is developed only three decades later by Ramsey and Rothman (1996). Motivated by this time-domain TR test, Hinich and Rothman (1998) derive its frequency-domain counterpart based on the bispectrum and Lim *et al*. (2008b) generalize the test to the next polyspectral measure using the trispectrum. Chen *et al*. (2000), Chen (2003), Racine and Maasoumi (2007) and Psaradakis (2008) provide additional TR tests to the literature.

2.3 First Empirical Issue: What Factors are Associated with a Higher Degree of Market Efficiency?

Though the bulk of the mainstream weak-form EMH literature focuses on testing the predictability of stock returns using advanced statistical tests, a small number of studies do take the extra step to identify the determinants of market efficiency by means of sub-period analysis. Subsection 2.3.1 provides a brief survey of these single-country sub-period studies, but unfortunately they do not shed much light on the driving forces of market efficiency. The main obstacle is their focus on the all-or-nothing notion of absolute efficiency. Given this shortcoming, Subsection 2.3.2 discusses the merit of relative market efficiency and the existing empirical measures, in particular those related to the weak-form EMH. The final subsection then outlines the issue addressed in Chapter 3 of this thesis.

[9] A time series is time reversible if the probabilistic structure of the series going forward is identical to that in reverse time; otherwise, it is time irreversible.

2.3.1 Sub-period analysis on the determinants of market efficiency

In the wake of the movement toward financial liberalization in developing countries, some researchers explore the issue of whether the opening of these emerging markets to foreign investors has any positive effect, by examining the state of informational efficiency before and after the date of liberalization. This inquiry is even more pertinent after the 1997 Asian financial crisis given that there is much discussion in the policy circles to reverse the previous liberalization measures by imposing some form of capital controls (see Kim and Singal, 2000a, b). The empirical evidence on this subject matter is rather inconclusive. Kim and Singal (2000a, b) and Füss (2005) find that, in general, stock markets become efficient after their policymakers allow the participation of foreign investors. The statistical results in Basu *et al*. (2000) provide weak support to the efficiency benefit of stock market opening. In contrast, Groenewold and Ariff (1998), Kawakatsu and Morey (1999a, b) and Laopodis (2003, 2004) report that their sampled markets are weak-form efficient even before the actual market opening date. Similarly, Maghyereh and Omet (2002) conclude that financial liberalization has no effect on market efficiency, as the Amman Stock Exchange remains inefficient after liberalization.

Other factors considered by previous efficiency studies include the changes in regulatory framework, the adoption of an electronic trading system, the implementation of a price limits system and the occurrence of financial crisis (see references cited in Lim *et al*., 2008c). Lim (2008a) argues that though the efficiency tests are conducted on sub-periods of pre- and post-changes in all the aforementioned empirical studies, their research framework still focuses on testing whether the random walk hypothesis can be rejected in those pre-determined sub-samples. In other words, the stock market under study is expected to undergo a complete transformation from an inefficient state to a perfectly efficient one in the aftermath of the event. Hence, it is not surprising to learn that most of these studies are not able to discern the effect of their postulated factors on market efficiency. This occurs when the adopted statistical tests either reject or cannot reject the null hypothesis of random walk in both sub-periods. Apart from the above shortcoming, the sub-period analysis is also subjected to the following limitations: (1) it does not control other possible confounding factors that might affect market efficiency in the long event window; (2) the analysis is on a country-by-country basis that often does not lead to conclusive evidence; (3) the characterization of market efficiency as a dichotomous zero-one variable precludes the extension from a single-country sub-period study to a broader multi-country investigation via cross-sectional or panel regression.

2.3.2 Absolute market efficiency versus relative market efficiency

Given that the literature is occupied with testing the absolute version of market efficiency, Lim (2008a) highlights the fact that little is known about differences in the degree of efficiency across markets and what characteristics are associated with a higher level of informational efficiency, even after more than four decades of empirical investigations. According to the author, the overwhelming evidence of nonlinear serial dependence across international stock markets suggests that no one market is perfectly efficient. In fact, Campbell *et al*. (1997), Lo and MacKinlay (1999) and Lo (2008) have repeatedly argued that perfect efficiency is an idealization that is unattainable in practice. Citing the work of Grossman and Stiglitz (1980), these three studies point out that if markets are perfectly efficient, there is no profit earned by information gathering, in which case there will be little reason to trade and markets will eventually collapse.[10] Hence, there must be sufficient profit opportunities or inefficiencies to compensate investors for the cost of trading and information gathering. Hence, Campbell *et al*. (1997: 24) offer the notion of relative efficiency, which is the efficiency of one market measured against another, for example the New York Stock Exchange versus the Paris Bourse, futures versus spot markets, or auction versus dealer markets. They argue that this concept is more practical than the all-or-nothing view taken by many of the conventional efficiency studies (see also Lo and MacKinlay, 1999 and Lo, 2008 for similar argument). Lim (2008a) concurs with this view since an empirical measure of relative efficiency will enable the investigator not only to determine whether the degree of informational efficiency varies across countries, but also to further identify the underlying contributing factors.

The merit of this concept has witnessed the emergence of a group of studies that examines market efficiency in the relative rather than absolute sense. The market model *R*-square statistic (Morck *et al*., 2000), the private information trading measure (Llorente *et al*., 2002) and the price delay measure (Hou and Moskowitz, 2005) has inspired extensive studies on stock market efficiency (for descriptions and empirical applications, see Lim and Brooks, 2009b). The first two approaches define relative efficiency as the amount of private firm-specific information being incorporated into stock prices via trading by informed investors, whereas the price delay measure is designed to capture the speed with which stock prices incorporate market-wide information. In the market microstructure literature, the probability of information-based

[10] Slezak (2003) further shows that as long as irrational investors exist and there is a positive cost to becoming fully rational, then irrational agents will persist and their trades will cause predictability in equilibrium. Under these conditions, even perfectly weak-form efficient markets are impossible.

trading (Easley *et al*., 1997) and the pricing errors (Hasbrouck, 1993) are two popular measures of stock price informativeness when high frequency transaction data are available. However, it is difficult to relate some of the above measures to the classic taxonomy of information sets outlined in Fama (1970).

Coming back to the weak-form EMH, the absolute value of the autocorrelation coefficient has been used to gauge how closely the stock price follows a random walk. The justification is that a more efficient price is closer to a random walk benchmark and hence exhibits less autocorrelation in either the positive or negative direction (see, for example, Gu and Finnerty, 2002; Boehmer *et al*., 2005; Alexander and Peterson, 2008; Chordia *et al*., 2008; Boehmer and Kelley, 2009; Boehmer and Wu, 2009).[11] Motivated by the appealing statistical property of the variance ratio statistic, some of these studies also employ its absolute deviation from one (see Gu and Finnerty, 2002; Griffin *et al*., 2007a, 2008b; Chordia *et al*., 2008; Boehmer and Kelley, 2009). This is because the variance ratio can be expressed as one plus a weighted sum of the autocorrelation coefficients for stock returns with positive and declining weights. These autocorrelation-based measures enable the aforementioned studies to examine, in cross-sectional or panel regression framework, the impact on market efficiency brought about by trading volume, return volatility, market liquidity, short sales restrictions, and institutional ownership.

[11] Using Fama's (1970) notion that efficiency implies a lack of return predictability, Chordia *et al*. (2005) examine strong-form EMH by regressing stock returns on lagged market order imbalances. The above approach of using return predictability from past order flows as an inverse measure of market efficiency has been adopted by Aktas *et al*. (2008) and Chordia *et al*. (2008). In this regression framework, the degree of strong-form market efficiency is captured by the lagged imbalance coefficient estimate.

In the literature on long memory of stock returns, several studies utilize the Hurst exponent to quantify the efficiency of stock markets. For instance, Di Matteo *et al*. (2005) discover there is a tendency for mature liquid markets to have values of the generalized Hurst exponent smaller than 0.5, whereas less developed markets have values greater than 0.5. Cajueiro and Tabak (2008a) rank country stock indices by means of the Hurst exponent and find that developed markets in general are more efficient than their emerging market counterparts. Using stock indices, Eom *et al*. (2008 a, c) document a strong positive relationship between the Hurst exponent and the hit rate from the nearest-neighbor prediction method, suggesting that lower degree of efficiency corresponds to greater predictability of future price changes. Cajueiro and Tabak (2005a), Brooks *et al*. (2008) and Lim (2008b) explore the factors that account for the cross-sectional variation in their estimated Hurst exponents. Zunino *et al*. (2008) employ the multifractal detrended fluctuation analysis to evaluate the multifractality degree of 32 stock markets. These authors then find robust evidence of a negative relationship between multifractality and the stage of market development by means of a binary dependent variable model. Other advanced tools from statistical physics that have been adopted for quantifying the degree of market efficiency are the approximate entropy statistic (see Oh *et al*., 2007; Eom *et al*., 2008b, c) and the Shannon entropy statistic (Risso, 2009).

2.3.3 How does Chapter 3 address the first empirical issue?

It is widely acknowledged in the literature that daily returns on stock market indices exhibit positive autocorrelations (see Ahn *et al*., 2002). However, the source of these serial correlation patterns is still very much been debated, in particular its implications on market efficiency. Boudoukh *et al*. (1994) categorize the prevailing views into three schools of thought. The first school, the loyalists, believes markets rationally process information and the existence of return autocorrelations is due to thin trading (Lo and MacKinlay, 1988, 1990a), frictions in the trading process (Cohen *et al*., 1980) and transaction costs (Mech, 1993) that cannot not be profitably exploited. Revisionists, on the other hand, defend market efficiency on the basis that return autocorrelations may reflect time-varying equilibrium expected returns generated by rational investor behavior which can be explained in the framework of intertemporal asset pricing models (for discussion, see Fama, 1991). Heretics, the third school, believe that markets are not rational and profitable trading strategies do exist even on a risk-adjusted basis. For instance, several existing behavioral models demonstrate that psychological biases like overconfidence, self-attribution and conservatism can explain why investors under- or over-react to information, hence generating positive return autocorrelations over short horizons (see, for example, Barberis *et al*., 1998; Daniel *et al*., 1998; Hong and Stein, 1999).

Despite the ongoing controversy, a more relevant issue here is whether the above schools of thought offer any empirically observable proxies for the source of return autocorrelations. The answer is an emphatic no. This is evidenced from the approaches taken by existing empirical studies to disentangle the three competing hypotheses (see Ogden, 1997; Ahn *et al*., 2002; Anderson *et al*., 2008). Fortunately, a number of extant theoretical models do make predictions about the determinants of return autocorrelations, which include the volatility of stock returns (Sentana and Wadhwani, 1992), trading volume (Campbell *et al*., 1993) and trade openness (Basu and Morey, 2005). Empirically, Gu and Finnerty (2002) employ the absolute values of the autocorrelation coefficient and variance ratio minus one to track the changing degree of market efficiency for the Dow Jones Industrial Average over 103 years from 1896 to 1998. In general, the magnitude of annual autocorrelation exhibits a downward trend since the late 1970s. Their subsequent regression analysis shows that the degree of weak-form efficiency is negatively related to return volatility and trading volume.

Following Gu and Finnerty (2002), Chapter 3 further explores the factors that are associated with a higher degree of informational efficiency. The absolute value of the variance ratio minus one is selected as the metric of relative weak-form market efficiency because its determinants are very well grounded theoretically. However, the empirical analysis in Chapter 3 differs from Gu and Finnerty (2002) in at least three aspects. First, instead of a single country, the annual data are drawn from 23 developing countries over the sample period from 1992 to 2006. Second, fixed effects panel regression is utilized to explain not only the variations of index return autocorrelations across countries but also over time. Third, apart from return volatility and trading volume, Chapter 3 brings the untested propositions of Basu and Morey (2005) to the data, examining the impact of both trade and financial openness on the weak-form efficiency of stock markets.

2.4 Second Empirical Issue: Does Market Efficiency Evolve over Time? Why?

The use of sub-period analysis in the mainstream weak-form EMH literature clearly demonstrates the awareness of researchers regarding the non-static characteristic of market efficiency. The possibility that market efficiency does evolve over time is best described by Self and Mathur (2006: 3154), who write: "*The true underlying market structure of asset prices is still unknown. However, we do know that, for a period of* *time, it behaves according to the classical definition of an efficient market; then, for a period, it behaves in such a way that researchers are able to systematically find anomalies to the behavior expected of an efficient market.*". In this regard, the characteristics of the market microstructure, limits to arbitrage, psychological biases, noise trading and the existence of market imperfections are those potential factors that can give rise to periods of departure from market efficiency. At the macro level, it is not unreasonable to expect market efficiency to evolve over time due to changes in macro institutions, market regulations and information technologies. To accommodate the changing degree of market efficiency over time, Lo (2004, 2005) proposes a new version of the EMH derived from evolutionary principles. Our discussion on the adaptive markets hypothesis (AMH) in Subsection 2.4.1 borrows heavily from Lo (2004, 2005). Following that, we survey an emerging group of literature that reports evidence of evolving market efficiency by means of a time-varying parameter model or rolling sub-samples. Lim and Brooks (2009c) highlight these somewhat neglected efficiency studies and relate the observed market dynamics to the AMH. Finally, Subsection 2.4.3 outlines the issue addressed in Chapter 4 of this thesis.

2.4.1 The adaptive markets hypothesis (AMH)

With the issue of rationality in human behavior at the heart of the controversy between the opposing camps of EMH and behavioral finance, Lo (2004, 2005) argues that valuable insights can be derived from the biological perspective and calls for an evolutionary alternative to market efficiency. More specifically, Lo (2004, 2005) proposes the new paradigm of adaptive markets hypothesis (AMH) in which the EMH can co-exist along behavioral finance in an intellectually consistent manner. The AMH has taken years to formulate since the idea of viewing financial markets from a biological perspective is singled out by Farmer and Lo (1999) as one of the frontiers of research in finance. This evolutionary idea has been followed up by Lo (1999, 2002) and Farmer (2002), before it is formalized in Lo (2004) as the AMH and further elaborated in Lo (2005). It is interesting to note that the ideas underlying the AMH have been inspired by several bodies of literature: bounded rationality in economics, complex systems, evolutionary biology, evolutionary psychology and behavioral ecology. Though evolutionary economics is now an established branch in economics after the seminal work of Nelson and Winter (1982), the applications of evolutionary concepts in the financial contexts are limited. The AMH is a major breakthrough that offers not only reconciliation to the current controversy in finance, but also concrete implications to the practice of investment management.

By coupling Simon's (1955) notion of bounded rationality and 'satisficing' with evolutionary dynamics, Lo (2004) argues that many of behavioral biases are in fact consistent with an evolutionary model of individuals learning and adapting to a changing environment via 'satisficing' heuristics. On the other hand, it is the impact of evolutionary forces on financial institutions and market participants that determines the efficiency of markets, and the performance of investment products, businesses and industries. Briefly, the precepts that guide the AMH as outlined in Lo (2005) are: (1) individuals act in their own self-interest; (2) individuals make mistakes; (3) individuals learn and adapt; (4) competition drives adaptation and innovation; (5) natural selection shapes market ecology; (6) evolution determines market dynamics. Despite its rather abstract and qualitative nature, the AMH offers a number of practical implications for portfolio management. Firstly, the equity risk premium varies over time according to the recent stock market environment and the demographics of investors in that environment.

Secondly, arbitrage opportunities do arise in the financial markets from time to time. Thirdly, investment products undergo cycles of superior and inferior performance in response to changing business conditions, the adaptability of investors, the number of competitors in the industry and the magnitude of profit opportunities available. Finally, survival is ultimately the only objective that matters for the evolution of markets and financial technologies.

With regards to the present context of evolving market efficiency, the second implication deserves further elaboration. Based on the evolutionary perspective, profit opportunities do exist from time to time. Though they disappear after being exploited by investors, new opportunities are continually being created as groups of market participants, institutions and business conditions change. This is consistent with the conjecture of Grossman and Stiglitz (1980) that sufficient profit opportunities must exist to compensate investors for the cost of trading and information gathering. In fact, Daniel and Titman (1999) have earlier highlighted the possible co-existence of EMH and behavioral finance by introducing the term 'adaptive efficiency'. These authors recognize the behavioral biases of most market participants but at the same time assume that other investors exist who can detect and profit from these biases by examining past price trends. More specifically, in a market that is adaptively efficient, profit opportunities do arise in historical data, but if investors learn from the past price history, these profit opportunities will gradually erode through time.[12]

[12] In the forecasting literature, temporary forecastability (Timmermann and Granger, 2004) and temporary market inefficiencies (Park and Irwin, 2007) are two leading explanations given for the counterintuitive positive forecasting results of technical trading rules during certain time periods.

A corollary of this implication is that market efficiency is not an all-or-none condition but is a characteristic that varies continuously over time and across markets. Lo (2005) argues that convergence to equilibrium, which is central to the EMH, is neither guaranteed nor likely to occur at any point in time. As such, it is incorrect to assume that the market must march inexorably toward some ideal equilibrium state or perfect efficiency.[13] Instead, the AMH implies more complex market dynamics, such as cycles, trends, bubbles, crashes, manias and other phenomena that occur in the financial markets. Lo (2004, 2005) offers a concrete example by computing the rolling first-order autocorrelation for monthly returns of the Standard & Poor's (S&P) Composite Index from January 1871 to April 2003. His graphical plot reveals the degree of efficiency, measured by the first-order autocorrelation coefficient, varies through time in a cyclical fashion with surprising result that the U.S. market is more efficient in the 1950s than in the early 1990s. The author claims that this finding is due to institutional changes in the stock market as well as the entry and exit of various market participants. Both studies do acknowledge that such cycles are not ruled out by the EMH in theory, but existing empirical implementation assumes markets are perpetually in equilibrium.

2.4.2 Empirical evidence of evolving market efficiency

Emerson *et al*. (1997) represents the first stock market study that applies a time-varying parameter model, estimated using the Kalman filter technique, to track the evolution of market efficiency over time. In their model, the time-varying autocorrelation coefficients are used to gauge the changing degree of return predictability, and hence evolving weak-form market efficiency. If the market under study becomes more

[13] As cited by Lo (2005), even a prominent practitioner like Bernstein (1999) has pointed out that the notion of equilibrium is rarely realized in practice. Instead, Bernstein (1999) suggests market dynamics are better characterized by evolutionary processes.

efficient over time, the smoothed time-varying estimates of the autocorrelation coefficient will gradually converge toward zero and become insignificant. This framework is later formalized by Zalewska-Mitura and Hall (1999) as 'test for evolving efficiency' (TEE). Since the emerging markets in Bulgaria and Hungary are still in the early stages of their development, Emerson *et al*. (1997) and Zalewska-Mitura and Hall (1999) argue that it is not sensible to address the issue of whether the stock markets in these transition economies are efficient or not. Indeed, it is hardly credible for newly established stock exchanges to be born efficient since it takes time for the price discovery process to become known. However, as market microstructures develop, within a finite amount of time, the level of efficiency in these infant markets will gradually improve. Hence, it is more relevant to examine whether they are becoming more efficient, but such an investigation cannot be conducted using those conventional weak-form EMH tests which assume a fixed level of market efficiency throughout the entire estimation period. This scenario requires a more dynamic framework and the time-varying parameter model emerges as a logical choice. Using their proposed test for evolving efficiency, the above two studies are able to depict the time paths taken by their sampled stock markets toward a higher level of efficiency.

The test for evolving efficiency is subsequently adopted to track the evolving efficiency of other stock markets in the Central and Eastern European transition economies that have just emerged out of the former communist bloc (see, for example, Zalewska-Mitura and Hall, 2000; Rockinger and Urga, 2000, 2001; Schotman and Zalewska, 2006). Rockinger and Urga (2000) argue that this approach appears to be the only way since there is no observable variable for emerging markets that can be used to quantify the improvement in informational efficiency. Hence, it is not surprising that the TEE literature has expanded to include stock markets in Africa (Jefferis and Smith, 2004, 2005), China (Li, 2003a, b), Jordan (Maghyereh, 2005), and the high-technology stocks in Europe (Pierdzioch and Schertler, 2007). In a parallel development, Kvedaras and Basdevant (2004) develop a time-varying variance ratio statistic, and subsequently apply the methodology to track the changing degree of stock market efficiency in Estonia, Latvia and Lithuania. Though all the aforementioned studies focus on emerging markets, Ito and Sugiyama (2009) report that even the developed U.S. stock market exhibits varying degrees of market efficiency from 1955 to 2006.

Another group of studies applies existing weak-form EMH tests in rolling sub-samples.[14,15] This approach captures the persistence of stock price deviations from a random walk benchmark over time in terms of: (1) linear serial correlations, using the rolling variance ratio test (Tabak, 2003; Kim and Shamsuddin, 2008); (2) unit root, by means of the rolling ADF unit root test (Phengpis, 2006); (3) nonlinear serial dependence, adopting the rolling bicorrelation test (Lim, 2007; Todea and Zoicas-Ienciu, 2008); (4) long memory, using the rolling Hurst exponent (Costa and Vasconcelos, 2003; Cajueiro and Tabak, 2004c, 2005d, 2006, 2008b; Zunino *et al.*, 2007); (5) the relative amount of non-redundant information via the rolling Lempel-Ziv complexity index (Giglio *et al.*, 2008) and the rolling Shannon entropy statistic (Risso, 2008). This flexible framework allows an investigator to: (1) assess the relative

[14] It is worth highlighting that the recursive estimation strategy has also been adopted to determine the persistence of deviations from a random walk, but it is relatively less popular (see de Lima, 1998; Self and Mathur, 2006). Perhaps, this is because the recursive technique does not differentiate whether the time-varying test statistics are due to a change in the underlying process or an increase in the power of the test arising from adding observations recursively.

[15] Timmermann (2008) notes that incomplete learning effects, structural changes in the return generating process and exogenous events can cause return predictability to evolve over time. The author proposes an adaptive forecast combination approach which employs rolling windows to estimate the model parameters and select the forecasting model. Using the U.S. stock returns as an illustration, the proposed approach is able to identify relatively short-lived periods with return predictability. His findings suggest that though stock returns are not predictable most of the time, there are episodes of local predictability.

efficiency of international stock markets by comparing the degree of stock price deviations from a random walk over the sample period under study (Cajueiro and Tabak, 2004a, b, 2005b; Lim, 2007; Giglio *et al*., 2008); (2) examine the impact of some postulated factors on the degree of market efficiency, such as the occurrence of financial crisis (Cheong *et al*., 2007; Lim, 2008c; Lim *et al*., 2008c) and the implementation of price limits system (Lim and Brooks, 2009d); (3) identify those events that are associated with periods of market inefficiency (Costa and Vasconcelos, 2003; Alvarez-Ramirez *et al*., 2008; Grech and Pamuła, 2008; Kim and Shamsuddin, 2008; Cajueiro *et al*., 2009); (4) determine the profitability of technical trading rules (Self and Mathur, 2006).

2.4.3 What additional light does Chapter 4 shed?

The previous findings of evolving market efficiency can be rationalized within the framework of adaptive markets hypothesis, though most of the empirical studies are published before the formulation of this new version of EMH.[16] Given that the rolling window approach reveals how often the random walk hypothesis is rejected by the test statistic over the full sample period, the percentage of sub-samples with a significant test statistic can be used to compare the relative efficiency of those sampled stock markets. Under this approach, a higher percentage indicates more persistent deviations from a random walk over the sample period, hence a lower degree of informational efficiency. Chapter 4 of this thesis adopts the rolling bicorrelation test advocated by Lim (2007) and extends his sample to a broad cross-section of stock markets in 50 countries. Our

[16] Several studies in the profitability literature examine the stability of technical trading profits over time, and it is generally found that the positive excess returns identified in the 1970s and 1980s have declined substantially in the mid-1990s (see Menkhoff and Taylor 2007; Park and Irwin, 2007; Neely *et al*., 2009). Neely *et al*. (2009) argue that profit opportunities do exist in financial markets, but these profits will erode through time as investors learn and compete to take advantage of them. The author further notes that these regularities are consistent with the AMH.

empirical investigation, however, does not merely compare the relative efficiency of international stock markets. Instead, we further explore the factors that are responsible for the cross-country variation in the degree of stock price deviations from a random walk over time.

The motivations for our inquiry are at least twofold. First, the widely cited paper by Morck *et al*. (2000) finds that stock prices move together more in poor economies (emerging markets) than in rich economies (developed markets). Their stock price synchronicity measure, in particular the average market model *R*-square statistic, has inspired extensive studies on stock market efficiency (for a survey, see Lim and Brooks, 2009b). Morck *et al*. (2000) argue that their synchronicity measure is inversely related to the amount of firm-specific information being incorporated into stock prices, where more firm-specific information corresponds to a lower market model *R*-square, and hence a higher degree of informational efficiency. Apart from comparing the degree of country-level market efficiency, this group of studies further explores the underlying determinants for the cross-country differences in stock price co-movement. Those identified significant factors include the degree of private property rights protection (Morck *et al*., 2000), public investor protection (Morck *et al*., 2000), stock market liberalization (Li *et al*., 2004), corporate transparency (Jin and Myers, 2006), securities laws (Daouk *et al*., 2006), short sales restrictions (Bris *et al*., 2007) and insider trading laws (Beny, 2007; Fernandes and Ferreira, 2009). In a similar vein, it would be interesting to determine whether country characteristics, in particular the quality of macro institutions, are driving the cross-country variation in the degree of stock price deviations from a random walk over time. The results will provide useful inputs to policymakers in designing the appropriate macro framework in order to ensure their stock markets are macro-efficient (see Jung and Shiller, 2005).

Second, the wave of financial liberalization not only opens up more opportunities for global cross-border portfolio investments, but also inspires more academic studies on the stock markets from a broader international perspective. More specifically, there is an increasing number of stock market studies that explore the determining factors for cross-country differences in the development of domestic stock market (Claessens *et al*., 2006; Li, 2007), internationalization of stock exchange activity (Claessens *et al*., 2006), stock price synchronicity (Morck *et al*., 2000; Jin and Myers, 2006), equity trading cost (Eleswarapu and Venkataraman, 2006), stock return-trading volume relation (Griffin *et al*., 2007b), high volume return premium (Kaniel *et al*., 2007), equity premium (Aggarwal and Goodell, 2008), co-movement in stock returns, liquidity and trading activity (Karolyi *et al*., 2007), stock market reaction to earnings announcements (DeFond *et al*., 2007; Griffin *et al*., 2008a), the degree of stock market integration (Carrieri *et al*., 2007) and stock market segmentation (Bekaert *et al*., 2008). Chapter 4 takes up one important issue yet to be addressed in extant cross-country studies, i.e. the degree of stock price deviations from a random walk over time.

2.5 Third Empirical Issue: Can the Existence of Temporal Dependence be Associated with News Events?

If the existence of serial dependence in the return series reflects investors' mis-reaction to information, it would be interesting to examine whether their presence coincides with days in which market-moving public news is announced. This is the issue pursued in Chapter 5 using intraday price data from the Malaysian stock market and news announcements in the media. The present section briefly discusses the related literature that motivates our investigation.

2.5.1 Event study versus event detection

The standard tool in the finance literature to assess the market's speed of price adjustment to information releases is the event study pioneered by Fama *et al*. (1969). This strand of literature focuses on testing the main implication of the efficient markets hypothesis that it is not possible for investors to derive positive abnormal rates of return by investing after the release of public information. More specifically, the methodology tests whether the abnormal returns, computed by subtracting expected normal returns from the actual returns, are significantly different from zero during the time of the event window (for a review of the event study methodology, see Armitage, 1995; MacKinlay, 1997; Binder, 1998). In a typical event study, the specific event of interest (such as news announcement related to earnings, stock splits, mergers and acquisitions or dividend disclosures) is selected *a priori*.

An alternative approach is to let the data first detect any abnormal trading behavior and then identify the associated news events. For instance, Cutler *et al*. (1989) select the 50 largest absolute one-day percentage changes in the S&P Composite Index from 1946 through 1987, and subsequently review coincident news reports in the *New York Times* to identify the proximate causes of these large price movements. Fair (2002) utilizes tick data on the S&P 500 Stock Index futures contract and four news providers (*Dow Jones News Service*, *Associated Press Newswire*, *New York Times* and *Wall Street Journal*) to match events to large 1- to 5-minute stock price changes. Kaminsky and Schmukler (1999) examine whether the 20 largest 1-day price changes for each of the nine Asian stock markets during the 1997 financial crisis can be explained by any economic or political news. The above procedure of matching big news to big price moves is common in the literature, applying to other asset markets such as bond, currency and futures (see Haugen *et al*., 1991; Fleming and Remolona, 1997; Andersen and Bollerslev, 1998; Bollerslev *et al*., 2000; Cai *et al*., 2001; Ahn *et al*., 2002; Fong and Koh, 2002; Fair, 2003).[17] However, the aforementioned studies are not directly related to market efficiency because large price changes per se do not shed light on the speed of stock price adjustment to new information.

2.5.2 Daily temporal dependence and news events

Nawrocki (1996) hypothesizes that economic events are important in generating temporal dependence in the stock market data. To test his hypothesis, the author follows the standard event study approach in terms of selecting those major events in advance, i.e. the U.S. President Nixon's announcement of wage-price controls on 15/8/1971, the Arab oil embargo against the U.S. on 17/10/1973, and the stock market crash on 19/10/1987. Subsequently, he computes the daily cross-sectional autocorrelation coefficients using a random selection of 125 stocks from the New York Stock Exchange, which capture the day-to-day changes in time series dependence. His results show that, after President Nixon's announcement on Sunday, the cross-sectional serial correlation for the next trading day is statistically significant. Since the other two major announcements are released to the media on a trading day, both events result in significant autocorrelation coefficient on the day they are publicly announced.

[17] This approach of event detection has also been adopted to determine whether the occurrences of structural breaks (see Andreou and Ghysels, 2002; Bekaert *et al*., 2002) and volatility spillovers (see Diebold and Yilmaz, 2008, 2009) are linked to public news releases.

Another group of literature instead adopts an event detection approach to identify those news events that occur on the days their sampled return series exhibit significant nonlinear serial dependence. These studies conjecture that return nonlinearities arise because investors are unsure of how to react when surprises hit the market, and hence they respond sluggishly. Lim *et al*. (2008a) first split the daily data of ten emerging Asian stock markets into equal-length non-overlapped time windows of 50 observations, followed by the application of the Hinich (1996) bicorrelation test to detect nonlinearity in each sub-period. Using the chronology of important financial, economic and political events in emerging markets provided by Geert Bekaert and Campbell Harvey, the matching procedure shows that most of the sub-periods with significant nonlinearity coincide with at least one event listed in the chronology. Romero-Meza *et al*. (2007), Lim (2008d) and Lim *et al*. (2009) adopt similar approach to identify those events that are responsible for the transient burst of significant nonlinear dependence in the stock index return series from Chile, Malaysia and China, respectively. The limitation with the above studies is that the time window often stretches more than five trading weeks, making it difficult to pinpoint the exact event that accounts for the detected nonlinear stock price behavior. To address this shortcoming, Lim *et al*. (2006) utilize intraday data at ten-minute intervals to compute the bicorrelation test statistic for each trading day. This shorter time window enables the authors to identify those daily news stories that are reported on days which their Malaysian intraday return series exhibit a significant bicorrelation test statistic.

2.5.3 Issue addressed in Chapter 5 of this thesis

Chapter 5 follows the framework set out by Lim *et al*. (2006), but computes the daily variance ratio test statistic instead of the bicorrelation statistic using minute-by-minute data from the Malaysian stock market. The main reason behind our choice is that the variance ratio statistic has a long tradition in empirical market microstructure studies. More specifically, a body of literature analyzes trading to non-trading return variance ratio in order to shed new light on the link between information flows and the asset price formation process. For instance, French and Roll (1986) compute per hour open-to-close and close-to-open return variance ratio and find that stock prices are more volatile during exchange trading hours than during non-trading hours. The authors attribute this phenomenon mainly to greater private information being produced during normal business hours (for corroborative evidence, see Barclay *et al*., 1990; Ito *et al*., 1998; Chordia *et al*., 2008). However, other studies using a similar methodology suggest the contrary, where public information releases emerge as the major source of short-term return volatility (see Harvey and Huang, 1991; Jones *et al*., 1994; Fleming *et al*., 2006).[18] It is worth mentioning that the open-to-close/close-to-open variance ratio focuses on the behavior of short-term volatility, which is conceptually distinct from the short- versus long-horizon variance ratio statistic for testing serial uncorrelatedness. In other words, the aforementioned studies examine the news-volatility relation, while our framework addresses the news-serial correlation link. The closest to our work is Ederington and Lee (1993, 1995) who examine the speed of adjustment to news releases

[18] In order to yield reliable statistical inference for this open-to-close/close-to-open variance ratio, Ronen (1997) proposes a joint testing procedure and George *et al*. (2008) suggest further refinement to this joint test via bootstrapping. However, for those papers like Ito *et al*. (1998) that examine changes in the intraday return volatility patterns using variance ratio, Andersen *et al*. (2001) develop a robust framework for high frequency data characterized by highly persistent conditional heteroskedasticity.

by comparing the serial correlation of consecutive intraday price changes during announcement and non-announcement periods.

Since news stories are reported daily in the Malaysian media, we compute the variance ratio statistic for each trading day using minute-by-minute stock returns. With the availability of high frequency stock price data, there is an increasing number of papers that take a microscopic view of time series dependence by estimating autocorrelations in intraday return series (recent studies include Tsutsui *et al*., 2007; Alexander and Peterson, 2008; Chordia *et al*., 2008; Boehmer and Kelley, 2009; Boehmer and Wu, 2009). However, computing daily autocorrelation coefficients or variance ratios from intraday data is relatively rare but not something new.[19] For instance, Wood *et al*. (1985) estimate autocorrelation coefficients from lags one to twenty minutes for each trading day, and then compute the percentage of days for which the *t*-statistics for the correlation coefficients are significant at the 5% level. With 495 1-minute return data available for each trading day, Bianco and Renò (2006) construct a time series of 751 daily variance ratios, and then examine whether these variance ratios are associated with measures of daily volatility and trading volume. Their regression results show that the serial correlation of intraday returns is positively and significantly related to both variables in the Italian stock index futures market. The same framework has been adopted by Bianco and Renò (2009), who also find a positive relationship between daily variance ratio and total volatility using data from S&P 500 Stock Index futures. In Chapter 5, we apply the wild bootstrapped automatic variance ratio test recently proposed by Kim (2009) to 1-minute return series from the Malaysian stock market on

[19] In sharp contrast, the literature on realized volatility is voluminous in which high-frequency intraday data are used to estimate daily volatility (see the survey paper by McAleer and Medeiros, 2008).

each separate trading day. Subsequently, for those days with significant return autocorrelations, we proceed to determine whether they are associated with major news stories in the media. This investigation will help to identify those market-wide news headlines which Malaysian stock investors mis-react.

2.6 Conclusion

This chapter brings together four strands of literature that have developed separately. The first group, which is by far the largest, focuses on testing whether stock returns are predictable from their past history of price changes. Numerous statistical tests have been developed, refined and applied to detect different types of deviations from a random walk such as linear serial correlations, unit root, nonlinear serial dependence and long memory. The empirical work to date in this mainstream weak-form EMH literature is largely concerned with absolute market efficiency which might be of great interest to the investment communities, but has less direct bearing on policymakers who strive to ensure their respective stock market performs its informational role efficiently. This shortcoming has prompted a large number of papers to examine market efficiency in its relative rather than absolute sense. Indeed, it has been proven to be a fruitful strategy, as these empirical studies not only identify those factors that foster greater informational efficiency, but they also show that stock market is not an economic sideshow. The third group of papers we survey challenges the notion of perpetual equilibrium assumed by mainstream weak-form EMH studies. To relax this assumption, the time-varying parameter model and rolling window approach are employed for tracking the evolution of market efficiency over time. An encouraging development is that the documented market dynamics find their theoretical foundation in the adaptive markets hypothesis.

The final group which consists of only a small number of papers infers the speed of price adjustment to news releases from the serial dependence of consecutive price changes.

The three empirical chapters in this thesis utilize existing weak-form EMH tests to address issues central to the final three groups of literature we survey. Firstly, previous empirical studies in the relative efficiency literature, using market model *R*-square statistic and the price delay measure, have identified a number of factors that foster greater informational efficiency. Chapter 3 shows that similar insight can be derived from the absolute value of the variance ratio minus one. In fact, it is more appealing because the determinants are well grounded in extant theoretical models. Secondly, Chapter 4 demonstrates that the above investigative analysis can also be conducted within the evolving efficiency literature. Using the rolling bicorrelation test, Chapter 4 not only assesses the relative efficiency of international stock markets, but further explores the factors responsible for the documented cross-country variation in the degree of stock price deviations from a random walk over time. Finally, Chapter 5 employs the variance ratio statistic to infer the speed of information incorporation, but adopts an event detection approach. More specifically, instead of examining the speed of adjustment to selected news events, we identify those public news stories that trigger investors' under- or over-reaction.

Though the implication of return serial correlations on market efficiency is still an unresolved controversy in the literature (see Boudoukh *et al.,* 1994), academics can largely agree that the four strands of literature surveyed in this chapter have improved our understanding of stock price behavior. Amid mounting evidence of return predictability, Fama (1991) still defends the EMH, arguing that these findings might reflect rational time-varying expected returns or could be the result of data-dredging and chance sample-specific conditions. However, knowing that there will be dissenting views, he writes: "*Still, even if we disagree on the market efficiency implications of the new results on return predictability, I think we can agree that the tests enrich our knowledge of the behavior of returns, across securities and through time.*" (pp. 1577). In a similar spirit, even if one disagrees on the informational efficiency interpretation of independence of successive price changes, at the very least, this thesis sheds additional light on the factors that give rise to serial dependence in stock return series.

DECLARATION FOR THESIS CHAPTER 3

Declaration by Candidate

In the case of Chapter 3, the nature and extent of my contribution to the work was the following:

Nature of contribution	**Extent of contribution (%)**
The initiation of idea, formulation of research questions, development of research framework, literature review, construction of cross-country database, data analysis (except variance ratio estimation) and interpretation, and writing up of the first draft.	75%

The following co-author contributed to the work:

Name	**Nature of contribution**
Jae H. Kim	Participated in the discussions on econometric issues, estimation of automatic variance ratio statistic, refining the draft paper, and acted as corresponding author in previous journal submission.

