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Non-linearities, Regime Switching and the Relationship between Asian Equity and Foreign Exchange Markets[¶]

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Non-linearities, Regime Switching and the Relationship between Asian Equity and Foreign Exchange Markets

Abstract

This paper explores the possibility of a non-linear relationship between Asian equity and foreign exchange markets. The non-linearity is modeled using a regime-switching Markov model. We find evidence of non-linearities where the effect of changes in the exchange rate on stock market returns is regime-dependent except for Hong Kong whose strong currency peg contributes into the segmentation of its stock and foreign exchange markets. Using a quadratic approximation, we find only limited evidence of non-linearities within each regime. The results lend little support to the proposition that moderate depreciations are associated with increases in stock returns while large ones, short of a currency crash, have negative effects on equity markets.

JEL Codes: E0, G0, G1

1. INTRODUCTION

For many countries, the actual benefits of currency depreciation are less impressive than what conventional wisdom predicts in terms of boosting export competitiveness to raising aggregate economic output. Though the views differ as to whether, how and to what extent it might be desirable to promote competitive depreciation to suit domestic economic interests, large depreciations have also the potential to increase credit risk and the burden of debt denominated in foreign currencies. They may constitute also the catalyst for adverse deflationary effects on output. The perception that hard exchange rate pegs and *de jure* or *de facto* pegs of managed floats are untenable also increases the potential for significant depreciations, which ultimately affect market sentiment. Downward pressures on exchange rates and downturns in market sentiment can be mutually reinforcing and result in higher uncovered exchange rate exposure and financial disruption.

Even if pegging does not provide strong incentives for the development and

use of hedging instruments, there are stronger reasons for economic agents to recognize the importance of foreign exchange exposure under flexible exchange rate arrangements. Large exchange rate fluctuations in an environment of increased international capital mobility affect the level of inflation predictability and the pricing of financial assets. Unexpected fluctuations in inflation targets and expectations can exert downward pressures on financial market valuation as drifts from the purchasing power parity rates have the potential to generate increased uncertainty on firms' cash flows and affect their market value.

Broadly defined, exposure to foreign exchange risk measures the sensitivity of the firm value, or the present value of expected future cash flows, to currency gyrations. The economic theory often assumes that export-oriented firms exhibit positive foreign exchange exposure to currency depreciation, which is likely to increase profit margins by lowering input costs. The negative exposure of import-oriented firms to depreciation has the potential to decrease stock prices and increase the required risk premium. The effect is asymmetric with respect to import-oriented firms but even purely domestic firms may still suffer from currency depreciation because of sustainable falls in aggregate domestic demand. The aggregate impact of exchange rate variations on stock market valuation is ultimately function of the trade imbalance within the economy.

The present study is an attempt to demonstrate empirically that the relationship between foreign exchange and stock returns is not necessarily linear. The testing methodology considers two non-exclusive forms of non-linearity. First, regime-dependency is accounted for through the estimation of regime switching Markov models of equity returns. While allowing for state-dependency, we examine also the significance of quadratic effects as an alternative form of non-linearity. This constitutes

an econometric test of the hypothesis that a small depreciation is beneficial to the economy but large ones can be detrimental. A large devaluation may generate major disruption of economic activity and affect adversely investment opportunity sets and the functioning of the financial system. It may ultimately alter the sign of this relationship. The existence of a critical level at which the nature of economic structure and firm exposure change has been also recognized by Booth (1996) who developed an economic model of non-linear exposure to exchange rate variations. Simulation results demonstrate that outside some boundary levels of exchange rate, the profit payoff function shows an asymmetric behavior. The critical levels correspond to trigger points at which government intervention and hedging with asymmetric payoff currency options become more likely or warranted.¹

Whereas the literature on non-linearity in nominal and real exchange rates is growing rapidly, with the exception of Schaller and van-Norden (1997), Ramchand and Susmel (1998) and Ang and Bekaert (1999) and others, there is scarce evidence on stock returns. There is even lesser evidence on the relation of stock return with exchange rate fluctuations.² The present study is an attempt to bridge this gap in the literature on regime-switching Markov model applications to stock returns. Moreover, we aim to improve the limited understanding of the dynamics of the linkage between

¹ Trigger points can be assimilated to a threshold beyond which the effect is either exacerbated or reversed in sign. Evidence of threshold effect as in Galbraith and Tkacz (2000) examination of the link between the yield spread and aggregate output is evidence of a form of asymmetry that allows for piecewise linear approximation. Among the rare attempts to model stock returns' non-linear exposure to exchange rate changes, Di Iorio and Faff (2000) investigate the asymmetry hypothesis in the Australian stock market and find evidence of asymmetry using daily rather than monthly observations.

