Currency Effects on International Equity Portfolios:

Evidence from Taiwan, Hong Kong, China and Singapore

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THESIS

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LIST OF ABBREVIATIONS

VAR	Vector Autoregressive (Model)
MARS	Multivariate Adaptive Regression Spline (Model)
ICAPM	International Asset Pricing Model
ADR	American Depository Receipt
APT	Arbitrage Pricing Theory
AUM	Asset Under Management
ETF	Exchange Traded Fund
FX	Foreign Exchange
CN	China
CNY	Chinese *yuan*
HK	Hong Kong
HKD	Hong Kong Dollar
SG	Singapore
SGD	Singapore Dollar
TW	Taiwan
TWD	(New) Taiwan Dollar

SUMMARY

Research has shown that during the 1997 Asian financial crisis, there exists a short-term relationship between the currency and stock markets. The stock market crash is led by the large-scale devaluation in Asian currencies, and currency depreciation also feeds back on the loss of the stock markets. The rare event reveals the inter-dependent relationship between the stock and currency markets; however, the understanding of their day-to-day relationship is also important, so that early warning signs of anomalies in international financial markets can be captured. This study investigates a post-crisis period of market performance from March 2003 to June 2012, using daily observations.

The linear Vector Autoregressive (VAR) model is first employed to study the lead-lag relation of past shocks from one market to the other. Consistent with existing literature, the VAR results vary by different countries. In Taiwan, there exists a two-way mapping relationship: 1-day and 2-day lagged currency returns positively affect the stock market returns; on the other hand, 1-day and 2-day lagged stock market returns also positively affect the New Taiwan dollar value. In Hong Kong, 1-day lagged stock market returns positively affect the value of Hong Kong dollar. In China, there does not exist any mapping relations. In Singapore, there exists a one-way positive mapping relation from the 1-day and 2-day lagged Singapore dollar returns to the stock market performance.

This study then uses multivariate adaptive regression spline (MARS) threshold modeling method to examine the possible nonlinear, interactive, and longer-term relationship. In a simple model, a single stock market performance is affected by its own past returns, past local currency movements, and the interaction of the past currency and stock returns. We allow for 10 lagged daily returns of stock market and currency to enter the MARS_VAR model, with maximum number of 30 knots and 2 interactions. In contrast to VAR modeling, the MARS_VAR results show that there is much more information in the returns time series. First, MARS_VAR discovers many nonlinear and interactive effects of lagged currency and stock returns. For example, in Taiwan, when the stock market return 2 days ago is more severe than -3.28% and the New Taiwan dollar value 2 days ago appreciates or depreciates less than 0.5257%, the Taiwan stock market is expected to fall significantly. Secondly, while the VAR model is able to capture only the extremely short-term relationship, MARS_VAR model successfully discovers up to 8 days of lagged currency returns affecting today's stock market performance. The MARS_VAR modeling makes intuitive sense because past shocks often do not have an influence unless the currency depreciates more than a threshold value and is accompanied by a previous slide of the stock market that is more severe than a threshold.

Based on the findings of the MARS_VAR results, trading strategies for risk management can be implemented. First, portfolio managers can locate the statistically significant negative condition(s) and be aware of the threshold values of lagged variables at which the conditional effects are switched on. Next, in anticipation of the falling portfolio value, risk managers can withdraw capitals invested in the corresponding stock market to avoid potential capital loss until the extreme condition is reversed. Utilizing the trading strategy, this study shows that the performance of the simulated portfolio has a lower overall return and risk profile over the 10-year investment period. With the same estimated MARS_VAR conditions, the out-of-sample simulation for the data period of June 2012 to August 2013, shows that the threshold values have the capability of predicting potential falls in the Hong Kong stock market, while preserving the upside potential of three other markets. We find both the in-sample and out-of-sample simulated portfolios yield slightly better risk-adjusted returns than a passively held benchmark due to the lower volatility exposure to the stock markets.

The countries covered in this study include Taiwan, Hong Kong, China, and Singapore, that are within the investment universe of the Greater China Fund. The four financial markets have their own independent central banks and financial regulatory authorities. Taiwan and Singapore adopt the free float exchange rate regime, Hong Kong adopts fixed exchange rate regime, and China has its exchange rate policy change from fixed to managed float just over the observation period. No existing research can link the choice of exchange rate regime to currency-stock market performance and that makes empirical studies more appealing. The dynamics in daily foreign exchange rate fluctuations and stock market movements of the four markets are interesting to analyze in terms of their lead-lag effect, the persistence of the effects, and how the relationship is nonlinear and interactive.

CHAPTER 1

INTRODUCTION

1.1 Motivation

The 1997 Asian financial crisis was a rare event in global financial history. It was a stock market crash led by the large-scale devaluation in Asian currencies. The inter-dependent relationship between the stock and currency markets suddenly becomes obvious during the crisis, and thus many researchers have attempted to investigate the special lead-lag inter-market relationship. On the other hand, there are few studies focusing on the usual relationship between the two markets. The understanding of their day-to-day relationship is as important, as, during crises. Investors who have risk exposure to international stocks would want to capture early warning signs of anomalies in international financial markets.

Returns on international equities consist of two parts: Stock returns and currency returns. The general belief of the relationship between the two markets is that the contemporaneous relation between the two market returns is extremely weak over the long run and that the investor's portfolio risk-reward profile can be improved by taking advantage of this additional currency diversification that can not be achieved with the construction of domestic-only equities. Nevertheless, knowing the overall low (linear) correlation of stock and currency returns in a portfolio can do only little to satisfy us on the day-to-day portfolio risk-reward dynamics. A more comprehensive picture using nonlinear methods such as MARS_VAR modeling should reveal how the two markets interact when currency depreciates instead of appreciating and when the stock market falls instead of rising.

The flip side of return is risk. Equity risk refers to the fluctuations in the stock prices; currency risk is caused by value changes in foreign currency with respect to the investor's home currency. The investor benefits when foreign currency appreciates, and on the other hand, the depreciation in foreign currency can offset stock returns. In the case of both equity and foreign currency experiencing negative returns, the investors suffer the most from their international investment. Double negative returns are quite commonly observed in the emerging Asian markets, particularly during the time preceding a financial crisis. Currency depreciation weakens the stock market and poor stock market performance feeds back to capital outflows of the country, which further devalues the currency. "When it rains, it pours" seems to characterize such "double negative" investment returns. Fortunately, the dynamic relationship at "double negative" returns can be accurately captured by the MARS_VAR nonlinear method as MARS_VAR relaxes the linearity assumption of right hand side variables and allows past shocks from the two series to affect each other. Furthermore, MARS modeling estimates threshold values of explanatory variables at which the double negative returns would take place. Using MARS_VAR methods enables us to forecast and manage the "double negative returns" events. This study contributes to the understanding of the dynamic relationship between the equity and currency markets, specifically on the lead-lag effect, the persistence of the effects, and how the relationship is nonlinear and interactive.

1.2 Background of currency risk management

US investors who hold international equity portfolios are exposed to equity risk as well as currency risk. Currency risk presents additional investment risk due to the different currencies in which international stocks are denominated from the investor's home currency. The exposure to currency risk brings return opportunity, when foreign currencies appreciate against home currency; on the other hand, foreign currency depreciation can directly impair the profits on the international equity portfolio if currency exposure is not appropriately hedged.

The debate on whether to hedge currency exposure of an international equity portfolio has been ongoing. The investment industry has proposed a currency overlay strategy, a type of hedge fund's portable alpha strategies or portfolio risk management strategy employed by institutional investors to diversify a portfolio or to gain outright exposure to currency markets. The overlay consists of long or short positions in highly liquid currency futures or forward contracts. A passive strategy is to choose a perfectly linearly correlated currency futures or currency forward contract with the underlying currency position and to remove a chosen level of currency volatility from the portfolio. A more active and tactical strategy is to bet on certain countries and their currencies and decide how much volatility is hedged while leaving other countries and their currencies exposed unhedged. Proponents argue that the tactical currency overlay operations can manage clients' currency exposures with the objective of generating profits while limiting currency risk. Existing academic literature disagrees on currency risk hedging practice. Statman (2003) studies hedged and unhedged global equity portfolios during 1988-2003 and discovers that their realized returns and risk are virtually identical. Morey and

Simpson (2001) study five developed equity markets over the period of 1974-1998 by employing a few currency trading strategies and find that only when domestic currency is undervalued based on the relative purchasing power parity theory can currency hedging yield a positive return on a risk-adjusted basis.

The goal of this thesis is to reveal if there is a dynamic relationship between stock returns and currency fluctuations. When perfectly hedged stock indices are analyzed, the empirical results show that the currency risk still cannot be perfectly hedged away, as the relationship between the two markets are dynamic, non-linear, and most importantly, interactive. Although the currency risk can not be perfectly hedged, it can be managed using the trade signals generated by the nonlinear MARS_VAR models. This study first analyzes the inter-market relationship from the four financial markets: Taiwan, Hong Kong, China, and Singapore, and then attempts to simulate a portfolio of four markets that trades according to the signals generated by MARS_VAR models. The simulation results show a lower volatility and better overall risk-reward characteristics when the portfolio is compared with a passive index benchmark.

1.3 The Greater China Fund and its investment universe

In the 1960-1990s, Taiwan, Hong Kong, and Singapore experienced rapid industrialization and economic growth. They are among the four "Asian tigers" along with South Korea, and present profitable investment opportunities. Since the late 1990s, the annual double-digit growth of China's economy provided US investors with an even more attractive investment risk-reward profile. The 1997 Asian financial crisis devastated the Hong Kong's stock market and currency, while China, Taiwan and Singapore were least affected. China's stock market has gradually become investable through continuing financial reforms and market deregulations. Nonetheless, due to the capital market size of China and the liquidity of Chinese stocks on the Shanghai Stock Exchange and Shenzhen Stock Exchange, the two stock exchanges that are overseen by China Securities Regulatory Commission, China's stock market is still characterized as an emerging market. Professional money managers seek investment opportunities by investing Chinese enterprises that list their stocks on Hong Kong Stock Exchange (HKSE), Taiwan Stock Exchange, and Singapore Stock Exchange, where great information transparency and market liquidity are provided. For example, H-share and red-chip stocks are listed on the HKSE. Red-chip stocks are listed on the HKSE, issued by the companies that are incorporated outside of China while doing business in China, with their ownership controlled by Chinese provincial or municipal governments. H-share stocks are issued by those companies that are incorporated in China and choose to list stocks on HKSE. Many of these companies have also listed their stocks in China as A-share stocks. The differences between H shares and their corresponding A shares are not only the currency denomination, but the accessibility by foreign investors. A shares, denominated in Chinese *yuan*, are open only to local investors or through qualified foreign institutional investors (QFII), whereas H shares, since traded on HKSE, are open to global investors. In balance of investment opportunities and liquidity of turning over portfolio assets, professional money managers must take advantage of those Chinese stocks listed outside of China. The concept of Greater China mutual fund thus emerged.

The Greater China funds invest in stocks traded on China, Hong Kong, Taiwan, and Singapore stock exchanges. There are few special cases when Chinese enterprises choose to list their stocks directly in the U.S. For example, Sohu.com, a Chinese-based online media company, chose to go public on NASDAQ in the United States. Fund managers may also choose to invest in these US-listed stocks should they see fit; however, these stocks, denominated in US investors' home currency, are not subject to direct foreign currency risk. Today the largest Greater China fund is managed by Franklin Templeton Investments, with assets of 1.2 billion worth of US dollar under management, as of October 2013. It is estimated that the category of Greater China funds consist of at least 2.2 billion worth of assets of US investors and since many more privately owned portfolios are looking to embrace the idea of Greater China investment, it is deemed important to analyze the day-to-day equity and currency risk exposure of the Greater China investment universe using advanced time series methods.

The remainder of this thesis is organized as follows: Chapter 2 reviews related literature on the linkage between stock and currency markets. Chapter 3 describes the data and statistical characteristics of the time series being analyzed. Chapter 4 presents the MARS_VAR model, the primary research method in this study. Chapter 5 first interprets the empirical results on the dynamic relationships between the stock market returns and foreign exchange rates series using both linear VAR model and nonlinear MARS_VAR model. The second part of Chapter 5 forecasts "double negative" events using out-of-sample data and discusses the forecasting ability of the MARS_VAR model. Chapter 6 summarizes this thesis and suggests potential future work.

CHAPTER 2

RELATED LITERATURE

2.1 Linkage between stock and currency markets

Solnik (1974), Sercu (1980), and Adler and Dumas (1983) have done extensive work on the currency risk premium of international equity. Portfolio theory such as the International Capital Asset Pricing Model (ICAPM) expands the domestic version of the Capital Asset Pricing Model (CAPM) to an international setting by adding either an inflation risk premium or a foreign exchange risk premium to the world market risk premium. Literature on the International Capital Asset Pricing Model (ICAPM) discusses currency risk systematically priced in international equity returns. Foreign exchange rates are assumed to be exogenous to and linearly correlated with equity returns. Solnik (1974) and Sercu (1980) propose the following model:

$$E(R_k) = \gamma_0 \; + \; \sum_{l=1}^{L} \gamma_l^f \beta_{kl}^f \; + \gamma^w \beta_k^w \;, \tag{2.1}$$

where:

$E(R_k)$ is the expected excess log return on the asset over the risk-free interest rate; R_k is denominated in the reference currency of country "L+1."