Candidate's Signature		**Date** **June 8, 2009**

Declaration by Co-author

The undersigned hereby certify that:

(1) the above declaration correctly reflects the nature and extent of the candidate's contribution to this work, and the nature of the contribution of each of the co-authors;

(2) they meet the criteria for authorship in that they have participated in the conception, execution, or interpretation, of at least that part of the publication in their field of expertise;

(3) they take public responsibility for their part of the publication, except for the responsible author who accepts overall responsibility for the publication;

(4) there are no other authors of the publication according to these criteria;

(5) potential conflicts of interest have been disclosed to (a) granting bodies, (b) the editor or publisher of journals or other publications, and (c) the head of the responsible academic unit; and

(6) the original data are stored at the following location(s) and will be held for at least five years from the date indicated below:

Location	**Department of Econometrics and Business Statistics,** **Monash University**

Co-author's Signature:

Jae H. Kim		**Date** **June 8, 2009**

CHAPTER 3

Trade Openness and the Informational Efficiency of Emerging Stock Markets★

3.1 Introduction

In this era of globalization, many of the world economies are becoming more open to international trade. For instance, in the database compiled by Wacziarg and Welch (2008), 25% of the 141 sampled countries had liberalized trade by the end of the 1970s. In the subsequent decade, another 21 economies initiated legal trade policy reforms. The 1990s witnessed the strongest wave of trade liberalization, with an additional 47 countries joining the long list of open economies. Only 35 countries remained closed as of 2001, which was the end of their sample period. Trade volume as a share of gross domestic product (GDP) has also grown sharply over the past three decades, especially for developing economies that were largely closed before 1970. This is evidenced by their 141% increase in the total trade/GDP ratio over the period of 1975-2005.[1] These phenomena have contributed to a huge body of literature that analyzes the effects of trade openness, especially its impact on the economic performance of developing countries (for a survey, see Winters, 2004; Santos-Paulino, 2005). Although the scope of research in recent years has moved beyond the goods market to the financial sector (see,

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[1] Emerging stock markets are defined by the Standard and Poor's Emerging Markets Database (EMDB) to consist of stock markets in the developing countries, i.e. low- and middle-income economies.

for example, Braun and Raddatz, 2007, 2008; Do and Levchenko, 2007; Baltagi *et al*., 2009), only two studies (i.e. Li *et al*., 2004; Basu and Morey, 2005) explicitly examine the association between trade liberalization and stock market informational efficiency in developing countries.[2]

On the theoretical front, Basu and Morey (2005) develop an asset pricing model with a non-trivial production sector to explore the effect of trade openness on the autocorrelation patterns of stock returns.[3] Their model shows that the opening of trade in the form of removing non-tariff barriers to the import of foreign intermediate inputs is crucial to the informational efficiency of stock market, where stock prices should eventually follow a random walk after trade liberalization. More specifically, in a closed economy with a binding constraint on the availability of intermediate inputs, the home country's production technology is subjected to diminishing returns to scale. Since a financial asset represents an ownership claim to the capital stock in the economy, the observed behavior of asset prices should also reflect the same diminishing returns property of the capital stock. A testable proposition resulting from the theoretical model of Basu and Morey (2005) is that the stock return autocorrelations are non-zero in a closed economy, with values that range from negative to positive numbers depending on

[2] Nevertheless, the studies by Li *et al*. (2004) and Basu and Morey (2005) measure different aspects of informational efficiency. The former employ the market model *R*-square statistic to infer the amount of firm-specific information being impounded into individual stock prices, whereas the latter utilize the variance ratio and unit root tests to examine the uncorrelatedness of past price changes. Using Fama's (1970) taxonomy of information sets, Basu and Morey (2005) consider the weak-form efficiency which is the focus of our Chapter 3, whereas the closest category for Li *et al*. (2004) would be the semi-strong-form as the information being considered is wider than past price changes.

[3] The connection between the stock market and real sector activity is not something new to the literature. Fama (1990) and Schwert (1990), for instance, find that current stock returns are highly correlated with future production growth rates, indicating that information about future cash flows is impounded in stock prices. Following the pioneering work of Brock (1982), a number of studies develop a class of asset pricing models which integrate production with the financial sector of the economy (for a discussion of the existing literature on production-based asset pricing models, see Cochrane, 2008a). On the other hand, the nexus between stock prices and productivity growth has also been explored in recent years by Beaudry and Portier (2005, 2006), Madsen and Davis (2006), and Davis and Madsen (2008).

the degree of risk aversion and production technology.[4] However, when trade barriers are removed, the level of imported intermediate inputs grows on par with the capital stock. Consequently, the return to capital does not fall as the economy grows and hence the growth process becomes self-sustaining. Building on the theoretical linkage between production technology and asset prices, Basu and Morey (2005) then show how the technological gain from trade openness gets transmitted to the equilibrium stock prices, generating an empirically testable proposition that the stock returns exhibit zero serial correlation in an open economy. Their theoretical model further shows that financial opening alone, that is, without trade reform, does not lead to an improvement in the informational efficiency of stock market.

After formulating their theoretical model, Basu and Morey (2005) bring their proposition to the data by using the trade liberalization dates compiled by Sachs and Warner (1995) and two statistical tests, variance ratio and unit root tests. Subject to the availability of stock return data, the authors examine the efficiency of nine markets during the period in which their economies were closed to trade. The results of both statistical tests show that the stock prices generally behave as a random walk in these pre-trade liberalization periods, which is inconsistent with their model prediction. This random walk behavior continues to hold during the post-liberalization periods, for which the authors apply the same variance ratio and unit root tests to the stock return data of 24 markets. Basu and Morey (2005) give two explanations for their unexpected finding that those sampled markets are efficient even before trade liberalization: (1) the

[4] The roles of risk aversion and technological returns to scale in determining the autocorrelation patterns of aggregate stock returns have been rigorously analyzed in the theoretical model of Basu and Vinod (1994). Other production-based asset pricing models that also address the time series behavior of stock returns include Balvers *et al*. (1990), Basu (1990, 1993), Cecchetti *et al*. (1990) and Basu and Samanta (2001).

statistical tests employed are of low power and hence are unable to test reliably for the random walk hypothesis in the pre-liberalization period; and (2) the actual effects of trade liberalization may arrive well before the official trade liberalization dates, as traders may become aware of a country's commitment to open trade in advance of its announcement of such a commitment.

In addition to the shortcomings highlighted by Basu and Morey (2005), there are other, more pertinent problems. First, although Sachs and Warner's (1995) trade liberalization dates allow researchers to gauge the differing effects of trade policy reforms on the degree of informational efficiency in each individual country, data availability renders it difficult to conduct a proper event study analysis.[5] Second, even in those countries for which stock data are available for the pre- and post-event windows, the changes in the return autocorrelations cannot be attributed solely to the official removal of trade restrictions. The existing literature also provides a number of theoretical models that make predictions about the determinants of return autocorrelations, such as the volatility of market returns (Sentana and Wadhwani, 1992) and trading volume (Campbell *et al.*, 1993). Third, the empirical research design in Basu and Morey (2005) focuses on the all-or-nothing notion of absolute market efficiency, where the stock market under study is expected to undergo a complete transformation from an inefficient state to a perfectly efficient one after trade liberalization.[6] In this regard, it is not only unrealistic to

[5] Stock data for emerging markets have only gradually become available in traditional data sources since the early 1990s. To further complicate matters, the convention in the literature is to set the window length between two and five years before and after an event (see, for example, Bhattacharya and Daouk, 2002; Bae *et al*., 2006; Fernandes and Ferreira, 2009).

[6] In fact, this is a common shortcoming in previous studies that explore the potential contributing factors of weak-form market efficiency, such as the changes in the regulatory framework, the opening of the domestic stock market to foreign investors, the implementation of a price limits system, the adoption of an electronic trading system, and the occurrence of financial crisis (see the references cited in Lim *et al*., 2008c). Hence, it is not surprising that after decades of empirical investigations, very little is known about the factors that are associated with a higher level of informational efficiency.

characterize market efficiency as a dichotomous zero-one variable, but this assumption precludes the extension from a single-country sub-period study to a broader multi-country investigation via cross-sectional or panel regression.

To the best of our knowledge, the relationship between trade openness and stock return autocorrelations has yet to be tested rigorously. In view of his finding that trade liberalization is a significant source of stock price appreciation, Henry (2000) suggests that there is positive value added to this line of inquiry. The lack of subsequent empirical studies provides the motivation for this chapter. In our empirical investigation, we use the index of trade freedom provided by the Heritage Foundation and the total trade/GDP ratio to capture the degree of trade openness across countries and over time. The variance ratio statistic is employed to determine the autocorrelation patterns of stock returns, exploiting the property that it is one plus a weighted sum of the autocorrelation coefficients for stock returns with positive and declining weights. However, instead of treating market efficiency as a dichotomous zero-one variable, we use the absolute value of the variance ratio minus one to infer the degree of informational efficiency. In all model specifications, two competing theoretical determinants of index return autocorrelations are included, namely trading volume and market return volatility. The investigation also considers the role of financial openness in explaining the variations of market inefficiency across countries and over time.

Our fixed effects panel regression results using data for 23 developing countries over the sample period 1992-2006 reveal that a greater level of *de facto* trade openness is associated with a higher degree of informational efficiency in these emerging stock markets, even after controlling for trading volume and market return volatility.

However, this negative relationship between trade openness and stock return autocorrelations does not hold when the *de jure* measure is used, suggesting that official trade reforms are insufficient to take advantage of returns to scale if they are not accompanied by increases in the actual level of trade flows. Further analyses find no significant association between the extent of financial openness and the degree of informational efficiency, and this conclusion is robust to various indicators of stock market liberalization and capital account openness. Though our key finding is broadly consistent with the theoretical prediction of Basu and Morey (2005), we highlight the possibility of alternative channels that can give rise to a positive relationship between *de facto* trade openness and stock market efficiency. At the country-level, we conjecture that the degree of international stock market integration is a possible link since trade openness is found to be a significant factor that helps to integrate stock markets across national borders (see Hooy and Goh, 2008). At the firm-level, trade openness is hypothesized to be positively related to market efficiency due to improved quality of information. Our argument is that trade openness signals higher future firm profitability and hence helps to reduce uncertainty about a firm's future earnings or cash flows. Zhang (2006b) finds evidence that greater information uncertainty about a firm's fundamentals exacerbates investors' under-reaction behavior and induces stronger short-term stock price continuation, suggesting that uncertainty delays the incorporation of information into stock prices.

The remainder of this chapter is structured as follows. Section 3.2 reviews the relevant literature. Section 3.3 discusses the issues related to our main metric of market efficiency. The next section then provides a description of the stock data, the cross-country indicators of trade liberalization and the selected control variables. Section 3.5

utilizes panel regression to examine the association between trade openness and the degree of market efficiency. The role of financial openness is considered subsequently. Section 3.7 discusses the possible channels that can give rise to a positive association between *de facto* trade openness and the degree of market efficiency. Suggestions on how our hypotheses can be empirically tested are also provided. The final section then concludes this chapter, along with some recommendations for future research.

3.2 A Review of Related Literature

In the weak-form EMH literature, a small number of studies do take the extra step to identify the determinants of market efficiency by means of sub-period analysis. Among the factors considered are the opening of the domestic stock market to foreign investors, the changes in regulatory framework, the adoption of an electronic trading system, the implementation of a price limits system and the occurrence of financial crisis (see references cited in Lim *et al*., 2008c). Unfortunately, these country-by-country sub-period studies do not shed much light on the driving forces of market efficiency, mainly because their research framework focuses on testing whether the random walk hypothesis can be rejected in those sub-periods of pre- and post-changes. Thus, an inconclusive finding may be reached when the adopted statistical tests either reject or cannot reject the null hypothesis of random walk in both sub-periods.

To explore the factors that are associated with a higher level of informational efficiency, a more fruitful empirical strategy is to examine market efficiency in the relative rather than absolute sense. In the context of weak-form EMH, previous studies generally employ the absolute value of the autocorrelation coefficient or the absolute deviation from one of the variance ratio to gauge how closely the stock price follows a random walk (see references cited in Subsection 2.3.2 of this thesis). The justification is that a more efficient price is closer to a random walk benchmark and hence exhibits less autocorrelation in either the positive or negative direction. Using the above autocorrelation-based measures of relative efficiency, Froot and Perold (1995) and Gu and Finnerty (2002) find that the developed U.S. stock market displays varying degrees of efficiency over their selected sample periods (see also Lo, 2004, 2005; Ito and Sugiyama, 2009). Other empirical studies instead explore the impacts on market efficiency brought about by limit-order book transparency (Boehmer *et al*., 2005), international cross-listing (Korczak and Bohl, 2005; Liu, 2007a), changes in securities transaction tax (Liu, 2007b), restrictions on short sales executions (Alexander and Peterson, 2008; Boehmer and Wu, 2009), changes in market liquidity (Chordia *et al*., 2008), greater institutional holdings (Boehmer and Kelley, 2009), and index membership changes (Liu, 2009).

On the theoretical front, a number of existing models do make predictions about the determinants of stock return autocorrelations. For instance, the theoretical model of Sentana and Wadhwani (1992) predicts a negative relation between market volatility and return autocorrelations. Briefly, these authors assume that there are two types of investors, rational expected utility maximizers and feedback traders, the latter in equilibrium induce serial correlations in stock returns. Their model incorporates both positive and negative feedback traders, and the observed sign of return autocorrelations reflects the relative market dominance of these two different types of feedback trading strategy. Positive (negative) stock return autocorrelations would tend to suggest that negative (positive) feedback traders are the dominant trading group. More importantly, their model yields a testable implication on the link between market volatility and return autocorrelations. For example, at low levels of volatility, negative feedback trading predominates and stock returns exhibit positive serial correlations. However, as volatility rises, positive feedback traders exert a greater influence on stock price movements, which then manifests itself in greater negative return autocorrelations.

On the empirical front, Sentana and Wadhwani (1992) find a significant inverse relation between volatility and return autocorrelations using U.S. stock index data. Subsequent studies from other national stock markets further confirm their model prediction that volatility induces sign reversal in return autocorrelations (see, for example, Koutmos, 1997; Booth and Koutmos, 1998; Faff *et al*., 2005; Venetis and Peel, 2005). Guided by the theoretical model of Sentana and Wadhwani (1992), some papers include return volatility as one of the potential determinants of stock return autocorrelations, and this explanatory variable consistently yields a negative and significant coefficient in their regression analyses (see McKenzie and Faff, 2003; McKenzie and Kim, 2007). The above negative association still holds even when the absolute value of the autocorrelation coefficient or the absolute deviation from one of variance ratio is used as the dependent variable (see Gu and Finnerty, 2002).

Another postulated theoretical determinant of stock return autocorrelations is trading volume. For instance, Campbell *et al*. (1993) investigate the empirical link between serial correlations of stock returns and the level of trading volume. Their preliminary exploration reveals that for both stock indices and individual large stocks, the first-order daily return autocorrelation tends to decline when volume increases. To explain this phenomenon, the authors model the interaction between liquidity traders and risk-averse expected utility maximizers who act as market makers. In their model, market makers must be compensated with higher expected returns for offsetting the shifting stock demands of liquidity traders. The intuition behind their work is as follows. A low return due to a drop in the stock price can be caused either by public news or an exogenous selling pressure by liquidity traders. The former gives rise to no volume while the latter generates trading among investors. Hence, low returns accompanied by high trading volume are more likely due to liquidity-driven selling activity, while those accompanied by low trading volume can be attributed to information-based trading. Though information-based trading will leave the expected stock returns unchanged, this is not the case for liquidity-based trading as market makers demand higher expected returns for absorbing the liquidity shocks. This implies that trading volume and return autocorrelations should be negatively related.

The model prediction of Campbell *et al*. (1993) has been tested in different ways, and the empirical findings are rather mixed. First, in order to measure both the statistical and economic significance of the volume/return relation, Conrad *et al*. (1994) and Parisi and Acevedo (2001) employ a contrarian portfolio strategy to exploit short-run stock return reversals. These two studies report negative return autocorrelations for heavily traded stocks while lowly traded stocks experience positive autocorrelations in returns. Using the information on trading activity in the construction of portfolio weights leads to an increase in profits for their contrarian trading strategy. Foster and Kharazi (2008) apply the same approach on the Iranian stock market but find no relation between trading volume and stock return autocorrelations. Second, regression analyses in McKenzie and Faff (2003) and Groenewold (2004) show that greater trading volume is generally associated with lower stock return autocorrelations. However, McKenzie and Kim

(2007) do not find a clear consensus on the nature of this relationship. Third, regardless of whether the absolute value of the autocorrelation coefficient or the absolute deviation from one of variance ratio is employed as the dependent variable, Gu and Finnerty (2002) find that trading volume consistently yields negative and statistically significant coefficient, as expected.

3.3 Measuring the Degree of Market Efficiency

This section discusses two issues related to market efficiency, as follows. (1) Does the evidence of serial correlations in stock returns indicate market inefficiency? (2) How should the degree of market efficiency be measured? In relation to (2), we employ a variance ratio statistic which automatically selects the value of optimal holding period, using a fully data-dependent method. In addition, we discuss the issue of how the problem of spurious index return autocorrelations induced by thin trading is addressed.

3.3.1 Stock return autocorrelations and market inefficiency

As mentioned earlier in Section 1.1 of this thesis, market efficiency has been defined in many different ways, and the literature has not yet produced an agreed-upon standard definition. Hence, it is important for researchers to clarify how they define and measure such efficiency. For instance, Chordia *et al*. (2005, 2008) at the outset of their papers clearly specify that they are examining market efficiency in the context of Fama (1970). We follow these authors in defining an efficient stock market as one in which new information is quickly and fully reflected in its current stock price. Given that price changes occur only in response to genuinely new information, which by definition is unpredictable, the resulting price changes must be unpredictable and random. In this regard, the evidence of significant return autocorrelations reflects investors' mis-reaction to information and hence implies market inefficiency in the sense of Fama (1970). For instance, Amihud and Mendelson (1989a), Damodaran (1993), Brisley and Theobald (1996) and Theobald and Yallup (1998, 2004) develop formal speed of adjustment estimators that are functions of autocorrelations to gauge the speed with which new information is reflected in prices of individual stocks or portfolios. Their research is motivated by extant behavioral models that show both investors' under- and over-reactions induce particular autocorrelation patterns in stock returns (see Barberis *et al*., 1998; Daniel *et al*., 1998; Hong and Stein, 1999).

However, loyalists and revisionists strongly defend market efficiency in the presence of serial correlations in stock returns (see Boudoukh *et al*., 1994). The former believe markets process information rationally and the existence of return autocorrelations is due to thin trading, trading frictions and transaction costs that cannot be profitably exploited. The revisionists argue that these return autocorrelations may reflect the time-varying equilibrium expected returns generated by rational investor behavior, which can be explained in the framework of intertemporal asset pricing models (for a discussion, see Fama, 1991). For instance, earlier theoretical papers, such as those by LeRoy (1973) and Lucas (1978), demonstrate that rational expectation equilibrium prices need not form a martingale sequence and that serial correlations in asset returns could be the result of time-varying expected returns. This controversy arises because the two aforementioned schools of thought adopt different definitions of market efficiency, that is, the lack of profitability (Jensen, 1978) and market rationality (Rubinstein, 2001).[7]

[7] One good example is Mech (1993), who finds evidence in support of his theoretical prediction that transaction costs induce index return autocorrelations by delaying price adjustments. He then concludes:

3.3.2 Absolute deviation from one of the variance ratio statistic

The variance ratio (VR) test of Lo and MacKinlay (1988) has been widely used in the extant literature to test for the weak-form efficiency of financial markets. It is based on the statistical property that if the stock price follows a random walk, then the variance of the *k*-period return is equal to *k* times the variance of the one-period return. For example, the variance of its five-day return is equal to five times the variance of its daily return. Since the seminal work of Lo and MacKinlay (1988), numerous methodological refinements have been proposed in the literature. Charles and Darné (2009b) provide a timely and comprehensive review of recent developments in the variance ratio tests of random walk hypothesis.

Let r_t denote an asset return at time t, where $t = 1, 2, ..., T$. The variance ratio for r_t with the holding period *k* is defined as:

$$VR(k) \equiv \frac{\sigma_k^2}{k\sigma_1^2} \tag{3.1}$$

where $\sigma_k^2 \equiv Var(r_t + r_{t-1} + ... + r_{t-k+1})$ is the variance of the *k*-period return. It can be rewritten as:

$$VR(k) = 1 + 2\sum_{i=1}^{k-1}\left(1 - \frac{i}{k}\right)\rho(i) \tag{3.2}$$

"*The implication is that markets are inefficient, in that prices do not always fully reflect all available information. However, investors are not irrational because there are costs that prevent this mispricing from being exploited.*" (pp. 343-344). Mech's conclusion suggests that the evidence of index return autocorrelations that are due to transaction costs satisfies Fama's (1970) price reflectivity-based definition, but not the more stringent versions of Jensen (1978) and Rubinstein (2001).

where $\rho(i)$ is the autocorrelation of r_t of order i. That is, the variance ratio is one plus a weighted sum of the autocorrelation coefficients for the asset return with positive and declining weights.

Under the null hypothesis of random walk, $VR(k)=1$ for all k, because the returns are serially uncorrelated with $\rho(i)=0$. $VR(k)<1$ indicates an overall negative serial correlation over the holding period k, whereas $VR(k)>1$ an overall positive serial correlation. As both positive and negative return autocorrelations represent departures from the random walk hypothesis, a number of recent studies employ the absolute deviation from one of the variance ratio statistic as their measure of relative market efficiency (see Gu and Finnerty, 2002; Griffin *et al*., 2007a; 2008b; Chordia *et al*., 2008; Boehmer and Kelley, 2009). Hence, our panel regression analysis employs $|VR(k)-1|$ as the dependent variable to examine the empirical relationship between trade openness and the extent of deviations from market efficiency.

It is worth highlighting that though the distributional properties of the VR test statistic are important for statistical inference, the point estimates of the variance ratio offer interesting financial insights. For instance, the study by Poterba and Summers (1988) is among the first to provide direct empirical evidence of mean reversion over long horizons where the $VR(k)$ for U.S. stock returns is found to be below unity. This mean reversion property of stock prices suggests the potential of positive expected profit to a contrarian investment rule, a strategy that buys stocks that have performed poorly in the past and sells stocks that have performed well (for an application, see Balvers *et al*., 2000). Furthermore, the existence of negative serial correlations in stock returns at some holding periods is a common presumption in all existing theories of stock market over-reaction (see De Bondt and Thaler, 1985, 1987). On the other hand, Lo and MacKinlay (1988) report positive autocorrelations for weekly market index returns over the short horizons. Similar findings of $VR(k) > 1$ have been reported by Patro and Wu (2004) for most of their sampled national stock markets. This return continuation suggests the potential of earning excess profit by buying past winners and selling past losers. Moreover, many theoretical explanations have been given to justify the existence of positive index return autocorrelations over short horizons (see Boudoukh *et al*., 1994).

3.3.3 Variance ratio estimation with automatic selection of the optimal holding period

To estimate the value of $VR(k)$, a choice of (holding periods) k values needs to be made. For example, a popular choice for the daily return is (2, 5, 10, 20) and that for the monthly return is (2, 4, 8, 16). However, these choices are often arbitrary and made with little statistical justification. In view of this, Choi (1999) proposes a fully automatic method, in which the optimal value of k is determined by using a completely data-dependent procedure. He considers an estimator for $VR(k)$ of the form:

$$V\hat{R}(k) = 1 + 2\sum_{i=1}^{T-1} m(i/k)\hat{\rho}(i) \tag{3.3}$$

where $\hat{\rho}(i)$ is the sample autocorrelation for the asset return at lag i, and $m(\cdot)$ is a weighting function with positive and declining weights. We follow Choi (1999) and use the quadratic spectral kernel for the weighting function of $m(\cdot)$, i.e.

$$m(x) = \frac{25}{12\pi^2 x^2}\left[\frac{\sin(6\pi x/5)}{6\pi x/5} - \cos(6\pi x/5)\right] \tag{3.4}$$

Choi (1999) states that $V\hat{R}(k)$ is a consistent estimator for $2\pi f_Y(0)$, where $f_Y(0)$ is the normalized spectral density for r_t at zero frequency. To choose the value of the lag truncation point (or holding period) k optimally, Choi (1999) proposes the use of Andrews's (1991) data-dependent method for spectral density at zero frequency. The full details of this method are given in Choi (1999). The variance ratio statistic $V\hat{R}(k)$ with the optimally chosen lag truncation point is denoted as $V\hat{R}(\hat{k})$. Hence, $\left|V\hat{R}(\hat{k})-1\right|$ is employed as our estimated measure of relative market efficiency.

3.3.4 Adjustment procedure for thin trading

It is widely acknowledged that thin trading can give rise to spurious index return autocorrelations. This is first recognized by Fisher (1966), and later addressed by Lo and MacKinlay (1988, 1990a), Stoll and Whaley (1990) and Miller *et al*. (1994) through their formal non-trading models. The intuition is that, in the case of daily returns, the closing prices recorded at the end of the day represent transactions that occur at different points in time for different stocks. If market-wide news is released near the end of the trading day, this new information will not be reflected in the closing prices of some infrequently traded stocks until the next day. Their lagged price adjustments will induce cross-autocorrelations with other frequently traded stocks that have incorporated the information, which subsequently lead to positive serial correlations in the market index returns.[8]

[8] According to Cohen *et al*. (1980), for a market index made up of large number of stocks, positive cross-autocorrelations among individual stocks' returns will induce positive autocorrelations in the index regardless of the signs of the individual stocks' autocorrelations. In a similar vein, Lo and MacKinlay (1990b) demonstrate that if individual stocks' returns exhibit weak negative serial correlations, for market index returns to be positively autocorrelated, there must be significant positive cross-autocorrelations across the constituent stocks.

We use the adjustment procedure proposed by Miller *et al*. (1994) to purge the effect of thin trading on index return autocorrelations.[9] This approach has been adopted by recent market efficiency studies (see Antoniou *et al*., 1997; Appiah-Kusi and Menyah, 2003; Al-Khazali *et al*., 2007; Rayhorn *et al*., 2007; Lim *et al*., 2009). Theobald and Yallup (1998, 2004) also correct for a thin trading effect that causes a downward bias in the speed of adjustment estimators. Briefly, the analysis in Miller *et al*. (1994) demonstrates that observed price changes can be adjusted by $(1-\varphi)$ to remove the impact of thin trading in the calculation of returns, where parameter φ measures the degree of trading infrequency. In applying their model to index returns, a moving average (MA) model in which the number of moving average components is equal to the number of non-trading days should be estimated. However, given the difficulties in identifying non-trading days, the authors show that the model is equivalent to estimating an autoregressive (AR) model of order one and that the residuals from such a model should be scaled up by $(1-\varphi)$ to remove the impact of thin trading in the calculation of return series.

More specifically, the adjustment procedure involves estimating an AR(1) model for r_t of the form:

$$r_t = \alpha_0 + \varphi r_{t-1} + u_t \tag{3.5}$$

where α_0 and φ are the parameters to be estimated, and u_t is an error term.

[9] In the empirical literature, several studies show that the thin trading of component stocks plays a relatively minor role in generating the observed market index return autocorrelations (see Perry, 1985; Atchison *et al*., 1987; Lo and MacKinlay, 1988, 1990a). However, this is disputed by Boudoukh *et al*. (1994) and Kadlec and Patterson (1999) who demonstrate that previous studies have understated the effect of thin trading.

The return series adjusted for the effect of thin trading is calculated as:

$$r_t^{adj} = \frac{e_t}{1-\hat{\varphi}} \tag{3.6}$$

where $\hat{\varphi}$ is the ordinary least squares estimator for φ, and e_t is the associated residual.

3.4 The Data

This section provides the details of the stock price data used to compute the absolute value of the variance ratio minus one, the proxies for our main explanatory variable of trade openness, and the selected control variables as prescribed by existing theoretical models.

3.4.1 Country stock indices

We collect daily indices of 23 emerging stock markets, using the market status defined by the Standard & Poor's *Global Stock Markets Factbook 2006*. The closing prices for the major stock index in each market, denominated in their respective local currency units, are collected from Thomson Datastream. Due to data quality and availability, our sample period spans from January 1, 1992 to December 31, 2006 for all markets. We calculate the log return, i.e. $r_t = \ln\left(p_t / p_{t-1}\right)$, where p_t is the closing price of the index on day t, and $\ln(\;)$ is the natural logarithm. The countries in our sample are Argentina, Brazil, Chile, China, Hungary, India, Indonesia, Israel, Jordan, Kenya, Malaysia, Mexico, Morocco, Pakistan, Peru, the Philippines, Poland, South Africa, South Korea, Sri Lanka, Thailand, Turkey and Venezuela.

3.4.2 Cross-country trade openness indicators

Before proceeding to our selected proxies for trade openness, we first discuss the fundamental data problem that stems from using Sachs and Warner's (1995) trade liberalization dates, which constitute the most comprehensive cross-country database of *de jure* trade policy openness in the extant literature. Sachs and Warner (1995) define an economy as open if none of the following five conditions applies: (1) non-tariff barriers cover 40 percent or more of trade; (2) the average tariff rates are 40 percent or more; (3) there was a black-market exchange rate that depreciated by 20 percent or more relative to the official exchange rate during the 1970s and 1980s; (4) the country has a socialist economic system; and (5) the country has a state monopoly on major exports. Whenever possible, these five openness criteria are employed by Sachs and Warner (1995) to establish a country's date of liberalization. Due to data limitations for many time periods, the dates of liberalization are often obtained from a wide array of secondary sources. Wacziarg and Welch (2008) extend the sample to 141 countries and update the trade liberalization dates to 2001.

As previously highlighted, the paucity of stock data on emerging markets renders it difficult to conduct a proper event study. Table 3.1 filters the database with the help of existing sources on the dates of establishment for stock exchanges (Bhattacharya and Daouk, 2002; Jain, 2005) and the starting dates of data availability for the monthly stock market indices in traditional data sources (Jain, 2005). From this table, it can be seen that there are 29 countries that do not have a stock market. Even for the 112 countries where stock market exists, other problems arise. In the end, there are only 13 countries for which monthly stock data are available for both before and after trade liberalization. In terms of daily frequency, however, only 10 countries (Argentina, Bangladesh, Brazil, Egypt, Kenya, Pakistan, the Philippines, South Africa, Sri Lanka, and Venezuela) fulfill the requirement to have at least two years of stock data available on either side of the liberalization date. Even for these emerging markets, the daily stock index data for the late 1980s and early 1990s are of poor quality, as the values remain unchanged for long periods of time.

Table 3.1: Profiles of Sampled Countries in Wacziarg and Welch (2008)

No.	Profile	Country
1.	No stock market exists (29)	Angola, Benin, Burkina Faso, Burundi, Central African Republic, Chad, Congo (Democratic Republic), Congo (Republic), Ethiopia, Gabon, Gambia, Guinea, Guinea-Bissau, Lesotho, Liberia, Madagascar, Mali, Mauritania, Myanmar, Niger, Rwanda, Senegal, Sierra Leone, Somalia, Syria, Tajikistan, Togo, Turkmenistan, Yemen
2.	Stock market exists, but economy always open (7)	Hong Kong, Norway, Portugal, Switzerland, Thailand, the United Kingdom, the United States
3.	Stock market exists, but economy remains closed (20)	Algeria, Belarus, China, Croatia, Estonia, Haiti, Iceland, India, Iran, Iraq, Kazakhstan, Malawi, Malta, Nigeria, Papua New Guinea, Russia, Swaziland, Ukraine, Uzbekistan, Zimbabwe
4.	Trade liberalized before stock market existed (25)	Albania, Barbados, Botswana, Bulgaria, Cameroon, Cape Verde, Cyprus, El Salvador, Georgia, Ghana, Guyana, Honduras, Jordan, Kyrgyz Republic, Latvia, Macedonia, Malaysia, Mauritius, Moldova, Mozambique, Nicaragua, Slovakia, Tanzania, Uganda, Zambia

Table 3.1 (Continued)

No.	**Profile**	**Country**
5.	Trade liberalized after stock market established, but stock data before liberalization are unavailable (47)	Armenia, Australia, Austria, Azerbaijan, Belgium, Bolivia, Canada, Chile, Colombia, Costa Rica, the Czech Republic, Denmark, the Dominican Republic, Ecuador, Finland, France, Germany, Greece, Guatemala, Hungary, Indonesia, Ireland, Israel, Italy, Ivory Coast, Japan, Lithuania, Luxembourg, Mexico, Morocco, Nepal, the Netherlands, New Zealand, Paraguay, Peru, Poland, Romania, Serbia and Montenegro, Singapore, Slovenia, South Korea, Spain, Sweden, Taiwan, Trinidad and Tobago, Tunisia, Uruguay
6.	Trade liberalized after stock market established, and stock data before liberalization are available (13)	Argentina, Bangladesh, Brazil, Egypt, Jamaica, Kenya, Pakistan, Panama, the Philippines, South Africa, Sri Lanka, Turkey, Venezuela

Sources: The timing of *de jure* trade liberalization is from Wacziarg and Welch (2008), and the dates of stock exchange establishment are taken from Bhattacharya and Daouk (2002), Jain (2005) and the exchanges' own websites. Jain (2005) provides the starting dates of data availability (at monthly or annual frequencies) for major stock market indices in traditional data sources such as Thomson Datastream, Morgan Stanley Capital International (MSCI), and Standard & Poor's Emerging Markets Database (EMDB). The entries in parentheses indicate the total number of countries.

The aforementioned problem does not hamper our efforts, as alternative *de jure* measures of trade openness are available in the extant literature (for a survey, see Santos-Paulino, 2005). Since 1995, the Heritage Foundation has tracked the march of economic freedom around the world with their annual 'Index of Economic Freedom'. This index covers ten categories of freedom, one of which is trade policy. More specifically, the trade freedom index, which grades trade freedom on a scale that ranges from zero to 100, is a composite indicator that measures the extent to which a government hinders the free flow of trade through tariff and non-tariff barriers. For instance, a country with zero trade-weighted average tariff rates and zero non-tariff barriers would be given the maximum score of 100.[10] The annual data are downloaded from http://www.heritage.org/Index/.

We also consider *de facto* measures of trade openness, for which trade volume (imports plus exports) as a share of GDP is the most popular proxy. The general argument favoring such a *de facto* measure is that it is outcome-based and results from the interaction between market forces and the enforcement of existing regulations. For instance, some countries do not have a very large trade flow even though they are quite open to international trade on a *de jure* basis. In contrast, there are countries that have strict trade restrictions but are ineffective in their actual enforcement; thus, their *de facto* level of trade openness is quite high.[11] The data on trade volume/GDP for our sampled countries are collected from the World Development Indicators. In addition to providing larger country coverage, our selected proxies capture the degree of trade openness across countries and over time. This is more realistic, as liberalization is typically a gradual process, rather than a one-time event that constitutes an instantaneous and complete removal of trade restrictions.

3.4.3 Control variables

The existing literature provides a number of theoretical models that predict the determinants of return autocorrelations. Guided by these models, our control variables include the volatility of market returns (Sentana and Wadhwani, 1992) and trading

[10] In the theoretical model of Basu and Morey (2005), trade opening is modeled as an elimination of non-tariff restrictions on the import of foreign intermediate inputs, but such data for broad cross-section of countries are hard to obtain.

[11] One good example is China, which is classified as closed by Wacziarg and Welch (2008) as of 2001, based on the undivided power of the Communist Party and the country's black market exchange rate premium.

volume (Campbell *et al*., 1993). Both variables are predicted to be negatively related to return autocorrelations. In our empirical analysis, return volatility is measured as the sample standard deviation of daily stock returns computed for each country in each year. Following the convention in existing studies (see, for example, Levine and Schmukler, 2006, 2007), our proxy for trading volume is the logarithm of one plus the turnover ratio, where turnover is computed as the total value of shares traded scaled by the total stock market capitalization. The panel data are collected from the World Development Indicators. In exploring the determinants of informational efficiency for the U.S. stock market, Gu and Finnerty (2002) find that the coefficients for return volatility and trading volume are negatively significant in their cross-sectional regression analysis, regardless of whether the absolute value of the autocorrelation coefficient or the absolute deviation from one of the variance ratio is employed as the dependent variable. This chapter not only extends their work to a broad cross-section of emerging stock markets, but also considers the potential role of trade openness, which is yet to be tested in the existing literature.

3.5 Trade Openness and Stock Market Efficiency

To examine the empirical relationship between trade openness and the degree of deviations from market efficiency, we estimate the following panel regression:

$$\left|VR_{it}-1\right| = \beta_1 TO_{it} + \beta_2 VOL_{it} + \beta_3 MV_{it} + \mu_t + \delta_i + \varepsilon_{it} \tag{3.7}$$

where $\left|VR_{it}-1\right|$ is our metric of informational efficiency for country i in year t, TO_{it} is the proxy for trade openness, followed by the set of control variables, that is, trading volume (VOL_{it}) and market return volatility (MV_{it}). Note that μ_t is a vector of the year-specific dummy variables to control for common shocks, δ_i represents the country fixed effects that are intended to control for time-invariant country-specific factors, and ε_{it} is an error term.

The ordinary least squares (OLS) standard errors will be unbiased as long as the regression residuals are independently and identically distributed. However, the independence assumption is often violated in finance panel datasets, since the residuals are expected to be correlated across years for a given firm/country (time-series dependence), or correlated across different firms/countries for a given year (cross-sectional dependence). The presence of such correlations will lead to gross under-estimation of OLS standard errors in panel regression and subsequent inflation of the *t*-statistics, as documented in the extensive Monte Carlo simulation results provided by Petersen (2009). Surprisingly, in his survey of the papers published in top three finance journals between 2001 and 2004, the author finds that 42% of those articles using panel regression do not adjust the standard errors to account for possible dependence in the residuals. Motivated by this concern, we follow recent cross-country studies to adjust the standard errors for heteroscedasticity and the errors terms that are correlated across years within a given country, but are independent across countries (see, for example, Doidge *et al*., 2007; Fernandes and Ferreira, 2008, 2009). The possible existence of cross-sectional dependence in each period is addressed using year dummies (μ_t).

Table 3.2: Summary Descriptions of the Variables

Variable	Description
	The Degree of Market Efficiency
$\lvert VR_{it} - 1\rvert$	The degree of market efficiency for country *i* in year *t* is measured in terms of the absolute value of the variance ratio minus one. We compute the annual measure of $\lvert VR-1\rvert$ using the data for stock index returns after adjusting for the confounding effect of thin trading. The daily stock indices denoted in local currency units for 23 emerging markets over the 1992 to 2006 period are collected from Thomson Datastream.
	Trade Openness
$DJTO_{it}$	Our proxy for *de jure* trade openness is the index on trade freedom provided by the Heritage Foundation. This index, which is graded using a scale that ranges from zero to 100, measures the extent to which a government hinders the free flow of trade through tariff and non-tariff barriers. The annual data are downloaded from http://www.heritage.org/Index/ for all 23 countries over the 1995 to 2006 period.
$DFTO_{it}$	Trade volume (imports plus exports) as a share of gross domestic product (GDP) measures the degree of *de facto* trade openness. The annual data for all of our sampled countries between 1992 and 2006 are collected from the World Bank's World Development Indicators.
	Stock Market Openness
$DJSMO_{it}$	A *de jure* measure of the intensity of stock market openness, using the Global Index (IFCG) and Investable Index (IFCI) compiled by Standard and Poor's/International Finance Corporation (S&P/IFC). We compute the ratio of the number of firms in the IFCI and IFCG for each country. The value ranges from zero to one, with zero indicating that the market is completely closed to foreign investors and one representing a completely open market with no foreign restrictions. The required data for all countries are collected from the *Emerging Stock Markets Factbook* (1995-2002) and the *Global Stock Markets Factbook* (2003-2006).

Table 3.2 (Continued)

Variable	Description
$DFSMO_{it}^{TF}$	A *de facto* indicator of the intensity of stock market openness based on actual total equity flows (equity inflows and outflows). This equity-based measure of openness is computed as $DFSMO^{TF} = (PEQA + FDIA + PEQL + FDIL)/GDP$, where $PEQA(L)$ and $FDIA(L)$ are the gross stocks of the portfolio equity and foreign direct investment assets (liabilities) respectively, and GDP denotes gross domestic product. The data for all of our sampled countries over the period 1992-2004 are downloaded from Philip Lane's website at http://www.tcd.ie/iiis/pages/people/plane.php.
$DFSMO_{it}^{IF}$	A *de facto* indicator of the intensity of stock market openness based on actual equity inflows and computed as $DFSMO^{IF} = (PEQL + FDIL)/GDP$, where $PEQL$ and $FDIL$ are the gross stocks of the portfolio equity and foreign direct investment liabilities, respectively. The data for all of our sampled countries over the period 1992-2004 are downloaded from Philip Lane's website at http://www.tcd.ie/iiis/pages/people/plane.php.
	Capital Account Openness
$DJCAO_{it}$	A *de jure* measure of the intensity of capital account openness constructed by Chinn and Ito (2006, 2008). This index takes on higher values the more open a country is to cross-border capital transactions. To avoid the complexity of interpreting the estimated coefficients, the index is adjusted so that their values range between zero and some positive figure. The data for all of our sampled countries over the sample period 1992-2006 are downloaded from Hiro Ito's website at http://web.pdx.edu/~ito/.
$DFCAO_{it}^{TF}$	A *de facto* indicator of the intensity of capital account openness based on actual total capital flows (capital inflows and outflows). This measure is computed as $DFCAO^{TF} = (FA + FL)/GDP$, where $FA(FL)$ refers to the gross stocks of foreign assets (liabilities), and GDP denotes gross domestic product. The data for all of our sampled countries over the period 1992-2004 are downloaded from Philip Lane's website at http://www.tcd.ie/iiis/pages/people/plane.php.