² Greater interest as in the studies by Turner, Startz and Nelson (1989), and more recently by Paudyal and Saldanha (1997), Dueker (1997) and Shawky and Marathe (1995) has been directed to regime switches in stock market volatility.

equity and currency markets. We jointly examine the degree and significance of stock return sensitivity to currency movements and its non-linear dependence on regime shifts. Using data on Asian financial markets, we also provide evidence on the properties of equity market responses to the Asian currency crisis. These issues are of importance to international portfolio management, risk hedging, market regulation and monetary policy.

The remainder of the paper is organized as follows. The following section reviews recent relevant literature. The third section presents the theoretical foundations of regime-switching Markov models. Section 4 discusses the empirical evidence on the dynamics of the exchange risk exposure. Section 5 concludes the paper.

2. RECENT LITERATURE

There is an extant literature on the relationship between stock market returns and changes in exchange rates which centers on the issue of whether foreign exchange risk is priced in equity markets. Choi (1986) proposed a model of firm valuation with exchange exposure in which foreign exchange risk translates into inflation risk.³ Roll (1992) offers a more recent comparative study of international stock market indices indicating that equity markets are indeed influenced by changes in exchange rates. Dumas and Solnik (1995) present evidence that deviations from purchasing power parity are reflected in the equity premium according to the conditional international capital asset pricing model (ICAPM). Choi, Hiraki and Takezawa (1998) and Doukas, Hall and Lang (1999) provide supportive evidence on the significance of the exchange

³ Foreign inflation risk, especially US inflation risk is found by Vassalou (2000) to be like currency risk, significant in the explanation of equity premium in international capital markets, a result that has important implications for the pricing and hedging of currency risk.

risk premium from the estimation of a multi-factor asset-pricing model using individual Japanese stock returns (rather than stock index data).

The non-stationarity of risk premia, which applies with greater force to exchange rates is explored by De Santis and Gerard (1998) who estimate the conditional version of the ICAPM using a parsimonious autoregressive conditional heteroskedasticity (ARCH) model allowing for both the conditional second moments and risk premiums to vary over time. There is evidence that the significant time-varying premium for foreign exchange risk has the potential of constraining the total equity premium to negative values. Accounting for non-stationarity however is no substitute for non-linearity. For not accounting for higher moments, the theoretical determination of foreign exchange risk premium according to the traditional mean-variance asset pricing or multi-factor models remains restrictive. Generally, the existence of securities with non-linear payoff structures imposes stricter restrictions on the joint probability distribution of security returns. The non-linearity of nominal exchange rates can be a significant determinant of the non-linearity of securities' payoff structures, and hence the non-linearity of the return generating process.

The evidence also suggests that the speed of mean reversion toward monetary equilibrium depends on the size of the deviation, which implies that the adjustment process may itself be non-linear. The non-linear dynamics of exchange rates and their economic implications can explain the asymmetric properties of firms' exposure to currency risk. Considering the observed tendency for financial prices to exhibit abrupt jumps and long-memory properties and for fluctuations to cluster into periodic or aperiodic volatility cycles, the dynamics of financial variables can hardly be understood within a linear framework. The non-linear modeling may necessitate at the theoretical

level a relaxation of the traditional paradigm's palatable assumptions of constant risk aversion and revisiting the hypotheses of rational and homogeneous expectations.⁴ The non-linear stochastic approach may also be justified by a non-uniform flow of information and the heterogeneous beliefs of market participants.

The above evidence indicates that modeling the relationship between stock returns and changes in the exchange rate using simple regression analysis is not likely to measure accurately foreign exchange exposure especially when there are shifts in the market structure. Discontinuous shifts in return variability may be due to systematic or unsystematic changes in business and financial risk accompanying currency fluctuations. The evidence warrants a fundamental analysis of currency risk exposure with alternative tests to non-linearity that include regime-switching Markov models. Regime-switching models are useful because they can better describe persistent stock market volatility by allowing returns to follow a mixture of normal distributions, which offers in turn plausible explanations of fat tails. A further justification is that the behavior of equity and currency markets may depend on distinct volatility regimes. This is of particular interest given the empirical regularity that volatility increases with bearish markets and decreases with bullish markets. If the nominal exchange rate can itself be described as a regime-dependent process, the implication is that a higher risk premium is required when stock investors recognize an increased likelihood of regime switching to higher exchange rate volatility.

