

NONLINEARITY AND OVERSEAS CAPITAL MARKETS:

Evidence from the Taiwan Stock Exchange

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Dissertation submitted to the Faculty of the
Virginia Polytechnic Institute and State University
in partial fulfillment of the requirements for the degree of

Doctor of Philosophy
in
Finance

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July 16, 1999
Blacksburg, Virginia

Keywords: Nonlinearity, Bispectrum, GARCH, STAR, Taiwan Stock Exchange

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(ABSTRACT)

Numerous studies have documented the existence of nonlinearity within various financial time series. But how important of a finding is this? This dissertation examines this issue from a number of perspectives. First, is the nonlinearity that has been found a statistical anomaly that is isolated to a few of the more widely known financial time series or is nonlinearity a statistical regularity inherent in such series? Second, even if nonlinearity is pervasive, does this finding have any practical relevance for finance practitioners or academics?

Using the relatively financially isolated but nonetheless well-traded Taiwan Stock Exchange as a case study, it is found that virtually all of the stocks trading on this exchange exhibit nonlinearity. The pervasiveness of nonlinearity within this market, combined with earlier results from other markets, suggests that nonlinearity is an inherent aspect of financial time series. Furthermore, closer examination of the time-paths of various measures of this nonlinearity via both windowed testing and recursive testing and parameter estimation reveals an additional complication, the possibility of nonstationarity. The serial dependency structures, especially for the nonlinear dependencies, do not appear to be constant, but instead appear to exhibit a number of brief episodes of extremely strong dependencies, followed by longer stretches of relatively quiet behavior. On average, though, these nonlinearities appear with sufficient strength to be significant for the full sample.

Continuing on to examine the relevance of such nonlinearities for empirical work in finance, a variety of conditionally heteroskedastic models were fit to the returns for a subsample Taiwanese stocks, the Taiwanese stock index, and stock indices for other stock markets, including New York, London, Tokyo, Hong Kong, and Singapore. In a majority of cases, such models appear to be successful at filtering out the extant nonlinearity from these series of returns; however, a variety of indicators suggest that these models are not statistically well-specified for these returns, calling into question the inferences obtained from these models. Furthermore, a comparison of the various conditionally heteroskedastic models with each other and with a dynamic linear regression model reveals that, for many of the data series, the inferences obtained from these models regarding the day-of-the-week effect and the extant autocorrelation within the data varied from model to model. This finding suggests the importance of adequately accounting for nonlinear serial dependencies (and of ensuring data stationarity) when studying financial time series, even when other empirical aspects of the data are the focus of attention.

Acknowledgements

I am indebted to numerous faculty members for their encouragement and helpful advice along the road toward my completion of this project. Had it not been for the combined guidance of Don Chance, George Morgan, Dilip Shome, Larry Lynch, and the late Dana Johnson, I may never have started on this endeavor. Once started on this path, Jesse Arnold, Jeff Birch and Aris Spanos helped raise the critical questions in my mind that led me to this area of research, while Doug Patterson, my committee chairman, showed me one way the questions that were raised related to research in finance and helped lead me to this specific path for my dissertation.

Once on this path, all of my committee members, including Don Chance, Randy Billingsley, Keying Ye, Anya McGuirk, and Doug Patterson, provided useful input. Dr. Patterson, of course, as the committee chairman, deserves extra mention for his help and input along the way, while Anya McGuirk provided support “above and beyond the call of duty.” Apart from my committee members, Dr. Tai Ma of the National Sun Yat-Sen University of Kaohsiung, Taiwan, played a crucial role in this project by providing me with all the data I needed.

On a more personal level, I must acknowledge my late Great-Uncle Paul, who embodied the motto, “elderly as a child, youthful as an adult, he is always a mixture of schoolboy and corporate president.” In addition to the specific encouragement he gave me at the start of this endeavor, his life has always served as an inspiration to me. Along the same lines, my parents, my brothers and sisters (Phillip, Pam, Todd, and Heather), my aunt and uncle, and my cousins all provided support and inspiration for me along the way. Similarly, various other friends, relatives, and neighbors also provided support. Of these, Mark Spangler stands out for his numerous political discussions that provided me with welcome breaks from seemingly never-ending research tasks.

Finally, I must acknowledge the support of my wife, Peggy, who I had not even met when I started work on this degree, but who has been by my side throughout the dissertation process, providing aid, support, encouragement, and plenty of needed study breaks. And last but not least, I must mention my son Henry, who came along in the middle of this project and has been very time-consuming, but has also, at times, provided a great deal of comic relief, as well as a sense of perspective.

To all of these people, I would like to say a simple, “Thank you.”

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Chapter 1

Introduction

Over the past decade, numerous studies have documented the existence of nonlinear serial dependence in financial markets (e.g., Hinich and Patterson (1985a), Scheinkman and LeBaron (1989), and Hsieh (1989)). Such findings have important implications throughout the field of finance, both in academics and in applied finance.