Table 3.2 (Continued)

Variable	Description
$DFCAO_{it}^{IF}$	A *de facto* indicator of the intensity of capital account openness based on actual capital inflows. This measure is computed as $DFCAO^{IF} = FL/GDP$, where FL refers to the gross stocks of foreign liabilities. The data for all of our sampled countries over the period 1992-2004 are downloaded from Philip Lane's website at http://www.tcd.ie/iiis/pages/people/plane.php.
	Control Variables
VOL_{it}	Our empirical proxy for trading volume is the logarithm of one plus the turnover ratio, where turnover is computed as the total value of shares traded scaled by the total stock market capitalization. The data for all countries over the sample period 1992-2006 are sourced from the World Bank's World Development Indicators.
MV_{it}	The volatility of market returns is measured by the sample standard deviation of daily stock returns computed for each country in each year. The stock data for 23 emerging markets over the 1992 to 2006 period are collected from Thomson Datastream.

3.5.1 An overview of the data

Our dependent variable is the absolute value of the variance ratio minus one, which measures the extent of the stock price deviations from a random walk. We compute the variance ratio statistic given in equation (3.3) for each country in each year using the return series adjusted for thin trading, as in equation (3.6). Table 3.2 contains the detailed definitions for all the variables used in this study, along with their respective data sources. Table 3.3 presents the descriptive statistics for the dependent variable and the entire set of regressors employed in the analysis throughout this chapter, including the indicators for financial openness which we address in Section 3.6. The correlation matrix between the variables is provided in Table 3.4. *De jure* and *de facto* trade openness is weakly correlated with the correlation coefficient of 0.3460, thus indicating that the official removal of trade barriers is not associated with a large increase in actual trade flows. More importantly, both indicators of trade openness exhibit weak correlations with the two control variables. The highest value of the correlation coefficient is 0.4430, that is, between trading volume and return volatility.

Table 3.3: Descriptive Statistics

	N	**Mean**	**Median**	**Standard Deviation**	**Maximum**	**Minimum**
|VR-1|	345	0.0121	0.0020	0.0293	0.3862	0.0000
DJTO	276	62.0399	65.0000	15.0985	83.0000	0.0000
DFTO	345	68.1138	58.0468	40.6462	228.8752	14.7310
DJSMO	345	0.5911	0.6809	0.3414	1.0000	0.0000
$DFSMO^{TF}$	299	0.3060	0.2368	0.2461	1.2612	0.0198
$DFSMO^{IF}$	299	0.2453	0.1977	0.1782	0.8166	0.0158
DJCAO	333	1.9585	1.7084	1.3535	4.3374	0.0000
$DFCAO^{TF}$	299	1.1074	1.0427	0.4474	3.1000	0.3739
$DFCAO^{IF}$	299	0.7539	0.7329	0.2863	1.9114	0.2160
VOL	345	0.4077	0.2904	0.3600	1.7830	0.0090
MV	345	1.4922	1.3144	0.8245	5.9515	0.2416
Countries	Argentina, Brazil, Chile, China, Hungary, India, Indonesia, Israel, Jordan, Kenya, Malaysia, Mexico, Morocco, Pakistan, Peru, the Philippines, Poland, South Africa, South Korea, Sri Lanka, Thailand, Turkey, Venezuela.					

Note: Table 3.2 describes all the variables listed above along with their respective data sources.

Table 3.4: Correlations for the Explanatory Variables

	DJTO	DFTO	DJSMO	$DFSMO^{TF}$	$DFSMO^{IF}$	DJCAO	$DFCAO^{TF}$	$DFCAO^{IF}$	VOL	MV
DJTO	1.0000									
DFTO	0.3460	1.0000								
DJSMO	0.2744	0.0538	1.0000							
$DFSMO^{TF}$	0.2880	0.4064	0.3557	1.0000						
$DFSMO^{IF}$	0.3057	0.5072	0.2939	0.9509	1.0000					
DJCAO	0.2875	0.1468	-0.1917	0.0955	0.1651	1.0000				
$DFCAO^{TF}$	0.3919	0.5789	0.0308	0.6774	0.6925	0.2900	1.0000			
$DFCAO^{IF}$	0.4043	0.5657	-0.0342	0.5025	0.5635	0.3609	0.9219	1.0000		
VOL	-0.2250	-0.1106	0.1391	-0.2329	-0.2352	-0.4082	-0.3627	-0.3970	1.0000	
MV	0.0267	-0.1114	0.3066	-0.2112	-0.2210	-0.2138	-0.2100	-0.1747	0.4430	1.0000

Note: Table 3.2 describes all the variables listed above along with their respective data sources.

3.5.2 Panel regression with de jure *trade openness measure*

Column (1) of Table 3.5 reports the coefficient estimates for our regression equation (3.7) with only the year dummies, using the trade freedom index provided by the Heritage Foundation as a proxy for *de jure* trade openness. Market turnover is highly significant with a negative sign, which is as expected and consistent with the well-documented negative association between trading volume and return autocorrelations. Return volatility, although significant at the 5% level, is positively related to the degree of informational efficiency, which contradicts Sentana and Wadhwani's (1992) model prediction. Our variable of interest, *de jure* trade openness, has an expected negative coefficient, but is not significant even at the 10% level.

The literature suggests that time-invariant country-specific characteristics, such as macro-level institutions (Eleswarapu and Venkataraman, 2006), trust (Guiso *et al*., 2008), legal origins (La Porta *et al*., 2008), culture (Chui *et al*., 2009) and investor protection (Giannetti and Koskinen, 2009), exert a significant influence on stock market trading activity. We account for these time-invariant omitted variables by using country fixed effects (δ_i). Column (2) shows that the inclusion of country dummies does not alter our basic results. *De jure* trade openness remains statistically insignificant, which indicates that a greater degree of trade openness in terms of the official removal of tariff and non-tariff barriers does not translate into an increased level of informational efficiency. Interestingly, there is a sharp increase in the *R*-square, from 13.37% (Column (1)) to 38.47% (Column (2)), when we add country fixed effects, thus suggesting that country characteristics are important sources of cross-country variation in return autocorrelations. This is not surprising, as there is growing empirical evidence on the important role played by country-specific factors, especially the quality of macro-level institutions (see, for example, Bushman and Piotroski, 2006; Chinn and Ito, 2006; Eleswarapu and Venkataraman, 2006; Alfaro *et al*., 2008; Papaioannou, 2009).

The coefficient for return volatility is still positive and statistically significant in Column (2), even after controlling for country fixed effects. Although inconsistent with Sentana and Wadhwani's (1992) model prediction, this result is justifiable. Excessive return volatility suggests that price changes are mainly noise-driven, rather than due to genuine information about the future dividends of firms (see Shiller, 1981). In this case, the stock price is less informationally efficient, as it conveys little information about future earnings. Our result is also consistent with the finding of McQueen *et al*. (1996), who employ the price delay measure to assess the speed with which new information is incorporated into stock prices. These authors perform cross-sectional tests on a sample of 1,077 U.S. common stocks to identify those factors associated with a delayed response to information. The most significant and robust result from their study is that stock return volatility, measured by the standard deviation of the monthly stock returns, is positively related to the price delay measure. This implies that the higher a stock's volatility, the slower the price adjusts to news. Since volatility is related to noise, McQueen *et al*. (1996) argue that their finding is consistent with Chan's (1993) model, which predicts stocks with noisy signals are likely to respond slowly to news.[12]

[12] Even if one disagrees and insists volatility arises due to the arrival of information, a market with more information produced can exhibit higher return autocorrelations because extraneous news events distract investors from reacting instantaneously (see Hirshleifer *et al*., 2009).

Table 3.5: Trade Openness and Stock Market Efficiency

	***De jure* Trade Openness** (1)	(2)	***De facto* Trade Openness** (3)	(4)
DJTO	-0.0003 (1.5771)	0.0000 (0.0859)		
DFTO			0.0000 (0.3085)	-0.0004^{**} (2.2292)
VOL	-0.0296^{***} (3.2267)	-0.0267^{**} (2.3465)	-0.0234^{***} (2.6967)	-0.0207^{**} (2.4382)
MV	0.0111^{**} (2.5345)	0.0219^{***} (4.6453)	0.0057^{*} (1.6717)	0.0140^{***} (3.8572)
Country Dummies	No	Yes	No	Yes
Year Dummies	Yes	Yes	Yes	Yes
Number of observations	276	276	345	345
Number of countries	23	23	23	23
R-square	0.1337	0.3847	0.0913	0.3293

Notes: Table 3.2 describes all the variables listed above along with their respective data sources.
The dependent variable is the absolute value of the variance ratio minus one, |VR-1|, which measures the extent of the deviations from market efficiency for country *i* in year *t*.
The entries in parentheses are the absolute values of the *t*-statistics. The standard errors for the OLS regressions are adjusted for heteroscedasticity and within-country correlation of the error terms.
***, ** and * indicate statistical significance at the 1%, 5%, and 10% levels, respectively.

From the regulatory perspective, containing excessive volatility and enhancing market efficiency are always at the core of policy objectives. A negative coefficient implies that there is a trade-off between market volatility and market efficiency (for further discussion, see Amihud and Mendelson, 1988, 1989a). Instead, our result suggests the contrary, that is, a higher level of volatility is associated with greater return autocorrelation. Since the evidence of zero serial correlation in stock returns reflects an instantaneous adjustment to information, greater return autocorrelation implies a slower reaction to news and hence a lower degree of informational efficiency. This suggests regulations or market trading systems that aim to contain excessive volatility might, at the same time, improve the informational efficiency of the market, perhaps by providing a cooling-off period to allow investors to re-evaluate market information.

Trading volume yields a negative and significant coefficient in both Columns (1) and (2), consistent with the theoretical prediction of Campbell *et al*. (1993). This result suggests that the lack of market liquidity is associated with greater return autocorrelations and hence slower reaction to news. A related study by Chordia and Swaminathan (2000) also finds that trading volume is a significant determinant of price delay, indicating that high trading volume stocks respond faster to market-wide information than low trading volume stocks. In unreported results, we replace the market turnover in Column (2) with stock market capitalization and the total value traded, but the coefficients for these two popular stock market development indicators are not statistically significant, thus confirming Lo and Wang's (2000) assertion that turnover offers the sharpest prediction of the relation between trading volume and the models of asset markets. The negative relation between trading volume and stock return autocorrelations suggests that those policy reforms which have positive effects on trading activity might enhance the informational efficiency of stock markets. One good example is the strong trend toward screen-based electronic trading systems on stock exchanges around the world.[13] More specifically, Jain (2005, 2008) finds that the electronic trading dummy has a statistically significant positive coefficient in the regression with market turnover as the dependent variable, and this effect is more pronounced in emerging markets than in developed ones. Our finding suggests the possibility that the documented benefits of automation might include improved informational efficiency due to the increases in trading volume.[14]

However, several studies find that higher trading costs (Domowitz *et al*., 2001), the internationalization process (Levine and Schmukler, 2006, 2007) and weak macro-level institutions (Eleswarapu and Venkataraman, 2006; Giannetti and Koskinen, 2009) adversely affect stock trading activity in emerging markets. On the basis of our result that lower trading activity is associated with a lower degree of market efficiency, the findings of these previous studies should be of great concern to policymakers in developing countries, as those factors can also impede the information incorporation process. We highlight here the key findings of the aforementioned papers. First, in a study of 33 emerging and 23 developed stock markets, Griffin *et al*. (2007a, 2008b) find that the former have significantly higher trading costs (see also Domowitz *et al*., 2001). The policy implication is unambiguous since it is natural to expect market with lower trading costs to attract more trading activity, and this inverse relation between trading costs and turnover is confirmed empirically by Domowitz *et al*. (2001). Second, Levine and Schmukler (2006, 2007) find that firms in emerging markets that issue depositary receipts or cross-list in international financial centers tend to experience a decrease in

[13] Based on the information compiled by Jain (2005), all the stock exchanges in our sampled countries except Kenya have replaced their physical trading floors with computerized trading systems, with the latest been Jordan in year 2000.

[14] A wider coverage of policy initiatives is provided by de la Torre *et al*. (2007) who examine the impacts of six major capital market reforms on the size and trading activity of domestic stock markets.

the domestic trading activity of their shares. Worse still, the drop in the turnover of these international firms is associated with a drop in the turnover of domestic firms that do not internationalize. This evidence of migration and spillover effects confirm the policy concern that internationalization is hurting the liquidity of domestic stock markets. Third, empirical analysis in Eleswarapu and Venkataraman (2006) reveals that improvements in a country's legal and political institutions significantly reduce equity trading costs. Giannetti and Koskinen (2009) find that weak investor protection reduces the incentives to participate in the domestic stock market for both local and foreign investors, consistent with their model predictions (see also references cited therein).

3.5.3 Panel regression with de facto *trade openness measure*

In the subsequent analysis, we use trade volume as a share of GDP to capture actual trade flows. The last two columns of Table 3.5 present the coefficient estimates for *de facto* trade openness, using the same set of control variables. Trading volume and return volatility retain their signs and statistical significance. The OLS specification in Column (3) yields a small and statistically insignificant coefficient for trade openness. After controlling for country fixed effects, trade openness has the expected negative sign and is statistically significant at the 5% level, thus suggesting that it mainly captures the time series variation in the degree of market efficiency.[15] In other words, as a country becomes more open and is increasingly engaged in international trade, the informational efficiency of its stock market will improve correspondingly. Although not reported here, we also run a similar regression as that in Column (4) but replace trade volume/GDP with imports/GDP. The basic results are barely affected, but the statistical significance

[15] The year dummies address the concern that the significant coefficient may pick up the common trend in market efficiency and trade openness. Nevertheless, we also re-estimate the model without time fixed effects and including a time trend only. Our unreported regression shows that trade openness is negative and significant, while the coefficient for the time trend is not statistically significant.

of trade openness is relatively lower, with a negative coefficient of -0.0006 and a *p*-value of 0.0653.

Although the positive relationship between trade openness and market efficiency is consistent with the theoretical prediction of Basu and Morey (2005), our result highlights the possibility that the transmission mechanism emphasized by their theory, i.e. technological returns to scale, might not be the driving force. This is because trade opening is modeled by these authors as an elimination of non-tariff restrictions on the import of foreign intermediate inputs, but our empirical proxy for *de jure* trade openness does not yield a statistically significant coefficient. This piece of evidence indicates that a greater degree of trade openness in terms of the official removal of tariff and non-tariff barriers does not translate into an increased level of informational efficiency. Instead, we find that it is the *de facto* trade openness that has the expected negative sign and is statistically significant at the conventional level, suggesting that what really matters for stock market investors is the actual level of economic integration in the reforming country with the world.

Our finding contradicts those reported by Li *et al*. (2004) who relate their annual market model *R*-squares for 17 emerging stock markets over the sample period 1990-2001 with measures of *de facto* trade openness and *de jure* stock market openness. When trade openness and stock market openness are entered separately into their fixed effects panel regression, both variables are significantly associated with relative market-wide return variation, with a positive coefficient for trade openness and the opposite sign for stock market openness. The positive coefficient suggests that a country’s engagement in international trade has an adverse effect on the informational efficiency of its stock market, measured in terms of the amount of firm-specific information being incorporated into stock prices. Li *et al*. (2004) justify their result on the grounds that trade openness induces greater specialization, thus reduces an economy's diversification across industries, perhaps turning industry factors into market factors and raising market-wide return variation. However, without an underlying theoretical model, it is difficult to specify the economic mechanism that associates trade openness with market model *R*-square. On the other hand, when both trade and financial openness are included in the same model specification, only the latter is significant but the sign switches to positive. The empirical relationship between financial openness and stock return autocorrelations is the subject of our investigation in the following section.

3.6 Financial Openness and Stock Market Efficiency

As mentioned in the introduction of this chapter, there are only two studies (i.e. Li *et al*., 2004; Basu and Morey, 2005) that explicitly examine the association between trade openness and the informational efficiency of the stock market. In sharp contrast, much greater emphasis has been placed on financial liberalization, especially in the weak-form EMH literature (see references cited in Subsection 2.3.1 of this thesis). However, all these previous studies examine market efficiency in the absolute sense, applying the autocorrelation-based tests on sub-periods of pre- and post-liberalization in each individual stock market. Due to the limitation of their research framework, it is not surprising that the empirical findings are rather inconclusive. Theoretically, Basu and Morey's (2005) model establishes that, in a closed economy, stock prices do not follow a random walk even if there is financial openness, thus highlighting the crucial role of trade opening. This section brings their proposition to the data, using indicators for stock market liberalization and capital account openness.

3.6.1 Panel regression with stock market openness measures

Similar to the case with trade openness, both the *de jure* and *de facto* measures of stock market openness are now considered. Although the official liberalization dates of Bekaert *et al*. (2005) have been widely adopted in the literature, 18 of the 23 sampled countries had liberalized their stock markets by 1992, which is the beginning of our sample period. This indicates little variation across countries or over time for the liberalization dummy variable.[16] Moreover, these market opening dates treat financial liberalization as a one-time event that constitutes an instantaneous and complete removal of barriers on foreign investment. However, most countries liberalize their stock markets by lifting individual restrictions gradually over time and it can take several years before a market is completely open to foreign investors. For instance, Henry (2007) points out that South Korea began allowing foreigners very limited access to its stock market through closed-end country funds as early as 1982, but the country only started lifting its statutory ceiling on foreign investment in 1992.

We follow Li *et al*. (2004) in using the Global Index (IFCG) and the Investable Index (IFCI) computed by Standard & Poor's/International Finance Corporation (S&P/IFC) to capture the extent of stock market openness and the evolution of subsequent changes in controls. Edison and Warnock (2003) argue that the ratio of the market capitalizations of

[16] To capture the effect of stock market liberalization using the dates provided by Bekaert *et al*. (2005), most studies employ stock data at a monthly frequency, which is available from as early as the 1970s in Standard & Poor's Emerging Markets Database (see, for example, Bae *et al*., 2006; Fernandes and Ferreira, 2009). Computing the variance ratios on an annual basis using only 12 observations raises the issue of reliability, but daily data for emerging markets are only available from the early 1990s.

a country's IFCI and IFCG indices provides a quantitative measure of the availability of the country's equities to foreigners, with values ranging from zero (completely closed to foreign investors) to one (completely open market with no foreign restrictions). The annual version of this index of investability is constructed using information drawn from the *Emerging Stock Markets Factbook* (1992-2002) and the *Global Stock Markets Factbook* (2003-2006). Unfortunately, data on market capitalization for the IFCI are no longer published in the latter. We explore an alternative method using these hardcopy sources by calculating the ratio of the number of firms in both indices for each country, and the computed value carries a similar interpretation to those based on market capitalization (see Bekaert *et al*., 2005). In fact, Bekaert *et al*. (2005) note that this measure may be less noisy, given the high degree of volatility in the stock returns of emerging markets.

De facto stock market openness is measured as the sum of equity inflows and outflows as a share of GDP. We also consider equity inflows as a share of GDP. The *International Financial Statistics* (IFS) published by the International Monetary Fund (IMF) is the standard data source for annual capital flows. Equity securities assets (line 78bkd) and equity securities liabilities (line 78bmd) include shares, stocks, participation, and similar documents (such as the U.S. depository receipts) that usually denote the ownership of equity. However, we utilize the External Wealth of Nations Mark II (EWN II) dataset provided by Lane and Milesi-Ferretti (2007), as these authors have cleaned up the basic IFS data with care, paying particular attention to valuation effects (see also Alfaro *et al*., 2008 for discussion on data issues). More specifically, the stock measures of portfolio equity assets and liabilities are constructed based on the cumulative equity outflows and inflows taken from the IFS, but they are adjusted for changes in the end-of-year U.S. dollar value of the domestic stock market. Another advantage of the EWN II dataset is that it contains information on the composition of international investment positions for 145 countries covering the period 1970-2004, though not every country has data for every year.

The summary statistics for our selected measures of *de jure* and *de facto* stock market openness are provided in Table 3.3. The correlation matrix in Table 3.4 shows that the index of investability is not highly correlated with the other regressors. Total equity flow, in contrast, has a relatively higher correlation with *de facto* trade openness (0.4064) than with *de jure* trade openness (0.2880). These correlations increase to 0.5072 and 0.3057, respectively, when equity inflow alone is considered. Table 3.6 reports the results where each of these measures enters separately into the panel regression. The variables for *de facto* trade openness, trading volume, and return volatility retain their earlier signs and statistical significance; irrespective of whether the *de jure* or *de facto* stock market openness measure is employed. However, only equity inflow is found to be significant, as shown in Column (6). The positive coefficient suggests that a higher degree of equity inflow is associated with greater return autocorrelations and hence with a lower degree of market efficiency.[17] In unreported exercises, we run similar regressions, but with total portfolio equity flows and portfolio equity inflows which exclude foreign direct investment. However, none of them is statistically significant.

[17] Return autocorrelations may arise if foreign investors that are largely institutional engage in a positive feedback trading strategy (see the theoretical model of De Long *et al*., 1990b). Shu (2008) shows empirically that positive feedback trading by institutions is one of the driving forces behind stock return momentum, supporting the theoretical prediction of De Long *et al*. (1990b). Sias (2007) provides a recent survey of the literature on whether institutional investors engage in positive feedback trading.

Table 3.6: Stock Market Openness and Stock Market Efficiency

	***De jure* Measure**		***De facto* Measure (Total Equity Flows)**		***De facto* Measure (Equity Inflows)**	
	(1)	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**
VOL	-0.0188**	-0.0201**	-0.0194**	-0.0205**	-0.0193**	-0.0207**
	(2.0874)	(2.3696)	(2.0199)	(2.2635)	(1.9985)	(2.2631)
MV	0.0126***	0.0138***	0.0136***	0.0155***	0.0140***	0.0162***
	(3.4287)	(3.8125)	(3.3979)	(3.8789)	(3.4836)	(4.0078)
DFTO		-0.0004**		-0.0004**		-0.0005**
		(2.2604)		(2.3693)		(2.5076)
DJSMO	0.0089	0.0089				
	(0.9355)	(0.9605)				
$DFSMO^{TF}$			0.0153	0.0267		
			(0.8516)	(1.4516)		
$DFSMO^{IF}$					0.0361	0.0540**
					(1.3767)	(2.0145)
Country Dummies	Yes	Yes	Yes	Yes	Yes	Yes
Year Dummies	Yes	Yes	Yes	Yes	Yes	Yes
Number of observations	345	345	299	299	299	299
Number of countries	23	23	23	23	23	23
R-square	0.3179	0.3314	0.3014	0.3202	0.3052	0.3267

Notes: Table 3.2 describes all the variables listed above along with their respective data sources.
The dependent variable is the absolute value of the variance ratio minus one, |VR-1|, which measures the extent of the deviations from market efficiency for country *i* in year *t*.
The entries in parentheses are the absolute values of the *t*-statistics. The standard errors for the OLS regressions are adjusted for heteroscedasticity and within-country correlation of the error terms.
***, ** and * indicate statistical significance at the 1%, 5%, and 10% levels, respectively.

A number of recent studies also examine the empirical link between financial openness and stock market informational efficiency, where the latter is proxied by the market model *R*-square statistic and price delay. However, the findings are at best mixed. For instance, Li *et al*. (2004) find that a greater degree of stock market openness is associated with a higher *R*-square when trade openness is included in the same specification. The degree of investability is only positively related to informational efficiency when sound institutions are in place. Using a sample of 25 emerging stock markets, Bae *et al*. (2006) obtain results from event study regressions that show market model R^2 decreases significantly after markets are opened up to foreign portfolio investments. However, when using time series measures of openness in their panel regression, the authors find that neither the degree of investability nor the size of portfolio flows with the U.S. is significantly related to the degree of informational efficiency. Fernandes and Ferreira (2009) find that stock market liberalization, proxied by the official liberalization dates of Bekaert *et al*. (2005), is not significantly related to the market model R^2 once they control for the enforcement of insider trading laws in their panel regression. Unlike the above country-level studies, the evidence from firm-level data is more encouraging. Using the price delay measure, Bae *et al*. (2008) find that a higher degree of investability is associated with a smaller price delay, indicating that the participation of foreign investors in the domestic stock markets of 35 developing countries facilitate faster incorporation of market-wide information. Unfortunately, all the aforementioned papers do not specify clearly the mechanism that associates financial openness with their measures of relative market efficiency.[18]

[18] In the absence of a theoretical model that establishes the positive association between financial openness and stock market informational efficiency, the general conjectures given include increased stock trading activity, greater transparency, stricter disclosure rules, improved quality of information, improved dissemination of information, and more informed trading by arbitrageurs.

3.6.2 Panel regression with capital account openness measures

We further test whether our earlier results are robust to alternative measures of financial openness by using a broader concept of capital account liberalization. Unlike stock market openings, there are more than a dozen capital control measures proposed in the literature, mainly based on the details given by the International Monetary Fund (IMF)'s *Annual Report on Exchange Arrangements and Exchange Restrictions* (for a survey, see Edison *et al*., 2004: Table 1; Miniane, 2004: Table 1). Given that there is no single index that is able to capture the complexity of real world capital controls, in particular the problems of aggregation and enforceability (for discussions, see Miniane, 2004; Chinn and Ito, 2006), our choice is hence determined by data accessibility and country/year coverage. Though the measure of the intensity of capital account openness constructed by Quinn (1997) is the most widely used in the empirical literature, the data are available only from 1950 to 1989 for 21 Organization for Economic Cooperation and Development (OECD) countries, and the coverage for 43 non-OECD countries is limited to certain years: 1958, 1973, 1982 and 1988. Even in the updated version by Quinn and Toyoda (2008) that expands the coverage to 94 countries, the index is constructed only up to the year 1999.

Guided by the above selection criteria, we employ two publicly available indicators of capital account liberalization. The first indicator is a *de jure* measure developed by Chinn and Ito (2006, 2008). This index of capital account openness is the first principal component of the binary variables that pertain to the cross-border financial transactions in the IMF's categorical enumeration and are reported in the *Annual Report on Exchange Arrangements and Exchange Restrictions*. A higher value on the index indicates that a country is more open to cross-border capital transactions. An advantage of this dataset is its wide coverage of 182 countries over a long time period from 1970 to 2006, though not every country has data for every year. For the *de facto* openness measure, our analysis draws upon the External Wealth of Nations Mark II (EWN II) dataset provided by Lane and Milesi-Ferretti (2007). More specifically, the second broad indicator of capital account openness is measured as the sum of the gross stocks of foreign assets and liabilities as a share of GDP. Their components are portfolio equity investment, foreign direct investment, external debt, financial derivatives, and total reserves minus gold. In addition to the aforementioned total capital flows, we also consider capital inflows.

The summary statistics for our selected measures of *de jure* and *de facto* capital account openness are provided in Table 3.3. For the former, the correlations with trade openness are very low (see Table 3.4). Even with total capital flow/inflow, the correlations are at most 0.3609. The correlations between *de facto* capital account openness and trade openness are relatively higher, falling within the range of 0.3919 and 0.5789. Table 3.7 reports the findings where each of these measures enters separately into the panel regression. The results do not alter our earlier conclusion with regard to the insignificant association between financial openness and the extent of deviations from market efficiency. The variables for *de facto* trade openness, trading volume, and return volatility retain their earlier signs and statistical significance in all model specifications. None of the indicators for capital account openness is significant. Interestingly, their coefficients are positive after controlling for trade openness, which contradicts the widely held perception that financial openness enhances the efficiency of the stock market.

Table 3.7: Capital Account Openness and Stock Market Efficiency

	***De jure* Measure**		***De facto* Measure (Total Capital Flows)**		***De facto* Measure (Capital Inflows)**	
	(1)	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**
VOL	-0.0186**	-0.0211**	-0.0199**	-0.0207**	-0.0201**	-0.0208**
	(2.0865)	(2.4155)	(2.1080)	(2.2965)	(2.1463)	(2.3078)
MV	0.0129***	0.0140***	0.0136***	0.0150***	0.0137***	0.0150***
	(3.4148)	(3.7114)	(3.3871)	(3.7777)	(3.4282)	(3.7836)
DFTO		-0.0004**		-0.0004**		-0.0004**
		(2.1535)		(2.1278)		(2.0493)
DJCAO	0.0016	0.0005				
	(1.0140)	(0.2988)				
$DFCAO^{TF}$			-0.0025	0.0053		
			(0.3724)	(0.7165)		
$DFCAO^{IF}$					-0.0069	0.0049
					(0.7194)	(0.4540)
Country Dummies	Yes	Yes	Yes	Yes	Yes	Yes
Year Dummies	Yes	Yes	Yes	Yes	Yes	Yes
Number of observations	333	333	299	299	299	299
Number of countries	23	23	23	23	23	23
R-square	0.3215	0.3334	0.2995	0.3153	0.3005	0.3145

Notes: Table 3.2 describes all the variables listed above along with their respective data sources.
The dependent variable is the absolute value of the variance ratio minus one, |VR-1|, which measures the extent of the deviations from market efficiency for country *i* in year *t*.
The entries in parentheses are the absolute values of the *t*-statistics. The standard errors for the OLS regressions are adjusted for heteroscedasticity and within-country correlation of the error terms.
***, ** and * indicate statistical significance at the 1%, 5%, and 10% levels, respectively.

3.6.3 Some caveats on the lack of relationship between financial openness and stock market efficiency

The results in this section do not lend strong support to the existence of a significant link between financial openness and stock market efficiency. Though our finding is consistent with the theoretical prediction of Basu and Morey (2005), the lack of a robust positive relationship is still puzzling from an information perspective. More specifically, the participation of foreign investors in local stock markets should improve the dissemination of information, and hence leads to faster incorporation of information into stock prices. For instance, Bae *et al*. (2006) find that financial liberalization indeed improves the local environment for disclosure, information production, and the analysis of information in 25 emerging stock markets. On the theoretical front, Froot and Perold (1995) show that the slow dissemination of market-wide information results in positive serial correlations in stock index returns. Consistently, the behavioral model of Hong and Stein (1999) also predicts that stock price under-reaction is the outcome of gradual dissemination of information across the investing public.

We contend that it is still premature to draw a strong conclusion on the lack of association between financial openness and market efficiency on two grounds. First, it is possible that the quality of domestic political institutions plays an important role for a country to reap the efficiency benefit from financial liberalization. For instance, Li *et al*. (2004) find that stock market openness is associated with a lower degree of informational efficiency in developing countries, but this can be avoided if sound institutions are in place as captured by the cross product of stock market openness and good government index. We use the same proxy for institutional quality as Li *et al*. (2004), which is available for 18 of our sampled countries. However, the interaction term between financial openness and the good government index has never been statistically significant. The main problem with this good government index is its time-invariant nature, since the effect of such variable cannot be distinguished from the country fixed effects. To address the role of institutional quality in the present setting, it is more appropriate to employ a time-varying institutional quality index, such as the International Country Risk Guide composite indicator published by the PRS Group (see Baltagi *et al*., 2009; Bekaert *et al*., 2009; Papaioannou, 2009).[19] The interaction of financial openness and institutions is worth pursuing in future studies as this inquiry sheds additional light on the pre-requisites for reaping the potential benefits of financial reforms.

Second, the use of aggregate country-level data may mask the true impact of financial liberalization, as there are different levels of openness among firms in the same country. In other words, when country-level restrictions on foreign investment are lifted, not all listed firms become eligible for foreign ownership. As stated previously, the empirical evidence on the positive link between financial openness and stock market efficiency is more encouraging when firm-level data is employed (see Bae *et al*., 2008). In future investigation, firm-level measures of openness to foreign investors may be used, which are available in Standard & Poor's Emerging Markets Database (see Mitton, 2006; Bae *et al*., 2008). Following Hong *et al*. (2000) and Chan and Hameed (2006), analyst coverage can be used as a proxy to test our conjecture that the speed of information dissemination is the channel that gives rise to a positive relationship between financial openness and stock market efficiency. To further disentangle the separate effect of trade

[19] Since 1980, the monthly issue of International Country Risk Guide (ICRG) produces political, economic, and financial risk ratings, and ICRG now monitors 140 countries. We do not have access to this data as they are available only through subscription (for details, see http://www.prsgroup.com/).

liberalization, the collection of firm-level trade openness data is worth pursuing (see Buch *et al*., 2009). The above suggested in-depth within-country analysis using firm-level data will provide a direct input to the policymakers of the country under study.

3.7 What Explains the Positive Relationship between De Facto Trade Openness and Stock Market Efficiency?

Our empirical results show that a greater level of *de facto* trade openness is associated with a higher degree of stock market efficiency, but this positive relationship does not hold when the *de jure* measure is used. On this basis, we argue earlier that there is a possibility the hypothesized technological returns to scale might not be the driving force because trade opening is modeled by Basu and Morey (2005) as an elimination of non-tariff restrictions on the import of foreign intermediate inputs. However, this could simply mean that official trade reforms are insufficient to take advantage of returns to scale if they are not accompanied by increases in the actual level of trade flows. As an indirect test of their proposed channel, we replace the contemporaneous value of trade openness with its lagged value, controlling for trading volume and return volatility. This is because it is reasonable to expect, if returns to scale is the channel, the impact of changes in trade openness to be gradual as the postulated transmission mechanism may take years to complete. Our unreported exercise finds that the variable of trade openness with a one-year lag is not significant, and nor do longer lags return significant results. To gain a deeper insight into the specific channel that relates trade openness to stock market efficiency, a more comprehensive analysis is required, although this is beyond the scope of this chapter.

Nevertheless, we discuss two potential channels, at the country- and firm-levels, that can give rise to a positive link between *de facto* trade openness and stock market efficiency. At the country-level, it is possible that a greater level of trade openness is associated with a higher degree of informational efficiency because the former promotes the integration of international stock markets.[20] For instance, Hooy and Goh (2008) employ panel regression to explore the potential determinants that account for the variations in stock market integration across countries and over time. These authors find that *de facto* trade openness is one of the three important drivers of market integration, consistent with their conjecture that economic integration as part of the globalization process should help to integrate stock markets across national borders. Though some recent studies straddle the two somewhat disparate strands of literature to simultaneously test for market integration and market efficiency (see Rockinger and Urga, 2001; Schotman and Zalewska, 2006), their empirical relationship has not been examined directly. Hooy and Lim (2009) provide the first evidence of a positive association between market integration and informational efficiency. More specifically, their panel regression results show that a more integrated market is associated with a faster stock price reaction to global market-wide information, even after controlling for standard determinants of price delay. The empirical findings that trade openness is associated with higher stock market efficiency and greater market integration documented respectively in this chapter and Hooy and Goh (2008) could set the stage for a richer theoretical exploration.

[20] It is worth noting that greater market integration does not necessarily go hand in hand with higher market efficiency. Lence and Falk (2005) illustrate within the setting of a standard dynamic general equilibrium asset-pricing model that these two important concepts are independent of one another.

Our firm-level explanation is based on an information perspective. While the speed of information dissemination is hypothesized to be the link between financial openness and stock market efficiency, the latter is positively related to trade openness due to improved quality of information. In particular, as a country becomes more open to international trade over time, its increased engagement signals higher future firm profitability, consistent with the interpretation of Henry (2000) and Chari and Henry (2008). We argue that when there is less uncertainty about a firm's future earnings or cash flows, investors tend to react faster to public information. On the contrary, greater information uncertainty about a firm's fundamentals exacerbates investors' under-reaction behavior and induces return autocorrelations. To test the role played by trade liberalization-induced changes in firm-specific expected future profitability, future studies can use the real value of sales and earnings taken directly from firms' income statements (see Chari and Henry, 2008). Our conjecture is related to an emerging literature that examines the relationship between information uncertainty and stock market anomalies (see Liang, 2003; Jiang *et al*., 2005; Zhang, 2006a, b; Francis *et al*., 2007). The most relevant one is Zhang (2006b) who hypothesizes that if investors under-react to public information, they will under-react even more in cases of greater information uncertainty. In the empirical investigation, Zhang (2006b) employs a battery of proxies for information uncertainty, namely firm size, firm age, analyst coverage, dispersion in analyst forecasts, return volatility and cash flow volatility. His results show that U.S. stocks for which information uncertainty is higher exhibit stronger short-term stock price continuation, suggesting that uncertainty delays the incorporation of information into stock prices.

3.8 Conclusion and Recommendations

In the extant literature, a number of studies develop a class of asset pricing models with a non-trivial production section to study the time series behavior of stock returns. For instance, Basu and Vinod (1994) examine the role of technological returns to scale in determining the autocorrelation patterns of stock returns. Building on the theoretical linkage between production technology and stock prices, Basu and Morey (2005) develop a production-based asset pricing model to explore the effect of trade openness on stock return autocorrelations. Two key predictions of their model are: (1) trade openness in the form of removing non-tariff barriers to the import of foreign intermediate inputs is both a necessary and sufficient condition for ensuring stock prices move more closely to a random walk; (2) financial opening alone, that is, without trade reform, does not lead to an improvement in stock market efficiency.

The empirical relationship between trade openness and stock market efficiency has largely been neglected. This chapter presents cross-country evidence using the data for 23 developing countries over the period 1992-2006. Our fixed effects panel regression results show that a greater level of *de facto* trade openness is associated with a higher degree of informational efficiency in these emerging stock markets, even after controlling for two other competing theoretical determinants – trading volume and market return volatility. However, this negative relationship between trade openness and stock return autocorrelations does not hold when the *de jure* measure is used. Subsequent analyses do not find evidence of a significant link between financial openness and stock market efficiency.

Though our findings are broadly consistent with the theoretical predictions of Basu and Morey (2005), we offer alternative explanations which may stimulate more extensive empirical work in future. First, the lack of association between financial openness and stock market efficiency may be due to the presence of threshold effects. For instance, several studies show that institutional quality is important for a country to reap the full benefits from financial liberalization (see Li *et al*., 2004; Chinn and Ito, 2006; Bekaert *et al*., 2009). An extensive interaction analysis on the threshold effects is worth pursuing as this will shed light on the set of pre-conditions for financial openness to deliver the efficiency benefit. Second, it is possible that a greater level of trade openness is associated with a higher degree of informational efficiency because the former promotes the integration of international stock markets. Even though market efficiency and market integration are two important concepts in finance, their relationship is often implied but not directly examined. One of the reasons is that the literature has long treated market efficiency as a yes or no question. The empirical findings that trade openness is associated with higher stock market efficiency and greater market integration documented respectively in this chapter and Hooy and Goh (2008) highlight their possible linkage, and thus open an interesting avenue for future research.