β_{kl}^f is a vector of returns on bonds that are perfectly correlated with foreign exchange rates with respect to the reference currency.

β_k^w is the expected excess return on the world market portfolio; β_k^w is denominated in the reference currency.

γ_0 is the intercept of the regression with respect to abnormal returns of asset k.

γ_l^f is the regression coefficient with respect to the sensitivities to each pair of foreign exchange rates in reference currency.

γ^w is the regression coefficient with respect to the sensitivity to world market returns.

Various problems are raised. First, the ICAPM was developed based on simplistic assumptions, since it assumes that purchasing power parity (PPP) holds at any point in time and therefore currency movements simply mirror the changes in inflation differentials of the two countries. This assumption is not empirically supported as relative PPP tends to hold only in the long run and under particular circumstances. Taylor and Taylor (2004) study short-run and long-run PPP of a large number of countries at various time horizons and find that "short-run [relative] PPP does not hold" and that "long-run [relative] PPP may hold in the sense that there is significant mean reversion of the real exchange rate." In addition, the pricing relationship suggested by ICAPM is based on contemporaneous correlations between stock returns and currency movements. Adler and Dumas (1984) examine exchange rate exposure of the firms and point out that the currency exposure is determined jointly with stock prices of the firms, assuming that the capital markets can fully and instantaneously react to changes in a country's currency level. Solnik (1987) finds that the relationship between domestic stock market returns and local currency movements can be either positive or negative given different periods of data samples. Jorian (1991) finds little evidence of (contemporaneous) foreign exchange rate risks being priced in US stocks. Bodnar(1993), Barton and Bodnar (1994), and Choi (1995) are unsuccessful in identifying the relationship between stock returns and exchange rate fluctuations. The International CAPM can serve as a framework for bridging the relation between stocks and currencies; however, in order to uncover the empirical relationship between the two asset classes, assumptions such as contemporaneous relationship and model linearity need to be relaxed.

Instead of using an asset pricing model, Dornbusch & Fischer (1980) use the goods market hypothesis to link currency movements to stock prices. They suggest that the changes in national currency value affect the stock prices via the channel of the competitiveness of domestic firms. Specifically, if the national currency value depreciates, the competitiveness of the exporting firms will increase as their goods and services become less expensive in the world market. Therefore, the profits of the firm increase, hence its stock price. On the other hand, currency depreciation decreases the competitiveness of the importing firms as their costs increase, and the firms stock price will drop as a result. The goods market hypothesis is a plausible macroeconomic fundamental approach and yet the empirical results depend on the countries being studies, in terms of the statistical significance of directional impacts between stock returns and currency fluctuations. In these studies, the contemporaneous co-movement between stock prices and exchange rates appears weak.

Unlike existing research that studies the contemporaneous correlations between stock and currency movements, this study uses time series models to explore the dynamic relationship between the two financial variables for four countries: Taiwan, Hong Kong, China, and Singapore. Linear time series models such as the Vector Autoregression (VAR) model have been employed to estimate the short-run intertemporal co-movement as well as long-run equilibrium relationship between stock and currency markets. The most extensive work is conducted by Nieh and Lee (2001), who employ Johansen's (1988, 1990, and 1994) five vector error correction model (VECM) to check comoving trends between stock prices and exchange rates for the G-7 countries. They find that there is no long-run equilibrium relationship between the two variables. Their VECM results show a significant one-day predicting power of the two financial assets for Germany, Canada, UK, Japan, and Italy. Specifically, one-day lagged currency depreciation causes German stocks to fall but Canadian and UK stocks to rise. The Japanese and Italian stocks cause their national currency to decrease in value the next day. Nieh and Lee only find a one-way mapping relationship between stock returns and currency movements. A relatively recent study on the relationship between currency depreciation and stock market returns as a part of financial crisis study by Fang (2000) finds that the depreciation in New Taiwan dollar contributed to the falling of Taiwanese stock market during the Asian financial crisis in 1997-1999.

This study proposes to use nonlinear time series methods, such as the Multivariate Adaptive Regression Splines (MARS)_VAR model, to shed some light on how past stock returns and currency movements can interactively affect current stock market performance. Often time the stock market performance is changed under multiple conditions that take place at the same time. For example, although a stock market can be uniformly affected by a previous appreciation of national currency, the effect does not have to take place unless the currency appreciation exceeds a threshold value and is accompanied by a previous slide of the stock market that is more severe than a threshold value. MARS provides accurate information on the estimated threshold values at which the conditional effects are switched on or off. We can then use the threshold values and predicted conditions to generate first warning signs of market anomalies and manage equity and currency risk exposure of the Greater China portfolio accordingly.

2.2 The choice of exchange rate regimes

The empirical evidence shows that countries adopting less flexible exchange rate regimes tend to experience lower overall stock market volatility. For example, the daily data of June 2003 - August 2013 shows that Hong Kong and China exhibit lower stock market volatility than Taiwan and Singapore. However, in surveying the literature on the relationship between the choice of a country's exchange rate regime and its stock market performance, there is little mentioned of the causality. The related literature is on the impact of the choice of exchange rate regimes on economic performance, although it has been a controversial topic in the macroeconomic literature. While there are no theories directly linking exchange rate regimes to output growth, there are empirical studies on the impact of exchange rate regimes on economic growth. Outlook on economic growth has been crucial information to analysts and professional money managers who make country allocation decisions. Levy-Yeyati and Sturzenegger (2003) study "the relationship between exchange rate regimes and economic growth for a sample of 183 countries over the period 1974-2000" and find non-industrial countries with less flexible exchange rate system to have slower Gross Domestic Product (GDP) growth and greater GDP volatility, whereas the economic growth rate of developed countries with pegged exchange rate system do not seem to differ from those with floating exchange rate system. In their study, they develop a *de facto* classification of exchange rate regimes using empirical observations. Those governments that choose floating system can actually trade foreign reserves to lower exchange rate volatility. On the other hand, those governments with fixed exchange rate regimes can periodically devalue their own currencies to "accommodate" their independent monetary policies. Thus, to truly classify a market to be floating or fixed, three variables can be observed and computed: "exchange rate volatility, volatility of exchange rate changes, and volatility of reserves." Levy-Yeyati and Sturzenegger find that "the distinction between low and high [credibility] pegs is largely irrelevant as a determinant of growth."

Another study on exchange rate regimes and cost of capital in emerging markets using a dynamic version of the arbitrage pricing theory (APT) finds that fixed exchange rate system cannot reduce stock market volatility and rather increase interest rate volatility and thus the cost of capital. Diez de los Rios (2009) argues that in theory, even though fixed exchange rate regime can reduce the uncertainty induced by currency movements and thus currency risk premium, in reality, the foreign exchange risk premium may not be priced in country-specific risk factor due to financial market integration. Additionally, the monetary authority can intervene in the bond market to defend the level of pegged foreign exchange rate level. Thus, while currency risk decreases, interest rate risk increases, and the empirical evidence shows that the magnitude of decreasing currency risk is not enough to lower the overall investment risk.

The above-mentioned literature seems to suggest that the relationship between the choice of exchange rate regimes and stock market performance be studied directly with empirical data and statistical methods.

CHAPTER 3

DATA

3.1 Data series

This study uses daily frequency data from March 2003 to June 2012. Data on Taiwan, Hong Kong, China, and Singapore stock markets are obtained from MSCI Inc. The MSCI company complied and published country stock market indices as performance indicators of national equity markets. These indices are among the most recognized benchmarks available in the investment industry. The data series obtained from MSCI Inc. include: the MSCI China Index, MSCI Hong Kong Index, MSCI Singapore Index, and MSCI Taiwan Index, all quoted in local currencies. Regional indices available on MSCI Inc. are computed as composite indices weighted by total market capitalizations of nations. The weights of each country vary everyday as the national stock market index fluctuates and stocks can be added to or removed from the indices. Because of the nature of market weighted indices, certain corporate events such as stock dividends and stock splits do not affect the index levels. Cash dividends are assumed to be reinvested. Thus, these market indices reflect total returns of the markets.

Data on daily foreign exchange rates are obtained from the Federal Reserve Board Table H.10. The listed rates are quoted in national currencies per US dollar and this study converts the rates such that each currency is expressed in US dollar. Rate of returns on market indices and foreign exchange rates are calculated as log differentials of daily closing prices of day t and day t-1, i.e., ($lnP_t - lnP_{t-1}$), or daily closing exchange rates of day t and day t-1, i.e., ($lnS_t - lnS_{t-1}$). All exchange rates are quoted in US dollars per unit of foreign currency. Some data observations are removed for the consistency of data availability. For example, in the United States, the bond market is closed on Columbus Day, so information on foreign exchange rates for the four foreign currencies is not available. Although the four Asian stock markets still operate on America's Columbus Day, the same-day data points on MSCI foreign country indices are removed. Similarly, when any of the four Asian countries observe holidays, the same-day currency and stock market data are removed.

3.2 Statistical properties of the data

3.2.1 Descriptive statistics

The 2,345 daily observations of stock and currency performance from March 5, 2003 to June 22, 2012 are listed in Table I. The stock market index level is set to be 100 on March 5, 2003. Over the observation period, the China stock market experiences the highest rate of return over the period, followed by Singapore, Hong Kong, and Taiwan. In terms of the market volatility measured by the standard deviation of daily rate of returns, the China stock market experiences the highest volatility, followed by Taiwan, Hong Kong, and Singapore. It is interesting to note that although the Taiwan stock market is the worst performer during the period, its lowest daily return is -6.9%, which is better than that of Singapore (-9.8%), Hong Kong (-12.6%), and China (-12.8%), respectively.

Listed in the last section of Table I are the stock returns in US dollars. These are "unhedged" market indices from US investors' viewpoint. Over the observation period, all the four national currencies experience appreciation in value against the US dollar. The Singapore dollar appreciates the most, followed by the Chinese *yuan* and New Taiwan dollar. Hong Kong dollar has slightly appreciated in value; however, Figure 3.1.5 shows that the Hong Kong dollar has been in a tight range of USD 0.1277-0.1297 per HKD as the Hong Kong Monetary Authority (HKMA) has adopted a linked exchange rate system since 1983. The current exchange rate is set to be USD 1 = HKD 7.75 (i.e., HKD 1 = USD 0.1290) as of September 1998. In China, the Chinese authorities de-pegged CNY from the US dollar and adopted a managed float exchange rate regime with reference to a basket of currencies in July 2005. Figures 3.1.6-3.1.7 show the change of China's exchange rate policy. The Chinese *yuan* has a one-time 2% revaluation on 7/22/2005. Both Taiwan and Singapore adopted floating exchange rate regimes. Since the exchange rate regime change, the volatility of Chinese currency market has become higher due to the fluctuations of the floating exchange rates. Over the observation period, all the currencies appreciate in value; therefore, the "unhedged" stock market returns in US dollar are higher than stock market returns in local currencies.

3.2.2 Stationarity of the series

The starting point of building any time series models is to distinguish whether the time series in question has a unit root structure. If a series has a unit root structure, then the series is not stationary. Using one or both unit root series to estimate the relationship between

Variable	Obs	Mean	Std. Dev.	Min	Max	DF test
MSCI Indices in local currency						
Taiwan	2345	151.89	22.58	93.07	203.51	-2.839*
Hong Kong	2345	176.28	41.01	89.64	273.24	-2.027
China	2345	285.9	114.61	92.65	586.29	-1.788
Singapore	2345	193.75	44.37	95.47	288.47	-2.156
MSCI Indices in US dollar						
Taiwan	2345	164.62	28.95	94.41	223.39	-2.667*
Hong Kong	2345	177.41	41.36	89.63	275.81	-2.034
China	2345	287.98	115.68	92.65	592.08	-1.790
Singapore	2345	232.03	71.12	94.25	347.19	-1.796
Foreign exchange rates in USD per unit of currency						
Taiwan	2345	0.031208	0.001556	0.028401	0.035088	-1.578
Hong Kong	2345	0.128568	0.000343	0.127732	0.129727	-3.516***
China	2345	0.136279	0.013388	0.120808	0.159261	-0.700
Singapore	2345	0.673372	0.074479	0.560601	0.832848	-0.650
Rate of returns on MSCI Indices						
Taiwan	2345	0.000176	0.014285	-0.069358	0.064993	-47.390***
Hong Kong	2345	0.000286	0.014099	-0.125614	0.104413	-48.181***
China	2345	0.000495	0.019202	-0.128445	0.140438	-47.422***
Singapore	2345	0.000315	0.012949	-0.098483	0.069409	-48.520***
Taiwan (in USD)	2345	0.000232	0.015525	-0.071721	0.082252	-46.707***
Hong Kong (in USD)	2345	0.000289	0.014139	-0.125680	0.104481	-48.096***
China (in USD)	2345	0.000499	0.019240	-0.128229	0.140379	-47.360***
Singapore (in USD)	2345	0.000442	0.014392	-0.097924	0.085605	-47.842***
Rate of returns on foreign currencies						
Taiwan	2345	0.000062	0.003183	-0.024848	0.034230	-53.180***
Hong Kong	2345	0.000002	0.000384	-0.002849	0.004522	-49.837***
China	2345	0.000112	0.001081	-0.009861	0.020187	-56.623***
Singapore	2345	0.000131	0.003579	-0.026949	0.022138	-49.198***

*Notation: ***: 1% of significance; **:5% of significance; *: 10% of significance*
Interpretation on the Dickey-Fuller test results:
All returns series and HKD series reject unit root hypothesis at 1% of critical value level.