The growing literature on non-linear economic and financial modeling

⁴ The divergence in investors' beliefs and expectations have given rise to competing behavioural theories of financial markets and models of "rational bubbles."

benefited from the development of various econometric techniques, which accommodate for stochastic parameters and for changes in market structure and variations in market response to information arrival.⁵ Recent applications in macroeconomics include studies by Raymond and Rich (1997) and Stanca (1999) of business cycle fluctuations. The regime switching methodology is also used in studies of exchange rate bubbles by van-Norden (1996) interest rates by Gray (1996), Ang and Bekaert (1998) and Dahlquist and Gray (2000). As with the speed of adjustment in short-term interest rate which is shown to be function of the size of deviation from the long-run mean, the speed of mean reversion towards exchange rate equilibrium is also shown by Taylor and Peel (2000) to depend on the size of the overvaluation or undervaluation.

3. MODELING NON-LINEAR EXPOSURE WITH MARKOV REGIME-SWITCHES

The economic exposure h_t of a firm to foreign exchange risk at time t can be defined as the sensitivity of its future expected cash flow c denominated in domestic currency to changes in the forward exchange rate z expressed in units of the domestic currency per unit of foreign currency.

$$h_t = E \left[\sum_t \frac{(\partial c_{t+t} / \partial z_{t+t})}{(1+p)^t} \right] \quad (1)$$

The marginal cash flow streams are discounted at the rate p representing the appropriate

⁵ This literature includes non-parametric nonlinear Granger causality tests and nonlinear cointegration tests as in Ma and Kanas (2000) and Yadav, Paudyal and Pope (1996). Most studies are concerned with the long-run relationship between exchange rates and economic fundamentals or with stock market integration. The relationship between the stock market and foreign exchange returns remains relatively unexplored.

foreign currency yield to maturity.⁶ The empirical examination of foreign exchange exposure has traditionally followed the methodology applied among others, by Friberg and Nydahl (1999), where logarithmic stock returns r_t are regressed on exchange rate returns z_t .

$$r_t = \mathbf{b}_0 + \mathbf{b}_1 z_t + \mathbf{e}_t \quad (2)$$

where $\mathbf{e}_t \sim N(0, \mathbf{S}_e^2)$ is a white noise disturbance term.⁷

The regression models assume that the exposure coefficient $\mathbf{b}$ is stable over time and the information structure is linear. The regression slope may also reflect the fact that both equity and currency rates are subject to the same shocks.⁸ If exchange rate movements reflect changes in the economic structure at particular points in time, two regression parameters should be estimated for each regime shift. The transition points are usually unknown *ex ante* and should be estimated. If the error variances can be assumed to be constant across regimes or alternatively, using maximum likelihood techniques, this estimation can be made by performing pairs of regressions for both regimes at different transition points and selecting on the basis of the lowest total sum of squared residuals. The two-state switching-regimes approach is used in the present study to examine the linkage between currency and stock markets.

A regime-switching Markov model can be viewed as a non-linear extension of

⁶ Ma and Kao (1990) consider also transactions exposure, which arises from delays in foreign currency payments and receipts. Translation exposure meanwhile measures the effect of exchange rate variations on financial statements. Economic exposure reflects the impact on the value of the entire business and the market value of the firm.

⁷ This regression testing approach was similarly adopted in studies by Bartov and Bodnar (1994), *inter alia*.

⁸ The argument applies with greater force to returns on stock indices. The sign of the coefficient estimate that reflects the net effect of changes in exchange rates depends on the relative importance of export and import-oriented firms in the stock index composition. Changes in the exchange rate can be favourable for some stocks and detrimental to others.

an autoregressive moving average (ARMA) process. The present study focuses on a simple two-case first-order Markov process for latent states of the relationship between stock market and exchange rate returns. This relation alternates between the two states according to discrete switches, which result from changes in the unobservable Markov chain state variable s_t . This variable takes the values 1 or 2 referring to periods of bull or bear markets, periods of increasing or diminishing returns or periods of high or low return levels.