As a next step to examine the channels through which stock market efficiency is related to openness, firm-level data will provide greater clarity than the aggregate country-level data. The theoretical model of Basu and Morey (2005) emphasizes the role of technological returns to scale. There are of course several other possible explanations. Using an information perspective, we argue that the participation of foreign investors in local stock markets should improve the dissemination of information, and hence leads to faster incorporation of information into stock prices. Analyst coverage is a suitable proxy to test this speed of information dissemination channel. Trade openness, on the other hand, is hypothesized to be positively related to market efficiency as the former signals higher future firm profitability and hence reduces uncertainty about a firm's future earnings or cash flows. To test our conjecture, future studies can use the real value of sales and earnings taken directly from firms' income statements to proxy for trade liberalization-induced changes in firm-specific expected future profitability.

While this chapter provides novel evidence of a positive relationship between trade openness and stock market efficiency, our empirical work can also be viewed as addressing the issue of whether those existing theoretical determinants are capable of explaining the variations of index return autocorrelations across countries and over time. Even without the guidance of a theoretical model, it is equally important to examine whether various market reforms/regulations undertaken worldwide such as the automation of trading system, short sales restrictions and insider trading laws achieve their intended objective of enhancing market efficiency.[21] It is worth highlighting that autocorrelation-based measures have been used in a series of recent papers to evaluate the overall effectiveness of short sales price tests under the U.S. Securities and Exchange Commission's (SEC) Regulation SHO Pilot (see SEC, 2007; Alexander and Peterson, 2008; Boehmer and Wu, 2009).[22] Hence, the present panel data investigation can be extended to examine the effects of securities regulations, using country-level data

[21] One of the main objectives of securities regulation is to promote higher level of market efficiency, in which the dissemination of relevant information is timely and is reflected in the price formation process. The objectives and principles of securities regulation can be downloaded from the website of International Organization of Securities Commissions (IOSCO), the leading international grouping of securities market regulators, at http://www.iosco.org/library/pubdocs/pdf/IOSCOPD154.pdf.

[22] The Regulation SHO Pilot temporarily suspended short sales price tests for approximately one third of the Russell 3000 stocks, starting from May 2, 2005 to August 6, 2007. The stated motivation for the suspension was to study in a controlled environment the effects of relatively unrestricted short selling on market volatility, price efficiency and liquidity. Such examination will assist the SEC in determining whether short sales price tests should be amended or removed.

on the introduction dates of electronic trading (Jain, 2005), the dates of insider trading laws enforcement (Bhattacharya and Daouk, 2002), and the feasibility of short selling (Charoenrook and Daouk, 2005; Bris *et al*., 2007).

DECLARATION FOR THESIS CHAPTER 4

Declaration by Candidate

In the case of Chapter 4, the nature and extent of my contribution to the work was the following:

Nature of contribution	**Extent of contribution (%)**
The initiation of idea, formulation of research questions, development of research framework, literature review, construction of cross-country database, data analysis and interpretation, writing up of the first draft, conference presentations, and correspondence with *Macroeconomic Dynamics*.	75%

The following co-author contributed to the work:

Name	**Nature of contribution**
Robert D. Brooks	Participated in the development of research questions and framework, discussions on econometric issues and interpretation of results, refining the draft paper, conference presentation, and acted as corresponding author in previous journal submission.

Candidate's Signature		**Date** June 8, 2009

Declaration by Co-author

The undersigned hereby certify that:

(1) the above declaration correctly reflects the nature and extent of the candidate's contribution to this work, and the nature of the contribution of each of the co-authors;

(2) they meet the criteria for authorship in that they have participated in the conception, execution, or interpretation, of at least that part of the publication in their field of expertise;

(3) they take public responsibility for their part of the publication, except for the responsible author who accepts overall responsibility for the publication;

(4) there are no other authors of the publication according to these criteria;

(5) potential conflicts of interest have been disclosed to (a) granting bodies, (b) the editor or publisher of journals or other publications, and (c) the head of the responsible academic unit; and

(6) the original data are stored at the following location(s) and will be held for at least five years from the date indicated below:

Location	**Department of Econometrics and Business Statistics,** **Monash University**

Co-author's Signature:

Robert D. Brooks		**Date** **June 8, 2009**

CHAPTER 4

Why Do Emerging Markets Experience More Persistent Stock Price Deviations from a Random Walk over Time?[★]

4.1 Introduction

In the extant literature, weak-form market efficiency is commonly examined within the framework of the random walk hypothesis. The logic behind the idea that efficient prices should follow a random walk, according to Malkiel (2003), is that price changes occur only in response to genuinely new information. But true news is by definition unpredictable, thus resulting price changes must be unpredictable and random.[1] In fact, the origin of the efficient markets hypothesis (EMH) is generally traced back to the landmark work of Samuelson (1965), who has been widely credited for giving academic respectability to the random walk hypothesis. More specifically, Samuelson (1965) demonstrates in an informationally efficient market, price changes must be unpredictable if they fully incorporate the expectations and information of all market

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1 In the market microstructure literature, the random walk hypothesis is central to the pricing errors measure developed by Hasbrouck (1993). More specifically, the informationally efficient price is assumed to follow a random walk, as it reflects the expected value of the stock conditional on all information available at the transaction time, including public information and private information inferred from order flow. Pricing error then measures the temporary deviation of the actual transaction price from the efficient random walk price that is due to non-information related market frictions. Boehmer *et al*. (2005), Bennett and Wei (2006), Boehmer and Kelley (2009) and Boehmer and Wu (2009) employ the pricing errors to measure the relative informational efficiency of stock prices in their empirical studies.

participants. Lo (2008) argues the concept has a counter-intuitive flavor to it: the more efficient the market, the more random the sequence of price changes generated by such a market, and the most efficient market of all is the one in which price changes are completely random and unpredictable. This is not an accidental process but achieved through the active participation of many investors who will pounce on even the smallest informational advantages at their disposal.

Unlike the mainstream weak-form EMH studies which focus on testing whether observed stock prices conform strictly to the random walk benchmark, this chapter instead compares the persistence of deviations from a random walk for aggregate stock price indices of 50 countries over the 1995-2005 sample period by means of a rolling window. The motivations for our inquiry are at least threefold. First, for each stock market, it is not unreasonable to expect market efficiency to evolve over the long period of 11 years due to changes in macro institutions, market regulations and information technologies. On the theoretical front, the adaptive markets hypothesis of Lo (2004, 2005) implies market efficiency is not an all-or-none condition but is a characteristic that varies continuously over time and across markets. There is also an expanding empirical literature tracking the evolution of market efficiency over time by means of a time-varying parameter model or a rolling estimation window. Second, our adopted research framework permits cross-country comparisons of the degree of stock price deviations from a random walk over the common sample period of 1995-2005. This is because the rolling window approach reveals how often the random walk hypothesis is rejected by the selected test statistic, and hence the percentage of sub-samples with a significant test statistic can be used to compare the relative weak-form efficiency of our sampled 50 stock markets. Furthermore, assessing the degree of market efficiency at the country-level is warranted in light of Paul Samuelson's dictum that the stock market is micro-efficient but at the same time macro-inefficient, implying that the EMH works better for individual stocks than it does for aggregate stock market indices (for details, see Jung and Shiller, 2005). Third, measuring informational efficiency in the relative rather than absolute sense allows us to further determine whether country characteristics, in particular the quality of macro institutions, can account for the documented variation across the 50 international markets.

Using the rolling bicorrelation test advocated by Lim (2007) to measure the degree of nonlinear departures from a random walk, we find that emerging stock markets in general experience more frequent price deviations than developed markets. Subsequent analysis shows that the degree of stock price deviations is negatively and significantly related to per capita gross domestic product (GDP). This result is not surprising since the classification of developed/emerging market is generally based on a country's income level as defined by the World Bank. Hence, the empirical challenge is to uncover the economic linkages that underlie the inverse relation between both measures. Most investigators often turn to market liquidity for explanation given that stock markets in developed countries generally exhibit a higher level of liquidity than those in developing countries (see Appiah-Kusi and Menyah, 2003; Lagoarde-Segot and Lucey, 2008; Lim *et al*., 2008a). According to Chordia *et al*. (2008), there should be smaller departures from a random walk benchmark when markets are more liquid due to increased arbitrage activity. The rationale is that trading frictions such as the lack of liquidity may impede the capitalization of information into stock prices, thereby undermining the ability of arbitrageurs to exploit deviations from the efficient random walk price. However, this possibility is ruled out by our regression analysis, which shows that the documented cross-country variation cannot be explained by differences in the level of market liquidity, regardless of whether market capitalization, total value traded or turnover ratio is employed as the proxy.[2]

In the absence of theoretical guide, the search for potential explanations of this country-level phenomenon can be exhaustive. We therefore follow the empirical strategy of Morck *et al*. (2000) to see which development measures are most correlated with the degree of stock price deviations, and whether they render per capita GDP insignificant in multivariate regression. Our analysis shows that the negative relation between the degree of stock price deviations and per capita GDP can largely be attributed to low income economies providing weak protection for private property rights. Morck *et al*. (2000) argue that weak property rights protection might cause arbitrageurs to shun the stock markets of these economies, leaving them to noise traders. Using firm-level data from the U.S., Chordia *et al*. (2008) report evidence supporting their conjecture that market liquidity stimulates arbitrage activity. Our finding instead highlights the importance of a strong private property rights institution in attracting the participation of informed traders, at least at the country-level. While Morck *et al*. (2000) assume arbitrage trading is responsible for the incorporation of firm-specific information into stock prices, the critical role of arbitrageurs in restoring price deviations and keeping the market efficient has been the cornerstone of modern financial economics. Hence, the lack of arbitrage trading due to weak property rights protection leads not only to a high degree of stock price synchronicity in the stock markets of low income economies as

[2] The annual data for these variables, collected from World Bank's World Development Indicators (WDI), are averaged over the sample period of 1995-2005. Our univariate regression shows that none of the variables, either in its original or logarithmic form, is significantly related with the degree of stock price deviations from a random walk.

reported by Morck *et al*. (2000), but also contributes to their frequent price deviations as documented in this chapter. The effect is further amplified by the dominance of noise traders who are prone to sentiment not fully justified by information, in which their correlated trading can cause stock prices to deviate from the random walk benchmark for long periods of time.

The remainder of this chapter is structured as follows. Section 4.2 reviews three related strands of literature that motivate the selection of the rolling bicorrelation test statistic as our measure of relative weak-form market efficiency. Following that, we discuss the source of the stock market data and briefly explain the rolling bicorrelation test. Section 4.4 presents the degree of stock price departures from a random walk for a broad cross-section of 50 stock markets. Sections 4.5 and 4.6 explore the underlying factors that are responsible for the documented cross-country variation. Further discussions of the empirical results, along with some suggestions for future research, are provided in Section 4.7. The final section then concludes this chapter.

4.2 A Review of Related Literature

This section reviews three separate strands of literature that motivate our selection of the rolling bicorrelation test statistic for comparing the degree of weak-form market efficiency at the country-level using aggregate stock price indices of 50 countries. More specifically, the adopted framework addresses the possibility of nonlinear serial dependence in stock returns, captures the persistence of stock price deviations over time, and assesses weak-form market efficiency in the relative rather than absolute sense.

4.2.1 The evolving efficiency of stock markets

The mainstream weak-form EMH studies surveyed in Section 2.2 of this thesis all assume a fixed level of market efficiency throughout the entire estimation period. Lo (2004, 2005) argues it is incorrect to make the assumption that the market is perpetually in an equilibrium state. The author then proposes a new version of the EMH based on evolutionary principles which allows market efficiency to vary continuously over time and across markets. According to his adaptive markets hypothesis, the main driving forces behind such market dynamics are the institutional changes in the stock market and the changing demography of market participants.

Empirically, there is an expanding literature tracking the evolution of market efficiency over time by means of a time-varying parameter model or a rolling estimation window. The first group pioneered by Emerson *et al*. (1997) estimates time-varying autocorrelation coefficients using the Kalman filter technique. The main issue addressed in these studies is whether newly established stock markets are becoming more efficient. Another category of studies applies existing weak-form EMH tests in rolling estimation windows. Examples are the rolling variance ratio statistic (Tabak, 2003; Kim and Shamsuddin, 2008), rolling ADF unit root test (Phengpis, 2006), rolling bicorrelation test (Lim, 2007; Todea and Zoicas-Ienciu, 2008), rolling Hurst exponent (Costa and Vasconcelos, 2003; Cajueiro and Tabak, 2004c, 2005d, 2006, 2008b; Zunino *et al*., 2007), rolling Lempel-Ziv complexity index (Giglio *et al*., 2008) and the rolling Shannon entropy statistic (Risso, 2008). The application of a rolling window essentially captures the persistence of stock price departures from a random walk benchmark over time. All the aforementioned studies report overwhelming evidence of evolving weak-form market efficiency, consistent with the prediction of AMH.

4.2.2 The relative efficiency of stock markets

In a parallel development, there are increasing number of studies which examine market efficiency in the relative rather than absolute sense (see the survey paper by Lim and Brooks, 2009b). In this literature, the degree of market efficiency is measured based on: (1) how much private firm-specific information is incorporated into stock prices, using the market model *R*-square statistic (Morck *et al*., 2000), the private information trading measure (Llorente *et al*., 2002) and the probability of information-based trading (Easley *et al*., 1997); (2) how quickly market-wide information is capitalized into stock prices using the price delay measure of Hou and Moskowitz (2005); (3) how closely stock prices follow a random walk using the conventional weak-form EMH tests and the pricing errors derived by Hasbrouck (1993). In the context of weak-form EMH, the commonly used measures of relative efficiency are the absolute value of the autocorrelation coefficient, the absolute deviation from one of variance ratio and the magnitude of the Hurst exponent (see references cited in Subsection 2.3.2 of this thesis). The notion of relative efficiency allows these studies not only to compare the degree of informational efficiency at the country- and firm-levels, but also to explore the factors associated with higher efficiency using cross-sectional or panel regression. The growing importance of this literature has motivated the World Bank's Financial Sector Development Indicators (FSDI) project to construct a composite indicator for comparing the efficiency of stock markets around the world.[3]

[3] To construct the composite efficiency index for each stock market, FSDI takes the average of three indicators, namely the market model *R*-square statistic, the private information trading measure and the implied equity transaction costs. The data are accessible at http://www.fsdi.org/.

In the emerging literature of evolving market efficiency, the rolling window approach reveals how often the random walk hypothesis is rejected by the test statistic over the full sample period. A meaningful comparative analysis can therefore be conducted by comparing how frequently stock prices deviate from a random walk over the sample period. Particularly, relative efficiency is inferred from the percentage of sub-samples with a significant test statistic, where a higher percentage indicates more frequent stock price deviations, and hence a lower degree of informational efficiency. Several studies adopt the rolling window approach not only to capture the changing dynamics of market efficiency, but also to: (1) assess the relative efficiency of their sampled stock markets (see Cajueiro and Tabak, 2004a, b, 2005b; Lim, 2007; Giglio *et al*., 2008); (2) examine the impact of some postulated factors on the degree of market efficiency, such as the occurrence of financial crisis (Cheong *et al*., 2007; Lim, 2008c; Lim *et al*., 2008c) and the implementation of price limits system (Lim and Brooks, 2009d).

4.2.3 Nonlinear departures from the random walk benchmark

To reiterate, the AMH postulates that market efficiency is a characteristic that varies continuously over time and across markets. However, the hypothesis does not specify the exact form of departures from market efficiency, nor does it offer any observable empirical proxies that can explain the changing dynamics of market efficiency. In the absence of theoretical guide or rather constraint, we then focus on nonlinear departures from the random walk benchmark as our metric of weak-form market efficiency. This is because nonlinear tests are more appealing from a statistical perspective than the autocorrelation-based procedures. For instance, when nonlinear dependence is present in the data, there exists a nontrivial gap between white noise and pure white noise. In fact, it is widely acknowledged that autocorrelation-based tests have no power against nonlinear processes with zero autocorrelation, such as the bilinear autoregressive, nonlinear moving average and threshold autoregressive processes. Hence, a misleading conclusion in favor of market efficiency could be delivered when the autocorrelation-based tests are insignificant.

Given that there is overwhelming evidence of nonlinearity in stock return series (see references cited in Lim *et al*., 2006), the empirical challenge is to explain why it arises in the first place. Though this is a rather neglected issue, several studies do speculate on the possible causes. Firstly, Brooks *et al*. (2000) conjecture that when surprises hit the market, the return series generally exhibit nonlinear dependence since investors are unsure of how to react, hence they response sluggishly (for a similar line of reasoning, see Lim *et al*., 2006; Hinich and Serletis, 2007). Secondly, Sarantis (2001) and Shively (2003) single out differences of opinion among investors as one of the causes that may lead to persistent nonlinear deviations from the equilibrium. This occurs because investors have additional private information, different prior beliefs, or they use different models to evaluate the impact of news. Thirdly, nonlinearity can arise due to the presence of market frictions such as transaction costs that may deter arbitrage trading (see Dwyer *et al*., 1996; Martens *et al*., 1998; Anderson and Vahid, 2001). Finally, McMillan (2003) argues that the most promising explanation is the interaction between arbitrageurs and noise traders where investor cognitive biases and limits to arbitrage can give rise to nonlinearity. This is because the existence of noise trader risk creates a band of inactivity within which deviations from equilibrium are left uncorrected by arbitrageurs (for this emerging behavioral explanation, see McMillan, 2005; McMillan and Speight, 2006). Hence, in addition to its statistical appeal, our focus on nonlinear serial dependence further contributes to this limited literature by providing additional light on the possible driving forces of widespread nonlinear dynamics in stock data.

4.2.4 A synthesis

Though there are many nonlinearity tests available in the literature, we only employ the bicorrelation test (Hinich, 1996) to detect nonlinear departures from the random walk benchmark. This is because the bicorrelation is the third-order extension of correlation, and hence can be incorporated into extant theoretical models of return autocorrelation to allow for possible nonlinear reaction to information.[4] In order to capture the persistence of nonlinear deviations for each stock market over the common sample period of 1995-2005, we follow Lim (2007) in computing the bicorrelation test statistic in rolling windows. Within this framework, relative efficiency is inferred from the percentage of time windows with significant bicorrelation test statistic, where a higher percentage corresponds to a lower degree of informational efficiency. Our study, however, does not merely compare the relative efficiency of the sampled 50 international stock markets. Instead, we further explore those potential factors that can explain the documented cross-country variation, in particular the quality of macro institutions.

[4] The bicorrelation or known as the third-order correlation is a correlation between the current return and previous autocorrelation coefficient, indicating that the process may be predictable from their own past values in a nonlinear manner. Brooks and Hinich (2001) demonstrate via their proposed univariate bicorrelation forecasting model that the bicorrelations can be used to forecast the future values of the series.

4.3 Data and Methodology

This section discusses the source of our stock market data, the bicorrelation test and some issues related to its empirical implementation.

4.3.1 The stock market data

We collect country indices at the daily frequency for 23 developed and 27 emerging stock markets from Morgan Stanley Capital International (MSCI). These indices are denominated in U.S. dollar so as to give us the perspective of an international investor. To ensure consistency, we use a common sample period for all the 50 markets, commencing from January 1, 1995 and ending on December 31, 2005. The choice of the starting date is dictated by data availability, since daily country indices for Czech Republic, Egypt, Hungary, Morocco and Russia are only available from December 31, 1994 onwards. For empirical analysis, all the collected data are transformed into a series of continuously compounded percentage returns by taking 100 times the log price relatives, i.e. $r_t = 100 \cdot \ln\left(p_t / p_{t-1}\right)$, where p_t is the closing price of the index on day t, and p_{t-1} the price on the previous trading day. The above sample period of 11 years yields a total of 2870 daily return series for each stock market.

Some basic information of the data is given here. Firstly, MSCI classifies a stock market as either ‘developed’ or ‘emerging’ based on the income level of the country as defined by the World Bank. Another consideration is the existence of investment restrictions such as currency repatriation restrictions, capital controls and foreign share ownership limitations. Using these criteria, a developed stock market must be in the World Bank’s high income economies, and there are no broad-based discriminatory controls against non-domiciled equity investors. An emerging market, on the other hand, is located in a low- or middle-income economy and has pervasive restrictions on foreign portfolio investment. Secondly, these country indices are end-of-period value-weighted indices of a large sample of companies in each country. To construct an MSCI Country Index, every listed security in the market is identified. Securities are free float adjusted, classified in accordance with the Global Industry Classification Standard, and screened by size and liquidity. MSCI then constructs its indices by targeting for index inclusion 85% of the free float adjusted market capitalization in each industry group within each country. By targeting 85% of each industry group, the MSCI Country Index captures 85% of the total country market capitalization while it accurately reflects the economic diversity of the market. These indices are computed consistently across markets, thereby allowing for a direct comparison across countries.

4.3.2 The bicorrelation test

The bicorrelation test of Hinich (1996) is a third-order extension of the standard correlation test for white noise, and is designed to detect the presence of significant bicorrelation coefficients (also known as the third-order correlation coefficients).[5,6] This subsection provides a brief description of the bicorrelation test statistic, henceforth denoted as the H statistic. The full theoretical derivation and some Monte Carlo

[5] The Hinich's (1996) bicorrelation test is very similar to the third-order moment test of Hsieh (1989). The third-order moment test is constructed to detect additive nonlinearity, given the null hypothesis of multiplicative nonlinearity. This is because the bicorrelation coefficients are all equal to zero under the null hypothesis of multiplicative nonlinearity. The alternative hypothesis is that the process has some non-zero bicorrelations, hence implying nonlinearity in the conditional mean. In extant empirical literature, the third-order moment test has been widely adopted to distinguish the source of nonlinearity (see, for example, Fujihara and Mougoué, 1997; Kohers *et al.*, 1997; Fernandes, 1998; Yadav *et al.*, 1999; Río and Santamaría, 2000; Robles-Fernandez *et al.*, 2004; Saadi *et al.*, 2006).

[6] However, there is one important difference between both statistical tests. Hsieh's (1989) test examines whether the estimated bicorrelation coefficients are individually significantly different from zero using the *t*-statistic. Hinich's (1996) test, on the other hand, is a joint test that the bicorrelation coefficients are all equal to zero using the chi-square statistic. Moreover, the asymptotic sampling properties of the bicorrelation test statistic are rigorously determined in Hinich (1996).

evidence on the small sample properties of the test statistic are given in Hinich (1996), Patterson and Ashley (2000) and Hinich and Patterson (2005).

Let the sequence $\{y(t)\}$ denote the observed sampled data process, where the time unit, t, is an integer. The data are standardized to have a sample mean of zero and a sample variance of one by subtracting the sample mean and dividing by its standard deviation.

Define $Z(t)$ as the standardized observations that can be written as:

$$Z(t) = \frac{y(t) - m_y}{s_y} \tag{4.1}$$

for each $t = 1, 2, ..., n,$ where m_y and s_y are the sample mean and sample standard deviation of the data, respectively.

The null hypothesis is that the transformed data $\{Z(t)\}$ are realizations of a stationary pure white noise process. Under the null hypothesis, the bicorrelation coefficients $C_{ZZZ}(r,s) = E\left[Z(t)Z(t+r)Z(t+s)\right]$ are all equal to zero for all r, s except when $r = s = 0.$ The alternative hypothesis is that the process has some non-zero bicorrelations in the set $0 < r < s < L,$ where L is the number of lags. Hence, if nonlinear dependence is present in the data generating process, then $C_{ZZZ}(r,s) \neq 0$ for at least one pair of r and s values.

The (r, s) sample bicorrelation coefficient is:

$$C_{ZZZ}(r,s)=(n-s)^{-1}\sum_{t=1}^{n-s}Z(t)Z(t+r)Z(t+s) \quad \text{for } 0\le r\le s \tag{4.2}$$

The H statistic and its corresponding distribution are:

$$H=\sum_{s=2}^{L}\sum_{r=1}^{s-1}G^2(r,s)\sim \chi^2_{L(L-1)/2} \tag{4.3}$$

where $G(r,s)=(n-s)^{\frac{1}{2}}C_{ZZZ}(r,s)$.

4.3.3 Empirical implementation of the bicorrelation test

The number of lags L is specified as $L=n^b$ with $0<b<0.5$, where b is a parameter under the choice of the user. All lags up to and including L are used to compute the bicorrelations. Based on the results of Monte Carlo simulations, Hinich and Patterson (2005) recommend the use of $b=0.4$ which is a good compromise between: (1) using the asymptotic result as a valid approximation for the sampling properties of the H statistic for moderate sample sizes; (2) having enough sample bicorrelations in the statistic to have reasonable power against non-independent variates.

Since the focus of this chapter is on nonlinear departures from a random walk, the autocorrelation structure in the data is removed by an autoregressive AR(p) fit. We use the minimum number of lags for which the correlation test statistic is insignificant at the 5% level. It is worth highlighting that the AR fitting is employed purely as a pre-whitening operation, and not to obtain a model of best fit. The bicorrelation test is then applied to the residuals of the fitted model, and any further rejection of the null hypothesis of pure white noise is due only to significant nonlinear dependence in the data.

Hinich and Patterson (2005) apply the bicorrelation test in equal-length non-overlapped moving time windows to detect epochs of transient nonlinear dependence in a discrete-time pure white noise process. Their results have prompted a series of papers to re-examine whether previous evidence of nonlinearity is identifiable over long stretches of time or is only present in limited sub-samples of the data (see references cited in Lim *et al*., 2006). However, Todea and Zoicas-Ienciu (2008) show that the use of non-overlapped time windows cannot accurately identify the sub-periods with nonlinear dependence because the test results depend on how the first day of the sample is chosen. The authors instead suggest using the rolling window approach to eliminate this 'first day effect'. In a parallel development, Lim (2007) also advocates computing the H statistic in rolling estimation windows in order to capture the persistence of nonlinear departures from a random walk over time, consistent with the literature of evolving market efficiency.

Though the rolling window approach is very popular in practice, there is no theory on how to select the length of the time window. According to Timmermann (2008), the shorter the window, the better the approach will be at identifying temporary fleeting predictability patterns, which may be missed by a long time window. However, the window length should be sufficiently long so that the statistical test does not suffer size distortion or inadequate power. In the present context, the deciding factor on how short the window length can be is the small sample properties of the bicorrelation test.

Previous studies generally set this parameter to 50 observations or less (see Lim *et al.*, 2006 and references cited therein). Such a small sample size may compromise the power of the test. Motivated by this concern, we instead compute the H statistic in rolling estimation windows of 200 observations. Our choice is based on the extensive Monte Carlo simulations conducted by Patterson and Ashley (2000) who examine the sizes and powers of six popular nonlinearity tests including the bicorrelation test (see also Ashley and Patterson, 2006). In this study, the H statistic in each rolling window is defined as significant if the null hypothesis of pure white noise can be rejected at the specified threshold level (or cut-off point) for the *p*-value, which is set at the 5% level of significance. To offer further improvement to the size of the test in small samples, bootstrapping with 1000 replications is used to determine a threshold for the H statistic that has a test size of 5% (for descriptions of the resampling method, see Hinich and Serletis, 2007). Hence, the null hypothesis is rejected in those windows when the *p*-value of the H statistic does not exceed the bootstrapped threshold level.

4.4 The Degree of Stock Price Deviations from a Random Walk over Time

This section discusses our results from the application of the rolling bicorrelation test on all the 50 MSCI country indices, and then compares the findings with previous country-level efficiency studies.

4.4.1 The degree of stock price deviations: country-by-country basis

In order to capture the persistence of nonlinear deviations for each stock market over the common sample period of 1995-2005, we compute the H statistic in rolling windows of 200 observations. Figure 4.1 plots, for the purpose of illustration, the *p*-value of the H

statistic in each rolling time window for two selected MSCI country indices, one for a developed market (Hong Kong), and another one for an emerging market (Sri Lanka). The vertical axis shows the *p*-values, while the horizontal axis is labeled with the dates of the time windows. The bootstrapped threshold level (or cut-off point) for those *p*-values is plotted as a horizontal line parallel to the x-axis. Graphically, the H statistic in each rolling window is defined as significant if its *p*-value does not exceed the bootstrapped threshold line. Our visual inspection reveals that both markets exhibit non-random walk behavior from time to time, but the emerging Sri Lankan market experiences more frequent nonlinear deviations than the developed market of Hong Kong. The observed differences in the degree of stock price deviations form the basis of our cross-country comparisons, where a higher percentage of time windows with significant H statistic indicates more frequent deviations, and hence a lower degree of weak-form market efficiency.

The results from the application of the rolling bicorrelation test on all the 50 MSCI country indices are summarized in Figure 4.2. This figure provides the percentage of rolling windows with significant H statistic, in descending order, for each stock market. As expected, emerging markets in general record a higher percentage, indicating a lower degree of informational efficiency. For instance, the final 13 spots at the tail end of the efficiency ranking list are all taken up by stock markets from developing countries.[7] However, there are some emerging markets that outperform their developed counterparts. In fact, the top five of the chart are occupied by emerging markets, with Hong Kong the only representative from developed countries. More specifically,

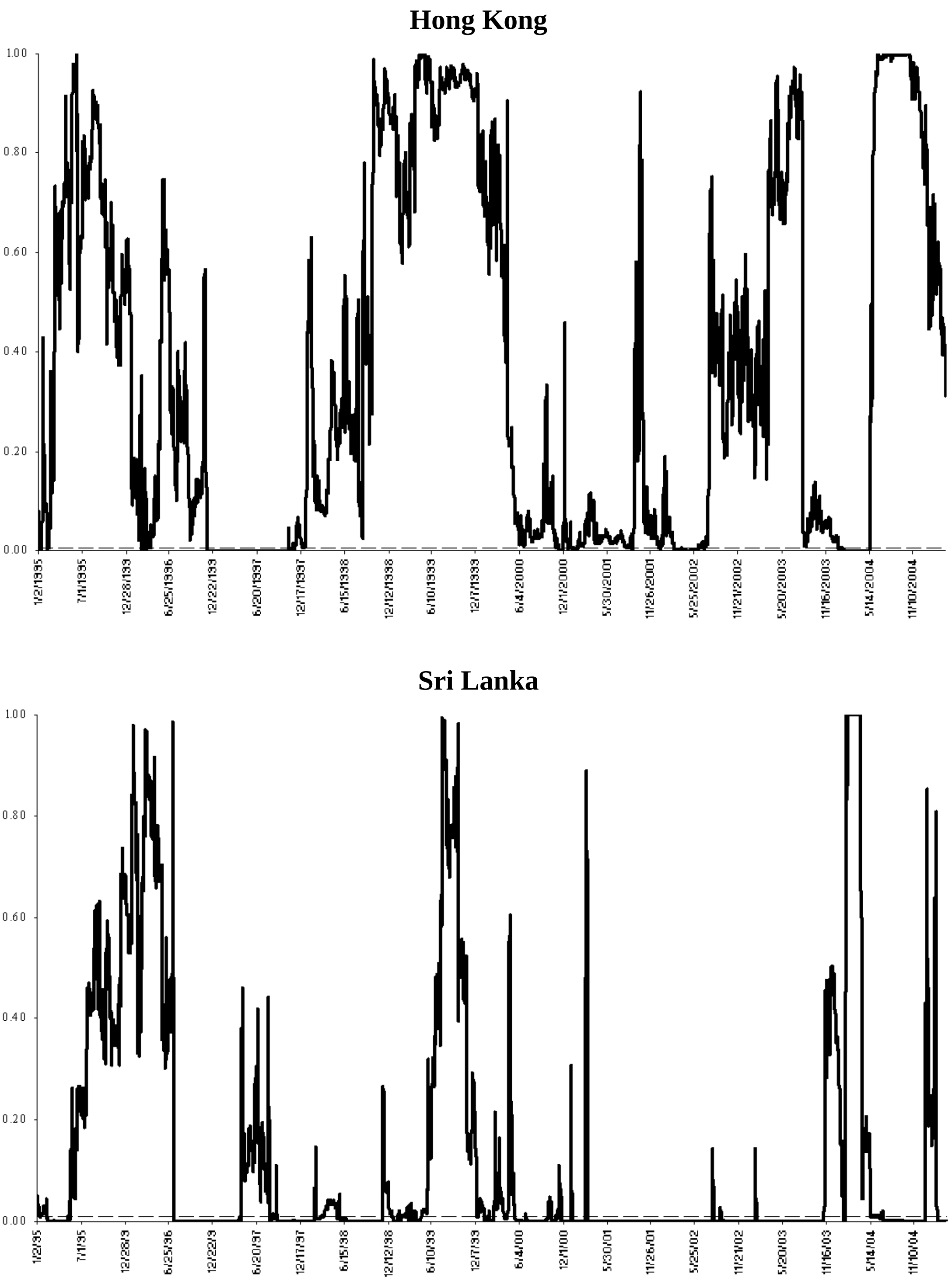
[7] MSCI only upgrades Greece to ‘developed market’ status in year 2001, suggesting that Greece is an emerging market for half of our sample period. If we categorize Greece as an emerging market, then the final 16 spots in the table are all occupied by developing economies.

Thailand (17.45%) is the most efficient market, followed by Jordan (17.75%), Hong Kong (18.35%), South Korea (24.12%) and Malaysia (25.84%). Somewhat surprising, the largest stock market in the world, United States, is ranked 31st, as 41.35% of the total rolling time windows exhibit strong evidence of nonlinear serial dependence in the stock return series.[8,9] Our results seem puzzling since it contradicts the conventional wisdom that all developed markets should be more efficient in incorporating information into prices than those markets from the developing economies.

[8] Though the U.S. market is widely regarded as efficient (see Malkiel, 2003), Lo and MacKinlay (1988) challenge this perception with their variance ratio test results showing aggregate U.S. stock indices do not follow a random walk (for details, see Lo and MacKinlay, 1999). On the other hand, there is widespread evidence of nonlinearity for stock data from the U.S. (see references cited in Lim *et al*., 2006).

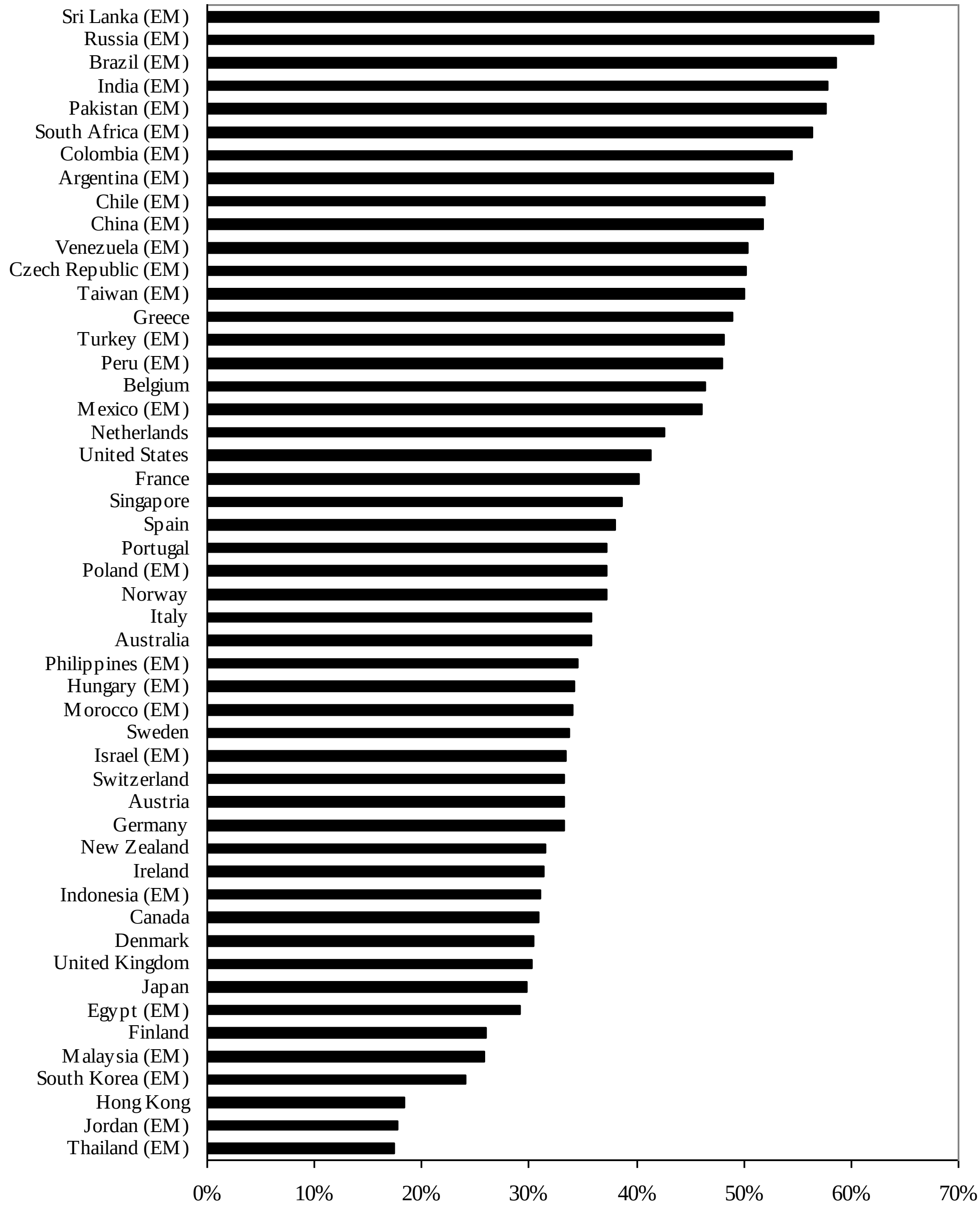
[9] In the context of evolving market efficiency, Lo (2004, 2005) computes the rolling first-order autocorrelation for monthly returns of the S&P Composite Index from January 1871 to April 2003. His graphical plot reveals the degree of efficiency varies through time with surprising result that the U.S. market is more efficient in the 1950s than in the early 1990s. Using a time-varying parameter model, Ito and Sugiyama (2009) also report that the U.S. stock market exhibits varying degrees of efficiency over the sample period from 1955 to 2006. More specifically, their graphical plot of the time-varying autocorrelation coefficients shows that the U.S. market is the most inefficient during the late 1980s and has become the most efficient at around 2000.

Figure 4.1: Time Series Plot for *p*-values of the *H* Statistic for Selected Countries



Notes: The y-axis shows the *p*-values of the *H* statistic, while the x-axis is labeled with the dates of the time windows. The horizontal line denotes the bootstrapped threshold level (or cut-off point) for those *p*-values. The *H* statistic in each rolling window is defined as significant if its *p*-value does not exceed the bootstrapped threshold line.

Figure 4.2: Percentage of Significant Rolling *H* Statistics across Countries



Notes: EM denotes an emerging market based on the classification of MSCI. The percentage of significant rolling *H* statistics indicates the percentage of rolling time windows in which the MSCI country index exhibits nonlinear departures from a random walk as detected by the *H* statistic over the sample period 1995-2005. With a window length of 200 observations, the total number of rolling time windows for each stock market is 2670. A higher percentage indicates more frequent price deviations, and hence a lower degree of weak-form market efficiency.

4.4.2 Comparison with previous country-level efficiency studies

To determine whether our results are indeed paradoxical, we revisit the degree of country-level market efficiency reported by previous studies. Lim and Brooks (2009b) review existing literature to assess whether emerging stock markets are indeed less efficient than their developed counterparts. While this conventional wisdom receives empirical support from extant cross-country comparative studies, their survey reveals there are some emerging markets that perform their informational role exceptionally well. We highlight some of their observations here. Appendix 4.1 (A-F) reproduce the complete efficiency ranking lists compiled from earlier papers.