TABLE I

DESCRIPTIVE STATISTICS OF DATA SERIES

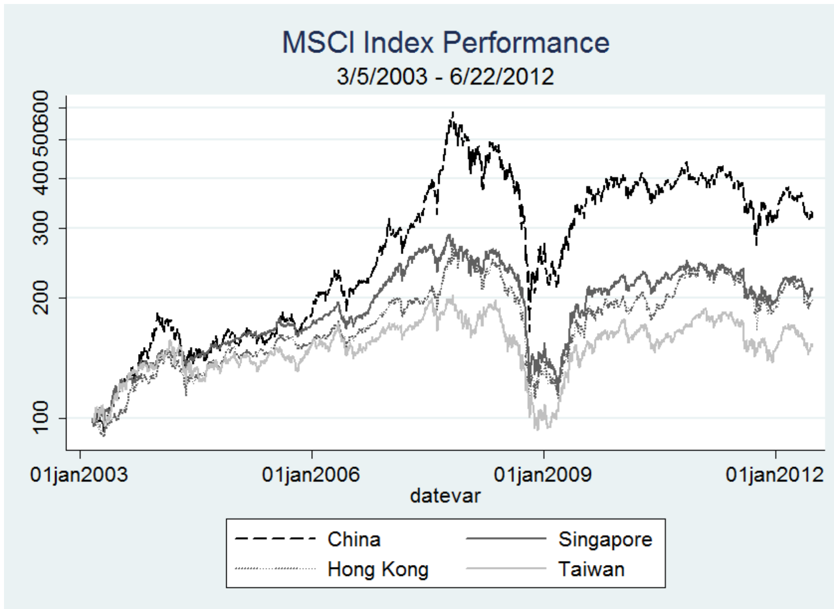

Figure 1. MSCI index performance 3/5/2003 – 6/22/2012

exchange rates and stock returns can yield spurious results. An exception that both series need not be differenced is if both series are co-integrated. If the co-integration test confirms that the stock-currency pair co-integrate, then both series need not be differenced to remove the unit root structure.

Stock market indices are known for their unit root properties. On the other hand, the log-differenced stock returns series are usually free of unit root problems. However, rigorous tests needed to be done to ensure that the series are stationary. Except the USD-HKD foreign exchange rates, all other three exchange rates series exhibit a trend. If the unit root structure is present, the exchange rates series need to be differenced to achieve stationarity.

Dickey-Fuller unit root test results

The Dickey-Fuller test is used to test for stationarity of the times series. We choose the Dickey-Fuller test instead of the augmented Dickey-Fuller test as the time series does not have a trend and potentially slow-turning around a mean. The test equation is:

$$\bigtriangledown Z_t = \alpha_0 + \theta Z_{t-1} + \alpha_1 \bigtriangledown Z_{t-1} + \alpha_2 \bigtriangledown Z_{t-2} + \cdots + \alpha_p \bigtriangledown Z_{t-p} + \alpha_t, \tag{3.1}$$

The number of lags(p) is determined by minimizing the Akaike information criterion (AIC) or by minimizing the Schwarz Bayesian information (BIC). In all cases of the eight time series, the appropriate number of lags is 2. The null hypothesis is that the series has a unit root:

$H_0 : \theta = 0,$

versus the alternative hypothesis of:

$H_A : \theta < 0.$

As shown in Table II, the test statistics show that all the stock and currency return series have no unit roots. The test statistics reject the null hypotheses at 1% critical value level. Thus, all stock and currency return series are stationary and do not need to be further differenced.

3.2.3 Cointegration of stock returns and currency returns series

Cointegration refers to the fact that two or more series share a stochastic trend. Engle and Granger (1987) suggest a two step process to test for cointegration using an OLS regression and

Currency Returns			
	Test Statistics	**1% CV**	**Test result**
New Taiwan dollar (TWD_r)	-28.53	-3.43	Reject unit root hypothesis
Hong Kong dollar (HKD_r)	-28.29	-3.43	Reject unit root hypothesis
Chinese Yuan (CNY_r)	-28.39	-3.43	Reject unit root hypothesis
Singapore dollar (SGD_r)	-28.84	-3.43	Reject unit root hypothesis
Stock Market Returns			
	Test Statistics	**1% CV**	**Test result**
Taiwan (l_tw_r)	-28.2	-3.43	Reject unit root hypothesis
Hong Kong (l_hk_r)	-27.32	-3.43	Reject unit root hypothesis
China (l_cn_r)	-27.84	-3.43	Reject unit root hypothesis
Singapore (l_sg_r)	-27.55	-3.43	Reject unit root hypothesis

TABLE II

DICKEY-FULLER UNIT ROOT TEST ON DAILY RETURN SERIES (LAGS 2)

a unit root test. The EG-ADF test first regresses variable x on variable y, gets the residuals of the regression, and finally runs an augmented Dickey-Fuller test on the residuals. We pair the four stock price index-foreign exchange rate series and perform the EG-ADF test. The results are reported in Table III. The test statistics show that the Taiwan stock price series and currency value are not cointegrated as the unit root test fails to reject the null hypothesis of having a unit root. This is the same case for Hong Kong, China, and Singapore. None of the paired variables cointegrate. The cointegration test results suggest that there is no long-run relationship between stock and currency markets in the four countries. In addition, the conintegration test results confirm that stock market index series and foreign exchange rate series need to be differenced to achieve stationarity before analysis proceeds.