When stock returns can be assumed to follow a stationary stochastic process in the absence of foreign exchange risk, they can be characterized by an autoregressive model (AR) or order k as

$$r_t = \mathbf{h}(s_t) + \sum_k \mathbf{j}_k(s_t) r_{t-k} + e_t \quad (3)$$

where the error terms $e_t \sim i.i.d. N(0, \mathbf{s}_e^2)$. In accounting for foreign exchange exposure, the AR model can be extended to express stock returns in terms of both lagged equity and lagged foreign exchange returns with each observation being drawn from a distribution that changes depending on the prevailing regime. The Markov regime-switching approach allows for long-run mean reversion and for stochastic regime-dependent trends in the pricing of foreign exchange risk. Each regime can be characterized by the magnitude and significance of the regression coefficients in the mean equation.

$$r_t = \mathbf{h}(s_t) + \sum_k \mathbf{j}_k(s_t) r_{t-k} + \sum_m \mathbf{z}_m(s_t) z_{t-m} + \mathbf{x}_t \quad (4)$$

where the error terms $\mathbf{x}_t \sim i.i.d. N(0, \mathbf{s}_x^2)$. The *ex ante* transition probability p_{ij} that state i will be followed by state j depends on the available information set Ω , the

transition probability matrix $\mathfrak{S}$ being

$$\mathfrak{S} = \begin{bmatrix} p_{11} & 1 - p_{11} \\ 1 - p_{22} & p_{22} \end{bmatrix} \quad (5)$$

where p_{11} and p_{22} are the probabilities that the return process remains in the same regime 1 and 2, respectively. The dynamics of the switches between the two regimes depend on the conditional transition probabilities. An observation belongs to a given state if the conditional probability of the regime is higher than 0.5.

$$p_{ij} = \Pr(s_t = j \mid s_{t-1} = i; \Omega_{t-1}), \text{ for } i = 1, 2 \text{ and } j = 1, 2 \quad (6)$$

Since the ultimate objective of this study is to examine the relation of stock returns with exchange rates, the distribution of equity returns in the regime-switching models is allowed to depend on both the regime state s and the observed returns on exchange rates z . The present analysis makes no explicit assumption however on exchange rates following a Markov regime-switching process. Currency returns are included in this setting as a potential influence on the stochastic process of equity returns. Consequently, the cumulative density function $\Psi(\cdot)$ will be conditioned not only on the state variable s but on z as well. The conditional distribution of stock returns is expressed as

$$\Psi(r_t \mid s_t, \Omega_{t-1}) = \frac{1}{\sqrt{2\pi\mathbf{s}_x}} \exp \left\{ -\frac{[r_t - \mathbf{h}(s_t) - \mathbf{j}(s_t)r_{t-1} - \mathbf{z}(s_t)z_{t-1}]^2}{2\mathbf{s}_x^2} \right\} \quad (7)$$

Given the cumulative density function $\Psi(\cdot)$ in equation (7) and the transition matrix, the transition probabilities can be determined. The values $p_{11} = \mathbf{w}_1 + \mathbf{J}_1 z_{t-1}$ and $p_{22} = \mathbf{w}_2 + \mathbf{J}_2 z_{t-1}$ represent the respective probabilities that regime 1 and 2 will occur next period given that the same regime is prevailing this period. If $\mathbf{J}_1$ (or $\mathbf{J}_2$) is equal to

zero, then p_{11} (or p_{22}) is a fixed value and the average duration of regime 1 (or regime 2) can be calculated as $(1 - p_{11})^{-1}$ (or $(1 - p_{22})^{-1}$). Using the standard normal distribution, $\mathbf{w}_1$ (or $\mathbf{w}_2$) can be converted into the probability p_{11} (or p_{22}). If $\mathbf{J}_1$ (or $\mathbf{J}_2$) is not equal to zero, then the probability value p_{11} (or p_{22}) is stochastic and dependent on lagged foreign exchange returns.

Under the restrictions that probabilities add to unity $\sum_i p_{ij} = 1$, for $i=1,2$ and $\sum_j p_{ij} = 1$, for $j=1, 2$ only the regime probabilities p_{11} and p_{22} can be out of the four probabilities, identified independently; the switching probabilities p_{12} and p_{21} being determined by derivation from the above restrictions.

$$\Pr(s_t = 1 | \Omega_{t-1}) = p_{11} \Pr(s_{t-1} = 1 | \Omega_{t-1}) + (1 - p_{22}) \Pr(s_{t-1} = 2 | \Omega_{t-1}) \quad (8)$$