The first group of studies relates the market model *R*-square statistic to the amount of firm-specific information being incorporated into stock prices, with more firm-specific information corresponding to a lower market model *R*-square, and hence a higher degree of informational efficiency. Morck *et al*. (2000) compute the R^2 statistic for 40 countries using weekly stock data of year 1995. Their results show that the Indonesian market is more efficient than those from the developed category- Finland, Sweden, Belgium, Hong Kong, Italy, Singapore, Greece, Spain and Japan. Notably, the latter five developed markets have higher R^2s than the emerging markets of Brazil, the Philippines, South Korea and Pakistan. Using weekly stock data for 30 countries from 1990 to 2001 and 10 more countries for part of the period, Jin and Myers (2006) find that the emerging markets of Colombia and Russia only trail behind Canada and Denmark, indicating that they are as efficient as the developed markets in incorporating firm-specific information into stock prices. Furthermore, the equal-weighted R^2s for Chile, Czech Republic, Peru and South Africa are lower than the average for developed markets. More recently, Fernandes and Ferreira (2008) expand the coverage to 47 countries using data from 1980 to 2003. Based on their ranking by market model *R*-square, the most efficient is the emerging market of Peru, pushing Canada into second place. Other emerging markets that make it to their top-10 list are China (4^{th}), Turkey (9^{th}) and South Africa (10^{th}). In another list compiled by Fernandes and Ferreira (2009), Czech Republic occupies the second spot behind the United States. Other outstanding emerging markets are Peru (5^{th}), Turkey (8^{th}) and China (9^{th}).

Using five different size-ranked portfolios, Griffin *et al*. (2007a, 2008b) compare the degree of informational efficiency for 56 international stock markets over the sample period 1994-2005. Their analysis reveals that the U.S. and U.K. stock markets exhibit the largest price delay measures for the bottom two size quintiles, indicating that their respective stock prices respond the slowest to market-wide information. This result is further reinforced by the autocorrelation-based measure which also captures the speed of stock price adjustment to information. More specifically, the absolute values of variance ratio minus one for the above two developed markets are larger than Venezuela, Israel, China and Turkey, especially for stocks in the bottom two size quintiles. On the other hand, the World Bank's Financial Sector Development Indicators (FSDI) project constructs a composite efficiency index for 58 stock markets using the average of the following three indicators: (i) the market model *R*-square statistic (Morck *et al*., 2000); (ii) the private information trading measure (Llorente *et al*., 2002); (iii) the implied equity transaction costs (Lesmond *et al*., 1999). A higher value for the composite efficiency index indicates a more efficient stock market. Though there are seven developed markets in the top-10 of their ranking table, the most efficient market is Mexico which relegates the United States to second place. Hungary and Peru are another two emerging markets that have been given high scores for their performance in information processing.

4.4.3 The degree of stock price deviations: developed versus emerging group

On a country-by-country basis, there are a few emerging markets that perform their informational role exceptionally well. However, developed markets as a group are still more efficient than their emerging counterparts. Panel B of Table 4.1 reports the means for emerging and developed markets. On average, the percentage of significant rolling H statistics for developed markets is 8.65% lower than emerging markets, conforming to the general expectation that the former are more efficient than markets in the latter category. The subsequent *t*-test of the equality of means between these two groups confirms that the difference is statistically significant at the 1% level.

For comparison with previous studies, Table 4.1 also presents the degree of country-level market efficiency reported by Morck *et al*. (2000), Jin and Myers (2006) and Fernandes and Ferreira (2008, 2009).[10] The Spearman rank correlation results in Panel A show that our efficiency measure correlates weakly with the market model *R*-square statistic. This is not surprising given that both measures examine different aspects of informational efficiency. More specifically, the percentage of significant rolling H statistics captures the degree of nonlinear stock price deviations from the random walk benchmark, while the market model R^2 proxies for the amount of firm-specific information incorporated into stock prices. Using Fama's (1970) classic taxonomy of information sets, the former measures the degree of weak-form market efficiency, while

[10] Fernandes and Ferreira (2008, 2009) compute the relative firm-specific stock return variation, which is precisely one minus the market model *R*-square. For consistency, we derive the market model R^2 from their reported median relative firm-specific stock return variation for each country.

the closest category for the latter would be the semi-strong-form since the information being considered is wider than those contained in past stock prices. Consistent with our efficiency measure, developed markets on average have lower R^2 than emerging markets, and the difference is statistically significant at least at the conventional 5% level of significance (see Panel B of Table 4.1).[11]

This chapter further explores whether cross-country variation in the degree of market efficiency can be traced to historically determined differences in legal tradition. This is motivated by the growing empirical evidence which highlights the ability of legal systems in accounting for cross-country differences in: (1) the level of financial intermediary and stock market development (Beck *et al*., 2001); (2) the ownership of banks by government (La Porta *et al*., 2002); (3) the extent of procedural formalism (Djankov *et al*., 2003); (4) the disclosure requirements, liability standards and public enforcement for violations of securities laws (La Porta *et al*., 2006); (5) the degree of creditor rights protection and the development of public credit registries (Djankov *et al*., 2007); (6) the level of protection afforded to minority investors (Djankov *et al*., 2008). To address this issue, we use the classification of legal systems (English common law, French civil law, German civil law and Scandinavian civil law) provided by Djankov *et al*. (2007). In sharp contrast to the significant role documented in the above-cited studies, our results presented in Panel C of Table 4.1 show that legal origin does not really matter for the degree of market efficiency.[12]

[11] Using the World Bank's FSDI composite efficiency index yields similar conclusion. The means for developed and emerging markets are 5.39 and 4.42, respectively. Our subsequent *t*-test of the equality of means between these two groups confirms that the difference is statistically significant at the 1% level.

[12] Using the Hurst exponents for 41 countries, Lim (2008b) also finds that there is no statistical association between the degree of long memory and the origin of laws.

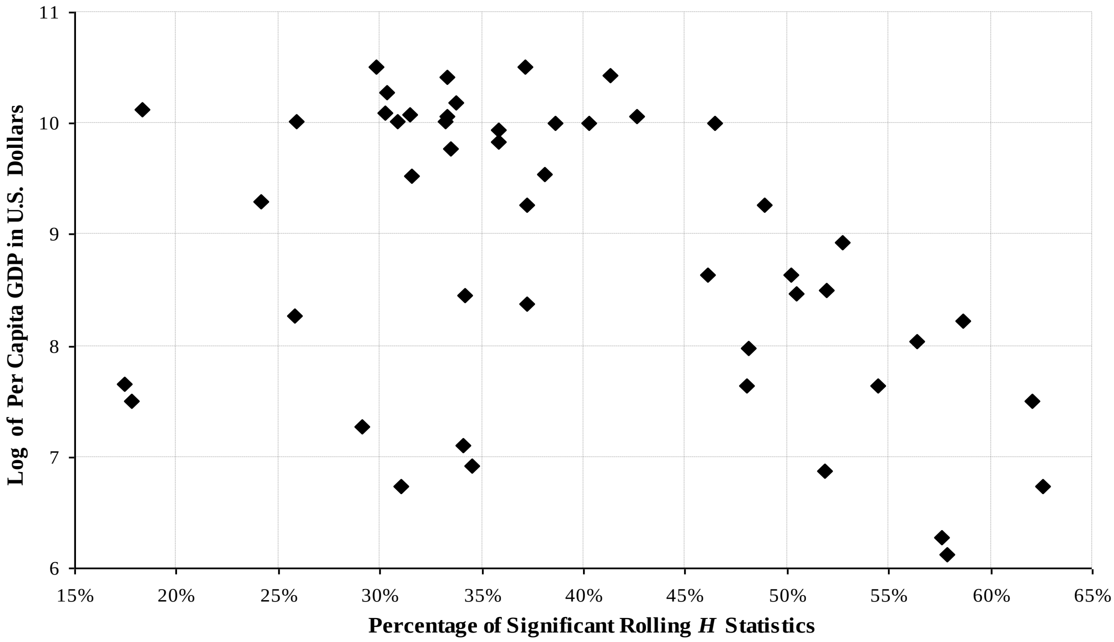
Table 4.1: Comparison with Previous Country-level Efficiency Studies

	ROLLH	MYY	JM1	JM2	FF1	FF2
Panel A: Spearman rank correlations						
ROLLH	1.000					
MYY	0.344 (0.030)	1.000				
JM1	0.064 (0.698)	0.662 (0.000)	1.000			
JM2	0.170 (0.301)	0.715 (0.000)	0.915 (0.000)	1.000		
FF1	0.275 (0.065)	0.402 (0.011)	0.547 (0.000)	0.515 (0.001)	1.000	
FF2	0.123 (0.409)	0.253 (0.115)	0.416 (0.008)	0.461 (0.003)	0.787 (0.000)	1.000
Panel B: Degree of market efficiency by market status						
Emerging markets average	0.436	0.273	0.326	0.268	0.248	0.472
Developed markets average	0.350	0.116	0.285	0.231	0.189	0.417
Test of equality of means	2.775 (0.008)	5.224 (0.000)	2.731 (0.010)	3.219 (0.003)	2.556 (0.014)	2.047 (0.046)
Panel C: Degree of market efficiency by legal origin						
Civil law average	0.397	0.205	0.312	0.252	0.217	0.431
English common law average	0.380	0.149	0.295	0.244	0.228	0.476
Test of equality of means	0.497 (0.622)	1.371 (0.179)	0.950 (0.348)	0.547 (0.588)	-0.368 (0.715)	-1.523 (0.134)

Notes: ROLLH denotes the proportion of significant rolling *H* statistics; MYY refers to Morck *et al*. (2000); JM1 is the equal-weighted R^2 while JM2 the variance-weighted R^2 from Jin and Myers (2006); FF1 and FF2 stand for the market model R^2 computed from Fernandes and Ferreira (2008, 2009), respectively. Two-tailed *p*-values are presented in parentheses.

Since the classification of developed/emerging market is generally based on a country's income level as defined by the World Bank, we further examine whether the degree of stock price deviations is related to per capita gross domestic product (GDP). Figure 4.3 plots the logarithm of per capita GDP against the percentage of significant rolling *H* statistics for each country, illustrating a clear and statistically significant negative correlation of -0.411, significant at the 0.3% level. The negative correlation with per capita income is stronger than those reported by Morck *et al*. (2000) for their market model R^2s (-0.394, significant at the 2% level). This piece of evidence suggests that stock indices in economies with high per capita income move more closely to a random walk. In contrast, nonlinear departures from random walk behavior in stock index returns are quite persistent over the sample period 1995-2005 for low- and middle-income economies. Morck *et al*. (2000) argue that this phenomenon suggests per capita GDP might be proxying for another measure of economic development which also exhibits a similar clustering effect.

Figure 4.3: Per Capita GDP and the Percentage of Significant Rolling *H* Statistics



4.5 What Does Per Capita GDP Really Proxy for?

In previous section, we document a highly significant negative correlation between the percentage of significant rolling H statistics and per capita GDP. Since there is no theoretical link between both variables, could per capita GDP be a proxy for another measure of economic development? To explore this issue, we follow the empirical strategy of Morck *et al*. (2000) to see which development measures are most correlated with the degree of stock price deviations, and whether they render per capita GDP insignificant in the multivariate regression.[13] It is worth highlighting that the percentage of significant rolling H statistics (denoted as *ROLLH*) is unsuitable as dependent variable in regression analysis because it is bounded within the interval [0, 1]. The standard econometric remedy is to transform *ROLLH* into a continuous variable over the range [-∞, +∞] using the log transformation $\xi = \log\left(\frac{ROLLH}{1-ROLLH}\right)$. Appendix 4.2 provides detailed definitions for all the variables employed in our country-level cross-sectional regressions, along with their respective data sources.

4.5.1 Structural variables

The first set of variables to be considered is related to the economic structural characteristics of each country. We use the same set of proxies as Morck *et al*. (2000):

[13] This approach has also been adopted by Alfaro *et al*. (2008) to explain the lack of capital inflows from rich to poor countries. In their study, the positive significance of log per capita GDP in 1970 demonstrates the presence of the 'Lucas Paradox'. To investigate the empirical role of different theoretical explanations for this paradox, Alfaro *et al*. (2008) identify those explanatory variables that render per capita GDP in 1970 insignificant when included in the multivariate regression. Interestingly, they find that log per capita GDP becomes insignificant only in those regressions where the index of institutional quality is included on its own or together with the other competing variables. Though both log years of schooling and restrictions to capital mobility are found to be important determinants, log per capita GDP still remains significant in their respective specifications, indicating these two variables cannot account for the paradox. This leads the authors to conclude that institutional quality is the leading explanation for the 'Lucas Paradox' during the period 1970-2000.

(1) the logarithm of the number of listed stocks (*NSTOCK*) to account for the effect of market size; (2) the variance of per capita GDP growth (*VARGDP*) to measure macroeconomic instability; (3) the logarithm of geographical size (*GEOSIZE*) to proxy for country size; (4) the industry and firm Herfindahl indices (*IHERF* and *FHERF*) to capture the effects of economic diversification, where higher values of these two indices indicate a lack of industry diversity and the dominance of a few large firms respectively. The descriptive statistics for our selected independent variables are provided in Panel A of Table 4.2. In fact, it is the common practice in subsequent cross-country efficiency studies to include the above set of variables, either to replicate the empirical findings of Morck *et al*. (2000) or to determine the explanatory power of additional variables (see Jin and Myers, 2006; Bris *et al*., 2007; Griffin *et al*., 2007a; Fernandes and Ferreira, 2009). If including these structural variables in our multivariate regression renders per capita income insignificant, we can then infer that per capita GDP proxies for these structural effects.

Table 4.2: Structural Variables and the Degree of Stock Price Deviations from a Random Walk

	GDP_i	$NSTOCK_i$	$VARGDP_i$	$GEOSIZE_i$	$IHERF_i$	$FHERF_i$
Panel A: Descriptive statistics						
No. of observations	49	50	49	50	47	47
Mean	8.853	5.855	0.0009	12.731	0.142	0.074
Median	9.260	5.581	0.0003	12.758	0.119	0.053
Maximum	10.511	8.825	0.0063	16.653	0.719	0.709
Minimum	6.126	3.924	0.0000	6.540	0.043	0.005
Standard deviation	1.303	1.124	0.0013	2.094	0.102	0.103
Panel B: Correlation matrix for the independent variables						
GDP_i	1.000					
$NSTOCK_i$	0.069 (0.638)	1.000				
$VARGDP_i$	-0.262 (0.069)	-0.262 (0.069)	1.000			
$GEOSIZE_i$	-0.370 (0.009)	0.265 (0.063)	0.105 (0.472)	1.000		
$IHERF_i$	-0.255 (0.088)	-0.460 (0.001)	0.591 (0.000)	-0.005 (0.973)	1.000	
$FHERF_i$	-0.215 (0.151)	-0.393 (0.006)	0.596 (0.000)	0.051 (0.733)	0.917 (0.000)	1.000
Panel C: Correlations between dependent and independent variables						
ξ_i	-0.378 (0.007)	-0.044 (0.760)	0.054 (0.711)	0.371 (0.008)	0.264 (0.073)	0.238 (0.108)
Panel D: Country-level cross-sectional regression						
Model: $\xi_i = \alpha_0 + \beta_1 GDP_i + \beta_2 NSTOCK_i + \beta_3 VARGDP_i + \beta_4 GEOSIZE_i + \beta_5 IHERF_i + \beta_6 FHERF_i + \varepsilon_i$						
ξ_i	-0.069 (0.007)	-0.022 (0.458)	-46.492 (0.077)	0.031 (0.041)	0.417 (0.562)	0.155 (0.819)
N = 46; F-statistic for regression = 4.300 (p-value= 0.002); R^2 = 0.398						

Notes: Appendix 4.2 describes all the variables listed above along with their respective data sources. Two-tailed p-values are given in parentheses.

Panel B of Table 4.2 displays the Pearson correlations between our selected regressors. Overall, the correlations reported here are consistent with those documented in Morck *et al*. (2000). Notably, per capita GDP is significantly and negatively correlated with a country's geographical size, but uncorrelated with other independent variables at the conventional 5% level of significance. When exploring the correlations between the dependent (ξ) and independent variables, only per capita GDP and geographical size are correlated with the percentage of significant rolling H statistics (see Panel C). We then proceed with the multivariate regression in Panel D of Table 4.2 to determine whether the structural variables, acting in concert, might uncover the economic linkages that underlie the inverse relation between the degree of stock price deviations and per capita GDP. Though country size, proxied by the logarithm of geographical size (*GEOSIZE*), can account for the cross-country variation in the dependent variable, it does not render per capita GDP insignificant, suggesting that the latter is not proxying for structural effects.

4.5.2 Private property rights protection

Morck *et al*. (2000) also find that per capita GDP does not serve as a proxy for structural variables. We then consider their second hypothesis, the institutional development explanation. These authors argue that weak property rights protection might cause arbitrageurs to shun the stock markets of low income economies, leaving these markets to noise traders. This is because informed investors may not be allowed to keep their profits in countries with insufficient private property rights protection. The critical role of arbitrageurs in restoring price deviations from the equilibrium and hence keeping the market efficient is widely recognized in the finance literature. Theoretically, the model of De Long *et al*. (1990a) predicts that when the proportion of noise traders in the market is above a critical level, this effect causes noise trading to grow in importance relative to informed trading, and the former eventually dominates the market. The above reasoning suggests that in countries with weak private property rights institutions, the lack of arbitrage trading and the correlated trading of sentiment-prone noise traders can cause stock prices to deviate from the random walk benchmark for long periods of time.

An important issue worth addressing here is why private property rights protection stands out among other institutional variables. Our survey of the finance literature reveals that the significant role of this variable is not confined to Morck *et al*. (2000), whose analysis shows that cross-country differences in property rights protection can explain why stock prices move together more in poor economies (emerging markets) than in rich economies (developed markets). Johnson *et al*. (2002), for instance, demonstrate that countries with weak private property rights protection discourage the reinvestment of firm earnings, even when bank credit is available, suggesting that secure property rights are both a necessary and sufficient condition for entrepreneurial investment. In the law and finance literature, the reason why legal traditions matter for the development of financial markets is associated with the proposition that British common law tends to place greater emphasis on private property rights than French civil law (see Beck and Levine, 2005). Further empirical findings that underline the importance of private property rights protection come from Claessens and Laeven (2003), Demirgüç-Kunt *et al*. (2004) and Beck *et al*. (2008b). Apart from its important role in finance, another consideration is that per capita GDP might be proxying for the effect of private property rights protection. This is motivated by the exploratory work of

Roll and Talbott (2003), who find that the proxy for property rights has the highest level of statistical significance in explaining the cross-country variation in per capita income.

Empirically, to capture the degree of private property rights protection in each country, Morck *et al*. (2000) construct a good government index using the sum of three indices taken from La Porta *et al*. (1998): (i) government corruption; (ii) the risk of expropriation of private property by the government; (iii) the risk of the government repudiating contracts. The composite good government index ranges from zero to thirty, with higher values indicate stronger protection of private property rights. We use the same good government index (*GOV*), which is available for 44 of our sampled countries. The univariate regression in column (1) of Table 4.3 shows that *GOV* is negatively and significantly related to the percentage of significant rolling H statistics, consistent with our hypothesis that stronger protection is associated with lower degree of stock price deviations. However, this index loses its explanatory power in column (2) after controlling for those previously employed structural variables. It is worth highlighting that Griffin *et al*. (2007a), in replicating the findings of Morck *et al*. (2000), show that the significant result of the latter study is not robust to alternative definitions of good government. Griffin *et al*. (2007a) stress that La Porta *et al.* (1999) do not even suggest any specific combinations of their indices as the most appropriate summary of good government. Elsewhere, when the good government index is included in the same model specification with other competing variables, such as the anti-director rights index (Morck *et al*., 2000), short sales restrictions (Bris *et al*., 2007), market liquidity (Bris *et al*., 2007) and insider trading laws (Fernandes and Ferreira, 2009), its explanatory power tends to degrade.

Table 4.3: Private Property Rights Protection and the Degree of Stock Price Deviations from a Random Walk

	(1)	(2)	(3)	(4)	(5)	(6)
GOV_i	-0.014 (0.027)	-0.023 (0.126)				
$INSTITUTE_i$			-0.018 (0.003)	-0.027 (0.060)		
$PPRPROTECT_i$					-0.006 (0.000)	-0.006 (0.045)
GDP_i		-0.007 (0.899)		0.014 (0.772)		-0.005 (0.899)
$NSTOCK_i$		-0.024 (0.427)		-0.028 (0.322)		-0.016 (0.577)
$VARGDP_i$		-86.581 (0.007)		-75.593 (0.013)		-51.631 (0.044)
$GEOSIZE_i$		0.023 (0.133)		0.026 (0.077)		0.021 (0.172)
$IHERF_i$		-0.450 (0.596)		0.295 (0.672)		0.433 (0.531)
$FHERF_i$		1.147 (0.185)		0.187 (0.775)		-0.002 (0.998)
Constant	0.125 (0.406)	0.311 (0.453)	-0.123 (0.002)	-0.346 (0.439)	0.210 (0.059)	0.102 (0.780)
N	44	41	50	46	50	46
F-statistics for the regression	5.263 (0.027)	3.840 (0.004)	9.621 (0.003)	4.487 (0.001)	14.779 (0.000)	4.608 (0.000)
R^2	0.111	0.449	0.167	0.453	0.235	0.459

Notes: The dependent variable is the percentage of significant rolling *H* statistics (*ROLLH*) over the sample period 1995-2005. We transform *ROLLH* using the log transformation $\xi = \log\left(\frac{ROLLH}{1-ROLLH}\right)$. Appendix 4.2 describes all the independent variables listed above along with their respective data sources. Two-tailed *p*-values are given in parentheses.

If what constitutes a good government is at the heart of the controversy, then a better indicator would be the Worldwide Governance Indicators (WGI) produced by the World Bank, measuring six dimensions of governance quality: (i) voice and accountability; (ii) political stability and absence of violence; (iii) government effectiveness; (iv) regulatory quality; (v) rule of law; (vi) control of corruption. We aggregate these six indicators into one single index to capture the overall quality of government (denoted as *INSTITUTE*), and the data are available for all the 50 sampled countries. The composite index ranges from -15 to 15, with higher values correspond to better government. We repeat earlier regressions but replacing the good government index (*GOV*) with the good institution index (*INSTITUTE*). However, the univariate and multivariate regressions results, presented in columns (3) and (4) respectively, remain qualitatively similar. Though per capita GDP has been rendered insignificant in the multivariate regression, the good institution index loses its explanatory power and is not significant at the conventional 5% level.

To reiterate, our conjecture is that a strong private property rights institution is important for attracting the participation of arbitrageurs in the stock market of a country, but the good government index (*GOV*) does not fully capture what it is supposed to. A more suitable empirical proxy for this specific purpose is the rating of private property rights protection, which is one of the ten freedoms covered by the Heritage Foundation in its annually compiled 'Index of Economic Freedom' (for users, see La Porta *et al*., 1999; Beck *et al*., 2003, 2008a, b; Claessens and Laeven, 2003; Roll and Talbott, 2003; Demirgüç-Kunt *et al*., 2004). The index (denoted as *PPRPROTECT*), ranges from zero to one hundred, examines the extent to which the government protects private property by enforcing the laws, as well as the extent to which private property is safe from expropriation. The more protection private property receives, the higher a country's score. Column (5) of Table 4.3 shows that *PPRPROTECT* is negatively and significantly related to the percentage of significant rolling H statistics. It remains significant at 5% level in multivariate regression that includes previously employed structural variables. More importantly, the inclusion of *PPRPROTECT* has rendered the logarithm of per capita GDP insignificant. This result suggests that the cross-country differences in private property rights protection underlie our earlier documented negative correlation between the degree of stock price deviations and per capita GDP. In other words, a weak private property rights institution is associated with more persistent stock price deviations from a random walk.

4.6 Other Competing Explanations and Robustness Check

We set out to explore other variables that are found to be significant in explaining why stock prices move together more in poor economies than in rich economies, namely the degree of public investor protection, corporate transparency and stock market openness (for a survey, see Durnev *et al*., 2004a). It would be interesting to see whether these competing variables subsume the significant effect of private property rights protection, as occurred to the good government index in previous studies using market model *R*-square statistic. To gauge the explanatory power of each variable, we follow earlier studies to include the same set of structural variables. Given that our sample size is limited in country-level cross-sectional regression, we address each competing explanation separately, rather than include all variables in one model specification.

4.6.1 Public investor protection

Another institutional development explanation offered by Morck *et al*. (2000) for the inverse relation between market model R^2 and per capita GDP is that countries with weak legal protection for public investors might impede the capitalization of firm-specific information into stock prices. The reason is that weak public investor protection encourages inter-corporate income-shifting by controlling shareholders which makes firm-specific information less useful to arbitrageurs, and thus renders firm-specific risk arbitrage unattractive in the stock markets of such economies. To measure the extent of public investor protection in each country, Morck *et al*. (2000) adopt the anti-director rights index (*ADRI*) constructed by La Porta *et al*. (1998). The value of the index ranges from zero to six, with a higher score indicating stronger protection afforded to minority investors. However, the authors find that *ADRI* is only significant with the expected negative coefficient in the sub-sample of developed economies. When both competing variables are included in the same regression, the anti-director rights index dominates and renders the good government index insignificant. Their result implies, in developed economies, providing public investors with weaker legal protection against corporate insiders is associated with lower degree of informational efficiency. On the other hand, the insignificance of *ADRI* when developing economies are included in the sample highlights that public investor protection only matters if private property rights are secure (for discussion, see Durnev *et al*., 2004a).

In cross-country empirical studies, the anti-director rights index (*ADRI*) is the most popular indicator for measuring the degree of public investor protection. However, the re-coding exercise conducted by Spamann (2006) finds that the original index is incorrectly measured and contains various coding errors. In response to the criticisms, Djankov *et al*. (2008) then present a revised index of anti-director rights (*NEWADRI*). Their methodology is later adopted by the World Bank's Doing Business project to construct an investor protection index (*PIPROTECT*) that measures the strength of minority shareholder protection against directors' misuse of corporate assets for personal gain. We use all three different proxies (*ADRI*, *NEWADRI* and *PIPROTECT*) to determine whether public investor protection can explain the degree of stock price deviations across countries, after controlling for private property rights protection and the same set of structural variables.

The results in Table 4.4 show that all the three proxies are not significant in univariate and multivariate regressions. Despite the insignificant role of public investor protection, private property rights protection (*PPRPROTECT*) still preserves its explanatory power, while rendering per capita GDP insignificant. This piece of evidence suggests that secure private property rights are both a necessary and sufficient condition for ensuring stock prices move more closely to a random walk. The argument is that the security of private property rights is fundamental as arbitrageurs will not trade if they expect to be unable to keep their profits. Hence, if property rights are insecure, the issue of whether investors are protected against expropriation by the insiders (*ADRI* and *NEWADRI*) or self-dealing transactions benefiting controlling shareholders (*PIPROTECT*) becomes immaterial.

Table 4.4: Public Investor Protection and the Degree of Stock Price Deviations from a Random Walk

	(1)	(2)	(3)	(4)	(5)	(6)
$ADRI_i$	0.021 (0.410)	0.019 (0.464)				
$NEWADRI_i$			-0.013 (0.650)	0.008 (0.805)		
$PIPROTECT_i$					-0.025 (0.171)	0.003(0.889)
$PPRPROTECT_i$		-0.007 (0.037)		-0.006 (0.048)		-0.006 (0.049)
GDP_i		-0.009 (0.825)		-0.002 (0.964)		-0.004 (0.914)
$NSTOCK_i$		-0.029 (0.354)		-0.018 (0.547)		-0.017 (0.571)
$VARGDP_i$		-72.577 (0.013)		-53.103 (0.046)		-52.380 (0.048)
$GEOSIZE_i$		0.016 (0.315)		0.022 (0.172)		0.021 (0.179)
$IHERF_i$		-0.160 (0.856)		0.442 (0.528)		0.459 (0.527)
$FHERF_i$		0.737 (0.402)		0.026 (0.970)		-0.012 (0.986)
Constant	-0.272 (0.002)	0.320 (0.439)	-0.149 (0.157)	0.060 (0.883)	-0.047 (0.671)	0.083 (0.833)
N	44	41	50	46	50	46
F-statistics for the regression	0.692 (0.410)	3.794 (0.003)	0.209 (0.650)	3.940 (0.002)	1.932 (0.171)	3.931 (0.002)
R^2	0.016	0.487	0.004	0.460	0.039	0.459

Notes: The dependent variable is the percentage of significant rolling H statistics (*ROLLH*) over the sample period 1995-2005. We transform *ROLLH* using the log transformation $\xi = \log\left(\frac{ROLLH}{1-ROLLH}\right)$. Appendix 4.2 describes all the independent variables listed above along with their respective data sources. Two-tailed p-values are given in parentheses.

4.6.2 Corporate transparency

Jin and Myers (2006) argue that weak protection for private property rights does not affect the market model R^2 if the firm is completely transparent. Instead, their theoretical model predicts that R^2 should be higher in countries where firms are less transparent to outside investors. In such situation of opaqueness, outside investors observe all market-wide information but only part of the firm-specific information. This limited information affects the division of risk bearing between outside investors and insider managers, shifting firm-specific risk from the former to the latter. The greater the degree of opaqueness, the more firm-specific risk relative to market risk the insiders have to absorb, while the portion borne by outside investors is correspondingly lower. Hence, the lower ratio of firm-specific risk to total risk for investors due to increased opaqueness leads to higher value of R^2. Using five different proxies for the degree of transparency or opaqueness, their model predictions are borne out, indicating that the lack of corporate transparency is associated with lower degree of informational efficiency. It is worth mentioning that, in all model specifications, the coefficient of the good government index is negatively significant, while the logarithm of per capita GDP remains insignificant. Hence, the empirical results of Jin and Myers (2006) suggest that opaqueness and private property rights protection are probably mutually reinforcing. However, corporate transparency losses its explanatory power when Fernandes and Ferreira (2009) add the proxy for enforcement of insider trading laws in the same model specification.

To address the empirical role of corporate transparency, we use a survey-based indicator from the Global Competitiveness Report for 1999 and 2000, which measures the level and effectiveness of financial disclosures in different countries. This disclosure score

(*DISCLOSURE*) has been used by Jin and Myers (2006) and Fernandes and Ferreira (2009) in their cross-country studies. We also employ the financial transparency measure (*FINTRANS*) constructed by Bushman *et al*. (2004), which captures the intensity and timeliness of financial disclosures, their interpretation and dissemination by analysts and the media. For the above indicators, a higher score signals greater degree of transparency. Individually, both *DISCLOSURE* and *FINTRANS* are significantly related to the percentage of significant rolling H statistics with the predicted negative signs, as documented in columns (1) and (3) of Table 4.5 respectively. However, in multivariate regressions, private property rights protection (*PPRPROTECT*) dominates the effect of corporate transparency, regardless of whether *DISCLOSURE* (column 2) or *FINTRANS* (column 4) is employed.

Table 4.5: Corporate Transparency, Stock Market Openness and the Degree of Stock Price Deviations from a Random Walk

	(1)	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**
$DISCLOSURE_i$	-0.092 (0.017)	0.110 (0.163)				
$FINTRANS_i$			-0.122 (0.003)	-0.031 (0.614)		
$GEQGDP_i$					-0.067 (0.024)	0.015 (0.664)
$PPRPROTECT_i$		-0.009 (0.012)		-0.007 (0.034)		-0.006 (0.044)
GDP_i		-0.003 (0.948)		-0.009 (0.849)		-0.007 (0.854)
$NSTOCK_i$		-0.024 (0.383)		-0.023 (0.445)		-0.016 (0.584)
$VARGDP_i$		-31.807 (0.219)		-59.243 (0.046)		-53.374 (0.042)
$GEOSIZE_i$		0.022 (0.159)		0.018 (0.241)		0.024 (0.166)
$IHERF_i$		0.608 (0.394)		-0.640 (0.441)		0.519 (0.476)
$FHERF_i$		-0.158 (0.809)		0.920 (0.263)		-0.069 (0.919)
Constant	0.295 (0.145)	-0.305 (0.443)	-0.175 (0.000)	0.354 (0.487)	-0.134 (0.002)	0.065 (0.864)
N	45	44	40	40	50	46
F-statistics for the regression	6.164 (0.017)	3.772 (0.003)	9.737 (0.003)	4.092 (0.002)	5.443 (0.024)	3.970 (0.002)
R^2	0.125	0.463	0.204	0.514	0.102	0.462

Notes: The dependent variable is the percentage of significant rolling *H* statistics (*ROLLH*) over the sample period 1995-2005. We transform *ROLLH* using the log transformation $\xi = \log\left(\frac{ROLLH}{1-ROLLH}\right)$. Appendix 4.2 describes all the independent variables listed above along with their respective data sources. Two-tailed *p*-values are given in parentheses.

4.6.3 Stock market openness

At the country-level, Li *et al*. (2004) relate their market model R^2s for 17 developing economies with measures of trade and stock market openness, taking into account the cross-country differences in institutional development. Trade openness is computed as imports divided by GDP relative to the country's share of world GDP, while data on stock market liberalization are taken from Edison and Warnock (2003). Their empirical findings indicate that stock market openness, and not trade openness, facilitates the incorporation of firm-specific information into stock prices and hence a higher degree of informational efficiency. However, this is true only when the institutions that protect private property rights are in place, as reflected in the negative and significant coefficient for the cross product of stock market openness and good government index. However, Fernandes and Ferreira (2009) find that stock market liberalization, proxied by the official liberalization date of Bekaert *et al*. (2005), is not significantly related to the market model R^2 once they control for the enforcement of insider trading laws in their panel regression.

The stock market openness indicators employed by Li *et al*. (2004) and Fernandes and Ferreira (2009) are *de jure* measures of liberalization, which are associated with the lifting of legal restrictions on equity flows. As noted by Kose *et al*. (2009a), many countries have capital controls that are quite strict on paper but are ineffective in their actual enforcement, so their *de facto* level of stock market openness is quite high. In contrast, many other countries do not have large equity flows even though they are quite open to global stock markets on a *de jure* basis. Hence, these authors argue that the distinction between *de jure* and *de facto* financial openness is crucial, and for many empirical applications the latter is more suitable. We therefore construct a *de facto* equity-based measure of openness (*GEQGDP*) using the dataset provided by Lane and Milesi-Ferretti (2007). It is computed as the sum of equity inflows and outflows as a share of GDP.

The univariate regression result presented in column (5) of Table 4.5 shows that *GEQGDP* is negatively and significantly related to the percentage of significant rolling H statistics, indicating that greater foreign equity flows are associated with a lower degree of stock price deviations. The most likely explanation is the improved dissemination of information, since we have earlier ruled out the liquidity channel in Section 4.1. For instance, using data from 25 emerging stock markets, Bae *et al*. (2006) find that financial liberalization improves the local environment for disclosure, information production and the analysis of information. However, *GEQGDP* losses its explanatory power when private property rights protection (*PPRPROTECT*) is included in the same regression. This multivariate regression result further supports our conjecture that a strong private property rights institution is crucial for attracting the participation of arbitrageurs, who play an important role in keeping the market efficient by eliminating deviations from the efficient price.

4.6.4 Robustness check

In their empirical study of the 'Lucas Paradox', Alfaro *et al*. (2008) find that institutional quality is the leading explanation because log per capita GDP becomes insignificant only in those regressions where the index of institutional quality is included on its own or together with the other competing variables. However, these authors acknowledge that their results might be spurious because per capita GDP depends on institutional quality. We share their concern here as private property rights protection also has a high correlation with per capita GDP (see Roll and Talbott, 2003). To ensure that property rights protection indeed has an independent effect on the degree of stock price deviations, we follow their empirical strategy based on the Frisch-Waugh theorem. In their suggested framework, the 'variable-specific' component of the private property rights index, defined as the residual from the regression of property rights protection on per capita GDP (denoted as *RESID_PPRPROTECT*), should have the explanatory power. On the other hand, the 'variable-specific' component of per capita GDP, defined as the residual from the regression of per capita GDP on property rights protection (*RESID_GDP*), should not have any explanatory power.

We re-estimate all the regressions in Tables 4.3 through 4.5, but replace the independent variable *GDP* with *RESID_GDP*. The results confirm that this 'variable-specific' component of per capita GDP has no explanatory power. The coefficient for *RESID_GDP* is similar to those reported earlier for *GDP* in all seven multiple regressions, as established by the Frisch-Waugh theorem. In a similar exercise, we re-run all the regressions but this round *PPRPROTECT* is replaced with *RESID_PPRPROTECT*. The findings show that the 'variable-specific' component of property rights protection has the explanatory power, and this is exactly what drives our results in Sections 4.5 and 4.6. Consistent with the Frisch-Waugh theorem, the coefficient for *RESID_PPRPROTECT* is exactly the same as those for *PPRPROTECT* reported in Table 4.3 through Table 4.5.

4.7 How Does Private Property Rights Protection Explain the Degree of Stock Price Deviations from a Random Walk over Time?

This section discusses the mechanism that can give rise to a negative association between private property rights protection and the degree of stock price deviations, namely the interaction between arbitrageurs and noise traders. Suggestions on how this conjecture can be empirically tested are also provided.

4.7.1 Our conjecture

Our empirical results consistently show that the proxy for private property rights protection dominates other potential variables in explaining the cross-country variation in the percentage of significant rolling H statistics. The evidence suggests that secure private property rights are both a necessary and sufficient condition for ensuring stock prices move more closely to a random walk. Our conjecture, consistent with Morck *et al*. (2000), is that a strong private property rights institution is crucial for attracting the participation of arbitrageurs, as these investors will not trade if they expect to be unable to keep their profits. It is widely recognized, in fact it is a cornerstone of modern financial economics, that arbitrageurs play a critical role in restoring price deviations and keeping the market efficient. Hence, the lack of arbitrage trading in low income economies due to weak private property rights protection will leave their stock price deviations uncorrected for long periods of time. Lee (2001) also highlights that many emerging markets have relatively few informed investors while noise traders dominate, but his reason is due to high arbitrage costs in these developing economies.

The low participation rate of arbitrageurs in the stock markets of those countries with weak private property rights protection should be a cause of concern to their respective policymakers. The theoretical model of De Long *et al*. (1990a) predicts that when the proportion of noise traders in the market is above a critical level, they create so much price risk that arbitrageurs are very reluctant to speculate against them. As their numbers grow, noise traders might eventually drive informed arbitrageurs out of the domestic market. Another consequence of noise traders' dominance is that stock prices can deviate from the random walk benchmark for persistent periods of time. Various explanations have been given in the literature, which include: (1) noise traders are prone to sentiment that is not fully justified by fundamental information, which is a key assumption in extant noise trader models (De Long *et al*., 1990a; Barberis *et al*., 1998); (2) noise traders trade systematically as a group due to psychological biases such as the representativeness heuristic, limited attention or the disposition effect (see Barber *et al*., 2009b); (3) rational arbitrageurs are reluctant to trade against mispricing due to noise trader risk or other circumstances that limit their arbitrage actions (De Long *et al*., 1990a; Shleifer and Summers, 1990; Shleifer and Vishny, 1997); (4) even if arbitrage ultimately works in restoring price deviations, it occurs with a delay due to synchronization risk, that is each arbitrageur is uncertain about the timing of other arbitrageurs' actions (Abreu and Brunnermeier, 2002, 2003).

4.7.2 Suggestions for future research

Generally, there is broad agreement in the literature that the interplay between arbitrageurs and noise traders can give rise to persistent stock price deviations. However, our explanation remains a conjecture because there is no theoretical or empirical work that establishes the link between property rights protection and the level of arbitrage or noise trading, though this hypothesis has been put forward almost a decade ago by Morck *et al*. (2000).[14] Nevertheless, we provide some suggestions on how this issue can be addressed in future studies.