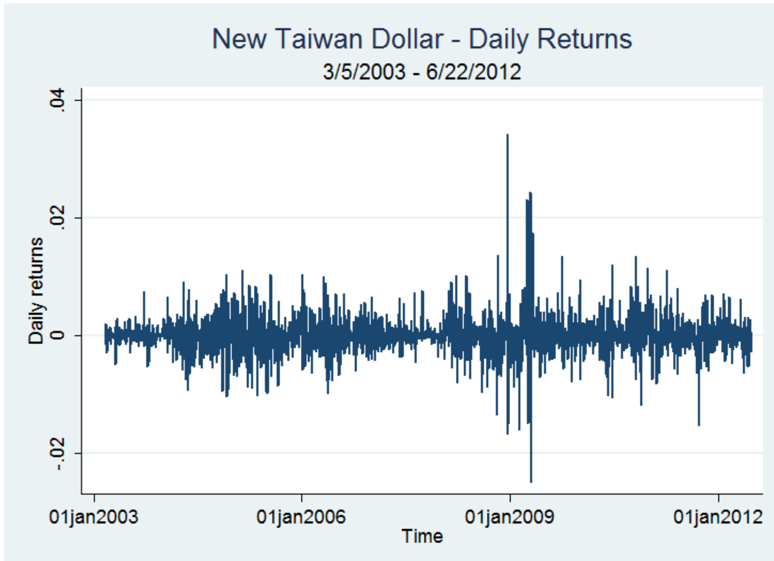

Figure 2. New Taiwan dollar – daily returns 3/5/2003 – 6/22/2012

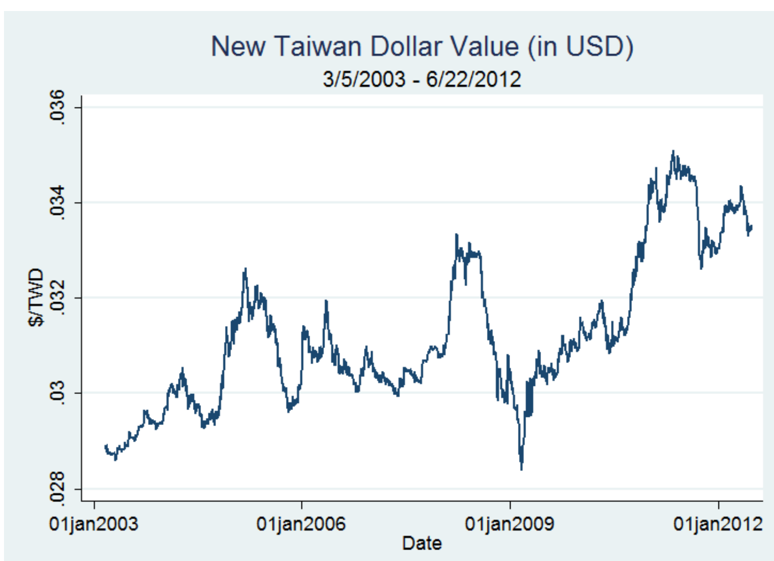

Figure 3. New Taiwan dollar value (in USD) 3/5/2003 – 6/22/2012

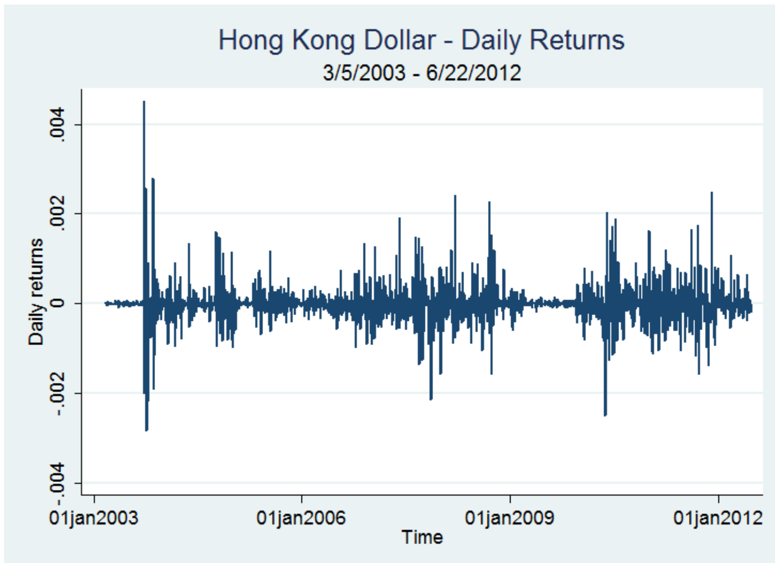

Figure 4. Hong Kong dollar – daily returns 3/5/2003 – 6/22/2012

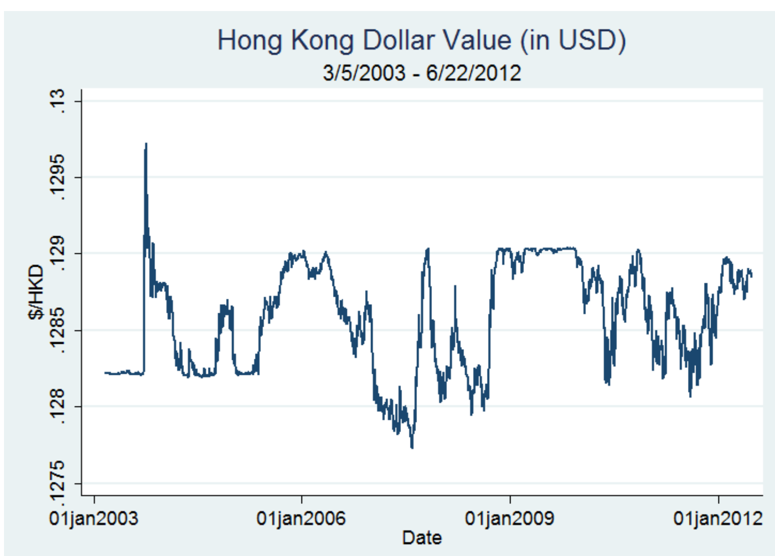

Figure 5. Hong Kong dollar value (in USD) 3/5/2003 – 6/22/2012

Figure 6. Chinese *yuan* − daily returns 3/5/2003 − 6/22/2012

Figure 7. Chinese *yuan* value (in USD) 3/5/2003 − 6/22/2012

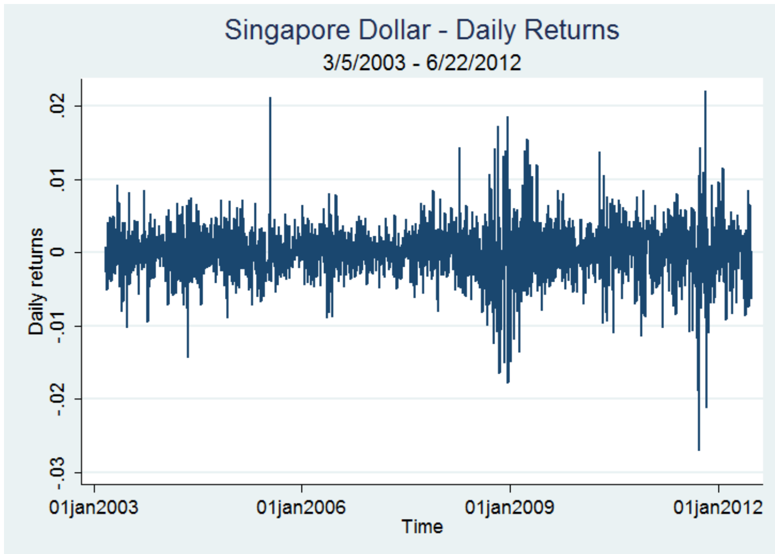

Figure 8. Singapore dollar - daily returns 3/5/2003 − 6/22/2012

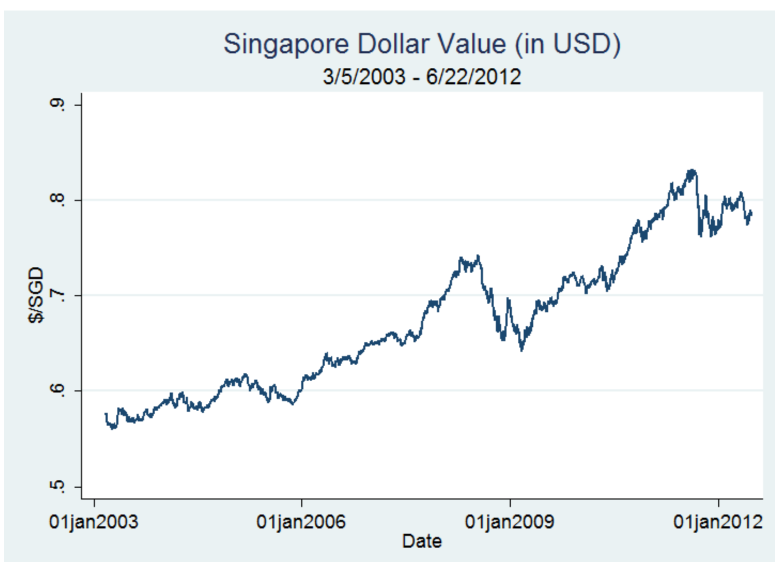

Figure 9. Singapore dollar value (in USD) 3/5/2003 − 6/22/2012

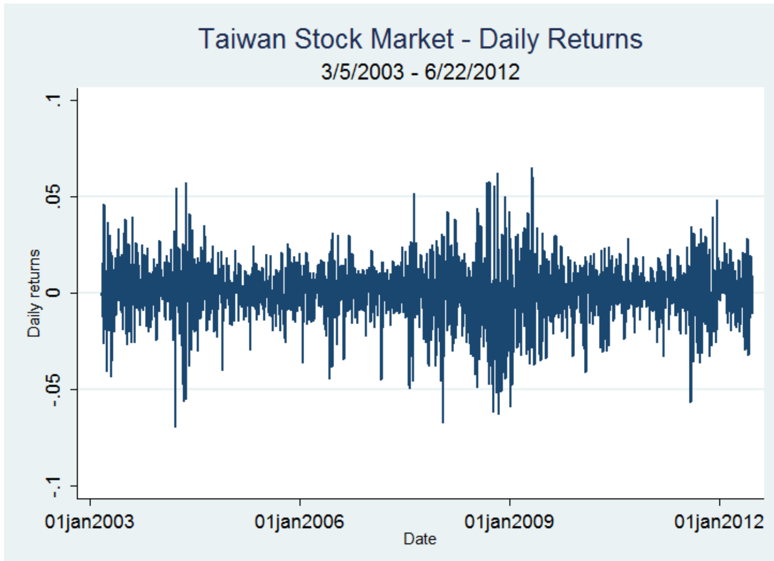

Figure 10. Taiwan stock market – daily returns 3/5/2003 – 6/22/2012

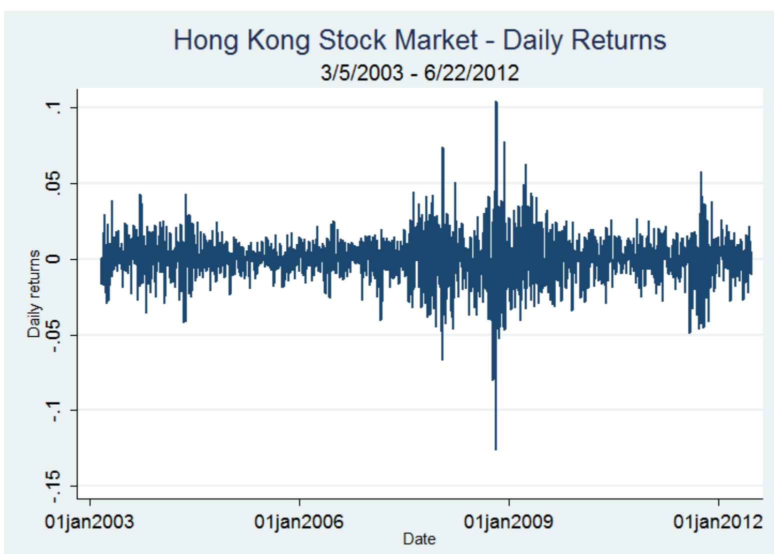

Figure 11. Hong Kong stock market – daily returns 3/5/2003 – 6/22/2012

Figure 12. China stock market – daily returns 3/5/2003 – 6/22/2012

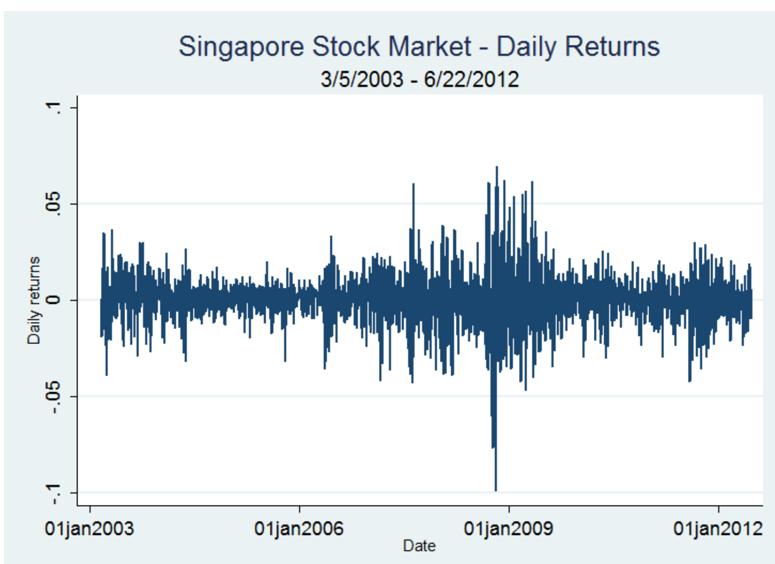

Figure 13. Singapore stock market – daily returns 3/5/2003 – 6/22/2012

Time series	EG-ADF test statistic Z(t)	1% critical value	5% critical value	10% critical value
TW stock market index TWD value	**-1.9**	-3.43	-2.86	-2.57
HK stock market index HKD value	**-1.56**	-3.43	-2.86	-2.57
CN stock market index CNY value	**-1.79**	-3.43	-2.86	-2.57
SG stock market index SGD value	**-2.49**	-3.43	-2.86	-2.57

TABLE III

COINTEGRATION TEST RESULTS

3.2.4 Correlations of the series

The literature has documented the low correlations between stock and currency markets. Using the entire data period that covers 2,345 daily observations, we find that indeed the contemporaneous correlations of Taiwanese stock market vs. New Taiwan dollar (0.2974), Hong Kong stock market vs. Hong Kong dollar (0.0997), Chinese market vs. Chinese *yuan* (0.0764), and Singapore stock market vs. Singapore dollar (0.2994) are all very weak. The complete correlation matrix is presented in Table IV.

	TW_Stock	HK_Stock	CN_Stock	SG_Stock	TWD	HKD	CNY	SGD
TW_Stock	1							
HK_Stock	0.58	1						
CN_Stock	0.58	0.87	1					
SG_Stock	0.56	0.72	0.7	1				
TWD	**0.3**	0.27	0.27	0.29	1			
HKD	0.11	**0.1**	0.1	0.08	0.18	1		
CNY	0.06	0.08	**0.08**	0.09	0.15	0.1	1	
SGD	0.25	0.3	0.32	**0.3**	0.43	0.26	0.15	1

TABLE IV

CORRELATION MATRIX

3.3 Granger test

Granger (1969) causality is examined on the stock returns and foreign exchange series. The test helps identify whether two series have a mapping relationship. A series x is said to *Granger* *cause* a series y if, and only if, a model that predicts y as a function of only its past has a greater sum of squares of the error term than a model that predicts y as a function of its own past and the past of x. Thus, in Equation 4.1, if $G_{21}(B) \neq 0$ and x_{1t} is exogenous, we can say that x_{1t} *Granger causes* x_{2t}.

The Granger causality tests of whether currency returns cause stock market returns are presented in Table V. In Taiwan and Singapore, currency returns *Granger cause* market returns as the regression model contains lagged currency returns is a better model than the one with only lagged stock market returns. In the case of China and Hong Kong, their currency returns do not *Granger cause* stock market returns.

Left-hand-side variable (LHS)	Right-hand-side variables (RHS)	Residual Sum of Squares (RSS)	F test (P. > F) on the other series
TAIWAN			
TW dollar	Lags(1/2).twd_r	0.02	–
TW dollar	Lags(1/2).twd_r L(1/2).l_tw_r	0.02	7.05 (0.0009**)
TW MKT	Lags(1/2).l_tw_r	0.48	–
TW MKT	Lags(1/2).l_tw_r L(1/2).twd_r	0.47	7.76 (0.0004**)
Interpretation: TWD returns *Granger cause* TW market returns; TW stock market returns also *Granger cause* TWD returns			
HONG KONG			
HK dollar	Lags(1/2).hkd_r	0	–
HK dollar	Lags(1/2).hkd_r L(1/2).l_hk_r	0	2.97 (0.0514**)
HK MKT	Lags(1/2).l_hk_r	0.46	–
HK MKT	Lags(1/2).l_hk_r L(1/2).hkd_r	0.46	1.57 (0.2088)
Interpretation: HKD returns do NOT *Granger cause* HK market returns HK stock market returns *Granger cause* HKD returns			
CHINA			
CN *yuan*	Lags(1/2).cny_r	0	–
CN *yuan*	Lags(1/2).cny_r L(1/2).l_cn_r	0	1.10 (0.3319)
CN MKT	Lags(1/2).l_cn_r	0.86	–
CN MKT	Lags(1/2).l_cn_r L(1/2).cny_r	0.86	0.70 (0.4970)
Interpretation: CNY returns do NOT *Granger cause* China market returns China stock market returns do NOT *Granger cause* CNY returns			
SINGAPORE			
SG dollar	Lags(1/2).sgd_r	0.03	–
SG dollar	Lags(1/2).sgd_r L(1/2).l_sg_r	0.03	0.63 (0.5351)
SG MKT	Lags(1/2).l_sg_r	0	–
SG MKT	Lags(1/2).l_sg_r L(1/2).sgd_r	0.39	13.22 (0.0000***)
Interpretation: SGD returns *Granger cause* SG market returns SG stock market returns do NOT *Granger cause* SGD returns			
*Notation: ***: 5% of significance; **: 10% of significance; *: 15% of significance*			

TABLE V

GRANGER CAUSALITY TEST RESULTS

CHAPTER 4

METHODS

The ultimate goal of this study is to uncover the relationship between stock returns and foreign exchange movements. First, a traditional approach of using the linear Vector Autoregression (VAR) model is employed for the purpose of comparing the estimation results with those of MARS threshold modeling. Secondly, the nonlinear method, MARS_VAR model, a variation built on the foundation of VAR model with some of the restrictive assumptions of VAR being relaxed, is employed to further explore the nonlinear relationship between the two markets.

4.1 Linear method: Vector Autoregression (VAR) model

The Vector Autoregression (VAR) model is employed to capture the possible two-way relationship between currency and equity markets. VAR allows for capturing co-movements of multiple series and expresses each variable as a linear function of the lagged values of the variable, lagged values of all other possible variable candidates, and an error term that are not serially correlated. In this study, the two time series under investigation are daily returns on a foreign currency expressed in a reference currency, i.e., the US dollar, and daily returns on a foreign equity market expressed in its local currency. The first series is the currency returns because it is believed that the daily fluctuations of foreign exchange rates can lead to movements of local stock returns. The second series is the stock market returns as we suspect a feedback relation from the local stock returns to the value of its country's currency. A reduced form VAR model without moving average terms can be expressed as:

$$\begin{bmatrix} G_{11}(B) & G_{12}(B) \\ G_{21}(B) & G_{22}(B) \end{bmatrix} \begin{bmatrix} FX_t \\ Stock_t \end{bmatrix} = \begin{bmatrix} u_{t,FX} \\ u_{t,Stock} \end{bmatrix} \tag{4.1}$$

where:

$G_{11}(B)$ is the effect of past values of FX on its current value; $G_{22}(B)$ is the effect of past values of Stock on its currency value. B is the lag operator, where $B^K X_T = X_{T-K}$. The parameters $G_{12}(B)$ and $G_{21}(B)$ capture the inter-relation between the series. The parameter $G_{12}(B)$ is the effect of past stock returns on current FX rates; $G_{21}(B)$ is the effect of past FX rates on current stock returns. The error terms $u_{t,FX}$ and $u_{t,Stock}$ capture the contemporaneous effects between the two series. Each of the error terms has a zero mean. In a properly identified model there is a constant variance, and the sequence of error terms is not serially correlated. The two components of the error vector, however, can be contemporaneously cross correlated. If the two error terms are found to be cross correlated at lag zero, the Cholesky decomposition is used to identify the model.