The transition probabilities can also be specified as nonlinear functions of the independent variables. In the case of first-order Markov regime-switching estimation of a quadratic relationship between equity and currency returns within each regime, the mean equation for regime s can be written as⁹

$$r_t = \mathbf{h}(s_t) + \mathbf{j}(s_t)r_{t-1} + \mathbf{z}(s_t)z_{t-1} + \mathbf{l}(s_t)z_{t-1}^2 + \mathbf{u}_t \quad (9)$$

where $\mathbf{u}_t$ represents identically and normally distributed error terms. The turning points in the relationship between stock and exchange rate returns specified in equation (9) are calculated as $-\mathbf{z}_1/(2\mathbf{l}_1)$ and $-\mathbf{z}_2/(2\mathbf{l}_2)$ in regimes 1 and 2, respectively. The conventional wisdom is that small depreciations of the domestic currency may be beneficial to the domestic stock market but large ones may be detrimental. If this

⁹ It is noted that dropping the assumption of linearity leaves an infinite number of asymmetric and non-linear models of financial time series. Fitting a quadratic form is like any other form, an arbitrary approach to non-linearity testing.

proposition of counterproductive quadratic depreciations is true, then the coefficients may be expected to show the signs $z_1 > 0$ with $I_1 < 0$ in regime 1 and/or $z_2 > 0$ with $I_2 < 0$ in regime 2. Since we make no assumption that if large depreciations have detrimental effects in one regime, they necessarily produce the same impact in the other, it is allowed for the empirical evidence in support of this proposition to be regime-dependent.

4. EMPIRICAL EVIDENCE

4.1. Data and Preliminary Tests

For the purposes of the empirical estimation, a sample of daily observations was drawn from Datastream database on stock price index and nominal spot exchange rates against the US dollar for a selection of Asian countries including Thailand, Indonesia, Philippines, Malaysia, Singapore, Korea and Hong Kong. An important aspect of the sample is its composition of countries that are believed to be strong competitors to one another. This implies that the beggar-my-neighbour competitive depreciation of a given currency may have systematic effects on the competitiveness of other economies. The “beggar-my-neighbour depreciation” feature of the sample is important for a better assessment of the asymmetric effects of currency changes, in particular devaluation on stock returns.

The foreign exchange rates are bid-ask average rates on London Foreign Exchange and money market at 5 p.m. using the UK pound as base currency. Prior to the currency crisis in late 1997, a multiple currency basket peg system was adopted by Thailand whereas a managed float system characterised the exchange regime prevailing in Indonesia, Philippines, Malaysia and Singapore. While Malaysian authorities fixed

the exchange rate of the ringgit against the U.S. dollar in September 1998, Hong Kong has had a perfectly fixed peg to the U.S. dollar since 1983. South Korea's exchange rate was allowed to fluctuate according to the market average rate system in the interbank foreign exchange market.

The stock price indices expressed in the relevant domestic currency are simple-weighted averages, except for the Japanese Nikkei 225, which is a value-weighted index. The other Asian stock price benchmarks are represented by the stock exchange of Thailand index, Jakarta composite index for Indonesia, Manila stock exchange composite index for the Philippines, Kuala Lumpur composite index for Malaysia, the Straits Times industrial index for Singapore, the Korea stock exchange composite for South Korea and the Hang Seng price index for Hong Kong.

The fact that stock prices are measured at local closing times poses the usual problem of non-synchronous trading with respect to London foreign exchange quotations and across regional equity markets as well. Lagged rather than contemporaneous currency returns are used in the estimation of regime-switching Markov models in order also to reduce measurement errors associated with the non-synchronous trading in regional stock markets and foreign exchange quotations in London. Differences in trading holidays across Asian stock markets are also accounted for by eliminating all observations for which at least, one regional equity market is closed. The reduction in the total number of observations is made on the basis of the simplifying assumption that there is no arrival of new information on trading holidays and in the attempt to maintain a common albeit not constant measurement interval.

The daily returns on currencies and equities are estimated as logarithmic growth rates. Figure 1 illustrates simultaneously the return series on both stock index and

exchange rates for a selection of countries. There are no strong deviations from the zero level of return on exchange rates except during the Asian currency crisis, which can be traced graphically to the last quarter of 1997. The majority of return series of exchange rates follow patterns similar to the Thai baht exchange rate, though Malaysia's adoption of a fixed exchange rate in September 1998 resulted in restricting its rate of return to zero. The strongest exception to the standard pattern is Hong Kong's peg to the US dollar, which persisted even during the financial turmoil.

The returns on the Japanese yen however have higher variability. Such is the case also of the returns on the Nikkei 225 stock average, which suggest a pattern of changing variability. The changing (and perhaps stochastic) volatility of returns is even more pronounced over the Asian currency crisis irrespective of the country taken into consideration. This observation lends little empirical support to a linear modeling of the relationship between currency and equity returns and increases the likelihood of the fitness of nonlinear modeling. The results of the Augmented Dickey-Fuller (ADF) tests for unit root in the returns on the stock market and exchange rates are reported in Table 1. Independent of the significance of intercepts and trend terms in the ADF regressions, there is evidence that all return series are stationary.