One suggested strategy is to identify who the noise traders are. Some studies single out individual retail investors as the prime candidates (Kumar and Lee, 2006; Frazzini and Lamont, 2008; Barber *et al*., 2009a, b). Their choice is based on previous empirical evidence that individual investors suffer from a variety of psychological biases and make suboptimal investment decisions (see references cited in Barber *et al*., 2009a). Institutional investors, in contrast, are reported to play the role of informed traders (Sias *et al*., 2006; Boehmer and Kelley, 2009; Yan and Zhang, 2009). For instance, the results in Boehmer and Kelley (2009) show that stocks with greater institutional ownership are priced more efficiently in the sense that their transaction prices more closely follow a random walk. Particularly, these authors find that institutions make stock prices more efficient by impounding on private information and providing liquidity to other traders whose trading would otherwise cause prices to deviate from the random walk benchmark.

The above discussion seems to suggest that a good proxy for noise trading (arbitrage trading) is the percentage of individual (institutional) investors in a particular market. However, this approach is subjected to an important caveat. While institutions are

[14] The closest that we can find is the paper by Giannetti and Koskinen (2009). Their theoretical model predicts that weak protection of minority shareholders reduces the incentives for domestic and foreign portfolio investors to participate in the domestic stock market. Using international data, the authors find that stronger investor protection is associated with higher rate of households' participation in the domestic stock market. On the other hand, there is growing empirical evidence that foreign portfolio investors avoid investing in countries with weak investor protection (see references cited in Giannetti and Koskinen, 2009).

regarded as better informed and more sophisticated investors, there is some evidence of institutional investors engaging in positive feedback trading and herding, which can move prices further away from their fundamental values (Badrinath and Wahal, 2002; Dennis and Strickland, 2002; Griffin *et al*., 2003; Puckett and Yan, 2008; Shu, 2008). On the other hand, Glushkov (2006) finds that institutional investors are holding relatively more of sentiment sensitive stocks in the 1990's, inconsistent with the idea that institutions are ready to arbitrage away any short-term price deviations caused by noise traders. The most convincing piece of evidence comes from Brunnermeier and Nagel (2004) who examine the response of hedge funds to the growth of the technology bubble. Hedge funds are widely regarded as the class of investors closer to the ideal of well-informed, well-financed and rational arbitrageurs. Their analysis shows that hedge funds as a whole do not exert a correcting force on stock prices but instead are riding on the bubble. While, the reluctance of arbitrageurs to trade against sentiment-driven mispricing cannot be rationalized within the conventional efficient markets paradigm, their results are consistent with the theoretical models of Abreu and Brunnermeier (2002, 2003) which predict rational investors might find it optimal to ride the still-growing bubble for a while, making their actions destabilizing rather than stabilizing.

A more promising strategy is to employ an investor sentiment index given that noise traders are generally subjected to sentiment (for a survey of existing sentiment proxies, see Baker and Wurgler, 2007).[15] However, the above suggestion would require future studies to construct a composite sentiment index for a broad cross-section of countries,

[15] Baker and Wurgler (2006) and Glushkov (2006) report that investor sentiment effects are stronger for stocks that are difficult to arbitrage. Barber *et al*. (2009a) find that the correlated trading activities of noise traders drive prices away from their fundamental values, and the impact is greatest for stocks with limited arbitrage opportunities which they define as having high level of idiosyncratic risk. Employing a similar proxy for arbitrage costs, Kumar and Lee (2006) show that investor sentiment has the greatest impact on the returns of stocks that are the costliest to arbitrage.

along the lines of Baker and Wurgler (2006, 2007) and Glushkov (2006). This is because existing datasets are mainly confined to the developed markets, especially the U.S. For instance, Robert Shiller has conducted regular questionnaire investor attitude surveys since 1989, but his stock market confidence indices, though available at http://icf.som.yale.edu/confidence.index/, only cover the behavior of U.S. and Japanese investors. Similarly, the sentiment indices derived from weekly online surveys conducted by 'sentix behavioral indices' (http://www.sentix.de/) are only for major stock markets in Europe, the U.S. and Japan (see Schmeling, 2007). Apart from the above direct survey-based measures, the composite sentiment index constructed by Baker and Wurgler (2006, 2007), available at http://pages.stern.nyu.edu/~jwurgler/, is confined to the U.S. market. While a number of studies report that the consumer confidence index correlates strongly with stock returns and hence can serve as a proxy for investor sentiment (see Lemmon and Portniaguina, 2006; Qiu and Welch, 2006), its validity in the U.S. cannot be generalized to other stock markets, mainly because consumers are not asked directly for their views on stock prices.

4.8 Conclusion

This chapter employs the rolling bicorrelation test to measure the degree of nonlinear departures from a random walk for aggregate stock price indices of 50 countries over the sample period 1995-2005. We find that stock markets in economies with low per capita GDP in general experience more frequent price deviations than those in the high income group. This clustering effect is not due to market size, market liquidity or other structural characteristics such as economic diversification, macroeconomic instability and country size. While the logarithm of geographical size is significantly related to the percentage of significant rolling H statistics, it does not render per capita GDP insignificant, suggesting that the latter is not proxying for structural effects. Instead, our results consistently show that the negative relation between the degree of stock price deviations and per capita GDP can largely be attributed to low income economies providing weak protection for private property rights. The proxy for private property rights protection remains significant even after controlling for other competing explanations such as public investor protection, corporate transparency and stock market openness.

Our results further reinforce the findings of Morck *et al*. (2000) on the importance of a strong private property rights institution for the stock market to perform its informational role efficiently. Both studies show that weak protection is associated with persistent stock price deviations from a random walk and a high degree of stock price synchronicity, respectively. In terms of policy prescription, Durnev *et al*. (2004a) call for reforms in transition economies, with sound property rights, solid shareholders rights, greater corporate transparency and stock market openness on their checklist. Our analysis shows that the last three reforms are of secondary importance. Instead, secure private property rights are both a necessary and sufficient condition for ensuring stock prices move more closely to a random walk. We hypothesize that the mechanism through which this occurs is the interaction between arbitrageurs and noise traders. More specifically, a strong private property rights institution is crucial for attracting the participation of arbitrageurs, as these investors will not trade if they expect to be unable to keep their profits. It is widely recognized that arbitrageurs play a critical role in restoring price deviations and keeping the market efficient. Hence, the lack of arbitrage trading in low income economies due to weak private property rights protection will leave their stock price deviations uncorrected for long periods of time. Our study also adds to the growing list of papers highlighting the importance of macro institutions to the economy (see, for example, Bushman and Piotroski, 2006; Chinn and Ito, 2006; Eleswarapu and Venkataraman, 2006; Alfaro *et al*., 2008; Papaioannou, 2009).

We do not rule out other potential mechanisms or alternative interpretations of the results. The present study does demonstrate, however, that property rights protection is an important factor in explaining the observed cross-country variation in the degree of stock price deviations from a random walk. With the mounting empirical evidence on the significant role of property rights protection, both at the macro and micro level, the policy implication for those low income economies is unambiguous. Having said so, reforming the property rights institutions is not an easy task. On one hand, the law view stresses historically determined differences in legal heritage shape private property rights protection. On the other hand, the endowment view, while concurring that property rights institutions are the outcome of exogenous factors that happened centuries ago, focuses on the conditions of the colony rather than the identity of the colonizer (for a survey, see Levine, 2005b). Pagano and Volpin (2005) dispute the role of historical accidents which implies institutions are hard to change, but instead argue that political institutions ultimately determine the degree to which any legal system effectively protects private property. Unfortunately, in many low income economies, Durnev *et al*. (2004a) note that the entrenched elites who control corporate sectors often undertake political rent-seeking to protect their interests, influencing politicians to avoid establishing secure private property rights for investors (see also Mishkin, 2009).

Finally, our focus on nonlinear departures from a random walk further contributes to the extant literature by providing additional light on the possible driving forces of widespread nonlinear dynamics in stock data. The results here are in favor of the behavioral explanation (see McMillan, 2003, 2005; McMillan and Speight, 2006), in which the interaction between arbitrageurs and noise traders gives rise to persistent nonlinear deviations from the random walk benchmark. However, this is still a conjecture. There are two ways to formally test this hypothesis, which we leave for future studies. First, investigators can construct a composite sentiment index because noise traders are generally subjected to sentiment. Using this proxy for a broad cross-section of countries, it is possible to determine whether noise trading is responsible for the persistent nonlinear deviations. Second, using idiosyncratic risk as a proxy for arbitrage costs (see Kumar and Lee, 2006; Barber *et al*., 2009a), future studies can examine whether individual stocks that are the costliest to arbitrage experience the most frequent nonlinear stock price deviations from a random walk.

Appendix 4.1A: Market Model R^2s from Morck *et al*. (2000)

Notes: The market model R-square statistics are taken from Panel C of Table 2 in Morck *et al*. (2000), covering 40 countries for year 1995. A lower value of R^2 signals more informative stock prices, hence a higher degree of informational efficiency.

Appendix 4.1B: Equal-weighted Market Model R^2s from Jin and Myers (2006)

Notes: The equal-weighted R^2s are taken from Table 2 in Jin and Myers (2006), covering 30 countries over 1990-2001 and 10 more countries for part of the period. A lower value of R^2 signals more informative stock prices, hence a higher degree of informational efficiency.

Appendix 4.1C: Variance-weighted Market Model R^2s from Jin and Myers (2006)

Notes: The variance-weighted R^2s are taken from Table 2 in Jin and Myers (2006), covering 30 countries over 1990-2001 and 10 more countries for part of the period. A lower value of R^2 signals more informative stock prices, hence a higher degree of informational efficiency.

Appendix 4.1D: Market Model R^2s from Fernandes and Ferreira (2008)

Notes: Fernandes and Ferreira (2008) compute the relative firm-specific stock return variation, which is precisely one minus the market model R-square. For consistency, we derive the market model R^2 from the median relative firm-specific stock return variation reported in Table 1 of Fernandes and Ferreira (2008). The sample period spans from 1980 to 2003, covering 47 countries. A lower value of R^2 signals more informative stock prices, hence a higher degree of informational efficiency.

Appendix 4.1E: Market Model R^2s from Fernandes and Ferreira (2009)

Notes: Fernandes and Ferreira (2009) compute the relative firm-specific stock return variation, which is precisely one minus the market model R-square. For consistency, we derive the market model R^2 from the median relative firm-specific stock return variation reported in Table 1 of Fernandes and Ferreira (2009). The sample period spans from 1980 to 2003, covering 48 countries. A lower value of R^2 signals more informative stock prices, and hence a higher degree of informational efficiency.

Appendix 4.1F: The World Bank's FSDI Equity Market Efficiency Index for 2004

Notes: The World Bank's Financial Sector Development Indicators (FSDI) project constructs a composite efficiency index using the average of the following three indicators: (i) the market model R-square statistic (Morck *et al.*, 2000); (ii) the private information trading measure (Llorente *et al.*, 2002); (iii) the implied equity transaction costs (Lesmond *et al.*, 1999). A higher value for the composite efficiency index indicates a more efficient stock market.

Source: http://www.fsdi.org/

Appendix 4.2: Summary Descriptions of Variables

Variable	Description
	The Degree of Stock Price Deviations from a Random Walk
$ROLLH_i$	The degree of stock price deviations from a random walk for country i is measured in terms of the percentage of rolling time windows in which its MSCI country index exhibits significant H statistic over the sample period 1995-2005. The H statistic in each rolling window is defined as significant if its *p*-value does not exceed the threshold level of 5%.
ξ_i	We apply the log transformation to $ROLLH_i$ as follows: $\xi_i = \log\left(\frac{ROLLH_i}{1-ROLLH_i}\right)$, so that ξ_i takes value between -∞ and +∞. In the country-level cross-sectional regression, ξ_i is employed as the dependent variable.
	Structural Variables
GDP_i	The data for per capita gross domestic product (constant 2000, U.S. dollars) are collected from World Development Indicators for all countries except Taiwan from 1995 through 2005. Our cross-sectional analysis takes the time series average of the logarithms of per capita GDP for each country.
$NSTOCK_i$	The data for total number of listed stocks are collected from Standard & Poor's (S&P) *Emerging Stock Markets Factbook* (1996-2002) and *Global Stock Markets Factbook* (2003-2006). The logarithms of the data for each country are averaged over the sample period 1995-2005.
$VARGDP_i$	The annual data for per capita GDP growth rate are collected from World Development Indicators for all countries except Taiwan from 1995 through 2005. To proxy for macroeconomic instability, we compute the variance of per capita GDP growth.
$GEOSIZE_i$	The geographical sizes of our sampled countries, in square kilometres, are obtained from http://www.countryreports.org/. Our analysis takes the logarithm of the data.
$IHERF_i$	The industry-level Herfindahl index, a measure of industrial concentration, is extracted from Fernandes and Ferreira (2009). The data are available for 47 of our sampled countries except Egypt, Jordan and Morocco.

Appendix 4.2 (Continued)

Variable	**Description**
$FHERF_i$	The firm-level Herfindahl index, a proxy for the degree of firm concentration, is extracted from Fernandes and Ferreira (2009). The data are available for 47 of our sampled countries.
	Private Property Rights Protection
GOV_i	We follow Morck *et al*. (2000) to construct their good government index by aggregating three indices taken from La Porta *et al*. (1998): (i) government corruption; (ii) the risk of expropriation of private property by the government; (iii) the risk of the government repudiating contracts. The composite good government index, available for 44 of our sampled countries, ranges from zero to thirty, with higher value indicates stronger protection of private property rights.
$INSTITUTE_i$	We use the 2006 Worldwide Governance Indicators (WGI) produced by the World Bank, covering all our sampled countries for 1996, 1998, 2000, and annually for 2002-2005. The data measure six dimensions of governance quality: (i) voice and accountability; (ii) political stability and absence of violence; (iii) government effectiveness; (iv) regulatory quality; (v) rule of law; (vi) control of corruption. For each available year, we aggregate the six indicators into one single index to capture the overall quality of government. The composite index ranges from -15 to 15, with higher value corresponds to better government. All the data are downloaded from the WGI's website at www.worldbank.org/wbi/governance/. Our cross-sectional analysis takes the time series average of the composite index for each country.
$PPRPROTECT_i$	We use the rating of private property rights protection extracted from the 'Index of Economic Freedom', published annually by the Heritage Foundation. The index, ranges from zero to one hundred, examines the extent to which the government protects private property by enforcing the laws, as well as the extent to which private property is safe from expropriation. The more protection private property receives, the higher a country's score. The data, available for all countries, are downloaded from http://www.heritage.org/Index/. The time series average over the sample period 1995-2005 for each country is used in the cross-country regression.

Appendix 4.2 (Continued)

Variable	Description
	Public Investor Protection
$ADRI_i$	The anti-director rights index, available for 44 of our sampled countries, is extracted from La Porta *et al*. (1998). The value of the index ranges from zero to six, with higher score indicates stronger protection afforded to minority investors.
$NEWADRI_i$	The revised anti-director rights index, available for all of our sampled countries, is extracted from Djankov *et al*. (2008). The value of the index ranges from zero to six, with higher score indicates stronger investor protection.
$PIPROTECT_i$	The World Bank's Doing Business project constructs an investor protection index that measures the strength of minority shareholder protection against directors' misuse of corporate assets for personal gain. The index distinguishes three dimensions of investor protection: (i) transparency of related-party transactions (extent of disclosure index); (ii) liability for self-dealing (extent of director liability index); (iii) shareholders' ability to sue officers and directors for misconduct (ease of shareholder suits index). The data come from a survey of corporate lawyers and are based on securities regulations, company laws and court rules of evidence. The strength of investor protection index is the average of the above three indices. The value of the composite index ranges from zero to ten, with higher score indicates stronger investor protection. The data, available for all of our sampled countries, are downloaded from http://www.doingbusiness.org/CustomQuery/.
	Corporate Transparency
$DISCLOSURE_i$	The Global Competitiveness Report for 1999 and 2000 include results from surveys about the level and effectiveness of financial disclosures in different countries. The disclosure score, available for 45 of our sampled countries, is extracted from Fernandes and Ferreira (2009). The score ranges from one to seven, with higher value signals greater degree of transparency.
$FINTRANS_i$	We use the financial transparency measure constructed by Bushman *et al*. (2004), which captures the intensity and timeliness of financial disclosures, their interpretation and dissemination by analysts and the media. The data are available for 40 of our sampled countries, and higher value indicates greater degree of transparency.

Appendix 4.2 (Continued)

Variable	**Description**
	Stock Market Openness
$GEQGDP_i$	We use a *de facto* indicator of the intensity of stock market liberalization based on actual equity flows. This equity-based measure of openness is defined as: $GEQGDP_i = \left(PEQA_i + FDIA_i + PEQL_i + FDIL_i\right)/GDP_i$, where $PEQA\left(L\right)$ and $FDIA\left(L\right)$ are the gross stocks of portfolio equity and foreign direct investment assets (liabilities) respectively, and GDP denotes gross domestic product. The data for all countries are downloaded from Philip Lane's website at http://www.tcd.ie/iiis/pages/people/plane.php The time series average over the sample period 1995-2004 for each country is used in the cross-country regression.

DECLARATION FOR THESIS CHAPTER 5

Declaration by Candidate

In the case of Chapter 5, the nature and extent of my contribution to the work was the following:

Nature of contribution	**Extent of contribution (%)**
The initiation of idea, formulation of research questions, development of research framework, literature review, construction of news database, data analysis (except variance ratio estimation) and interpretation, and writing up of the first draft.	75%

The following co-author contributed to the work:

Name	**Nature of contribution**
Jae H. Kim	Participated in the discussions on econometric issues, computation of wild bootstrapped automatic variance ratio test, and refining the draft paper.

Candidate's Signature		**Date** **June 8, 2009**

Declaration by Co-author

The undersigned hereby certify that:

(1) the above declaration correctly reflects the nature and extent of the candidate's contribution to this work, and the nature of the contribution of each of the co-authors;

(2) they meet the criteria for authorship in that they have participated in the conception, execution, or interpretation, of at least that part of the publication in their field of expertise;

(3) they take public responsibility for their part of the publication, except for the responsible author who accepts overall responsibility for the publication;

(4) there are no other authors of the publication according to these criteria;

(5) potential conflicts of interest have been disclosed to (a) granting bodies, (b) the editor or publisher of journals or other publications, and (c) the head of the responsible academic unit; and

(6) the original data are stored at the following location(s) and will be held for at least five years from the date indicated below:

Location	**Department of Econometrics and Business Statistics,** **Monash University**

Co-author's Signature:

Jae H. Kim		**Date** **June 8, 2009**

CHAPTER 5

Return Autocorrelations and Salient News Events: A Study of the Malaysian Stock Market during the Asian Crisis

5.1 Introduction

It is a common observation that the mass media always attach news events to daily stock price movements.[1] The study by Cutler *et al*. (1989) is one of the earliest to explore the link between news stories in the media and stock price movements. These authors select the 50 largest absolute one-day percentage changes in the Standard & Poor's (S&P) Composite Index from 1946 through 1987, and subsequently review coincident news reports in the *New York Times* to identify the proximate causes of these large price movements. They find that many of the largest daily price changes in the U.S. stock market occur on days when there are no major news events. On the other hand, only 15 out of the 49 big events that dominate headlines in the media follow an index movement of more than 1.5 percent. This led the authors to conclude that movements in stock price reflect something other than information about fundamentals. Fair (2002) utilizes tick data on the S&P 500 Stock Index futures contract and newswire searches to match events to large 1- to 5-minute stock price changes. Only 69 of the 220 days with extraordinary price activities are associated with major market-moving media events.

[1] For instance, the recent swine flu outbreak (later referred by World Health Organisation as 'influenza A H1N1') in Mexico has been widely reported in the media as a significant market mover for major stock markets across the globe on April 27, 2009, with headlines such as "Flu outbreak depresses markets" (*Wall Street Journal*, http://online.wsj.com/article/SB124082918450558901.html), "Asian stock markets retreat amid swine flu fears" (*China Post*, http://www.chinapost.com.tw/business/asia/asian-market/2009/04/27/205896/Asian-stock.htm), and "Stocks drop amid swine flu concerns" (*New York Times*, http://www.nytimes.com/2009/04/28/business/28markets.html).

The author notes that there have been hundreds of important macroeconomic announcements between 1982 and 1999, but only a small fraction has led to a large stock price change. Kaminsky and Schmukler (1999) identify 20 largest 1-day price changes for each of the nine Asian stock markets during the 1997 financial crisis. Thirty four percent of the 180 days with large price changes cannot be explained by any economic or political news, which the authors attribute to investors' herding behavior.[2]

The link between information and stock prices plays a key role in many theoretical models. In particularly, the speed of information incorporation is central to market efficiency, given that an efficient market is characterized as one in which the stock price responds to new information accurately and in a timely manner. Though its implications on market efficiency are still very much been debated (see Boudoukh *et al*., 1994), the existence of non-zero return autocorrelations has been widely interpreted as reflecting investors' mis-reaction (i.e. under- or over-reaction) to information. For instance, the well-known behavioral models of Barberis *et al*. (1998), Daniel *et al*. (1998) and Hong and Stein (1999) rationalize how under- or over-reaction to news can give rise to positive return autocorrelations. Amihud and Mendelson (1989a), Damodaran (1993), Brisley and Theobald (1996) and Theobald and Yallup (1998, 2004) develop formal speed of adjustment estimators which are functions of autocorrelations in order to gauge the speed with which new information is reflected in prices of individual stocks or

[2] All the above studies focus on stock price movements at the aggregate level using broad market indices. Ryan and Taffler (2004) apply similar approach of event matching at the firm-level, and find that 65% of companies' major price changes are related to firm-specific news releases. Another strand of literature formally examines the link between news and stock prices in regression setting but the evidence is at best mixed. Roll (1988) shows that a large percentage of individual stocks' price movements cannot be explained by firm-specific news. Using the number of news releases, Berry and Howe (1994) and Mitchell and Mulherin (1994) give credible confirmation to the difficulty of linking absolute stock returns to public information. In contrast, studies using scheduled macroeconomic news generally yield significant announcement effects (see Jain, 1988; McQueen and Roley 1993; Boyd *et al*., 2005; Andersen *et al*., 2007).

portfolios. Empirically, Ederington and Lee (1993, 1995) examine the speed of adjustment to news releases by comparing the serial correlation of consecutive intraday price changes during announcement and non-announcement periods. Our contention is that, if significant serial correlations in stock return series reflect market mis-reaction to information, it would be interesting to examine whether their presence coincides with days in which market-moving public news is announced.

The literature on news-returns, news-volatility and news-trading volume relations is voluminous and spans across asset classes. In sharp contrast, the link between news and return autocorrelations has been largely neglected. One of the major obstacles is that the autocorrelation-based tests require a sample size of at least 200 observations for estimation. This makes any kind of meaningful association to daily news reports impractical as there are many major events that occur during a year. Hence, it is not surprising to learn that the analysis in previous studies is generally confined to the application of autocorrelation-based tests on sub-periods of pre- and post changes, even though the dates of certain events such as financial liberalization, trading systems automation and financial crisis are known (see references cited in Lim *et al*., 2008c). Nawrocki (1996) tackles the above problem by computing the cross-sectional autocorrelation coefficient for each day using a random selection of 125 stocks from the New York Stock Exchange. This cross-sectional approach provides the number of observations needed for efficient estimation of serial dependence on a daily basis. The empirical results support his hypothesis that major economic events are important in generating temporal dependence in the U.S. stock market data. Yilmaz (2003) applies two multiple variance ratio tests in rolling sub-samples with 1,000 daily observations to detect the changing degree of market efficiency and then identifies the associated news events. However, it is difficult to pinpoint in a 4-year rolling estimation window the precise dates when the variance ratio test statistics are insignificant. We advocate the use of high-frequency minute-by-minute data to detect significant return autocorrelations for each trading day, which will then permit investigators to search through a news events database to identify the proximate causes.

Our proposed framework differs from the event study methodology pioneered by Fama *et al*. (1969) in two significant ways. First, the standard event study approach assesses the market's speed of price adjustment to information releases by testing whether the abnormal returns are significantly different from zero during the time of the event window. We instead infer the speed of information incorporation based on the statistical significance of return autocorrelations. Second, in a typical event study, the specific event of interest is selected *a priori*. Our framework is to first identify investors' mis-reaction for each trading day, and then searches for salient news events that can be associated with those detected significant return autocorrelations. For empirical analysis, intraday asset prices and news releases are indispensable. On the grounds of data availability, this chapter limits the investigation to the Malaysian stock market during the 1997 Asian financial crisis. Despite its narrow scope, our study represents a major step toward providing a direct association between return autocorrelations and news events. Moreover, the choice of a crisis period is interesting because a number of studies show that the stock market responses to news depend on the state of the economy (see McQueen and Roley, 1993; Boyd *et al*., 2005; Andersen *et al*., 2007). Our analysis will also shed light on the claim of herding behavior by Kaminsky and Schmukler (1999). This is because return autocorrelations can arise when investors herd or act as positive feedback traders (see De Long *et al*., 1990b; Cutler *et al*., 1990; Shu, 2008).[3] In fact, the possibility of herding and positive feedback trading during the Asian financial crisis is a subject of considerable interest (see Choe *et al*., 1999; Kim and Wei, 2002; Bowe and Domuta, 2004).

We adopt the wild bootstrapped automatic variance ratio test (denoted henceforth as the WBAVR test) recently proposed by Kim (2009) to detect significant serial correlations in the 1-minute transaction returns of the Kuala Lumpur Composite Index (KLCI). The test has been shown to possess good small sample properties under conditional heteroskedasticity and avoids the arbitrary selection of holding periods in existing variance ratio tests. Our results show that only 141 out of the total 373 trading days during the Asian crisis exhibit significant return autocorrelations at the 1% level. This indicates that stock prices in the remaining 62% of trading days follow a random walk, which in the present context implies that new information is incorporated into stock prices within one minute. Using our news database, we find that 29 out of the 141 trading days with significant return autocorrelations can be associated with major market-moving media events. We hypothesize that this is due to a higher level of information uncertainty, and hence the market needs more time to fully grasp the implications of the above news. On the other hand, there are 17 events widely considered as major market movers that do not trigger rejection of the null hypothesis by the WBAVR test. The result suggests that even though these media stories induce large price changes, there is no evidence of market mis-reaction. Finally, 37 percent of the trading days with significant return autocorrelations cannot be explained by any

[3] According to Nofsinger and Sias (1999), herding is a group of investors trading in the same direction over a period of time (for classification of existing herding theories, see Bikhchandani and Sharma, 2001; Hirshleifer and Teoh, 2003). Feedback trading is defined as a special case of herding, where past returns are used as the common information signal.

economic or political news, which we interpret as indicative of investors' herding behavior not driven by information.

The remainder of this chapter is structured as follows. Section 5.2 reviews the relevant literature. Following that, we discuss the sources of the stock market data and news events. A brief explanation of the WBAVR test is also provided in Section 5.3. We present the empirical results in Sections 5.4 and 5.5. The final section then concludes this chapter, along with some recommendations for future research.

5.2 A Review of Related Literature

To highlight the attention given to the relationship between information and stock prices, this section first surveys the literature on news-returns, news-volatility and news-trading volume relations. We then review previous studies that examine return autocorrelations at the intraday level and justify our selection of the wild bootstrapped automatic variance ratio test.

5.2.1 News and the stock market

The literature on the relationship between information and asset prices is voluminous and spans across asset classes. We limit our survey to the stock markets. The first group of studies examines the impact of news on stock price changes. Jain (1988) reports that two of the five macroeconomic announcement surprises are significantly associated with stock price changes. Bernanke and Kuttner (2005) document a strong and consistent response of the stock market to monetary policy surprises. McQueen and Roley (1993) find a significant relationship between macroeconomic news and stock prices by allowing the relation to vary over different stages of the business cycle. Pursuing a similar line of inquiry, Boyd *et al*. (2005) establish that the stock market responds positively to news of rising unemployment in expansions and negatively in contractions. Andersen *et al*. (2007) confirm that the stock market responses to news do vary over the U.S. business cycle. More specifically, bad macroeconomic news has the expected negative stock market impact during contractions, but a positive impact during expansions. Using stock data from nine Asian countries during the 1997 financial crisis, Kaminsky and Schmukler (1999) run a regression of price changes on eight dummy variables representing different categories of news. With the exception of fiscal news, all other information releases have a significant impact on stock market returns. There is also evidence that investors react more strongly to bad news than good news. Focusing on the same crisis, Hayo and Kutan (2005) find that IMF-related bad and good news have a significant effect on six emerging stock market returns.

The second strand of literature explores the impact of news on the volatility of stock returns. Earlier papers generally use unconditional volatility measures such as the absolute stock returns and generate weak results regarding the news-volatility relation (see Berry and Howe, 1994; Mitchell and Mulherin, 1994; Chan *et al*., 2001). In contrast, the effect of news on the conditional volatility yields significant results. Using a GARCH model, Flannery and Protopapadakis (2002) report that six of the 17 macroeconomic announcement surprises (i.e. balance of trade, employment report, housing starts, real Gross National Product, money supply M1 and M2) have a significant coefficient in the conditional variance equation. The result in Chan and Wei (1996) shows that political news increases the conditional volatility of both blue-chip and red-chip shares traded on the Hong Kong stock market. Kalev *et al*. (2004) find that the news variable exerts a positive and significant impact on the conditional volatility of stock returns in their GARCH specification, even after controlling for the potential effects of trading volume and the high opening volatility. Fong and Koh (2002) employ the Markov switching EGARCH model to examine the impact of political uncertainty on stock price volatility. The authors report that external events account for three-quarters of the high volatility periods, while the remaining volatile periods coincide with major domestic political events in Hong Kong. Wongswan (2006) finds that macroeconomic announcements in the U.S. and Japan have an economically and statistically significant impact on the intraday stock return volatility of Korea and Thailand.

The relationship between public information and trading volume is also a subject of considerable interest. Jain (1988) examines the trading volume responses to five macroeconomic announcements, but none of them are statistically significant, indicating that market participants do not differ substantially in their interpretations of the news effects. Using the number of news releases by newswires, Berry and Howe (1994) and Mitchell and Mulherin (1994) find a positive and statistically significant relationship between public information and trading volume. Flannery and Protopapadakis (2002) examine the impact of 17 macroeconomic announcement surprises and find that eight of them significantly increase trading volume. Kalev *et al*. (2004) report that the de-trended trading volume increases as the number of news announcements per interval is higher. However, this relation is neither strong nor consistent across their selected individual companies. Using minute-by-minute intraday data, Wongswan (2006) documents a large and significant association between developed economies' (i.e. Japan and the U.S.) macroeconomic announcements and emerging markets' (i.e. Korea and Thailand) trading volume.

In terms of the categories of news, the literature can be divided into four major groups. First, the bulk of the studies examine regularly scheduled macroeconomic announcements, which are released widely at precisely identifiable times (see, for example, Jain, 1988; McQueen and Roley 1993; Fair, 2002; Flannery and Protopapadakis, 2002; Boyd *et al*., 2005; Wongswan, 2006; Andersen *et al*., 2007). The second group of literature focuses on firm-specific news using comprehensive databases of headlines about individual companies (see Roll, 1988; Ryan and Taffler, 2004). The third category limits their empirical investigation to salient political and economic events (see Cutler *et al*., 1989; Chan and Wei, 1996; Kaminsky and Schmukler, 1999; Chan *et al*., 2001; Fong and Koh, 2002). The final group instead proxies public information by the amount of new releases per unit of time (see Berry and Howe, 1994; Mitchell and Mulherin, 1994; Kalev *et al*., 2004).

5.2.2 Serial correlation of intraday stock returns

With the availability of high frequency stock price data, there is an increasing number of papers that take a microscopic view of time series dependence by estimating autocorrelations in intraday return series (recent studies include Tsutsui *et al*., 2007; Alexander and Peterson, 2008; Chordia *et al*., 2008; Boehmer and Kelley, 2009; Boehmer and Wu, 2009). However, computing daily autocorrelation coefficients or variance ratios from intraday data is relatively rare but not something new.[4] For

[4] In sharp contrast, the literature on realized volatility is voluminous in which high-frequency intraday data are used to estimate daily volatility (see the survey paper by McAleer and Medeiros, 2008).

instance, Wood *et al*. (1985) estimate autocorrelation coefficients from lags one to twenty minutes for each trading day, and then compute the percentage of days for which the *t*-statistics for the correlation coefficients are significant at the 5% level. With 495 1-minute return data available for each trading day, Bianco and Renò (2006) construct a time series of 751 daily variance ratios, and then examine whether these variance ratios are associated with measures of daily volatility and trading volume. Their regression results show that the serial correlation of intraday returns is positively and significantly related to both variables in the Italian stock index futures market. The same framework has been adopted by Bianco and Renò (2009), who also find a positive relationship between the daily variance ratio and total volatility using data from S&P 500 Stock Index futures.

To detect significant serial correlations in the 1-minute transaction returns of KLCI for each trading day, we adopt the WBAVR test because it addresses three methodological issues in one unified framework. First, the conventional individual (Lo and MacKinlay, 1988) and multiple variance ratio tests (Richardson and Smith, 1991; Chow and Denning, 1993) are asymptotic tests which provide poor approximation to the finite sample distribution of the variance ratio statistic, hence giving rise to severe size distortions and low power in small samples. Several alternatives have been proposed to circumvent this problem and wild bootstrap method is one of them (see the survey paper by Charles and Darné, 2009b). In a series of Monte Carlo simulation exercises, Kim (2006), Kim and Shamsuddin (2008) and Kim (2009) show that the wild bootstrap greatly improves the small sample properties of existing variance ratio tests. Second, the widely reported volatility clustering effects present in high frequency stock data play to the strength of the wild bootstrap, since it is specifically designed to replicate the conditional and unconditional heteroskedasticity present in the data.[5] Third, in the empirical applications of variance ratio tests, it is customary to examine the variance ratios for several holding periods, but these choices are often arbitrary and made with little statistical justification. Choi (1999) proposes a completely data-dependent procedure to determine the optimal value of the holding period. However, Kim (2009) shows that the automatic variance ratio test suffers from serious size distortions when the return is conditionally heteroskedastic. In sharp contrast, the wild bootstrapped automatic variance ratio test shows no size distortion for a sample size as small as 100, and has power substantially higher than the wild bootstrapped Chow and Denning's (1993) test and the power-transformed joint test of Chen and Deo (2006).

5.3 Data and Methodology

This section discusses the sources of our stock market data and news events. A brief explanation of the wild bootstrapped automatic variance ratio (WBAVR) test is given in the final subsection.

5.3.1 The Malaysian intraday stock data

In this study, we focus on the impact of news on the stock market at the aggregate level using broad market indices. In the present context, the Kuala Lumpur Composite Index

[5] Andersen *et al*. (2001) dispute the robustness of earlier papers like Ito *et al*. (1998) that examine changes in the intraday return volatility patterns using variance ratio methodology. This is because high frequency returns are characterized by highly persistent conditional heteroskedasticity that renders the standard variance ratio procedure unreliable. Recognizing this shortcoming, Andersen *et al*. (2001) then develop a robust tool for the high frequency data setting. Though these authors note that their investigation has no direct bearing on the variance ratio tests of serial uncorrelatedness, the effect of conditional heteroskedasticity has to be properly accounted for in order to draw reliable statistical inference.

(KLCI) is widely accepted as the barometer of the Malaysian stock market.[6] On April 18, 1995, the number of constituent stocks in the KLCI was fixed at 100, and the frequency of index calculation was increased to every 60 seconds. High-frequency minute-by-minute KLCI data are sourced from the Kuala Lumpur Stock Exchange (KLSE).[7] Our sample period covers the Asian financial crisis from July 1997 to December 1998. Trading at the exchange is from Monday to Friday, except on public holidays. In the early part of our sample period, the trading hours in local time are from 09:30 to 12:30 for the morning session, and reopens after lunch break at 14:30 until 17:00 for the afternoon session. Effective December 15, 1997, KLSE began the morning session at 09:00 instead of 09:30.

We construct continuously compounded returns from transaction prices sampled at the 1-minute interval. The main reason for our choice of 1-minute data is to provide a sufficient number of observations so that the WBAVR test shows good size and power properties. We discard the prices for the first five minutes as it could capture investors' reaction to overnight information at the start of the trading day. For instance, a number of studies find that the negative autocorrelation of open-to-open returns is consistent with investors' over-reaction to information accumulated overnight (see Amihud and Mendelson, 1989b; Chelley-Steeley, 2001, 2005). Given the change in trading hour for the morning session, we have 325 1-minute transaction prices for each trading day for the period 1/1/1997-12/12/1997 (116 trading days), and 355 observations per day for the rest of the sample period (257 trading days).

[6] The Malaysian stock market, formerly known as the Kuala Lumpur Stock Exchange (KLSE) was officially renamed as *Bursa Malaysia* on April 20, 2004. The official website for the Exchange is http://www.klse.com.my/website/bm/. Given that our sample period is before the name change, we use KLSE to address the Exchange.

[7] We thank Kim-Leng Goh for his generosity in sharing the KLCI intraday data for the period July 1996 to April 1999.

It is well-known that the observed transaction returns of individual stocks will be negatively autocorrelated due to transaction prices bouncing between the bid and the ask prices (see Roll, 1984). The common remedy in extant intraday serial correlation literature is to use the midpoints of the bid-ask quotes instead of transaction prices (see Chordia *et al*., 2005, 2008; Alexander and Peterson, 2008; Boehmer and Kelley, 2009; Boehmer and Wu, 2009).[8] However, the issue of spurious negative autocorrelation induced by bid-ask bounce does not arise in this study because our analysis focuses on index rather than individual stocks. For instance, having established that bid-ask errors are the major source of negative serial correlations in individual security returns, Conrad *et al*. (1991) then use their model to rationalize the strong positive autocorrelations in portfolio transaction returns. The reason given is that the bid-ask errors are cross-sectionally uncorrelated and are diversified away in the portfolio formation process.[9] Anderson *et al*. (2008) decompose stock return autocorrelations into four components, namely non-synchronous trading effect, bid-ask bounce, partial price adjustment and time-varying risk premia. These authors argue that the contribution of bid-ask bounce to portfolio return autocorrelations is generally negligible.

[8] It is also a common practice in empirical studies of realized volatility to use the midpoints of bid and ask prices. A number of recent papers provide formal treatments with the development of integrated volatility estimators that are robust to the presence of market microstructure noise (see, for example, Bandi and Russell, 2006, 2008; Hansen and Lunde, 2006; Mancino and Sanfelici, 2008). However, there is still no formal procedure in existing variance ratio tests that corrects for the market microstructure effect.

[9] On the other hand, Conrad *et al*. (1991) note that the autocorrelations generated by bid-ask errors are likely to be smaller for larger firms because they have narrower bid-ask spreads. Their conjecture is consistent with previous studies which find the first-order return autocorrelations of larger firms' stocks tend to be positive (see French and Roll, 1986). With regard to this point, the KLCI is a value-weighted market index of 100 companies traded on the Malaysian stock market. For inclusion in the index, one of the criteria is that the company needs to be in the top 50% of market capitalization and has at least 5% of the total market capitalization of the stock exchange.