In the special case where $G_{12}(B) = G_{21}(B) = 0$, Equation 4.1 reduces to two Autoregressive (AR) models: Equation 4.2 and Equation 4.3.

$$G_{11}(B)FX_t = u_{t,FX}, \quad (4.2)$$

$$G_{22}(B)Stock_t = u_{t,Stock} \quad (4.3)$$

In the case of Equation 4.2 and Equation 4.3, the two series are independent of each other without being influenced by the past values of the other series. The two error terms $u_{t,FX}$ and $u_{t,Stock}$ also become uncorrelated if sufficient lags are estimated. As we expect the existence of some form of inter-market mapping relation, we expect to see that at least one of $G_{12}(B)$ and $G_{21}(B)$ shows statistical significance. If the estimate of $G_{21}(B)$ is significant, then the past currency market performance has an impact on the equity market performance; if $G_{12}(B)$ is significant, the past equity market performance has an impact on the currency market performance.

4.2 Nonlinear method: MARS_VAR model

The major difference between a VAR model and a Multivariate adaptive regression splines (MARS)_VAR model is that the MARS_VAR model relaxes some of the restrictive assumptions of linearity of variables in the model for every period. The variables on the right hand side (RHS) of the equation are allowed the possibility that the effect of RHS variables on the left hand side variable can be impacted by an unknown threshold τ^* which alters the relationship. For example, an equation can be written as:

$$y = a + c_1 * max(x - \tau^*,\ 0) - c_2 * max(\tau^* - x,\ 0) + e, \tag{4.4}$$

where τ^* is a constant value estimated by Multivariate Adaptive Regression Splines (MARS). In this case, τ^* is a threshold value that determines what the equation is. If x value at time t is higher than τ^*, then the equation is reduced to

$$y = a + c_1 * (x - \tau^*); \tag{4.5}$$

if however, x value at time t is lower than τ^*, then the equation is reduced to

$$y = a - c_2 * (\tau^* - x). \tag{4.6}$$

If x value is equal to τ^*, then y = a. The MARS model can also estimate interactive effects between RHS variables. For example, the model can be expressed as:

$$y = a + c_1 * max(x - \tau_1^*,\ 0) - c_2 * max(\tau_1^* - x,\ 0) + c_3 * max\{(x - \tau_1^*)(z - \tau_2^*),\ 0\} + e, \tag{4.7}$$

and there can be three scenarios of this equation:

$$y = a + c_1 * (x - \tau_1^*) + e, \quad when\ x > \tau_1^*,\ \ and\ z < \tau_2^*; \tag{4.8}$$

$$y = a - c_2 * (\tau_1^* - x) + e, \quad when\ x < \tau_1^*; \tag{4.9}$$

$$y = a + c_1 * (x - \tau_1^*) + c_3 * \{(x - \tau_1^*)(z - \tau_2^*)\} + e, \quad when\ x > \tau_1^*\ and \quad z > \tau_2^*. \tag{4.10}$$

The MARS estimation process determines the transformed vectors (x - τ_1^*), (τ_1^* - x), (x-τ_1^*)(z- τ_2^*) first and then solves for coefficients a, c_1, c_2, and c_3.

The MARS algorithm builds models from two truncated functions of the predictors (x) of the form: [1].

$$(x - \tau)^+ = \begin{cases} x - \tau, & when\ x > \tau; \\ 0, & otherwise \end{cases} \tag{4.11}$$

and

$$(\tau - x)^+ = \begin{cases} \tau - x, & when\ x < \tau; \\ 0, & otherwise \end{cases} \tag{4.12}$$

Hastie, Tibshirani, and Friedman (2009) describe the two functions as "a reflected pair" and serve as "basis functions for linear or nonlinear expansion that approximates some true underlying function f(x)". A collection of basis functions will be "a collection of all reflected pairs

[1] The notations in Equation 4.11 through Equation 4.13 follow Section 9.4 *MARS: Multivariate Adaptive Regression Splines*, by Hastie, Tibshirani, and Friedman (2009)and *Statistica*'s Quick References

for each input X_j with knots at each observed value x_{ij} of that input." The MARS model for a dependent variable Y can be expressed in the following form:

$$Y = f(x) = \beta_0 + \sum_{m=1}^{M} \beta_m h_m(X), \tag{4.13}$$

where β_0 and β_m are parameters of the model, and each h_m is a function in the collection of basis functions, or a product of two or more such functions. M is the total number of terms in the model. Using a standard linear regression, the coefficients β_m are estimated given a choice of the h_m, by minimizing the sum of squares residual. The goal is to estimate β_m and the knots τ for each basis function estimated from the data. The maximum interaction order of the variables in this study is 2 for interpretation purpose. When the maximum interaction order is set to be 1, the variables do not have interactions and thus the model is additive, as is in Equation 4.4; when the maximum interaction order is set to be 2, the model is pairwise interactive, as is in Equation 4.7. By allowing the variable candidates to interact at the maximum interaction order of 2, we can discover the joint forces of lagged currency returns and lagged stock market returns altogether affecting today's stock performance. During the forward step-wise part of the algorithm, a number of basis functions are added to the model. The optimal fit is when the smallest residual sum of squares are achieved. At this point, the model typically over-fits the the data, and thus in the following step, a backward procedure is implemented by removing those basis functions that can least improve the residual squared error. To measure the goodness of fit of the model, the Generalized Cross Validation (GCV) error is computed. The GCV takes the residual error and the size of the model into consideration.

The MARS_VAR model uses the MARS techniques and identifies a model with the same right hand side variables in both equations. It can uncover the interactive effects of pairs of lagged stock and currency returns on the current stock and currency market performance while taking into consideration of the possible two-way relationship between stock and currency markets.

CHAPTER 5

RESULTS

5.1 Vector Autoregression (VAR) model results

The results of Granger tests performed on each pair of currency-stock market time series (see Section 3.2) suggest that there are dynamics of two-way relationships between the currency and stock markets among the four countries. The Granger tests suggest that there exists a two-way relationship of the markets in Taiwan; a one-way mapping from currency to stock market in Singapore; a one-way feedback from stock market to currency market in Hong Kong. China does not show statistical significance in any of the mapping relations. To more accurately estimate the possible two-way relationship between stock market and currency returns, the VAR model is employed. The estimation results are presented in Table VI.

Similar to the findings by Nieh and Lee (2001), the VAR model results show a short-run relationship between the stock and currency returns for all four markets. Consistent with the Granger test results, for the Taiwan market, there exists a two-way mapping relationship between the currency and the stock market. 1-day and 2-day lagged currency returns positively affect the stock market returns. That is, the appreciation (depreciation) in New Taiwan dollar stimulates (hurts) Taiwanese stock market performance. On the other hand, 1-day and 2-day lagged stock market returns also positively affect the New Taiwan dollar value. For the Hong Kong market, there exists a one-way mapping relationship from the stock market to the currency market. 1-day lagged stock market returns positively affect the value of Hong Kong dollar. For the Chinese market, there does not exist any mapping relations. The stock market rallies do not cause the Chinese *yuan* to appreciate or depreciate in value. The value of the Chinese *yuan* is highly correlated with its past shocks. For the Singapore market, there exists a one-way mapping relationship from the currency market to the stock market but not the other way around. The 1-day and 2-day lagged Singapore dollar returns positively affect the stock market performance. The results of the VAR model estimations are presented in Table VI.

LHS variable	Lagged RHS variables	TAIWAN	HONG KONG	CHINA	SINGAPORE
FX (Currency)	FX t-1	-0.1196865***	-0.0350943**	-0.1678676***	-0.02
	FX t-2	-0.0404597**	-0.0565188***	-0.0659597***	-0.0340423*
	Stock t-1	**0.0152404*** **	**0.0013002*** **	0	0
	Stock t-2	**0.0099997*** **	0	0	0.01
Stock	FX t-1	0.3436048***	1.204429*	0.39	**0.3101254*** **
	FX t-2	0.2194042***	0.65	-0.15	**0.2672082*** **
	Stock t-1	-0.01	0	0.02	-0.033705*
	Stock t-2	-0.01	0.05559***	0.02	0.02

*Notation: ***: 5% of significance; **: 10% of significance; *: 15% of significance*
Interpretation:
Taiwan: Two-way relationship exist between stock & currency markets
Hong Kong: Stock market has a feedback relationship to currency
China: No relationship between stock and currency markets
Singapore: Currency affects Singapore market returns

TABLE VI

VECTOR AUTOREGRESSION (VAR)RESULTS

5.2 MARS_VAR model results

The linear VAR model was found to capture only the extremely short-run relationship between stock market returns and currency returns for three of the four markets. Much more information in the returns times series can further be explored with a MARS_VAR model.

In a simple model, a single stock market performance is affected by its own past returns and past local currency movements. We allow for 10 lagged daily returns of stock market and currency to enter the MARS_VAR model. That covers approximately two weeks of daily market data. The MARS_VAR model is a shrinkage technique, and therefore the lagged variables that cannot help reduce the residual sum of squares of the model will not enter the final estimation equation. Maximum number of knots is set to be 30 to allow for exploration of extreme conditions or anomalies of financial events, and maximum the interaction order is set to be 2.

Taiwan

The estimation reveals interesting findings. First of all, there exists a two-way relationship between Taiwan stock market and currency market. In addition, the past stock market returns and currency returns up to 8 days ago have significant influence on today's stock market performance. This is not found in a linear VAR model, which only finds a 2-day predicting power of the variables. Lagged TWD returns at t-1, t-2, t-6, and t-8 affect today's Taiwan stock market performance. On the other hand, lagged Taiwan stock market returns at t-2, t-4, t-5, t-6, t-7, and t-8 affect today's New Taiwan dollar value. In the first equation estimating lagged variable effects on Taiwan stock market, there is a condition (condition #22 in Table VIII) that can affect the stock market by -5560.1964 * (-0.0328 - l_tw_r{2})*[twd_r{2} (-0.005257)] when the stock market return 2 days ago is more severe than -3.28% and the New Taiwan dollar appreciates or depreciates less than -0.5257%. This condition yields the largest drop in the stock market. The same condition gives a negative effect on current Taiwan dollar value by -428.19 * (-0.0328 - l_tw_r{2})*[twd_r{2} (-0.005257)]. In addition, the more distant the variable values are from the threshold values, the higher impact the condition is. The MARS_VAR estimation result also shows that of the 2,345 observations, there are 52 observations that meet this condition. This condition can be used to generate trade signals for portfolio managers to stay away from the Taiwan stock market in order to avoid expected investment loss.

#	**Threshold/ Marginal Effect**	**on Stock Mkt**	**t**	**on FX Mkt**	**t**	**Non Zero**	**%**	**Importance**	**#**
2	TWD_R{ 8}>-0.008872048	0.19	0.48	7.14E-002	0.82	2315	99	12	2
3	TWD_R{ 8}<-0.008872048	4.33	4.29*	0.57	2.49*	19	0	36.4	3
4	L_TW_R{ 7}>-0.040189444	20.69	3.11*	3.89	2.58*	2285	97	37.7	4
	TWD_R{ 8}>-0.008872048								
5	L_TW_R{ 7}<-0.040189444	-285.97	-3.85*	-62.46	-3.72*	29	1	54.2	5
	TWD_R{ 8}>-0.008872048								
6	L_TW_R{ 2}>0.034746424	122.38	5.31*	2.98	0.57	24	1	8.3	6
	TWD_R{ 8}>-0.008872048								
7	L_TW_R{ 2}<0.034746424	-22.89	-3.58*	-4.09	-2.82*	2290	98	41.2	7
	TWD_R{ 8}>-0.008872048								
8	L_TW_R{ 6}>0.010482156	-355.26	-4.44*	103.41	5.72*	4	0	83.5	8
	TWD_R{ 8}<-0.008872048								
9	L_TW_R{ 6}<0.010482156	-65.46	-1.26	1.23	0.11	15	0	1.5	9
	TWD_R{ 8}<-0.008872048								
10	L_TW_R{ 8}>-0.034296765	-8.87	-3.89*	-1.16	-2.25*	2266	97	32.8	10
	TWD_R{ 8}>-0.008872048								
11	L_TW_R{ 8}<-0.034296765	-64.19	-3.24*	-0.65	-0.14	48	2	2.1	11
	TWD_R{ 8}>-0.008872048								
12	L_TW_R{ 2}>-0.032802379	-0.2	-3.34*	-2.74E-002	-2.02*	2275	97	29.5	12
13	L_TW_R{ 2}<-0.032802379	-4.56	-5.17*	-0.23	-1.15	59	2	16.9	13
14	L_TW_R{ 2}<-0.032802379	5792.9	4.06*	486.25	1.5	55	2	22	14
	TWD_R{ 2}>-0.005916256								