4.2. Regime Dynamics and Currency Risk Exposure

We estimate three Markov regime-switching models. With reference to equation (3), *Model 1* features the first-order regime-switching model for equity returns that excludes any influence from currency returns in the mean equation or transition probabilities. *Model 2* features a linear relationship between equity and foreign exchange returns in each state of the world (see mean equation (4)). In this context,

asymmetries arise where the estimated parameters suggest that the linear responses of equity returns differ in each regime. *Model 3* features a quadratic relationship between stock market and foreign exchange returns in each state (see mean equation (9)). This model enables us to investigate nonlinearities in each regime where we can investigate the hypothesis that the effect of small movements in currency returns may differ qualitatively (and quantitatively) from large movements. Asymmetries will be present if either regime is characterised by an individual quadratic form. *Models 2* and *3* offer the opportunity to measure the deepness of the impact of changes in currency rates on stock market returns. Our investigation with both these models also considers non-linearities through the impact of foreign exchange returns on the *duration* of stock returns within a particular regime. We therefore model the transition probabilities so that they may depend on currency returns.

Table 2 reports the estimates of the regime-switching model that excludes any influence of currency returns (*Model 1*). In contrast, Table 3 reports the estimation results based on *Model 2* with linear effects from currency returns in each regime. The likelihood ratio test based on the respective estimates for *Models 1* and *2* for each country suggests that *Model 2* is preferred to *Model 1* (excluding foreign exchange returns) at the 5% significance level. Judging from the estimated values of the conditional mean parameters in Table 3, two regimes of stock returns can be identified for all countries. For each country, these regimes are associated with drift terms of opposite signs. As some of the drift coefficients appear to be insignificant, the regimes can be described as ‘high returns’ and ‘low returns’ states, each associated with a significant mean-reversion term. An examination of the estimated exchange rate coefficients z_1 and z_2 , which measure the effect of currency returns in the mean

equations suggests that stock returns are likely to be adversely affected by depreciation. Indeed, in 9 out of 16 cases we can identify a negative and significant foreign exchange coefficient, which can be contrasted with the only 4 cases of positive and significant coefficient. The negative relation between stock and currency returns suggests that equity markets are likely to respond to foreign exchange devaluation with a decrease in prices accompanied with an increase in the required risk-premium.

If there is evidence that z_1 is significantly different from z_2 , then nonlinearities in the relationship between currency and stock returns is confirmed. The cases where these coefficients are significant and of the same sign include Thailand and Malaysia. For these countries, further testing strongly rejected the null of ($z_1 = z_2$) and therefore confirmed nonlinearities with $c^2(1) = 80.130$ and $c^2(1) = 636.857$ respectively. Where significance is present in at least one regime, we find that z_1 is of opposite sign to z_2 for Indonesia, Philippines, Singapore, South Korea and Japan. However, with respect to Hong Kong, there is no evidence that foreign exchange returns influence stock market returns. Thus, an overall examination of the mean equation suggests that nonlinearities are confirmed in all cases except Hong Kong.

The other dimension to the presence of nonlinearities is whether the transition probabilities are influenced by currency returns. There is evidence that J is statistically significant with respect to Singapore (regime 1) and Malaysia (regime 2), and albeit at the 10% level, for the Philippines (regime 1). In the case of Singapore, the evidence that $J_1 > 0$ suggests that an increase in foreign exchange return, i.e. depreciation might increase the duration of the regime of 'high' stock returns. In the case of Malaysia, the opposite applies where depreciation might actually increase the duration of regime 2, a

regime of ‘low’ equity returns. Since $J_1 < 0$ for the Philippines, it can be argued that depreciation might reduce the duration of regime 1 of ‘low’ stock returns. Thus, purely on the basis of examining the transition probabilities (rather than the mean equations), this analysis suggests that domestic currency depreciation is favourable to the Singaporean and Philippines stock markets, but detrimental to Malaysian equities.