From the point of view of investors, the possibility that securities follow a nonlinear stochastic process could have either or both of the following implications—securities returns which appear random and exhibit little or no autocorrelation may actually be highly predictable, or, alternatively, investment risks which appear to be manageable may suddenly escalate wildly out of control, beyond all expectations. Similarly, for finance academics and practitioners involved in the pricing of derivative securities and the development of dynamic hedging strategies, the potential implications of securities' following nonlinear dynamics are no less dramatic. Because assumptions about the stochastic process generating securities' returns are of primary importance in designing hedges and pricing derivatives, if the assumed stochastic processes do not adequately depict the full complexity of the true generating processes, then any derivatives in question may be mispriced, and people and institutions may have imperfect hedges which expose them to unwanted risks.

Moreover, the possibility of nonlinear dependencies in securities' returns may also have important implications not only for finance practitioners but also for researchers involved in the empirical testing of finance theories. For valid inferences to be drawn from a statistical test, the statistical assumptions underlying the test must be met. Typically, these assumptions include having observations which are independent and identically distributed. While estimators can often be developed which are robust to relaxations of the assumption of identical distributions, the independence assumption is usually crucial. However, given the possibility of nonlinear dependencies, finding that the data are uncorrelated will be insufficient to prove that the assumption of independence is a valid one. If tests indicate the existence of nonlinear dependencies within a given data set, then these dependencies must first be adequately modeled before financial theories can be tested.

Given the necessity of modeling the nonlinear dependencies in financial data, countless researchers have somewhat successfully turned to the “ARCH” (AutoRegressive Conditionally Heteroscedastic) family of models (see Bollerslev, Chou, and Kroner (1992) for an overview). Interestingly, although the ARCH family of models contains an infinite variety of possible specifications, the simple GARCH(1,1) model, given by:

$$\begin{aligned}\varepsilon_t &= z_t \sigma_t, \\ z_t &\sim NIID(0,1) \\ \sigma_t^2 &= \omega + \alpha \varepsilon_{t-1}^2 + \beta \sigma_{t-1}^2\end{aligned}$$

is found to suffice in most applications.

Thus, the evidence so far is that returns (or log price innovations) on financial markets exhibit nonlinear dependencies, but that GARCH(1,1) models seem to sufficiently (but not necessarily statistically adequately) model or “capture” these dependencies in many cases. However, much of this evidence has been drawn from the widely traded financial markets of well developed countries, especially the United States and Japan. Given the increasing importance of “emerging markets” to the investment world and the world economy, this leads to a number of important questions concerning the universal applicability of these findings.

Are nonlinear dynamics in financial markets a universal occurrence? Furthermore, if nonlinear dependencies do exist in a given market, how pervasive are they throughout that market? Do all the securities traded on that market exhibit nonlinear dynamics, or only some fraction of these securities? Also, can GARCH(1,1) models or similar models adequately describe the dynamics of these markets, or is a more complicated model required? In other words, given that these markets do exhibit nonlinear dependencies, are they of a form similar to that of other, more developed, markets, or do they seem to exhibit different types of nonlinear dependencies? More fundamentally, could any model with stable parameters adequately describe the stochastic behavior of these securities, or is their behavior governed by a stochastic generating process that is subject to parameter nonstationarity? This last question is especially relevant in the case of possible nonlinear dependencies, because such dependencies can lead to behavior which is observationally similar to that exhibited by nonstationary dynamic processes. For example, data generated by an ARCH(q) process are observationally equivalent to data generated by a time-varying parameter MA(q) process. Furthermore, healthy, dynamic, growing economies are inherently subject to unanticipated structural changes, which could easily lead to nonstationarities in securities’ returns. However, the return generating processes for even well developed markets may be subject to instability or nonstationarity, as the results of Hinich and Patterson (1996) indicate.

Given these questions and observations, the next question to ask is, if one were to be singled out, which emerging market should be chosen to examine the answers to these questions? In order to explore whether the existence of nonlinear dynamics is universally inherent in financial markets, a market which is relatively isolated from the financial mainstream should be chosen. As was noted above, previous studies of nonlinear dependence and nonlinear dynamics have focused on widely traded markets such as the New York Stock Exchange, the Tokyo Stock Exchange, and the major foreign exchange markets. The fact that many of the same groups of investors are active in all of these markets, however, means that factor shocks could spill over from one market into another, and back. Thus, the openness of these markets could allow international feedback effects which would influence their dynamics. Furthermore, all of these markets have associated futures and options markets which could conceivably also contribute to intermarket feedback effects. However, internationally isolated markets are also more likely to be relatively illiquid. This possibility could lead to econometric measurement problems which would complicate any investigation into the stochastic generating mechanism of securities’ returns. Therefore, the best candidate for study would be a market which meets the seemingly contradictory requirements of being relatively financially isolated from the world community and other financial markets while nonetheless generating heavy trading volumes. Given these requirements, the best candidate is the Taiwan Stock Exchange.