TABLE VII

MARS_VAR RESULTS ON TAIWAN

#	Threshold/ Marginal Effect	on Stock Mkt	t	on FX Mkt	t	Non Zero	%	Importance	#
15	L_TW_R{ 2}<-0.032802379	1857.56	3.02*	188.28	1.35	4	0	19.8	15
	TWD_R{ 2}<-0.005916256								
16	L_TW_R{ 2}<-0.032802379	437.57	3.8*	-22.45	-0.86	38	1	12.6	16
	TWD_R{ 1}>-0.000658111								
17	L_TW_R{ 2}<-0.032802379	58.03	0.3	-149.75	-3.37*	20	0	49.2	17
	TWD_R{ 1}<-0.000658111								
18	TWD_R{ 1}>-0.008872048	0.24	2.34*	-6.68E-002	-2.84*	2315	99	41.4	18
19	TWD_R{ 1}<-0.008872048	1.45	1.26	1.78	6.85*	19	0	100	19
20	TWD_R{ 1}>-0.008872048	-35.9	-1.77	-6	-1.31	275	11	19.1	20
	TWD_R{ 6}>0.002996506								
21	TWD_R{ 1}>-0.008872048	31.31	2.54*	-3.45	-1.23	2039	87	18	21
	TWD_R{ 6}<0.002996506								
22	L_TW_R{ 2}<-0.032802379	-5560.2	-3.82*	-482.19	-1.46	52	2	21.4	22
	TWD_R{ 2}>-0.005257473								
23	L_TW_R{ 7}>-0.045097302	-9.21E-002	-1.41	-2.82E-002	-1.92	2315	99	28	23
24	L_TW_R{ 7}<-0.045097302	2.24	2.67*	0.61	3.23*	19	0	47.2	24
25	L_TW_R{ 5}>0.000189697	-292.26	-3.06*	-125.56	-5.82*	13	0	85	25
	TWD_R{ 1}<-0.008872048								
26	L_TW_R{ 5}<0.000189697	-266.48	-2.26*	-64.19	-2.41*	6	0	35.2	26
	TWD_R{ 1}<-0.008872048								
27	L_TW_R{ 4}>-0.045097302	-1.33	-2.92*	-3.07E-002	-0.3	2297	98	4.3	27
	L_TW_R{ 7}>-0.045097302								
28	L_TW_R{ 4}<-0.045097302	-16.96	-2.7*	-1.74	-1.22	17	0	17.9	28
	L_TW_R{ 7}>-0.045097302								

TABLE VIII

MARS_VAR RESULTS ON TAIWAN (CONT'D)

Hong Kong

MARS_VAR estimation shows that lagged HKD returns at t-1, t-4, t-7, and t-10 affect today's Hong Kong stock market performance. On the other hand, lagged Hong Kong stock market returns at t-1, t-2, t-4, t-6, t-7, t-8, t-9, and t-10 affect today's Hong Kong dollar value, although it's only the stock market returns 1 day ago that has a statistically significant effect on HKD value. This makes intuitive sense since Hong Kong dollar is linked to the value of US dollar, the local stock market performance should not have a dominating influence on the exchange rate level.

On the risk management of Hong Kong stocks, if portfolio managers can be cautious about market conditions #20 and #21, they can potentially avoid extremely negative loss on their equity portfolios. Condition #20 is met when Hong Kong stock market 10 days ago returns higher than 1.98% and Hong Kong dollar value 7 days ago changes more than 0.0218%. When this condition is met, the stock market is expected to slide by -1655.0106 * (l_hk_r{10} - 1.98%) * (hkd_r7 - 0.0218%). The more frequently occurring condition is when Hong Kong stock market 10 days ago returns higher than 1.98% and Hong Kong dollar value 7 days ago changes less than 0.0218%, the stock market is expected to slide by -1281.0208 * (l_hk_r{10} - 1.98%) * (0.0218% - hkd_r{7}).

#	Threshold/ Marginal Effect	on Stock Mkt	t	on FX Mkt	t	Non Zero	%	Importance	#
2	L_HK_R{ 1}>-0.042314005	5.76E-002	2.84*	1.25E-003	2.07*	2315	99	54.7	2
3	L_HK_R{ 1}<-0.042314005	1.48	6.45*	2.02E-003	0.3	19	0	7.8	3
4	L_HK_R{ 1}<-0.042314005	-69989.08	-10.3*	18.72	0.92	6	0	2.4	4
	HKD_R{ 4}>0.0000898213								
5	L_HK_R{ 2}>0.037280598	1.21	9.91*	5.90E-003	1.62	25	1	42.9	5
6	L_HK_R{ 2}<0.037280598	-7.18E-002	-1.3	1.62E-003	0.99	2309	98	26.1	6
7	L_HK_R{ 2}<0.037280598	-0.15	-0.28	-9.07E-003	-0.56	2263	96	14.7	7
	L_HK_R{ 4}>-0.032305394								
8	L_HK_R{ 2}<0.037280598	-9.75	-5.02*	6.06E-002	1.04	45	1	27.6	8
	L_HK_R{ 4}<-0.032305394								
9	L_HK_R{ 2}>0.037280598	-11835.93	-4.4*	72.1	0.9	4	0	23.7	9
	HKD_R{ 10}>0.00028173								
10	L_HK_R{ 6}>0.03324703	0.43	3.74*	2.58E-003	0.75	35	1	19.8	10
11	L_HK_R{ 6}<0.03324703	7.38E-002	3.53*	1.20E-004	0.19	2299	98	5.1	11
12	L_HK_R{ 7}>0.037280598	-0.47	-3.55*	5.22E-004	0.13	25	1	3.5	12
13	L_HK_R{ 7}<0.037280598	-2.75E-002	-0.6	1.01E-003	0.74	2309	98	19.4	13
14	L_HK_R{ 1}<-0.042314005	61.72	3.79*	0.26	0.54	13	0	14.2	14
	L_HK_R{ 3}>-0.019179344								

TABLE IX

MARS_VAR RESULTS ON HONG KONG

#	Threshold/ Marginal Effect	on Stock Mkt	t	on FX Mkt	t	Non Zero	%	Importance	#
15	L_HK_R{ 1}<-0.042314005	-10.21	-1.19	8.17E-003	0.32	6	0	0.8	15
	L_HK_R{ 3}<-0.019179344								
16	L_HK_R{ 7}<0.037280598	0.89	1.74	-1.98E-002	-1.3	2291	98	34.4	16
	L_HK_R{ 9}>-0.042314005								
17	L_HK_R{ 7}<0.037280598	-11.16	-4.34*	-5.03E-003	-0.66	17	0	1.7	17
	L_HK_R{ 9}<-0.042314005								
18	L_HK_R{ 10}<0.019811346	-7.72E-002	-3.36*	-1.05E-004	-0.15	2199	94	4	18
19	L_HK_R{ 1}>-0.042314005	237.89	4.23*	-6.34	-3.79*	24	1	100	19
	HKD_R{ 1}>0.001197705								
20	L_HK_R{ 10}>0.019811346	-1655.01	-2.67*	26.87	1.45	20	0	38.4	20
	HKD_R{ 7}>0.000218236								
21	L_HK_R{ 10}>0.019811346	-1281.02	-5.71*	-23.8	-3.55*	115	4	93.9	21
	HKD_R{ 7}<0.000218236								
22	L_HK_R{ 2}<0.037280598	2.14	2.19*	-1.03E-002	-0.36	2291	98	9.4	22
	L_HK_R{ 7}>-0.042314005								
23	L_HK_R{ 2}<0.037280598	16.81	3.86*	-1.61E-002	-0.12	17	0	3.3	23
	L_HK_R{ 7}<-0.042314005								
24	L_HK_R{ 2}<0.037280598	23.04	4.14*	-7.71E-002	-0.46	23	1	12.2	24
	L_HK_R{ 8}>0.037280598								
25	L_HK_R{ 2}<0.037280598	-0.24	-0.47	-4.69E-003	-0.31	2285	97	8.2	25
	L_HK_R{ 8}<0.037280598								

TABLE X

MARS_VAR RESULTS ON HONG KONG (CONT'D)

China

Recall that the VAR estimation results (Table VI) show no statistically significant relation between China stock market and the Chinese *yuan* value. The MARS_VAR estimation results uncover a few interactive relations between the two variables. The most significant relations are China stock market returns 3 days ago interacting with Chinese *yuan* returns 9 days ago (condition #6) and China stock market returns 3 days ago interacting with Chinese *yuan* return 5 days ago (condition #5). In terms of lagged China stock market returns affecting the value of Chinese *yuan*, MARS_VAR estimation results show lagged China stock market returns at t-1, t-2, t-3, t-5, t-6, t-7, and t-9 all play a role in affecting the value of Chinese *yuan*. These lagged stock variables become active after the paired lagged currency variables are turned on by the conditions.

In terms of equity risk management in China, portfolio managers can avoid investing in China stock market if condition #27 is met. This condition becomes effective when l_cn_r{3} is lower than 5.94% and cny_r{6} is higher than -0.01609%. The stock market is expected to drop by 1207.4001 * (-0.0594 - l_cn_r{3}) * [cny_r{6} (-0.0001609)).

#	Threshold/ Marginal Effect	on Stock Mkt	t	on FX Mkt	t	Non Zero	%	Importance	#
2	L_CN_R{ 3}>-0.05940507	5.60E-002	2.03*	-4.43E-003	-2.61*	2315	99	86.5	2
3	L_CN_R{ 3}<-0.05940507	-11.24	-8.79*	1.28E-002	0.16	19	0	5.4	3
4	L_CN_R{ 3}<-0.05940507	3120.36	10.8*	12.92	0.73	10	0	24.1	4
	CNY_R{ 5}>0.000263304								
5	L_CN_R{ 3}<-0.05940507	12584.69	5.27*	-52.65	-0.36	9	0	11.9	5
	CNY_R{ 5}<0.000263304								
6	L_CN_R{ 3}<-0.05940507	-412.17	-8.86*	-5.3	-1.85	6	0	61.3	6
	L_CN_R{ 9}>0.011214964								
7	L_CN_R{ 1}>-0.05940507	6.73E-002	2.84*	-9.97E-005	-0.69	2315	99	2.3	7
8	L_CN_R{ 1}<-0.05940507	1.61	3.44*	1.90E-002	0.66	19	0	21.8	8
9	L_CN_R{ 3}>-0.05940507	-12.18	-2.08*	1.08	2.98*	2296	98	99	9
	CNY_R{ 9}>-0.003000978								
10	L_CN_R{ 3}>-0.05940507	-129.49	-4.8*	-5.64E-002	-0.34	18	0	1.1	10
	CNY_R{ 9}<-0.003000978								
11	L_CN_R{ 1}>-0.05940507	-4.29	-3.86*	-0.21	-3.01*	119	5	100	11
	L_CN_R{ 5}>0.028265122								
12	L_CN_R{ 1}>-0.05940507	0.13	0.38	4.84E-002	2.29*	2195	94	75.9	12
	L_CN_R{ 5}<0.028265122								
13	L_CN_R{ 7}>0.047241398	1.02	4.54*	3.89E-002	2.81*	25	1	93.3	13
14	L_CN_R{ 7}<0.047241398	-0.12	-3.63*	9.27E-004	0.47	2309	98	15.5	14

TABLE XI

MARS_VAR RESULTS ON CHINA

#	Threshold/ Marginal Effect	on Stock Mkt	t	on FX Mkt	t	Non Zero	%	Importance	#
15	L_CN_R{ 7}>0.047241398	-3.18	-1.21	-0.38	-2.35*	16	0	78	15
	L_CN_R{ 9}>-0.008262155								
16	L_CN_R{ 7}>0.047241398	-26.34	-5.28*	0.29	0.96	9	0	31.7	16
	L_CN_R{ 9}<-0.008262155								
17	L_CN_R{ 2}>-0.052602345	-0.29	-0.74	-1.06E-002	-0.45	2282	97	14.8	17
	L_CN_R{ 7}<0.047241398								
18	L_CN_R{ 2}<-0.052602345	-19.18	-6.41*	-0.12	-0.67	26	1	22.2	18
	L_CN_R{ 7}<0.047241398								
19	L_CN_R{ 1}<-0.05940507	-151.55	-4.17*	0.24	0.11	6	0	3.6	19
	L_CN_R{ 7}>0.011214964								
20	L_CN_R{ 1}<-0.05940507	13.74	1.31	0.23	0.35	13	0	11.7	20
	L_CN_R{ 7}<0.011214964								
21	L_CN_R{ 6}>0.028265122	2.62	2.83*	5.00E-002	0.88	123	5	29.1	21
	L_CN_R{ 7}<0.047241398								
22	L_CN_R{ 6}<0.028265122	2.19	5.52*	2.06E-002	0.84	2185	93	27.8	22
	L_CN_R{ 7}<0.047241398								
23	L_CN_R{ 1}>0.000078496	63.65	4.56*	-0.4	-0.47	11	0	15.6	23
	L_CN_R{ 3}<-0.05940507								
24	L_CN_R{ 1}<0.000078496	103.93	6.22*	-0.27	-0.26	8	0	8.6	24
	L_CN_R{ 3}<-0.05940507								
25	L_CN_R{ 3}<-0.05940507	138.34	8.96*	0.54	0.57	15	0	18.8	25
	L_CN_R{ 4}>-0.031239836								
26	L_CN_R{ 3}<-0.05940507	117.17	4.17*	0.13	0.75	4	0	2.5	26
	L_CN_R{ 4}<-0.031239836								
27	L_CN_R{ 3}<-0.05940507	-1207.4	-2.84*	23.53	0.9	11	0	29.8	27
	CNY_R{ 6}>-0.000160949								
28	L_CN_R{ 3}<-0.05940507	-649.31	-1.94	-17.83	-0.87	8	0	28.7	28
	CNY_R{ 6}<-0.000160949								

TABLE XII

MARS_VAR RESULTS ON CHINA (CONT'D)

Singapore

Like in Taiwan, the lagged currency and stock returns actively affect today's stock market performance and foreign exchange rate movement. There is a two-way relationship between stock and currency markets. Lagged Singapore dollar returns at t-1, t-2, t-5, t-6, t-8, and t-10 affect today's stock market performance; lagged Singapore stock market returns at t-1, t-2, t-4, t-6, t-7, t-8, and t-9 affect today's Singapore dollar movement. There is more than a 2-day predicting power in Singapore market and that is not uncovered by a linear VAR model.