Figure 2 plots the inferred probabilities of being in regime 1 at any point in time. What is clear is the general increase in regime volatility after July 1997 where stock markets moved much more sharply between the two regimes. Some stock markets, most notably Malaysia have been generally more stable over the entire study period but even these were subject to increased volatility towards the end of 1997. The conditional probability of being in regime 1 before the financial crisis is close to unity for the Philippines and approaches zero for Malaysia, Singapore and Hong Kong while regime classification is more difficult to determine for the remaining countries. The financial turmoil does not seem to have the effect of shifting stock returns permanently from one regime to another. The inferred probabilities differ with respect to the exact point in time at which regime instability increases sharply. The period of higher frequency of regime switches in Thailand and Philippines seems to precede (and may have precipitated) similar episodes of greater regime variability in other countries. Though the sequence and propagation of increased regime switching seems to mimic the contagion patterns of the currency crisis, it does not constitute strong evidence of stock market anticipation.

Table 4 reports the results from estimating regime-switching models with a quadratic approximation in each regime (*Model 3* with mean equation (9)). At the 5% significance level there is evidence that changes in foreign exchange rates influence the

transition probability of regime 2 for the Philippines and Japanese stock returns. The positive coefficients J_2 imply that depreciations are likely to be associated with longer durations of the regimes of 'high' and 'low' stock returns, respectively. The results indicate also that I_1 and/or I_2 are significant at the 5% level in the cases of Indonesia, Malaysia, Singapore, Korea and Japan. For each of these countries, it is possible to identify at least one quadratic relationship between exchange rates and stock market returns across the two regimes. This is true also for Thailand and the Philippines but at the 10% significance level. Though these coefficients are not always significant for both regimes, there is evidence that when I_1 is significant, it tends to take the opposite sign of I_2 and vice-versa. This result suggests that the non-linear relationship identified in each regime is likely to be also asymmetric across regimes. As in Table 3, for Hong Kong there is no evidence that foreign exchange returns influence stock market returns.

We can now consider the hypothesis that a small depreciation (moderate increase in lagged currency returns) is associated with an increase in stock market returns while a large depreciation is actually detrimental to equity returns. This scenario will be present if $(z > 0, I < 0)$ for either regime 1 or regime 2 or for both states. There is weak evidence from Indonesia and Korea where $z_1 > 0$, but I_1 appears in each case, short of taking the opposite sign, insignificantly different from zero. Japan is the country that offers closest evidence for this proposition for regime 2 with a turning point of $z_{t-1} = 0.371$ (however, z_2 is significant only at the 10% level). But this evidence of counterproductive effects from quadratic depreciations seems to be regime-dependent. Indeed, Japan is also associated at the 5% level with opposite quadratic effects $(z_1 < 0, I_1 > 0)$ in regime 1 giving a turning point of $z_{t-1} = 23.420$. This pattern,

found also for Korea (regime 2) as well as the Philippines (regime 2) at the 1% and 10% levels respectively, implies that moderate depreciations may be detrimental while large ones may still be beneficial for these countries' equity returns. In contrast, the alternative pattern ($z < 0, I < 0$) most significant for Indonesia (regime 2) and Malaysia (regime 1) giving their respective turning points as $z_{t-1} = -16.150$ and $z_{t-1} = -3.764$, suggests that depreciations have an unambiguously negative impact on stock market returns for these countries. The absence of evidence for the ($z > 0, I > 0$) pattern suggests that it is not likely for large depreciations to positively influence stock returns when small devaluations do as well.

As it may be ultimately function of the trade imbalance within the economy, the conflicting evidence obtained across Asian countries is hardly surprising. Recognising the fact that exposure to foreign exchange risk varies across export-oriented and import-oriented firms, the aggregate impact of exchange rate variations on the behaviour of stock price benchmarks may remain indeterminate. In countries such as Indonesia and Malaysia, our evidence suggests that when significant, large depreciations are, much like small ones, likely to have unambiguously detrimental effects on stock markets. Our evidence on the proposition that moderate depreciations are likely to be associated with increases in stock returns while large depreciations have negative impact on equity returns is rather weak. This pattern is rare, appears to be regime-dependent and relies on low levels of statistical significance. The only support, albeit weak, that Japanese markets lend to the hypothesis of counterproductive quadratic depreciations may be reflective of investors' perceptions that moderate yen depreciations are conducive to stronger competitive advantage for Japanese firms. Large devaluations however may be reflective –but we take no position on this– of decreasing investors' confidence and

growing concern over worsening economic fundamentals. Across other Asian countries, currency depreciations small and large can be invariably reminiscent of past currency crises and the signal of future financial turmoil for other Asian countries.