The Taiwan Stock Exchange, headquartered in Taipei in the Republic of China on Taiwan, has been completely closed to foreign investors, and there have been no options or futures traded on Taiwan's stock market, until only recently. Thus, while this market is presently becoming more integrated into the world market, it has until recent years been isolated from many possible sources of feedback effects, so that the issue of whether nonlinear dynamics are inherent within all financial markets can be better examined using recent data from Taiwan's stock market. Furthermore, despite the prohibitions on foreign investment in the Taiwan stock market, so that its traders are not widely dispersed throughout the world community, the market is nevertheless very heavily traded by the Taiwanese themselves. With a population of approximately only 20 million people, with less than one hundred fifty stocks in which to invest, and with only about 30% to 40% of the outstanding shares of a typical firm actually available for public trading (with most of the remaining shares being closely held), the Taiwanese have provided sufficient liquidity to their market to have propelled it on a few occasions to the position of the world's most heavily traded stock market in terms of daily dollar trading volume. Thus, among foreign stock exchanges, the Taiwan Stock Exchange should be the least vulnerable to liquidity-based empirical problems such as nonsynchronous trading, which can induce dependencies in high frequency data and adversely affect econometric results in general. Therefore, among potential isolated markets which could be studied, the Taiwan Stock Exchange is the only one which could be sampled on a daily or weekly basis, so that nonstationarity is less of a problem for a given sample size, while incurring few or none of the potential problems resulting from lack of liquidity. Thus the Taiwan Stock Exchange provides the ideal alternative to the markets which have already been studied for the existence of nonlinear dependence.

On the other hand, an examination of nonlinear dynamics on the Taiwan Stock Exchange may also provide additional information related to an issue of great importance and concern to Taiwan's investors. After reaching average daily trading volumes in excess of \$6 billion (U.S.), briefly making it the world's largest stock exchange by dollar volume, the Taiwan stock market suffered a dramatic decline. From a peak of 12,495 on 10 February 1990, the Taiwan Stock Exchange Weighted Stock Index (the Taiex) fell nearly 80% to a nadir of 2,560 on 1 October 1990. Although this has not had the severely traumatic effects on Taiwan's economy that the Nikkei's collapse had on Japan's, Taiwan's GDP growth has nonetheless slowed subsequent to the Taiex's collapse.

One possible explanation for the market collapse is that persistence in volatility subsequent to some shock led risk-averse investors to sell off their shares until stock prices fell to levels where their expected returns would be commensurate with their new, higher levels of risk. Along these lines, Chou (1988) utilized the previously mentioned GARCH(1,1) model to examine the similar, albeit less dramatic, decline in the U.S. stock market in 1974. GARCH-type models, assuming they are well-specified, are particularly well-suited to examining this issue, because the parameters of the variance equation provide a measure of the "volatility persistence" of the stochastic process underlying the stock returns. The closer is the sum of these parameters (excluding the intercept term) to one, the greater is the "persistence" of volatility shocks, and the more permanent are changes in the overall level of volatility as a result of such shocks. Thus, if Taiwan's stock market exhibits nonlinear dependencies similar to those of other equity markets, if such nonlinear dependencies appear to be stable and not episodic, and if in addition to being stable they can also be adequately captured by GARCH-type models, then the parameters of such

fitted models can also provide information about the levels of volatility persistence on Taiwan's market.

In the pages following, all of the above questions will be examined. Chapter Two will provide a review of the literature on nonlinearity and related empirical topics, while Chapter Three will provide some additional background information about Taiwan and the Taiwan Stock Exchange. In Chapters Four and Five, all of the stocks listed on Taiwan's stock exchange will be examined to determine whether the returns of such stocks exhibit nonlinear behavior and how stable and pervasive such behavior is throughout the market, both intertemporally, within the returns of each stock, and cross-sectionally, across all the stocks traded on the market. Chapter Four focuses on the existence and pervasiveness of serial dependencies within Taiwan stock returns, while Chapter Five focuses on the behavior and stability of such serial dependencies over time. Chapters Six and Seven will more closely study a subsample of the Taiwan Stock Exchange's stocks, together with a number of important stock market indices for comparison, to examine how fitting various candidate models to their return series affects the nonlinearity test results. Chapter Six focuses on linear modeling and explores the clues it yields about the form of any existing nonlinear dependencies, while Chapter Seven examines whether some of the more popular or promising candidate nonlinear models can adequately account for or "capture" the nonlinear serial dependencies in these time series and further explores some of the implications of these models as fitted. Finally, Chapter Eight will discuss the conclusions obtained from the previous chapters along with some possible directions for future research.