To manage equity market risk, portfolio managers should be cautious about condition #4. This condition is met when the stock market return 9 days ago is lower than -3.773% and Singapore dollar 8 days ago appreciates more than 0.436%. When this market condition is met, the current stock market is expected to drop by -727.17363*(-0.03773 - l_sg_r9)*(sgd_r{8} - 0.00436). When the same condition is met, the current foreign exchange rate is also expected to drop by -47.461610*(-0.03773 - l_sg_r{9})*(sgd_r{8} - 0.00436).

#	**Threshold/ Marginal Effect**	**on Stock Mkt**	**t**	**on FX Mkt**	**t**	**Non Zero**	**%**	**Importance**	#
2	L_SG_R{ 9}>-0.037731343	7.92E-002	3.36*	-5.79E-004	-0.83	2315	99	1.8	2
3	L_SG_R{ 9}<-0.037731343	-0.32	-1.8	-0.24	-4.63*	19	0	100	3
4	L_SG_R{ 9}<-0.037731343	-727.17	-7.9*	-47.46	-1.74	3	0	37.7	4
	SGD_R{ 8}>0.004365953								
5	L_SG_R{ 9}<-0.037731343	9997.95	5.01*	-64.27	-0.11	3	0	2.4	5
	SGD_R{ 10}>0.004365953								
6	L_SG_R{ 2}>-0.037731343	-6.20E-002	-1.93	-1.15E-002	-1.21	2315	99	26.3	6
7	L_SG_R{ 2}<-0.037731343	-2.91	-7.11*	-0.14	-1.12	19	0	24.3	7
8	L_SG_R{ 2}>-0.037731343	1.25	2.38*	-0.11	-0.71	2209	94	15.3	8
	L_SG_R{ 4}>-0.021220277								
9	L_SG_R{ 2}>-0.037731343	6.69	4.49*	1.52	3.46*	105	4	74.9	9
	L_SG_R{ 4}<-0.021220277								
10	L_SG_R{ 2}<-0.037731343	62.75	3.97*	-0.13	-0.28	16	0	0.6	10
	L_SG_R{ 9}>-0.031585692								
11	L_SG_R{ 2}<-0.037731343	273.55	6.74*	30.15	2.51*	3	0	54.4	11
	L_SG_R{ 9}<-0.031585692								
12	L_SG_R{ 9}>-0.037731343	-11.4	-4.83*	0.3	0.43	1595	68	9.2	12
	SGD_R{ 1}<0.001579363								
13	L_SG_R{ 2}>-0.037731343	-0.7	-1.46	0.12	0.84	2298	98	18.1	13
	L_SG_R{ 6}>-0.037731343								
14	L_SG_R{ 2}>-0.037731343	14.97	7*	1.66	2.63*	16	0	56.8	14
	L_SG_R{ 6}<-0.037731343								

TABLE XIII

MARS_VAR RESULTS ON SINGAPORE

#	Threshold/ Marginal Effect	on Stock Mkt	t	on FX Mkt	t	Non Zero	%	Importance	#
15	L_SG_R{ 2}>-0.037731343	-16.99	-6.66*	-1.25	-1.65	53	2	35.8	15
	L_SG_R{ 7}<-0.028324334								
16	SGD_R{ 2}>-0.002667854	-0.19	-1.63	-9.09E-002	-2.58*	1945	83	55.9	16
17	SGD_R{ 2}<-0.002667854	-0.9	-4.91*	-9.40E-002	-1.74	389	16	37.6	17
18	SGD_R{ 2}>-0.002667854	30.91	1.34	-3.06	-0.45	1382	59	9.7	18
	SGD_R{ 6}>-0.001266179								
19	SGD_R{ 2}>-0.002667854	122.32	4.26*	16.63	1.96	562	24	42.4	19
	SGD_R{ 6}<-0.001266179								
20	L_SG_R{ 8}<-0.035511555	-17.44	-4.75*	-2.19	-2.02*	24	1	43.7	20
	L_SG_R{ 9}>-0.037731343								
21	L_SG_R{ 1}>-0.013869455	0.79	1.3	0.48	2.7*	2090	89	58.4	21
	L_SG_R{ 2}>-0.037731343								
22	L_SG_R{ 1}<-0.013869455	7.07	4.53*	1.44	3.12*	224	9	67.5	22
	L_SG_R{ 2}>-0.037731343								
23	L_SG_R{ 9}>-0.037731343	23.95	3.64*	2.67	1.37	131	5	29.7	23
	SGD_R{ 5}>0.004988498								
24	L_SG_R{ 9}>-0.037731343	-2.58	-1.29	-0.84	-1.42	2183	93	30.7	24
	SGD_R{ 5}<0.004988498								

TABLE XIV

MARS_VAR RESULTS ON SINGAPORE (CONT'D)

5.3 Trading strategy and portfolio performance

With the MARS estimation results, we can then formulate a stock trading strategy that can tactically avoid significant downside risk of the stock market. Based on the MARS_VAR estimation results presented in Section 5.2, the following simple equity trading strategy is implemented. The goal is to mitigate downside risks of the stock markets. Thus, when the most extreme and negative market conditions are met, i.e. the value of the basis function is nonzero, we consider the trade "warning" signals being generated, and investment capitals will be withdrawn from the corresponding stock market(s) to avoid anticipated investment loss from the stock market.

Suppose a stock portfolio initially invests in the four markets equally. That is, every market receives 25% of the initial portfolio value. When a trade signal in a market is generated, the portfolio manager withdraws all the money from the corresponding market and holds the proceeds in a cash account. When the trade signal clears on the next trading day, the portfolio manager invests the cash back to the market again. Trade signals can last more than one trading day, depending on the market conditions of lagged currency and lagged stock market returns. For simplicity, the interest rate is assumed to be 0% on the cash account.

The daily performance of this simulated portfolio is compared with a passively held benchmark portfolio that has equal exposure to the four markets throughout the simulation period, i.e., 3/18/2003 − 6/22/2012.

Table XV recaps the extreme market conditions. Table XVI demonstrates the trade signals being generated on selective trading days. Table XVII, Figure 14, and Figure 15 present the performance of simulated portfolio against the benchmark index.

The simulated portfolio has a lower overall return than the passive benchmark over the simulation period. On the daily returns distribution, the simulated portfolio appears to have higher daily returns on the left tail. For example, at 1 percentile of the distribution, the simulated portfolio's return is -2.95%, which is better than the benchmark's -4.07%; the lowest daily returns for the simulated portfolio and benchmark are -6.51% and -7.99%, respectively. However, at higher percentile of the distribution, the simulated portfolio's return obviously trails behind the benchmark. In terms of the portfolio risk, measured by standard deviation of daily returns, is also lower than the benchmark. The risk-adjusted return, measured by the ratio of return over risk, is higher for the simulated portfolio than the benchmark. From portfolio performance measurement's viewpoint, the higher risk-adjusted return of the portfolio has better performance as it achieves higher portfolio return by exposing to the same one unit of risk.

5.4 Out-of-sample portfolio performance

The next step is to perform out-of-the sample test. Based on the extreme criteria, threshold values and coefficients analyzed in previous sections, we test how well the portfolios trade under these extreme conditions. Table XVIII lists the average daily returns and risk profile of the four simulated market portfolios over the June 25, 2012 Aug 2, 2013 period. There are 290 daily observations, following the in-sample data period analyzed in Chapters 3 and 5.2-5.3. The

Taiwan (TW)	l_tw_r(2)	<	-0.03
And	twd_r(2)	>	-0.01
Hong Kong (HK1)	l_hk_r(10)	>	0.02
And	hkd_r(7)	>	0
(HK2)	l_hk_r(10)	>	0.02
And	hkd_r(7)	<	0
China (CN1)	l_cn_r(3)	<	-0.06
And	l_cn_r(9)	<	0.01
(CN2)	l_cn_r(3)	<	-0.06
And	cny_r(6)	>	0
Singapore (SG)	l_sg_r(9)	<	-0.04
And	sgd_r(8)	>	0

TABLE XV

EXTREME MARKET CONDITIONS AND THRESHOLD VALUES

result shows that the MARS_VAR model works extremely well on the Chinese stock market because many extreme conditions are met and those extreme daily losses are avoided because of the trade warning signals. Out of the 290 ex-ante trading days, there are 19 days being forecasted to meet the extreme condition criteria. Thus, on those trading days, capitals are withdrawn from China's stock market. The simulated Chinese stock portfolio returns 0.0345% daily on average whereas the long-only Chinese market benchmark returns only 0.0293% daily on average over the simulation period. On the risk profile, the standard deviation of daily returns for the simulated Chinese stock portfolio is 1.06%, which is lower than that of the benchmark at 1.11%. Figure 19 shows the daily returns on the simulated Chinese portfolio as well as the difference between simulated and actual portfolio returns.

Date	**TW**	**HK1**	**HK2**	**CN1**	**CN2**	**SG**
03/19/03	1	0	1	0	1	0
03/20/03	1	0	1	1	1	0
03/21/03	1	0	1	0	1	0
03/24/03	1	0	1	0	1	0
03/25/03	1	0	1	1	1	0
03/26/03	1	0	1	0	1	0
03/27/03	1	0	1	2	1	0
03/28/03	1	0	1	1	1	0
03/31/03	1	0	1	1	1	0
04/01/03	1	0	1	1	1	0
04/02/03	2	1	2	0	1	0
04/03/03	1	0	1	1	1	0
04/04/03	1	0	1	1	1	0
04/07/03	1	0	1	0	1	0
04/08/03	1	0	1	1	1	0
04/09/03	1	0	1	0	1	0
04/10/03	1	0	1	0	1	1
04/11/03	1	0	1	1	1	1
04/14/03	1	0	1	1	1	0
04/15/03	1	0	1	2	1	0
04/16/03	1	0	1	0	1	0
04/17/03	1	0	1	2	1	0
04/18/03	1	1	2	1	1	0

TABLE XVI

DEMONSTRATION OF GENERATED TRADE SIGNALS WHEN MARKET CONDITIONS ARE MET (VALUE=2)

Portfolio	**Obs**	**Mean**	**Std. Dev.**	**Min**	**Max**
Actual TW	2335	0.02%	1.43%	-6.94%	6.50%
Simulated TW	2335	0.01%	**1.38%**	-6.94%	6.50%
Actual HK	2335	0.03%	1.41%	-12.56%	10.44%
Simulated HK	2335	**0.03%**	**1.31%**	-12.56%	8.79%
Actual CN	2335	0.05%	1.92%	-12.84%	14.04%
Simulated CN	2335	0.04%	**1.72%**	-11.25%	10.51%
Actual SG	2335	0.03%	1.29%	-9.85%	6.94%
Simulated SG	2335	**0.03%**	**1.27%**	-7.68%	6.94%

TABLE XVII

DESCRIPTIVE STATISTICS OF SIMULATED PORTFOLIO RETURNS (3/18/2003 – 6/22/2012)

The simulated portfolio in Hong Kong returns are in line with its market benchmark. In Taiwan and Singapore, none of the trading days fall into the extreme conditions. This means that the capitals are never withdrawn from the market, so that the portfolio can fully participate in the up-trending market performance. The extreme condition for the Hong Kong market is met 5 times but because of the actual daily returns over this period are less severe than they are predicted, the simulated portfolio's overall return is still in line with the benchmark. On the portfolio risk front, the withdrawal of the funds on those 5 days helps lower Hong Kong portfolio's overall risk, as measured by standard deviation of daily stock returns.