5.3.2 Our news events database

In this study, we explore whether the detected significant return autocorrelations can be associated with salient political and economic events that have market-wide impact. Hence, firm-specific announcements are not expected to have a systematic effect on the stock market index. Our news events database is constructed at a daily frequency from two major sources. First, Kaminsky and Schmukler (1999) analyze the type of news that lead to the 20 largest 1-day stock price changes during the 1997 financial crisis for nine Asian countries, namely Hong Kong, Indonesia, Japan, Korea, Malaysia, the Philippines, Singapore, Taiwan and Thailand. These authors collect their news, local and foreign, from *Bloomberg* and cross-check with other financial newspapers. Their working paper version provides the list of events that move the nine stock markets in those days of extreme market jitters. The second important source of information is the annual reports of the Securities Commission (SC) for the years 1997 and 1998.[10] More specifically, the two annual reports provide a detailed account of those major events that the Securities Commission believes are the primary market movers for the Kuala Lumpur Composite Index. The main indicators used by this regulatory body for drawing inference are the price changes and trading volume. Using these two sources, we can then determine whether the market-moving news events singled out by Kaminsky and Schmukler (1999) and the Securities Commission also trigger significant serial correlations in the underlying return series of KLCI. To complement the database, we also use the chronology of major events during the Asian crisis provided by the International Monetary Fund (IMF, 1998).

[10] Briefly, the Securities Commission established on March 1, 1993 under the Securities Commission Act 1993 is a self-funding statutory body in Malaysia with investigative and enforcement powers. Apart from discharging its regulatory functions, the Securities Commission is also obliged by statute to encourage and promote the development of the securities and futures markets in Malaysia. Further information on the Securities Commission can be obtained from its official website at http://www.sc.com.my.

5.3.3 Wild bootstrapped automatic variance ratio (WBAVR) test

In Chapter 3, the automatic variance ratio (AVR) test of Choi (1999) is used to measure the degree of weak-form market efficiency. In this chapter, we use its wild bootstrap version to test for the hypothesis of no return autocorrelation, with improved small sample properties. Note that some of the equations are repeated here for completeness of discussion in this chapter.

Let Y_t be an asset return at time t, where $t = 1, 2, ..., T$. Choi's (1999) AVR test statistic takes the following form:

$$VR(k) = 1 + 2\sum_{i=1}^{T-1} m(i/k)\hat{\rho}(i) \tag{5.1}$$

where $\hat{\rho}(i)$ is the sample autocorrelation of order i and $\hat{\mu}$ is the sample mean of Y_t. Note that $m(\cdot)$ is a weighting function with positive and declining weights. We follow Choi (1999) and use the quadratic spectral kernel for the weighting function so that

$$m(x) = \frac{25}{12\pi^2 x^2}\left[\frac{\sin(6\pi x/5)}{6\pi x/5} - \cos(6\pi x/5)\right] \tag{5.2}$$

According to Choi (1999), $VR(k)$ given in (5.1) is a consistent estimator for the normalized spectral density for Y_t at zero frequency. Under the null hypothesis that Y_t is serially uncorrelated, Choi (1999) shows that:

$$AVR(k) = \sqrt{T/k}\,[VR(k) - 1]/\sqrt{2} \xrightarrow{d} N(0,1) \tag{5.3}$$

as $k \to \infty$, $T \to \infty$, $T/k \to \infty$, when Y_t is generated from a martingale difference sequence with proper moment conditions. In order to choose the value of lag truncation point (or holding period) k optimally, Choi (1999) adopts a data-dependent method of Andrews (1991) for the spectral density at the zero frequency. The automatic variance ratio test statistic with the optimally chosen lag truncation point is denoted as $AVR(\hat{k})$.

To complement the $AVR(\hat{k})$ test, we use the normal critical values of 2.576 and -2.576 for 1% level of significance. This is based on the asymptotic approximation using the limiting distribution given in (5.3). However, this approximation can be inadequate in small samples, especially when Y_t is subject to conditional heteroskedasticity. An alternative is to use the wild bootstrap of Mammen (1993), which provides critical values or *p*-values of the test that does not rely on asymptotic approximation. Following Kim (2006), the wild bootstrap for $AVR(\hat{k})$ is conducted in three stages as below:

(i) Form a bootstrap sample of T observations $Y_t^* = \eta_t Y_t$ $(t = 1,\ldots,T)$ where η_t is a random sequence with $E(\eta_t) = 0$ and $E(\eta_t^2) = 1$;

(ii) Calculate $AVR^*(\hat{k}^*)$, the AVR statistic obtained from $\{Y_t^*\}_{t=1}^{T}$; and

(iii) Repeat (i) and (ii) B times to form a bootstrap distribution $\{AVR^*(\hat{k}^*; j)\}_{j=1}^{B}$.

The two-tailed *p*-value of the test is obtained as the proportion of the absolute values of $\{AVR^*(\hat{k}^*; j)\}_{j=1}^{B}$ greater than the absolute value of $AVR(\hat{k})$. The $100(1-2\alpha)\%$ confidence interval for the test can be obtained as the interval $[AVR^*(\alpha), AVR^*(1-\alpha)]$, where $AVR^*(\alpha)$ represents the αth percentile of $\{AVR^*(\hat{k}^*; j)\}_{j=1}^{B}$. If the test statistic $AVR(\hat{k})$

lies outside this interval, the null hypothesis is rejected at the $(1-2\alpha)$ level of significance.

5.4 Weak-form Market Efficiency at the Intraday Level

We first apply the WBAVR test on the 1-minute transaction returns of the KLCI for each trading day, where the number of bootstrap replications is set to 1,000. Table 5.1 summarizes the results for our sample period from July 1997 to December 1998. With 373 trading days during the Asian crisis, there are a total of 141 days (approximately 37.80%) that trigger a rejection of the null hypothesis of serial uncorrelatedness at the 1% level of significance. It is worth highlighting that all the significant automatic variance ratio (AVR) statistics are greater than unity, suggesting the presence of positive serial correlations in stock returns for those trading days. Setting the level of significance to 5% witnesses a marginal increase in significant AVR statistic.

The above results complement the existing literature in four significant ways. First, Bianco and Renò (2006) apply Lo and MacKinlay's (1988) heteroskedasticity-consistent variance ratio test to 1-minute returns for each of their 751 trading days. The authors find that the significant intraday return autocorrelations for Italian stock index futures are mostly negative, which they claim is largely due to the bid-ask bounce effect. Given the predominantly positive return autocorrelations, our empirical findings support the conjecture of Conrad *et al*. (1991) and Anderson *et al*. (2008) that the contribution of bid-ask bounce to index return autocorrelations is generally negligible.

Table 5.1: WBAVR Test Results for Crisis Period

	1% Level of Significance	5% Level of Significance
Total number of trading days	373	373
Total number of trading days with significant AVR statistic	141	176
Total number of trading days with AVR statistic significantly less than unity	0	2
Total number of trading days with AVR statistic significantly greater than unity	141	174

Note: The significance of the AVR statistic is based on the wild-bootstrap *p*-value.

Second, we rule out thin trading as the major source of those significant positive return autocorrelations. Cohen *et al*. (1980) note that a value-weighted market index gives more weights to large capitalization stocks, and hence exhibits smaller positive autocorrelations than a similarly constructed equally-weighted market index. In our study, the KLCI is a value-weighted market index of 100 companies that are actively traded and have at least 5% of the total market capitalization of the stock exchange. We further apply the WBAVR test on 1-minute transaction returns for the pre-crisis period from July 1996 to June 1997. The results in Table 5.2 show that there is less rejection of the null hypothesis during our selected tranquil period. For instance, at the 1% level of significance, only 4.03% of the total trading days record a significant AVR statistic, as compared to 37.80% in the crisis period. This suggests that thin trading plays a relatively minor role in generating those detected significant positive market index return autocorrelations.

Table 5.2: WBAVR Test Results for Pre-crisis Period

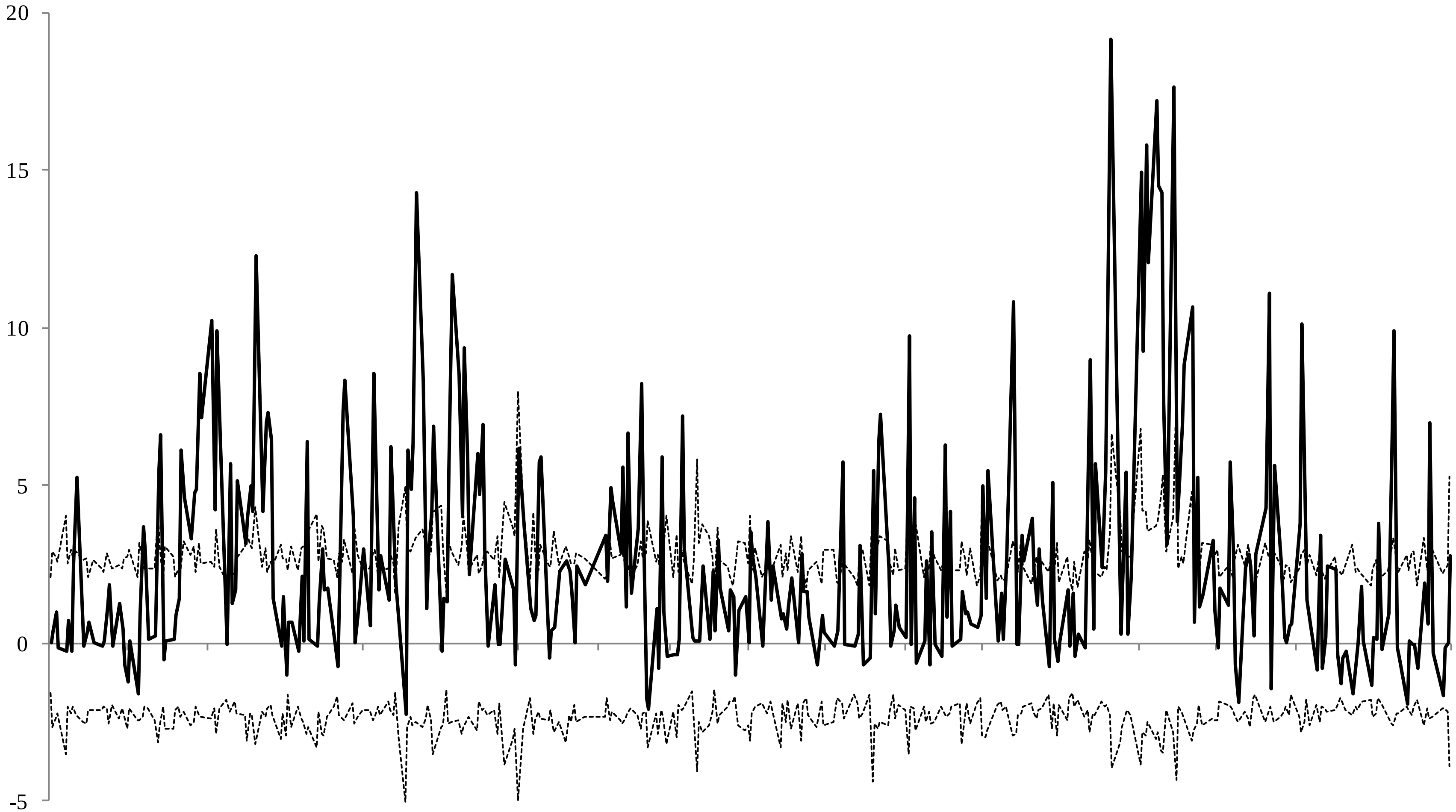
	1% Level of Significance	5% Level of Significance
Total number of trading days	248	248
Total number of trading days with significant AVR statistic	10	32
Total number of trading days with AVR statistic significantly less than unity	1	15
Total number of trading days with AVR statistic significantly greater than unity	9	17

Note: The significance of the AVR statistic is based on the wild-bootstrap *p*-value.

Third, Chordia *et al*. (2005) investigate the speed of convergence to weak-form efficiency by examining how long it takes the market to remove return autocorrelations after prices adjust to their new equilibrium levels. These authors select the 150 largest stocks listed on the New York Stock Exchange to avoid the problem of thin trading, and compute the first-order serial correlation coefficient for 5-minute returns. Their results show that these stocks conform well to weak-form efficiency over intervals as short as five minutes. By comparing the serial correlation coefficients during announcement and non-announcement periods, Ederington and Lee (1995) report an even impressive speed of adjustment in the interest rate and foreign exchange futures markets. More specifically, they find that the market price begins adjusting within the first 10 seconds of the scheduled macroeconomic news release and the adjustment is completed within 40 seconds. Our results demonstrate that the emerging Malaysian stock market also exhibits such high degree of efficiency. For instance, during the crisis period, 62% of the trading days report statistically insignificant return autocorrelations at the 1% level, suggesting that new information is incorporated into stock prices within one minute. In the pre-crisis tranquil period, the Malaysian market records even higher efficiency, with 96% of the trading days showing the stock index following a random walk.

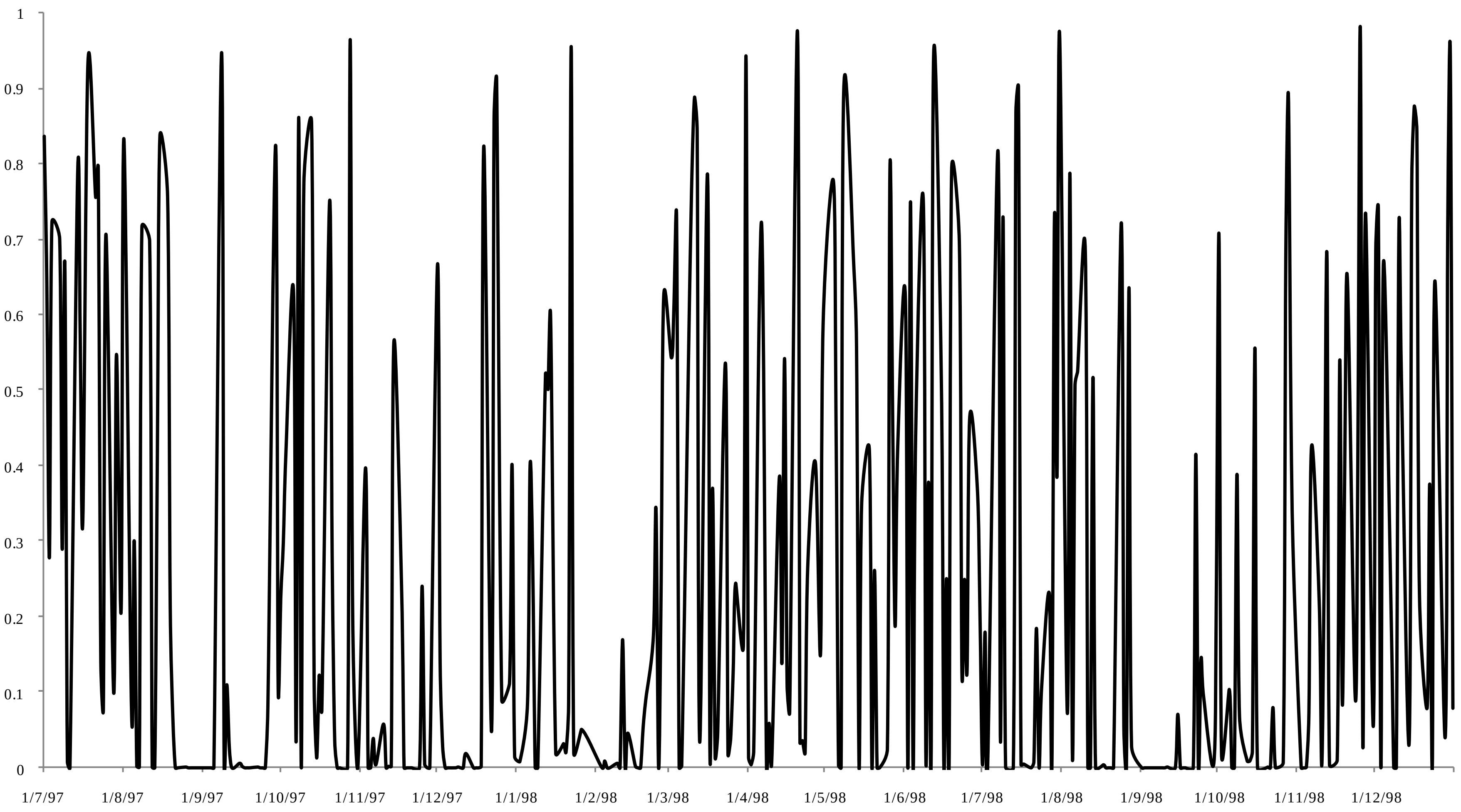
Fourth, there is an expanding literature tracking the evolution of market efficiency over time by means of a time-varying parameter model or a rolling estimation window (see references cited in Subsection 2.4.2 of this thesis). The main objective of applying this dynamic framework is to know when and why the market experiences deviations from market efficiency. For instance, Yilmaz (2003) applies two multiple variance ratio tests in rolling sub-samples with 1,000 daily observations and then identifies the events that trigger significant return autocorrelations. However, it is difficult to pinpoint in a 4-year rolling estimation window the precise dates when the variance ratio test statistics are insignificant. The above limitation can be overcome by using high-frequency minute-by-minute data. Figures 5.1 and 5.2 plot the values of the automatic variance ratio statistic minus one (with their 99% confidence intervals) and the *p*-values of the WBAVR test, respectively. The x-axis is labeled with the exact dates of the trading day. Section 5.5 then conducts a search of our daily news database to identify the proximate causes of these significant return autocorrelations.

Figure 5.1: Time Series Plot for Automatic Variance Ratio Statistic minus One during the Crisis Period



Notes: The y-axis shows the values of the automatic variance ratio statistic minus one (AVR-1), while the x-axis is labeled with the dates of the trading day. The dashed lines denote the 99% confidence intervals.

Figure 5.2: Time Series Plot for *p*-values of the WBAVR Test during the Crisis Period



Notes: The y-axis shows the *p*-values of the WBAVR test, while the x-axis is labeled with the dates of the trading day.

5.5 Potential Explanations for Significant Positive Return Autocorrelations

As noted in the previous section, the significant return autocorrelations are predominantly positive, which are generally interpreted in the literature as investors' mis-reaction to new information. Besides behavioral biases as in Barberis *et al*. (1998) and Daniel *et al*. (1998), other potential explanations of how news might drive return autocorrelations include investor inattention, slow information dissemination, information uncertainty and herding/positive feedback trading. Though these theories are formulated for longer-horizon returns, they should be better tested here since news events are generally recorded at a daily frequency. Given that our framework focuses on market-wide news events that exhibit a high level of salience generated by their coverage in major newspapers, we rule out investor inattention as the possible source of market under-reaction.[11] On the other hand, since mass media such as the newspapers play an important role in disseminating information to the broadest audience, especially in emerging stock markets like Malaysia, we discard the possibility that under-reaction is the outcome of gradual diffusion of information across the investing public as postulated by Hong and Stein (1999). Moreover, intense media coverage has been given to stock markets during the Asian crisis.

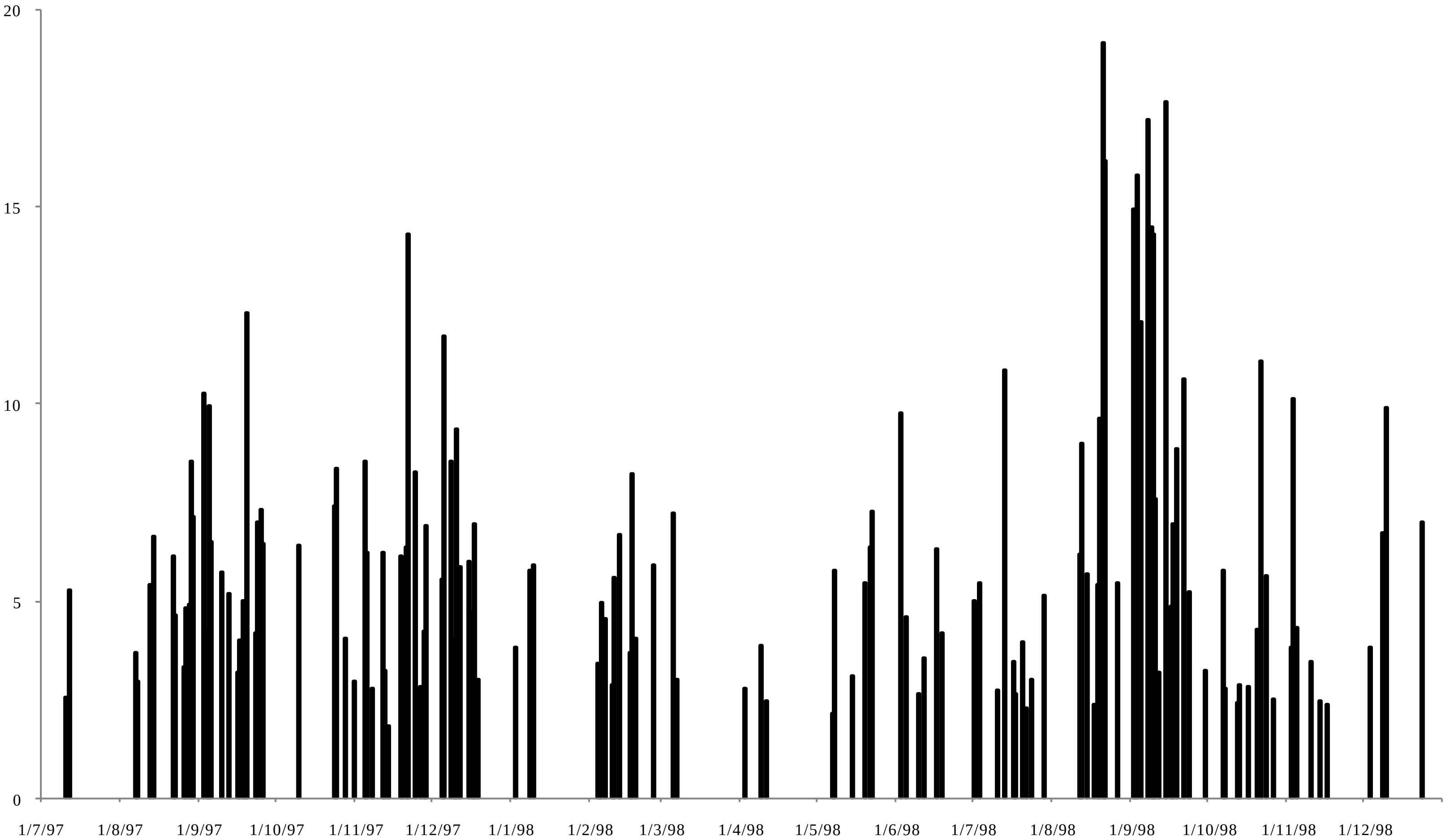
[11] A number of theoretical models predict that when investors face attention constraints in information processing, the stock price does not promptly response to new information (see Hirshleifer and Teoh, 2006; Peng and Xiong, 2006; DellaVigna and Pollet, 2009). Empirical studies generally provide evidence in favor of this inattention-based explanation for under-reaction to public information (see Hou *et al*., 2008; Loh, 2008; Peress, 2008; DellaVigna and Pollet, 2009; Hirshleifer *et al*., 2009). Nevertheless, we test this hypothesis in the spirit of DellaVigna and Pollet (2009) who find that post-earnings announcement drift is of greater magnitude for Friday announcements than those on other weekdays, which the authors attribute to weekend distractions. More specifically, we compute and report the average absolute value of automatic variance ratio statistic minus one for Monday (2.2523), Tuesday (3.0247), Wednesday (2.9344), Thursday (3.2184) and Friday (3.0136). Our tests of equality of means show that their differences are not statistically significant.

The matching of the occurrence of significant return autocorrelations to news events permits us to further delineate the potential sources, which are discussed in Subsections 5.5.1 and 5.5.2. To avoid spurious association, we set the probability of Type I error to be 0.01 before regarding a trading day as exhibiting significant serial correlations in the KLCI return series, and hence market mis-reaction. Figure 5.3 provides a graphical depiction of those days with return autocorrelations significant at the 1% level.

5.5.1 Significant return autocorrelations on big news days

We determine whether the market-moving news events singled out by Kaminsky and Schmukler (1999) and the Securities Commission also trigger significant serial correlations in the underlying return series of KLCI. Table 5.3 provides the list of trading days in which those significant return autocorrelations coincide with major market-moving news events. Our matching procedure is able to identify 29 events that have a major impact on the Malaysian stock market, not only causing large price changes, but also investors' mis-reaction. Several interesting observations are highlighted here. First, the market not only mis-reacts to local news, but also to news originating in other markets. Foreign news events, mainly from Indonesia, account for 50% of the 29 events. This result is not surprising as Baig and Goldfajn (1999) and Kaminsky and Schmukler (1999) also document a significant impact of cross-border news on the local stock markets, suggesting the existence of cross-country spillover effects during the Asian crisis. The former, in particular, find that the Malaysian and Indonesian stock markets react significantly to each other's news. Second, there are 5 events related to announcements of IMF actions. Hayo and Kutan (2005) also find that IMF-related news has a significant effect on six emerging stock market returns during the Asian crisis.

Figure 5.3: Significant Automatic Variance Ratio Statistic minus One during the Crisis Period



Notes: The y-axis shows the values of the automatic variance ratio statistic minus one (AVR-1), while the x-axis is labeled with the dates of the trading day. The figure plots only those days with AVR-1 significant at the 1% level. For clarity, the insignificant AVR-1 is set to zero.

Table 5.3: Significant Return Autocorrelations that Coincide with Big News

Date	AVR-1	Market-moving News Events
11/07/1997	5.2599	The Central Bank of the Philippines announces that it will allow the peso to float in a wider range. Indonesia widens the trading band for rupiah from 8 percent to 12 percent (IMF).
27/08/1997	4.8960	The KLSE announces that the 100 component stocks of the KLCI will be classified as ‘designated securities’ with trading in these stocks limited to delivery before sale. Regulated short selling, and stock borrowing and lending, are also suspended (SC, IMF).
28/08/1997	8.5634	Tighter credit as reserve requirements rise in Malaysia (KS).
29/08/1997	7.1444	Bank Indonesia introduces selective credit controls on rupiah trading (IMF).
5/09/1997	6.4922	Unexpected lifting of the index-linked stocks’ designated status by KLSE. The Malaysian government announces significant cutbacks in public spending and the deferral of several mega projects (SC, KS).
23/10/1997	7.3902	Hong Kong’s stock index falls 10.4% after it raises bank lending rates to 300% to fend off speculative attacks on the Hong Kong dollar (SC).
31/10/1997	2.9715	IMF and Indonesia agree on $23 billion financial support package (IMF).

Notes: AVR-1 refers to the automatic variance ratio statistic minus one. Entries in parentheses denote the sources of the news events, which come from (1) KS- Kaminsky and Schmukler (1999); (2) SC- 1997 and 1998 annual reports of the Securities Commission; (3) IMF- International Monetary Fund (1998).

Table 5.3 (Continued)

Date	AVR-1	Market-moving News Events
18/11/1997	6.1573	United Engineers Malaysia (UEM) announces it has acquired a 32.6% stake in its parent company Renong Berhad. This surprise announcement raises concerns over the extent of transparency in corporate restructuring activities in Malaysia (SC, KS).
20/11/1997	6.3708	The Malaysian government announces it has taken over the Bakun Dam project from Ekran Berhad. This announcement exacerbates widespread concerns of possible government-sanctioned bail-outs of financially-troubled companies (SC, KS).
21/11/1997	14.3287	Korea requests IMF assistance (IMF).
5/12/1997	11.7199	The Malaysian Deputy Prime Minister (DPM) announces additional austerity measures and government spending cuts. The government slashes its estimate of 1998 GDP growth to 4-5% from 7%, and targets reducing the current account deficit to 3% of GNP by 1998. The DPM also assures that there is no impending measure to impose foreign exchange controls (SC).
8/12/1997	8.5233	Thai authorities close 56 of the suspended finance companies (IMF).
11/12/1997	5.8800	High interest rates and weakening ringgit cause Malaysian stocks to drop (KS).
2/01/1998	3.8013	Malaysia announces plans for mergers of finance companies. Indonesia announces plans to merge four out of seven state-owned banks (IMF).

Notes: AVR-1 refers to the automatic variance ratio statistic minus one. Entries in parentheses denote the sources of the news events, which come from (1) KS- Kaminsky and Schmukler (1999); (2) SC- 1997 and 1998 annual reports of the Securities Commission; (3) IMF- International Monetary Fund (1998).

Table 5.3 (Continued)

Date	AVR-1	Market-moving News Events
10/02/1998	5.5951	Ringgit surges on expectations that Indonesia may introduce a currency board (KS).
12/02/1998	6.6930	The IMF may not support Indonesian plans to peg the rupiah to the dollar (KS).
16/02/1998	3.6612	The IMF warns that it may withhold emergency credit to Indonesia if it pegs the currency (KS).
10/04/1998	2.4574	Indonesia signs new letter of intent on economic program with IMF (IMF).
6/05/1998	2.1460	Social unrest in Indonesia caused by students riots (KS).
21/05/1998	6.3837	The Malaysian government announces the formation of an asset management company to manage the non-performing loans and assets of troubled companies pledged to banking institutions. Suharto resigns as Indonesian president after 32 years in power (SC).
23/07/1998	2.9814	The Malaysian government releases the National Economic Recovery Plan (SC).
28/07/1998	5.1255	The Malaysian government announces the postponement of the proposed US$2 billion international bond sale to raise capital to stimulate the economy due to the downgrading of Malaysia's credit ratings by both Moody's Investors Service and Standard & Poor's (SC).
17/08/1998	2.3823	The Russian government announces a *de facto* devaluation by widening the trading band of the Russian ruble and 90-day moratorium on payment by Russian commercial banks to foreign creditors (SC).

Notes: AVR-1 refers to the automatic variance ratio statistic minus one. Entries in parentheses denote the sources of the news events, which come from (1) KS- Kaminsky and Schmukler (1999); (2) SC- 1997 and 1998 annual reports of the Securities Commission; (3) IMF- International Monetary Fund (1998).

Table 5.3 (Continued)

Date	AVR-1	Market-moving News Events
19/08/1998	9.6512	Russia fails to pay its debt on GKO or treasury bills, officially falling into default (SC).
1/09/1998	14.9588	The Malaysian government introduces wide-ranging foreign-exchange controls aim at ending speculation on the Malaysian currency (SC).
2/09/1998	9.2649	The Malaysian ringgit is fixed at RM3.80 to the US dollar. The Deputy Prime Minister is dismissed from the Cabinet, and this leads to a series of street demonstrations (SC).
16/10/1998	2.8163	In the U.S., the Federal Open Market Committee (FOMC) cuts 0.25% off the fed funds rate and discount rate, leading to a rally in the global stock markets including Malaysia (SC).
23/10/1998	5.6271	The Federal budget, which emphasizes on fiscal stimulus, is tabled in the Malaysian Parliament (SC).
3/11/1998	10.1236	The Securities Commission announces that it will be putting in place a scheme aims at resolving the problems of troubled stockbroking companies on an industry-wide basis (SC).

Notes: AVR-1 refers to the automatic variance ratio statistic minus one. Entries in parentheses denote the sources of the news events, which come from (1) KS- Kaminsky and Schmukler (1999); (2) SC- 1997 and 1998 annual reports of the Securities Commission; (3) IMF- International Monetary Fund (1998).

The above result suggests that the market takes more than one minute to fully incorporate the impact of those 29 events. One possible explanation is that there is greater uncertainty on the implications of the news. For instance, Zhang (2006b) hypothesizes that if investors under-react to public information, they will under-react even more in cases of greater information uncertainty. In the empirical investigation, Zhang (2006b) employs a battery of proxies for information uncertainty, namely firm size, firm age, analyst coverage, dispersion in analyst forecasts, return volatility and cash flow volatility. His results show that U.S. stocks for which information uncertainty is higher exhibit stronger short-term stock price continuation, suggesting that uncertainty delays the incorporation of information into stock prices.

It is worth highlighting that there are 17 events singled out by Kaminsky and Schmukler (1999) and the Securities Commission as major market movers but the 1-minute return series exhibit insignificant serial correlations. The result suggests that even though the above media stories induce large price changes, there is no evidence of market mis-reaction. Even if there is, it takes the market less than one minute to remove return autocorrelations after the price adjusts to its new equilibrium level. Perhaps, there is less uncertainty on the valuation impact of these events. One puzzling result is the insignificant return autocorrelations on July 2, 1997. It is widely acknowledged that the Asian crisis starts when the Bank of Thailand announces a managed float of the currency on July 2, effectively devaluing the baht by 15% in onshore markets and by 20% in offshore markets (see references cited in Lim *et al.*, 2008c). There is only evidence of mis-reaction to crisis-related news on July 11, when the Central Bank of the Philippines announces that it will allow the peso to float in a wider range. Indonesia also widens the trading band for rupiah from 8 percent to 12 percent (IMF). Perhaps, the accumulation of negative news from several neighboring countries suggests a full-blown regional financial crisis is forthcoming, causing great anxiety and uncertainty in the investment communities.

5.5.2 Significant return autocorrelations on no-news days

Kaminsky and Schmukler (1999) analyze the type of news that lead to large 1-day price changes for nine Asian stock markets during the 1997 financial crisis. They find that 34 percent of those days of extreme market jitters cannot be explained by any fundamental news, which the authors attribute to investors' herding behavior. Kaminsky and Schmukler (1999) justify their interpretation of herding on the basis that the financial press generally points to investors' concerns about the domestic economy even though no economic news is released.[12] Indeed, their interpretation is consistent with the literature where herding is held responsible for large price movements, though there is still a debate on whether such trading moves prices towards or away from fundamental values (for discussion, see Nofsinger and Sias, 1999). In the framework of Kaminsky and Schmukler (1999), when there is no news on days of market jitters, it could imply this type of non-information based herding behavior is destabilizing stock prices.

We infer the presence of herding behavior among noise traders from the evidence of significant serially correlated returns in minute-by-minute stock data during no-news days.[13] In a previous study, Ederington and Lee (1995) examine the speed of adjustment

[12] These authors do not rule out alternative explanations such as (1) the presence of noise trading; (2) investors' delayed reaction to news on previous day, which take them several days to fully grasp its impact; (3) the reaction to news only known by informed investors.

[13] Several papers employ formal statistical measures to examine the possibility of herding and positive feedback trading during the Asian financial crisis (see Choe *et al*., 1999; Kim and Wei, 2002; Bowe and Domuta, 2004). The possibility of herding has recently been explored using intraday trading data by Gleason *et al*. (2004), Christoffersen and Tang (2009) and Patterson and Sharma (2009).

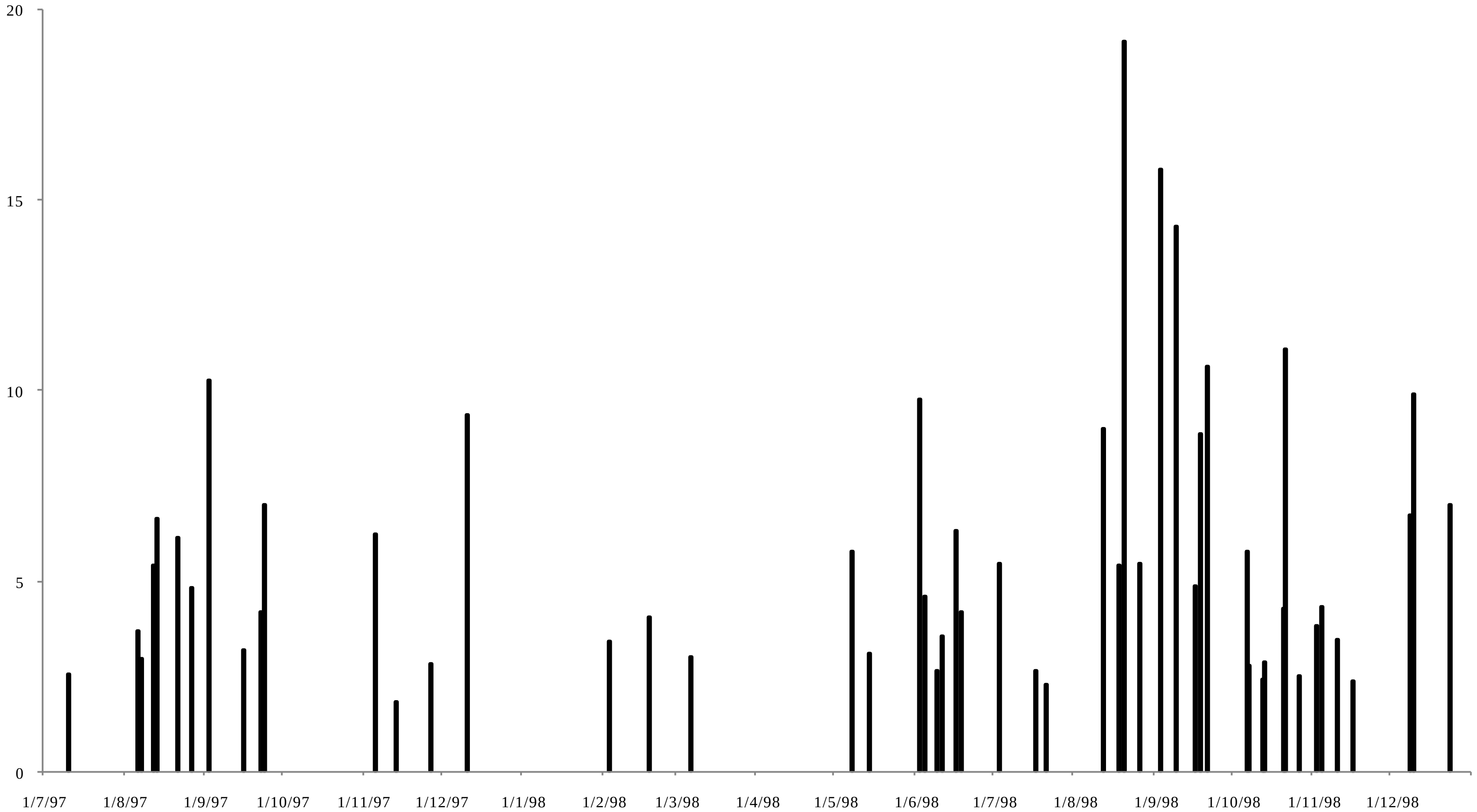
to news releases by comparing the serial correlation of consecutive intraday price changes during announcement and non-announcement periods. They report that there is no significant correlation between returns during no-news periods. However, this is not the case with the Malaysian stock market. Our previous matching exercise is able to identify only 29 events, leaving 112 trading days unaccompanied by big news. It is possible that some important political and economic news do not induce large price changes. For instance, Cutler *et al*. (1989) find that only 15 out of the 49 big events that dominate headlines in the media follow an index movement of more than 1.5 percent. Hence, we should not rule out the possibility that the significant return autocorrelations in those 112 trading days are associated with important news events but they are not big enough to cause large price changes.

To identify no-news days instead of no big news days, we use the events database provided in the working paper version of Baig and Goldfajn (1999). These authors collect daily news mainly from *Reuters* and *Bloomberg*, but they also cross-check across different sources to verify the date and content. It is worth highlighting that Baig and Goldfajn (1999) do not simply seek out the news behind large stock price movements. Instead, the events are included based on whether they represent changes in the fundamentals of an economy. Unfortunately, their database covers the Asian crisis up to May 1998, so we use the chronology of major events during the Asian crisis available on *http://www.pbs.org/wgbh/pages/frontline/shows/crash/etc/cron.html* for the rest of the sample period. Our second stage of event matching shows that 52 days with significant return autocorrelations cannot be explained by any economic or political news, suggesting the source is due to non-informational reasons which Roll (1988: 566) describes as " … occasional frenzy unrelated to concrete information.". This evidence is interpreted here as indicative of investors' herding behavior not driven by information, which could move prices away from their efficient random walk benchmark. We acknowledge that some of the events in this second round of matching exercise might not be the main cause of market mis-reaction, but the return autocorrelations in those 52 days are indeed not accompanied by any important news. In other words, our framework provides the lower bound on the proportion of significant return autocorrelations attributable to herding, which is 37 percent in the present context. Figure 5.4 provides a graphical depiction of those significant return autocorrelations occur on days with no news.