Portfolio	Obs	Mean	Std. Dev.	Min	Max
Actual TW	290	0.04%	0.87%	-2.41%	3.25%
Simulated TW	290	0.04%	0.87%	-2.41%	3.25%
Actual HK	290	0.07%	0.88%	-2.91%	3.21%
Simulated HK	290	0.07%	**0.87%**	-2.91%	3.21%
Actual CN	290	0.03%	1.11%	-3.19%	3.33%
Simulated CN	290	**0.03%**	**1.06%**	-3.19%	3.33%
Actual SG	290	0.05%	0.65%	-2.72%	2.36%
Simulated SG	290	0.05%	0.65%	-2.72%	2.36%

TABLE XVIII

DESCRIPTIVE STATISTICS OF SIMULATED PORTFOLIOS (6/25/2012 − 8/2/2013)

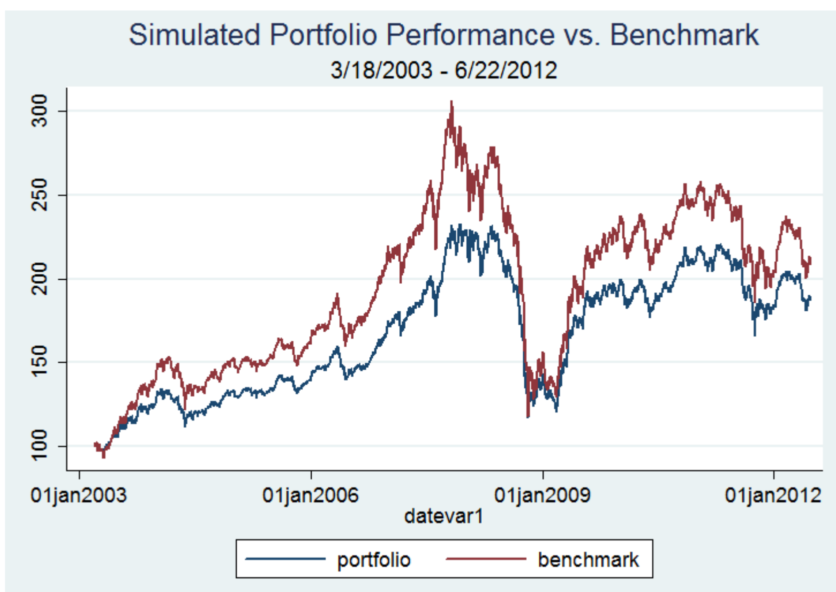

Figure 14. Simulated portfolio performance vs. benchmark 3/18/2003 − 6/22/2012

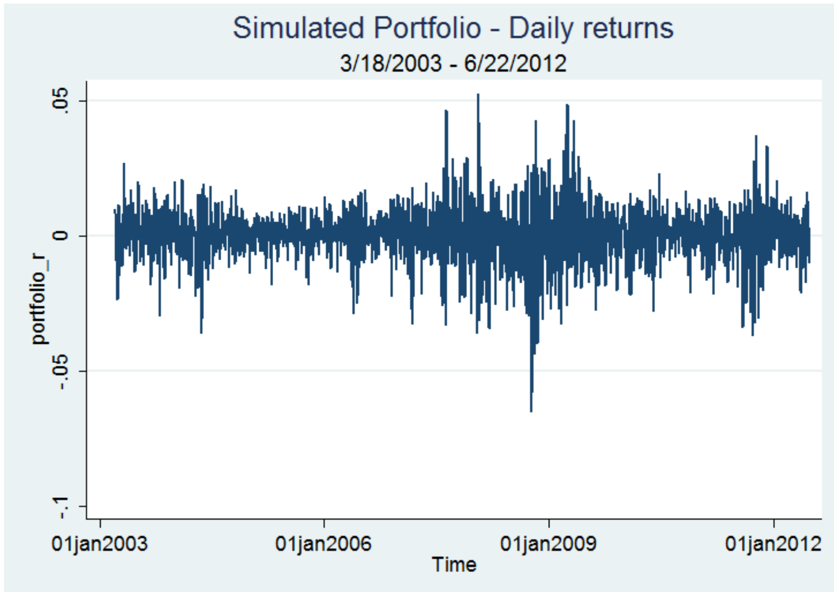

Figure 15. Simulated portfolio – daily returns 3/18/2003 – 6/22/2012

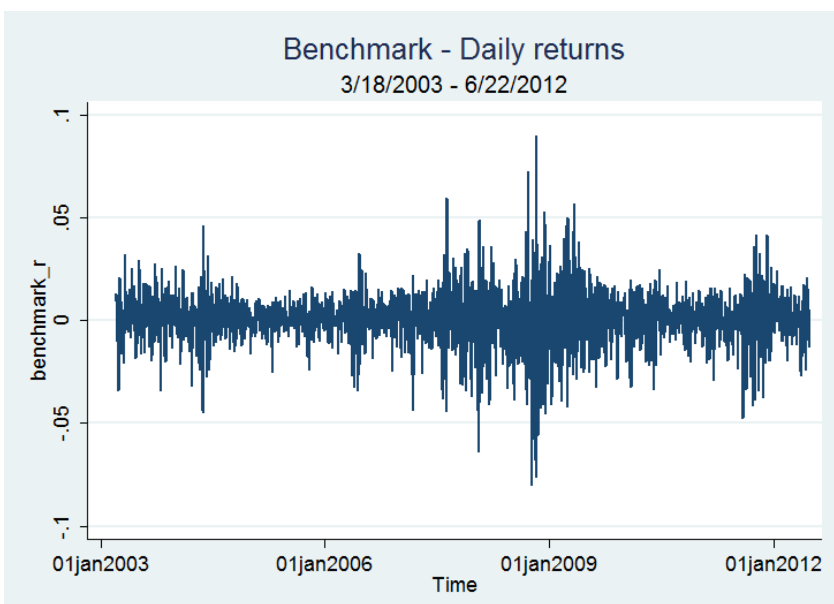

Figure 16. Benchmark – daily returns 3/18/2003 – 6/22/2012

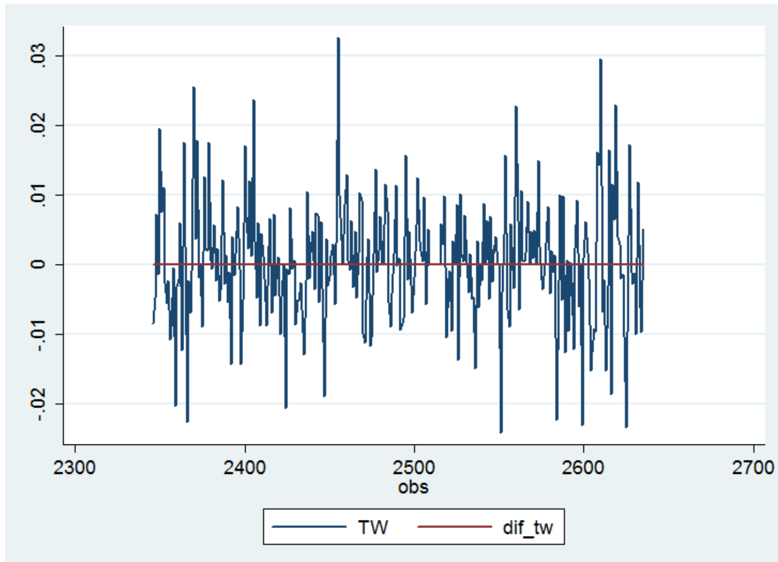

Figure 17. Out-of-sample performance of Taiwan 6/25/2012 − 8/2/2013

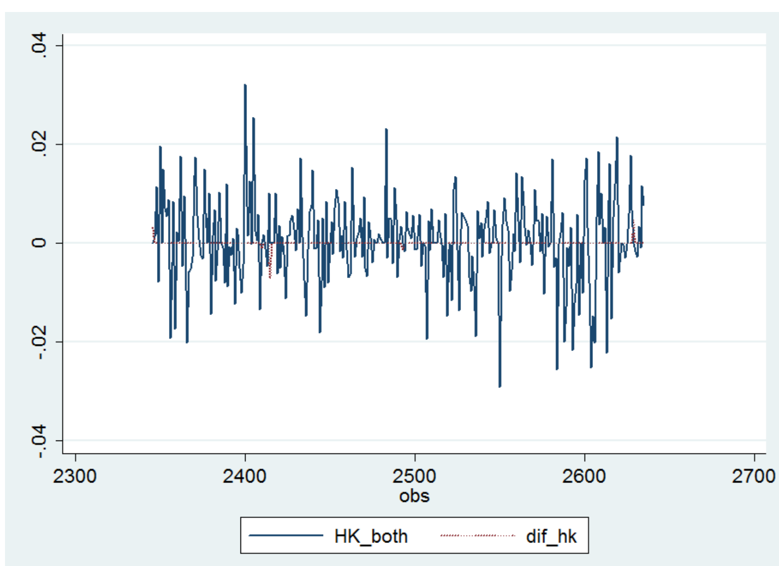

Figure 18. Out-of-sample performance of Hong Kong 6/25/2012 − 8/2/2013

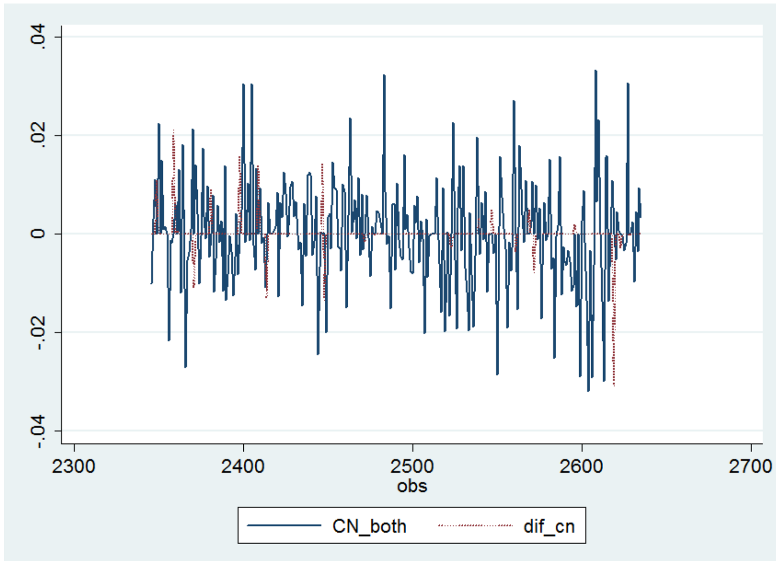

Figure 19. Out-of-sample performance of China 6/25/2012 − 8/2/2013

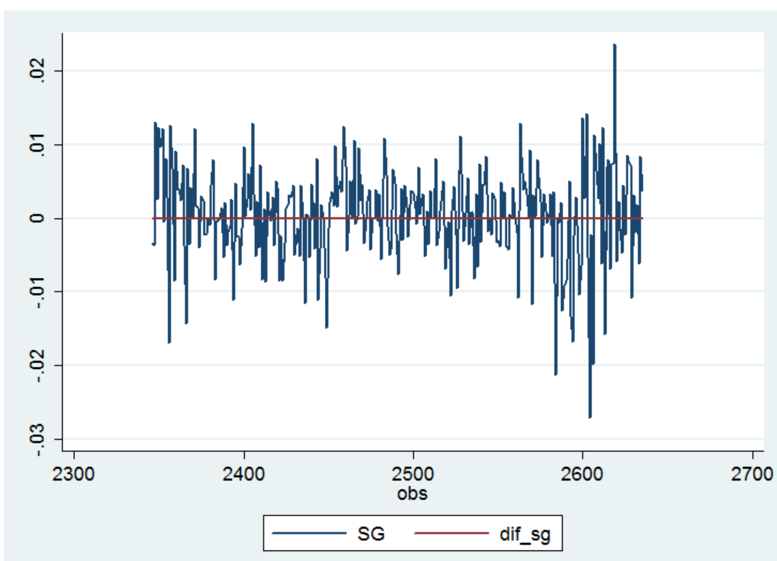

Figure 20. Out-of-sample performance of Singapore 6/25/2012 − 8/2/2013

CHAPTER 6

CONCLUSION AND FUTURE WORKS

The linear model VAR reveals very little information about the relationship between currency and stock markets. Consistent with the findings of previous researchers, there is a short-run, at most two-day predicting power between the two markets. Also consistent with existing research findings, the direction of the mapping relation varies by different countries. For China, there exists no apparent relation between the markets. For Singapore, there exists a one-way mapping relation from the currency market to the stock market. For Hong Kong, the one-way mapping relation is from the stock market to the currency. For Taiwan, there exists a two-way mapping relation with 2-day predicting power.

To extend previous work, this study employs a nonlinear model MARS_VAR to explore more about the relationship between the two markets. The results are exciting. We find that not only the currency returns have longer-run effects on the stock markets, but interactive effects of the lagged stock returns and lagged currency returns are detected. The lagged variables become effective when they exceed a threshold value. When certain extreme market conditions are met, the model can predict the current stock market to fall.

The findings of this study have significant meanings in risk management of financial assets. Specifically, the threshold values estimated by the MARS model reveal certain conditions at which the stock market can react to past information more drastically and experience extremely negative loss. Fortunately, portfolio managers can utilize these estimated threshold values and extreme conditions to manage downside risk of their actively managed portfolios. As shown in Chapter 5.2, when the extremely negative market conditions are met, capital is withdrawn from the corresponding market withdrawn to avoid expected portfolio loss. This trading strategy can be implemented on a single-market portfolio or a multiple-market portfolio.

The investment industry has long believed that there is excellent diversification benefit between stock market and the currency market because of their low contemporaneous relation. This study reveals that while contemporaneous correlation is low between the two markets, their relation is underestimated since lagged stock and currency returns can still affect the current performance of the stock market in an interactive and nonlinear way.

This study only discusses the relationship between a single equity market being affected by its own lagged returns and single currency's lagged returns. As financial markets are more integrated, it is possible for a single stock market being influenced by multiple currencies. In fact, the International CAPM (ICAPM) proposed by Solnik (1974) and Sercu (1980) does consider the effects of multiple foreign exchange risk premia with the contemporaneous influence of the world equity market excess returns is accounted for. Nevertheless, the empirical work suffers from severe multicollinearity problems. Vassalou (2000) attempts to remedy the econometric problem by constructing a common component index and a residual exchange rate index. The new problem is that researchers can see only a composite currency risk premium instead of a particular currency's. Using the MARS_VAR model to estimate lagged currency effects with multiple currencies should help solve the multicollinearity problems as MARS is a variable reduction technique. MARS threshold modeling also provides the advantage of seeing variables interacting. This can be an interesting expansion of existing work on International Asset Pricing.

Another limitation of this study is that the trading strategy mentioned in Chapter 5.2 does not measure the exact distance of current market condition to the threshold value of the extreme market condition. The marginal effect of the extreme market condition gets larger when the threshold value is further exceeded. The magnitude of the marginal effect can be scored on a scale such that capital withdrawal from the affected market is done based on the degree of urgency. This may help minimize excessive cash drag in the investment account. With a more complex MARS_VAR model and sophisticated stock trading strategies in place, the portfolio risk management can be improved accordingly.

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