A number of studies show that return autocorrelations can arise when investors herd or act as positive feedback traders. For instance, De Long *et al.*'s (1990b) theoretical model demonstrates that when noise traders follow a positive feedback trading strategy, the price pressure causes positive correlation patterns in stock returns at short horizons. The authors also show that rational arbitrageurs do not exert a correcting force to eliminate these correlation patterns in returns but instead accentuate them by jumping on the bandwagon with those noise traders (see also the feedback trading model of Cutler *et al*., 1990). Empirically, Shu (2008) finds that positive feedback trading by institutions is one of the driving forces behind stock return momentum. On the other hand, it is well-known that noise traders are prone to sentiment not fully justified by information (see De Long *et al*., 1990a; Barberis *et al*., 1998), and their correlated trading patterns can cause stock prices to deviate from their fundamental values (see Barber *et al*. 2009b). Even the Securities Commission admits in their annual reports the important role played by investor sentiment in influencing the movements of the general stock market index in Malaysia.

One final note is given here. If significant return autocorrelations are due to investors' mis-reaction to news, then it is better characterized as over-reaction during no-news days. This is because the model of De Long *et al*. (1990b) characterizes positive return autocorrelations as the result of market over-reaction to news, because such news (past returns) triggers positive feedback trading. On the other hand, Gutierrez and Kelley (2008) highlight several theories that predict the market over-reacts to price movements unaccompanied by publicly released news, which they labeled as implicit news. For instance, momentum traders in the model of Hong and Stein (1999) will over-react to price movements. Daniel and Titman (2006) show that investors tend to over-react to intangible news, which these authors define as price movements unrelated to accounting performance measures. Empirically, Chan (2003) provides evidence that the market over-reacts to news implied by large price movements in the absence of publicly released news.

Figure 5.4: Significant Automatic Variance Ratio Statistic minus One on No-news Days



Notes: The y-axis shows the values of the automatic variance ratio statistic minus one (AVR-1), while the x-axis is labeled with the dates of the trading day. The figure plots only those days with significant AVR-1 at the 1% level but no fundamental news is reported on the media.

5.6 Conclusion and Recommendations

In this chapter, we propose a novel framework to explore the direct relationship between news events and stock return autocorrelations. Our contention is that, if significant serial correlations in the return series reflect market mis-reaction to information, it would be interesting to examine whether their presence coincides with days in which market-moving public news is announced. We advocate the use of high-frequency minute-by-minute data to detect significant return autocorrelations for each trading day. The primary contribution of our research design is that it permits investigators to search through daily news stories to identify the possible explanations of return autocorrelations. On the grounds of data availability, this chapter limits the investigation to the Malaysian stock market during the 1997 Asian financial crisis.

We first apply the wild bootstrapped automatic variance ratio test recently proposed by Kim (2009) to detect significant serial correlations in the 1-minute transaction returns of the Kuala Lumpur Composite Index (KLCI). Our results show that only 141 out of the total 373 trading days during the Asian crisis exhibit significant return autocorrelations at the 1% level. This indicates that stock prices in the remaining 62% of trading days follow a random walk, which in the present context implies that new information is incorporated into stock prices within one minute. Using our news database, we find that 29 out of the 141 trading days with significant return autocorrelations can be associated with major market-moving media events. We hypothesize that this is due to higher level of information uncertainty, and hence the market needs more time to fully grasp the implications of the above news. On the other hand, there are 17 events widely considered as major market movers but the 1-minute return series exhibit insignificant serial correlations. This finding suggests that even though the above media stories induce large price changes, there is no evidence of market mis-reaction. Finally, 37 percent of the trading days with significant return autocorrelations cannot be explained by any economic or political news, which we interpret as indicative of investors' herding behavior not driven by information.

Our proposed framework has wide applications in its present form. First, the investigation can be extended to other countries using country-specific news. For instance, Geert Bekaert and Campbell Harvey provide a chronology of important financial, economic and political events in 55 emerging markets from the early 1970s until June 2004.[14] A construction of such database with a daily frequency (see also Cuadro-Sáez *et al*., 2009) will be useful for identifying the events that are associated with significant return autocorrelations. Second, future studies can consider other types of news, in particular regularly scheduled macroeconomic announcements. Third, the use of individual stocks and company news releases, as in Ryan and Taffler (2004), will provide more credible evidence on the link between information and return autocorrelations. Last but not least, the methodology can be adopted to examine the news-return autocorrelations relation in other asset markets such as bond, currency and futures.

Though our proposed framework is subject to further refinements, we hold the view that the relationship between news and return autocorrelations deserves more attention than it presently receives. Since we only focus on salient news events, it does not capture the rate of information flow that arrives around the clock. The number of stories released by

[14] The URL is http://www.duke.edu/~charvey/Country_risk/couindex.htm.

news providers per unit of time, as in Berry and Howe (1994), Mitchell and Mulherin (1994), Melvin and Yin (2000) and Kalev *et al*. (2004), is an ideal proxy for a formal examination on the relation between news and return autocorrelations. This line of inquiry is important because it might uncover another fundamental source of return autocorrelations. The logic behind the idea that efficient prices should follow a random walk is that price changes occur only in response to genuinely new information (see Malkiel, 2003). Since true news is by definition unpredictable, the resulting price changes must be unpredictable and random. Following this line of reasoning, price changes are expected to be serially correlated if the arrival of news does not occur independently over time.[15] Indeed, several empirical studies do report significant autocorrelations for the arrival rate of public information from newswires (see Berry and Howe, 1994; Jones *et al*., 1998; Melvin and Yin, 2000; Kalev *et al*., 2004). Hence, it is possible that the autocorrelation in the news-generating process not only leads to serial dependency in return volatility (see Jones *et al*., 1998; Kalev *et al*., 2004), but also serial correlations in stock returns. Our conjecture that the correlation pattern in information flow is an important source of return autocorrelations has yet to be explored in the extant literature, but we hope our discussion will stimulate more extensive empirical work in the future.

[15] The Mixture of Distribution Hypothesis (MDH) posits that the variance of returns is positively related to the rate of information arrival. Empirically, a number of studies find that conditional volatility can be explained partly by autocorrelation in the information arrival process (see Jones *et al*., 1998; Kalev *et al*., 2004). Andersen (1996) highlights that different types of news have different stochastic arrival processes and hence have different implications for return volatility persistence.

CHAPTER 6

Summary, Recommendations and Conclusion[★]

6.1 Summary of the Thesis

The present section summarizes the key findings of this thesis by directly answering the three research questions addressed in Chapters 3 through 5.

6.1.1 What factors are associated with a higher degree of market efficiency?

In the weak-form EMH literature, a small number of studies do take the extra step to identify the determinants of market efficiency. Among the factors considered are the opening of the domestic stock market to foreign investors, the changes in the regulatory framework, the adoption of electronic trading systems, the implementation of price limits system and the occurrence of financial crisis. However, the findings from these country-by-country sub-period studies are inconclusive, mainly because their research framework focuses on testing whether the random walk hypothesis can be rejected in those sub-periods of pre- and post-changes. In other words, the stock market under study is expected to undergo a complete transformation from an inefficient state to a perfectly efficient one in the aftermath of the event, treating market efficiency as a dichotomous zero-one variable.

[★] Subsections 6.2.1 through 6.2.3 of this chapter have been expanded and prepared in a manuscript entitled "The speed of stock price adjustment to market-wide information". An earlier version was uploaded to the Social Science Research Network (SSRN) eLibrary, available at http://ssrn.com/abstract=1412231. The paper is currently under review in *Research in International Business and Finance*.

To explore the factors that are associated with a higher level of informational efficiency, a more fruitful empirical strategy is to examine market efficiency in the relative rather than absolute sense. We employ the absolute value of the variance ratio minus one as our metric of relative market efficiency, since the existence of return autocorrelations indicates investors' mis-reaction to new information. Furthermore, a number of existing theoretical models do make predictions about the determinants of return autocorrelations. We therefore bring these competing propositions to the data, employing the empirical proxies for trading volume, market return volatility, trade openness and financial openness. More specifically, the annual data for the aforementioned variables are drawn from 23 developing countries over the sample period of 1992-2006.

Our empirical investigation employs fixed effects panel regression to explain not only the variations of index return autocorrelations across countries but also over time. The key findings and implications can be summarized as follows. First, market turnover is highly significant with a negative sign, which is as expected and consistent with the well-documented negative association between trading volume and stock return autocorrelations. This result suggests that the lack of market liquidity is associated with greater return autocorrelations, hence slower reaction to news. A related study by Chordia and Swaminathan (2000) also finds that trading volume is a significant determinant of price delay, indicating that high trading volume stocks respond faster to market-wide information than low trading volume stocks. The above negative association suggests policymakers should be cautious with those reforms that adversely affect stock trading activity, as they can further impede the information incorporation process.

Second, a higher level of market return volatility is associated with greater return autocorrelations and hence a lower degree of informational efficiency, which contradicts Sentana and Wadhwani's (1992) model prediction. However, our result is justifiable because excessive return volatility suggests that price changes are mainly noise-driven and not related to information (see Shiller, 1981). Our result is also consistent with the finding of McQueen *et al*. (1996), who find that stock return volatility is positively related to the price delay measure. This implies that the higher a stock's volatility, the slower the price adjusts to news. Since volatility is related to noise, McQueen *et al*. (1996) argue that their finding is consistent with Chan's (1993) model, which predicts stocks with noisy signals are likely to respond slowly to news. Even if one disagrees and insists volatility arises due to the arrival of information, a market with more information produced can exhibit higher return autocorrelations because extraneous news events distract investors from reacting instantaneously (see Hirshleifer *et al*., 2009). From the regulatory perspective, our finding implies that regulation that aims to contain excessive volatility might, at the same time, improve the informational efficiency of the market.

Third, a greater level of *de facto* trade openness is associated with a higher degree of informational efficiency in the 23 emerging stock markets under study. However, this negative relationship between trade openness and stock return autocorrelations does not hold when the *de jure* measure is used, suggesting that official trade reforms are insufficient to take advantage of returns to scale if they are not accompanied by increases in the actual level of trade flows. Though our result is broadly consistent with the theoretical prediction of Basu and Morey (2005), we highlight the possibility of alternative channels that can give rise to a positive relationship between *de facto* trade openness and stock market efficiency. At the country-level, we conjecture that the degree of international stock market integration is a possible link as trade openness is found to be a significant factor that helps to integrate stock markets across national borders (see Hooy and Goh, 2008). At the firm-level, trade openness is positively related to market efficiency due to improved quality of information. Our argument is that trade openness signals higher future firm profitability and hence helps to reduce uncertainty about a firm's future earnings or cash flows. Zhang (2006b) finds evidence that greater information uncertainty about a firm's fundamentals exacerbates investors' under-reaction behavior and induces stronger short-term stock price continuation, suggesting that uncertainty delays the incorporation of information into stock prices.

Last but not least, we find no significant association between the extent of financial openness and the degree of informational efficiency, and this conclusion is robust to various indicators of stock market liberalization and capital account openness. However, the lack of association between financial openness and stock market efficiency may be due to the presence of threshold effects, especially the quality of domestic political institutions. For instance, Li *et al*. (2004) find that stock market openness is associated with a lower degree of informational efficiency in emerging markets. These countries only reap the full efficiency benefit from financial liberalization when sound institutions are in place as captured by the cross product of stock market openness and the good government index. Though our result is consistent with the theoretical prediction of Basu and Morey (2005), the lack of a robust positive relationship between financial openness and stock market efficiency is still puzzling from an information perspective. We argue that the participation of foreign investors in local stock markets should improve the dissemination of information, and hence lead to faster incorporation of information into stock prices. Our conjecture draws from the theoretical papers of Froot and Perold (1995) and Hong and Stein (1999) that stock price under-reaction is the outcome of gradual dissemination of information across the investing public.

6.1.2 Does market efficiency evolve over time? Why?

There is an expanding empirical literature that challenges the notion of perpetual equilibrium assumed by mainstream weak-form EMH studies. By means of a time-varying parameter model or a rolling estimation window, this group of studies either tracks the changing degree of stock market efficiency over time or reports frequent stock price deviations from a random walk benchmark over the sample period under study. An encouraging development is that the documented market dynamics find their theoretical foundation in the adaptive markets hypothesis proposed by Lo (2004, 2005).

Using the rolling bicorrelation test, we find evidence that the aggregate stock price indices of 50 countries do experience varying degrees of nonlinear departures from a random walk over the common sample period of 1995-2005. More specifically, stock markets in economies with low per capita GDP in general experience more frequent price deviations than those in the high income group. We then explore those factors that can explain why the degree of stock price deviations varies widely across countries. Our results consistently show that the negative relation between the degree of stock price deviations and per capita GDP can largely be attributed to low income economies providing weak protection for private property rights. The proxy for private property rights protection remains significant even after controlling for other competing explanations such as public investor protection, corporate transparency and stock market openness. This piece of evidence suggests that secure private property rights are both a necessary and sufficient condition for ensuring stock prices move more closely to a random walk.

We hypothesize that the mechanism that can give rise to a negative association between private property rights protection and the degree of stock price deviations is the interaction between arbitrageurs and noise traders. More specifically, strong private property rights institution is crucial for attracting the participation of arbitrageurs, as these investors will not trade if they expect to be unable to keep their profits. It is widely recognized that arbitrageurs play a critical role in restoring price deviations and keeping the market efficient. Hence, the lack of arbitrage trading in low income economies due to weak private property rights protection will leave their stock price deviations uncorrected for long periods of time. This situation can become worse if the theoretical prediction of De Long *et al*. (1990a) materializes, i.e. informed arbitrageurs might eventually be driven out of the domestic market if the number of noise traders exceeds a critical level. The consequence of noise traders' dominance in the market is that their correlated trading can cause stock prices to deviate from the random walk benchmark for persistent periods of time.

Our results further reinforce the findings of Morck *et al*. (2000) on the importance of strong private property rights institutions for the stock market to perform its informational role efficiently. Both studies show that weak protection is associated with persistent stock price deviations from a random walk and a high degree of stock price synchronicity, respectively. With the mounting empirical evidence on the significant role of property rights protection, the policy implication for those low income economies is unambiguous. However, reforming the property rights institutions in these countries is not an easy task due to political pressure from the entrenched elites.

6.1.3 Can the existence of temporal dependence be associated with news events?

We propose a novel framework to explore the direct relationship between news events and stock return autocorrelations. Our contention is that, if significant serial correlations in the return series reflect market mis-reaction to information, it would be interesting to examine whether their presence coincides with days in which market-moving public news is announced. We advocate the use of high-frequency minute-by-minute data to detect significant return autocorrelations for each trading day. The primary contribution of our research design is that it permits investigators to search through daily news stories to identify the possible explanations of return autocorrelations. On the grounds of data availability, we limit our investigation to the Malaysian stock market during the 1997 Asian financial crisis.

We first apply the wild bootstrapped automatic variance ratio test recently proposed by Kim (2009) to detect significant serial correlations in the 1-minute transaction returns of the Kuala Lumpur Composite Index (KLCI). Our results show that only 141 out of the total 373 trading days during the Asian crisis exhibit significant return autocorrelations at the 1% level. This indicates that stock prices in the remaining 62% of trading days follow a random walk, which in the present context implies that new information is incorporated into stock prices within one minute. The speed of adjustment is impressive for an emerging stock market. For instance, using the 150 largest stocks listed on the New York Stock Exchange, Chordia *et al*. (2005) find that the U.S. market takes five minutes to remove return autocorrelations after prices adjust to their new equilibrium levels. More importantly, our proposed framework is able to pinpoint the exact dates those significant return autocorrelations occur, which is an elusive goal for previous studies applying the variance ratio tests in rolling sub-samples. This allows us to conduct a search of our daily news database to identify the proximate causes of the detected significant return autocorrelations.

We find that 29 out of the 141 trading days with significant return autocorrelations can be associated with major market-moving media events. It is worth highlighting that the market not only mis-reacts to local news, but also to news originating in other markets. Foreign news events, mainly from Indonesia, account for 50% of the 29 events. We hypothesize that this is due to a higher level of information uncertainty, and hence the market needs more time to fully grasp the implications of the above news. On the other hand, there are 17 events widely considered as major market movers but the 1-minute return series exhibit insignificant serial correlations. This finding suggests that even though the above media stories induce large price changes, there is no evidence of market mis-reaction. Even if there is, it takes the market less than one minute to remove return autocorrelations after the price adjusts to its new equilibrium level. Perhaps, there is less uncertainty on the valuation impact of these events. Finally, thirty seven percent of the trading days with significant return autocorrelations cannot be explained by any economic or political news, which we interpret as indicative of investors' herding behavior not driven by information.

6.2 Recommendations for Future Studies

Apart from the extensions suggested in each of the three empirical chapters, this section highlights some issues that have been under-researched in the existing literature. While these recommendations might fall under the weak-form EMH, it is more appropriate to categorize them under the broader scope of informational efficiency simply because their focus is on the speed of stock price adjustment to information.

6.2.1 More investigative studies using autocorrelation-based speed of adjustment estimators

The main theme of this thesis is that temporal dependence, in particular return autocorrelations, reflects under- or over-reaction of stock price to the arrival of new information. The speed of information incorporation is central to market efficiency, given that an efficient market is characterized as one in which stock price responds instantaneously to news. Since the seminal work of Fama *et al*. (1969), the event study methodology has become the primary tool for assessing the speed of stock price adjustment to various kinds of public information. Instead of specific types of events, a different strand of literature considers more general information signals. Amihud and Mendelson (1989a), Damodaran (1993), Brisley and Theobald (1996) and Theobald and Yallup (1998, 2004) develop formal speed of adjustment estimators which are functions of autocorrelations in order to gauge the speed with which new information is reflected in prices of individual stocks or portfolios. Another empirical approach designed for a similar purpose is the price delay measure proposed by Brennan *et al*. (1993) and Mech (1993), which involves a regression of each individual stock's weekly returns on contemporaneous and four weeks of lagged domestic market index returns. If the stock responds immediately to local market-wide news, then the coefficient for contemporaneous market returns will be significantly different from zero, but none of the coefficients for lagged market returns will differ from zero. These measures are appealing as Hillmer and Yu (1979: 321) rightly point out: "*no matter how rapidly a market adjusts to new information, the adjustment process cannot be completed instantaneously*".

The price delay measure has slowly gained acceptance in the mainstream finance literature. By means of regression analysis, previous price delay studies have identified a set of factors responsible for preventing the swift incorporation of market-wide information into stock prices. Among the significant determinants are firm size (Brennan *et al*., 1993), analyst coverage (Brennan *et al*., 1993), transaction costs (Mech, 1993), institutional ownership (Badrinath *et al*., 1995; Hou and Moskowitz, 2005; Park and Chung, 2007), stock return volatility (McQueen *et al*., 1996), trading volume (Chordia and Swaminathan, 2000), market liquidity (Hou and Moskowitz, 2005), short sales restrictions (Chen and Rhee, 2007; Saffi and Sigurdsson, 2007; Boehmer and Wu, 2009), intra-industry effect (Hou, 2007), and the degree of stock accessibility to foreign investors (Bae *et al*., 2008). In sharp contrast, empirical studies using autocorrelation-based estimators mainly focus on measuring the speed of adjustment (see also Amihud and Mendelson, 1989b; Roll, 1995; Chan and Ariff, 2002; Marisetty, 2003; Theobald and Yallup, 2005). The only additional insight is given by Theobald and Yallup (2004) who find that large capitalization stocks have higher speed of adjustment coefficients than low capitalization stocks, even after adjusting for thin trading. Hence, it would be interesting for future studies to examine whether those important determinants of price delay can also explain the differential speed of adjustment captured by the autocorrelation-based estimators. This is because the existence of return autocorrelations due to under-reaction to information is consistent with the prediction of extant behavioral models of Barberis *et al*. (1998) and Hong and Stein (1999).[1]

6.2.2 An empirical measure to capture the speed of adjustment to global market-wide public information

All of the previously cited studies utilize the price delay measure to assess the speed of individual stock price adjustment to information, in which the domestic market index return is employed as the relevant local market-wide news to which stock responds. The only exception is Bae *et al*. (2008) who consider global market-wide news by regressing individual stock returns on contemporaneous and lagged world market returns.[2] A logical extension is to compare the speed with which the aggregate stock market in each country reacts to global market-wide public information, using the world market return as the common benchmark.[3]

This involves the following unrestricted model:

$$r_{i,t}^{m} = \alpha_i + \beta_i r_t^{w} + \sum_{k=1}^{4} \delta_{i,k} r_{t-k}^{w} + \varepsilon_{i,t} \qquad (6.1)$$

where t is a one-week period time index, $r_{i,t}^{m}$ is the domestic market index return for country i, r_t^{w} is the world market return, and $\varepsilon_{i,t}$ is an error term.

[1] On the other hand, Froot and Perold (1995) develop a model that shows the slow dissemination of market-wide information results in positive serial correlations in stock index returns.
[2] The importance of global information is also acknowledged by studies using market model *R*-square statistic though the U.S. market index return is used to proxy for global news (see Morck *et al*., 2000; Jin and Myers, 2006; Fernandes and Ferreira, 2008, 2009).
[3] The relevant information for the price delay measure is the market-wide public information, which differs from the market-wide private information introduced by Albuquerque *et al*. (2008). Similarly, our proposed country-level price delay measure captures the speed of adjustment to global market-wide public information, which is different from the global market-wide private information documented by Albuquerque *et al*. (2009).

The restricted model constrains the coefficients for the lagged world market returns to zero:

$$r_{i,t}^{m} = \alpha_i + \beta_i r_t^{w} + \varepsilon_{i,t} \tag{6.2}$$

The *R*-squares from equations (6.1) and (6.2) are used to calculate the standard price delay measure: [4]

$$Delay = 1 - \frac{R^2_{restricted}}{R^2_{unrestricted}} \tag{6.3}$$

The larger the value of the delay measure, the more variation in the domestic market index returns that is captured by the lagged world market returns, indicating greater delay in the response of aggregate stock market to global market-wide news that has common effects across countries.

The motivations behind this country-level price delay measure are at least twofold. First, DeFond *et al*. (2007) and Griffin *et al*. (2008a) explore cross-country differences in the stock market reactions to a specific event, namely earnings announcements. Our proposed measure complements their work in that it captures cross-country variation in the speed of adjustment to common information. It would be interesting to examine whether the reactions to global information also vary over time and across countries. Another avenue is to determine whether the significant determinants identified by these two studies, the information dissemination mechanism (Griffin *et al*., 2008a) and the

[4] Several versions of the price delay measure have been proposed in the literature (see McQueen *et al*., 1996; Chordia and Swaminathan, 2000; Hou and Moskowitz, 2005; Bae *et al*., 2008; Chiang *et al*., 2008).

legal institution (DeFond *et al*., 2007; Griffin *et al*., 2008a), can explain any variation documented by the country-level price delay measure. Second, there is a growing interest in comparing the relative efficiency of international stock markets, with the market model *R*-square statistic the most popular empirical measure (see references cited in Lim and Brooks, 2009b). Despite its popularity, the validity of the information-efficiency interpretation of market model R^2 has been challenged by a number of recent studies (see Ashbaugh-Skaife *et al*., 2006; Hou *et al*., 2006; Kelly, 2007; Teoh *et al*., 2008). For instance, Hou *et al*. (2006) and Teoh *et al*. (2008) both find evidence supporting their conjecture that a lower market model *R*-square is instead associated with lower degree of market efficiency. In the midst of this controversy, the price delay measure provides a robustness check to further verify the policy prescriptions given by those market model R^2 studies, which include private property rights protection, public investor protection, stock market liberalization, corporate transparency, securities laws, short sales restrictions and insider trading laws (see references cited in Subsection 2.4.3 of this thesis).

6.2.3 Explanations for stock market under-reaction to market-wide information

Though previous studies have shed light on those significant firm-level determinants of price delay, some of them still require further explanation. For instance, Chordia and Swaminathan (2000) show that low trading volume stocks respond more slowly to market-wide information than high trading volume stocks. In the extant literature, trading volume has been used to proxy for illiquidity and investor inattention. Can it be that low trading volume stocks take a longer time to reflect new information because investors are not paying attention to them? Brennan *et al*. (1993) find that an increase in the number of analysts following a firm does improve the speed of adjustment. Is it possible that high analyst-following stocks respond faster because analysts facilitate the dissemination of public information to the investors? In the theoretical model of Barberis *et al*. (1998), under-reaction to information occurs because investors exhibit a conservatism bias, but this behavioral explanation is difficult to test empirically. The present subsection singles out two possible mechanisms that can delay stock price reaction, namely limited investor attention and slow dissemination of information. However, the empirical challenge for future studies is to search for suitable proxies that can provide a clean test of these competing hypotheses.

The investor inattention hypothesis postulates that the stock price takes a longer time to reflect new information simply because the stock does not attract the attention of investors. A number of theoretical models predict that when investors face attention constraints in information processing, the stock price does not promptly response to new information (see Hirshleifer and Teoh, 2006; Peng and Xiong, 2006; DellaVigna and Pollet, 2009). Empirical studies generally provide evidence in favor of this inattention-based explanation for under-reaction to public information. For instance, DellaVigna and Pollet (2009) find that post-earnings announcement drift is of greater magnitude for Friday announcements than those on other weekdays, which the authors attribute to weekend distractions. Hirshleifer *et al*. (2009) show that the response of stock price to earnings surprises is delayed on high news days because extraneous earnings announcements by other firms distract investors from valuing the given firm. Using stock turnover as a proxy for investor inattention, Hou *et al*. (2008) find that high volume stocks exhibit stronger over-reaction driven price momentum, but post-earnings announcement drift due to under-reaction is more pronounced among low volume stocks that receive less investor attention. On the other hand, the results in Loh (2008) reveal that low attention stocks have larger stock recommendation drifts as investors are inattentive to information contained in stock recommendations.

Given that all the aforementioned studies focus on the response of the stock price to specific news events, it would be interesting to investigate whether investor inattention also contributes to the delayed reaction to common information. A standard proxy used to capture investor inattention is stock turnover (Hou *et al*., 2008; Loh, 2008). However, turnover may be confounded by other factors such as market liquidity (see Levine and Schmukler, 2006) or differences of opinion among investors (see Harris and Raviv, 1993; Berkman *et al*., 2009). To disentangle these effects, one empirical strategy is to use residual turnover, obtained from estimating a cross-sectional regression of stock turnover against indicators for illiquidity and divergence of opinion (see Loh, 2008). A popular proxy for the former is Amihud's (2002) price impact measure (for a menu of liquidity measures, see Goyenko *et al*., 2009), whereas the latter is proxied by the dispersion in analysts' earnings forecasts (Diether *et al*., 2002) or the diversity in analysts' forecasts (Doukas *et al*., 2006). On the other hand, Hou and Moskowitz (2005) employ a set of proxies to test the investor inattention hypothesis, which include analyst coverage, institutional ownership, number of shareholders and employees, regional exchange membership, advertising expenses and remoteness (for example, average airfare and distance from all airports to firm headquarters). While the theoretical explanation is appealing, future research effort should be directed to constructing a suitable indicator for investor inattention. For instance, Peress (2008) uses the number of articles published about the announcing firm in the *Wall Street Journal* as a proxy for investor inattention. Media coverage is a good alternative because news is a primary mechanism for catching investors' attention, and has the added advantage that it is independent of the trading process.

Another potential explanation is the slow information dissemination hypothesis which postulates that investors are slow to react because the information is slow to reach them. In the theoretical model of Hong and Stein (1999), stock price under-reaction is the outcome of gradual dissemination of information across the investing public (see also Froot and Perold, 1995). Hong *et al*. (2000) and Doukas and McKnight (2005) present supportive evidence using data from the U.S. and European markets, respectively. In both empirical studies, residual analyst coverage serves as the proxy for the rate of information flow, where the residual comes from a regression of analyst coverage on firm size. Their results show that less analyst coverage is associated with a slower speed of adjustment because a relatively small number of analysts are involved in collecting and disseminating information to the market. On the other hand, Griffin *et al*. (2008a) employ press freedom to proxy for news dissemination mechanism, and it is found to be one of the factors that can explain why stock market reactions to earnings announcements vary widely around the world.[5]

In an extensive cross-country study, Griffin *et al*. (2008b) adopt the variance ratio statistic and price delay to compare the relative efficiency of 56 international stock markets. The results from the variance ratio statistic suggest that individual stock and portfolio returns in emerging markets do not deviate more from a random walk than those in developed markets. Consistently, the delay measure shows that prices in

[5] In their cross-country study, Bushman *et al*. (2004) measure information dissemination by the penetration of the media channels in the economy, using the average rank of countries' per capita number of newspapers and televisions.

emerging markets incorporate past market-wide information more quickly than prices in developed markets. Both sets of findings challenge the conventional wisdom that developed markets should be more efficient. Griffin *et al*. (2008b) rule out the possibility that the variance ratio statistic and price delay measure fail to capture the speed of public information incorporation because these two methods are well tested in the literature. Instead, the authors suggest the concept of informational efficiency is too narrow as it ignores information production. They show in a conceptual framework that a firm with little news will have faster incorporation than a firm with a lot of news. Using analyst coverage as a proxy, the authors find that firms in emerging markets have less public information production, which they argue is the main reason why emerging markets appear more efficient in terms of information incorporation.

We disagree with the argument of Griffin *et al*. (2008b) that the empirical measure of informational efficiency should be expanded to include the extent of information production, especially when comparing the relative efficiency of international stock markets that are characterized by wide differences in information production. Our contention is that the level of information production is just one of the factors that might impede the swift incorporation of public information into stock prices. For instance, a market with more information produced can exhibit a higher price delay because extraneous events distract investors from reacting instantaneously (see Hirshleifer *et al*., 2009). There is also an issue of whether analyst coverage is a good proxy for information production. Some studies instead measure the rate of public information arrival to the market by the number of stories released by news providers (see, for example, Berry and Howe, 1994; Mitchell and Mulherin, 1994; Melvin and Yin, 2000;

Kalev *et al*., 2004). These unresolved issues indicate that more work still needs to be done for explaining the delayed reaction to market-wide information.

6.2.4 Allowing for stock price to respond nonlinearly to new information

In the mainstream finance literature, return autocorrelation is the focal point of most theoretical models. For instance, the well-known behavioral models of Barberis *et al*. (1998), Daniel *et al*. (1998) and Hong and Stein (1999) rationalize how under- and over-reactions can give rise to positive autocorrelations over short horizons. However, given the complexities in stock markets with a diverse set of market participants, it is difficult to justify why the temporal dependence generated by such a slow market response should be confined to a linear form. Several studies do question this assumed linear relationship between successive price changes. Firstly, Antoniou *et al*. (1997) argue that the behavior of uninformed traders to delay their reactions, because they do not have the resources to fully analyze the information or because the information is not reliable, may result in the stock price responding nonlinearly to information. Secondly, Brooks *et al*. (2000) conjecture that when surprises hit the market, the return series generally exhibit nonlinear dependence since investors are unsure of how to react, hence they respond sluggishly (for a similar line of reasoning, see Lim *et al*., 2006; Hinich and Serletis, 2007). Thirdly, Sarantis (2001) and Shively (2003) single out differences of opinion among investors as one of the causes that may induce nonlinearity in returns.

We hold the view that a dynamic model with disagreement among investors is the natural framework to explore the nonlinear stock price reaction to information. In recent years, heterogeneous agent modeling of financial markets is becoming increasingly popular in the academic literature (for a survey, see Hommes, 2006). In these models, stock markets are populated with heterogeneous agents and the same information can be interpreted in different ways by traders. This differential interpretation will not lead to a uniform market reaction. Instead, sequences of secondary reactions triggered by the initial event will slowly unfold over a period of time. For instance, Brock and Hommes (1998) show that when heterogeneous expectations among traders are introduced into a standard asset pricing equilibrium model, it can even produce chaotic asset price dynamics. On the other hand, Hong and Stein (2007) highlight three mechanisms that can generate investor disagreement: (1) gradual information flow; (2) limited investor attention; (3) differences in the prior beliefs that investors hold. As discussed in Subsection 6.2.3, the slow dissemination of information and limited investor attention are two leading theoretical explanations for stock market under-reaction to market-wide information. However, one cannot rule out the possibility that the delayed reaction can give rise to nonlinear dynamics in stock returns, especially when investors differ in the way they interpret the same public news.

6.2.5 Exploring the roles of stock market to the real economy

Throughout this thesis, our focus is on informational efficiency and its determinants, as if it is an end in itself. However, Morck *et al*. (1990) point out that market efficiency would not be important if the stock market does not affect economy activity, in particular the allocation of investment resources in the real sector. According to Dow and Gorton (1997), efficient market studies have thus far taken for granted that informational efficiency implies economic efficiency.[6] To establish the link between an efficient stock price and efficient allocation of investment resources, these authors

[6] For instance, Fama (1970: 383) writes: "*In general terms, the ideal is a market in which prices provide accurate signals for resource allocation: that is, a market in which firms can make production-investment decisions, and investors can choose among the securities that represent ownership of firms' activities under the assumption that security prices at any time "fully reflect" all available information.*".

develop a theoretical model which shows that the stock market indirectly guides managers' investment decisions by transferring information about investment opportunities and information about managers' past investment decisions. Other theoretical papers that analyze the feedback effect from stock prices to real investment decisions include Subrahmanyam and Titman (2001), Dow and Rahi (2003), Dow *et al*. (2008), Foucault and Gehrig (2008), and Goldstein and Guembel (2008).

The above theoretical link has only been examined empirically in recent years, partly due to the availability of relative market efficiency measures. In a cross-country study, Wurgler (2000) reports that countries with developed financial sectors are associated with better allocation of capital, in the sense that these countries increase investment more in their growing industries and decrease investment more in their declining industries. One of the channels through which financial development improves capital allocation is the information contained in stock prices that helps managers to distinguish between good and bad investments. More specifically, Wurgler (2000) finds that the market model *R*-square statistic is negatively and significantly related to their measure of capital allocation efficiency. Using U.S. firm-level data, Durnev *et al*. (2004b) document a robust cross-sectional positive association across industries between their measure of investment efficiency (deviation in Tobin's marginal *q* ratio from its optimal level) and the market model *R*-square statistic, indicating that industries with more informative stock prices allocate capital more efficiently. Chen *et al*. (2007) show that informational efficiency, measured by the market model *R*-square and probability of informed trading, has a strong positive effect on the sensitivity of corporate investment to stock prices. This piece of empirical evidence suggests that firm managers learn from the information in stock prices and incorporate it in their corporate investment decisions.

While consistent with extant theoretical models, the firm-level studies by Durnev *et al*. (2004b) and Chen *et al*. (2007) focus solely on the U.S. and their results cannot be generalized to other economies especially those from developing countries. Hence, it warrants more in-depth investigation to ascertain the association between informational efficiency and allocative efficiency in each individual country using firm-level data. Given the controversy surrounding the interpretation of the market model *R*-square, several measures of relative informational efficiency should be employed in order to provide reliable statistical inference. It would also be interesting to determine whether the evidence that financial liberalization improves allocative efficiency documented by Galindo *et al*. (2007) and Abiad *et al*. (2008) is robust to the inclusion of stock price informativeness.

If a more efficient stock price results in a more efficient allocation of investment resources, it is expected to have beneficial ramifications on long-term economic growth. In the finance and growth literature, some theoretical models emphasize that well-functioning financial markets ameliorate information asymmetries, thereby foster efficient resource allocation and stimulate economic growth (for details, see the survey paper by Levine, 2005a). Empirically, Atje and Jovanovic (1993), Levine and Zervos (1998), Rousseau and Wachtel (2000) and Beck and Levine (2004) find a significant role for stock market liquidity in promoting economic growth. However, Levine (2005a) highlights that existing theories do not draw the connection between market liquidity and economic growth very tightly. Clearly, more research is needed, and stock price efficiency is one potential channel linking stock market development to economic growth. Durnev *et al*. (2004a) is thus far the only study that pursues this issue. Using data from 56 countries over the 1990-2000 period, their panel regression results show that the market model *R*-square is negatively and significantly related to real per capita GDP growth and total factor productivity growth, after controlling for standard growth determinants. This piece of empirical evidence supports the hypothesis that higher informational efficiency fosters allocative efficiency and hence induces higher economic growth. Another promising research avenue is to determine whether stock price informational efficiency is the mechanism through which financial openness boosts total factor productivity growth in particular (see Bonfiglioli, 2008; Bekaert *et al*., 2009; Kose *et al*., 2009b) and economic growth in general (see Bekaert *et al*., 2001, 2005).

6.3 Concluding Remarks

The list of unresolved issues suggests that stock market informational efficiency will continue to be an exciting avenue of research in financial economics for many years to come. Apart from time and space constraints, some of the suggested extensions or recommendations cannot be pursued in this thesis because of resource constraints. For instance, the use of firm-level data which are currently beyond our reach can provide further confirmation of our empirical results, and hence deeper insights on the issues examined in Chapter 3 through 5. Nevertheless, our discussions and analyses do identify several promising directions for stock market research. The present thesis represents a series of small steps of a career-long research agenda toward better understanding of stock market's roles in the economic system.

We conclude this thesis with three general guides which might be useful for future empirical research on stock market efficiency. First, Fama (1991) acknowledges that the extreme version of EMH where stock price fully reflects all available information is surely false since it is unrealistic to expect zero information and trading costs. The author even concedes that market efficiency per se is not testable due to the unavoidable joint-hypothesis problem. Despite this disappointing fact, the literature on market efficiency continues to grow over the past few decades, and will continue to be an interesting research area. However, we hold the view that a more fruitful research strategy is to stop treating market efficiency as a yes or no question. As described by Lee (2001), given that the financial market is always in a continuous state of adjustment, market efficiency is a journey and not a destination. Hence, the research focus should be on how, when and why the stock price becomes efficient.

Second, proponents of the EMH always dismiss negative empirical evidence on the grounds that those detected predictable patterns do not give rise to profitable investment strategies.[7] For instance, Malkiel (2003, 2004, 2005) defends his long-held view that the stock market is remarkably efficient in adjusting to new information, with the strongest evidence comes from his analysis which shows professional investment managers are not able to outperform index funds that simply buy and hold the broad stock market portfolio. Lee (2001) disagrees on this point, arguing that the inability of active managers to beat the market tells us more about the state of labor markets and therefore has little bearing on the market efficiency debate. Perhaps it is time to return to basics by focusing on the capability of stock market in processing newly arrived information. More specifically, given the impossibility of an instantaneous price adjustment process, the empirical research design should directly capture the speed with which the stock price incorporates new information.

[7] In this group of studies, market efficiency is often granted the presumption of innocence, i.e. the market is presumed to be efficient unless conclusively proven otherwise.

Third, the trade-based notion of EMH is widely used because it has direct implications for real world investment practices. However, this ‘beat the market’ version of the EMH does not shed much light on how, when and why the stock market becomes efficient. As a result, market inefficiency is devoid of policy implications. Moreover, there is a presumption that the market is highly efficient and hence it should be allowed to operate freely (for discussion, see Daniel *et al*., 2002). Due to the above limitations, future research design should focus primarily on the information processing role of stock market which yields implications far beyond those to the investment communities. For instance, an understanding of the determinants of informational efficiency is likely to provide useful policy guides to stock exchange regulators for the optimal design of markets, trading protocols and regulatory policies to protect investors. In a broader context, theoretical and empirical findings show that there is a strong link between informational efficiency and the allocation of investment resources in the real sector. This warrants the attention of policymakers to avoid substantial misallocation of resources that has a negative impact on long-term economic growth.

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