5. CONCLUSION

This paper examined investors' perceptions of foreign exchange risk in Asian stock markets. Regime-switching models provide evidence of non-linearities in the relationship between exchange rate and equity returns. The effect of changes in the exchange rate on stock market returns is regime-dependent except for Hong Kong whose strong currency peg contributes to the segmentation of its stock market from foreign exchange. Judging from the inferred regime probabilities and regime durations, Asian stock markets moved much more sharply between two regimes of low and high stock market returns after the onset of the financial crisis. The increased frequency of regime switches is indicative of greater uncertainty and stronger tendency for higher volatility of equity returns during currency crises.

Though the evidence on the asymmetric effects of moderate and substantial depreciations seems to differ across countries, casual empiricism suggests that controlled devaluation can be eventually overtaken by market forces, driven either by game-theoretic rounds of further devaluations or by the shifting focus of risk-averse global investors across financial markets. Much like raising interest rates, which may be viewed as a sign of monetary instability at times of financial turmoil, small 'beggar-my-neighbour' competitive devaluations may increase expectations of further large depreciations and become part of the problem rather than the solution. A parallel can also be drawn between the proposition of currency depreciation as a form of 'foreign

exchange leverage' and theories of firms' decisions on 'financial leverage.' The argument that marginal benefits from the tax-deductibility of interest payments may be offset by heightened probabilities of financial distress and insolvency cannot easily be dismissed. Likewise, however marginal or high the desirable benefits of currency depreciation are, it may still be perceived as having the potential to precipitate full-fledged currency crises through self-fulfilling rational expectations or irrational herding behaviour. In light of the empirical evidence reported in the present study, the literature on the nonlinear features of foreign exchange exposure would certainly benefit from further analysis based on macroeconomic fundamentals as well as behavioural finance.

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Figure 1. Time series of currency and stock returns for selected Asian countries

Figure 2. Regime 1 inferred probabilities for Asian stock market returns

Table 1. Unit root test results

Return Series	Stock Index	Exchange Rate
Thailand	-10.868	-9.338
Indonesia	-10.498	-9.172
Philippines	-10.504	-11.037
Malaysia	-11.908	-12.634 ^a
Singapore	-10.896	-12.219 ^a
South Korea	-11.347	-9.846
Hong Kong	-11.395	-14.323
Japan	-11.774	-11.823

Notes: The unit root tests in return levels are augmented Dickey-Fuller tests with neither intercept nor trend. The lag length is chosen according to the Schwarz information criteria. If necessary, additional lags are added until the equation residuals are free from serial correlation. MacKinnon 1% critical value for rejection of the unit root hypothesis is -2.5672 . ^a Unit root test with trend and intercept, MacKinnon 1% critical value is -3.9697 .

Table 2. State-dependent linear effects (Model 1)

	Drift term		Autoregressive term		Transition Probabilities		Volatility S_e	Log Likelihood
	Regime 1	Regime 2	Regime 1	Regime 2	w_1	w_2		
	h_1	h_2	j_1	j_2				
Thailand	0.026	-0.090	1.062 ^a	-0.119 ^a	-1.868 ^a	0.853 ^a	2.637 ^a	-2862.0
Indonesia	-0.153 ^b	0.081	1.060 ^a	-0.106 ^a	-0.941 ^a	0.168	1.687 ^a	-2536.4
Philippines	-0.110	0.018	1.199 ^a	0.008	-1.742 ^a	1.399 ^a	2.076 ^a	-2677.6
Malaysia	-0.041	0.068	0.723 ^a	-0.431 ^a	0.107	-0.230	2.889 ^a	-2908.7
Singapore	0.005	0.006	1.115 ^a	-0.146 ^a	-0.641 ^b	1.361 ^a	1.126 ^a	-2265.6
South Korea	-0.030	0.058	0.473 ^a	-0.393 ^a	-0.325	-0.731 ^c	2.897 ^a	-2899.9
Hong Kong	-0.005 ^c	0.190	0.261 ^a	-0.834 ^a	1.962 ^a	-2.153 ^a	2.816 ^a	-2855.4
Japan	0.070	-0.167 ^b	-0.432 ^a	0.267 ^a	-0.845	-1.346	1.896 ^a	-2577.4

Notes: ^a, ^b and ^c denote significance at the 1, 5 and 10 per cent levels. The mean equation for regime 1 is $r_t = h_1 + j_1 r_{t-1} + e_{1t}$ where r denotes stock market returns, the mean equation for regime 2 is $r_t = h_2 + j_2 r_{t-1} + e_{2t}$, w_1 (w_2) determines the constant transition probability of remaining in regime 1 (2) given that regime 1 (2) has already occurred.

Table 3. State-dependent linear effects (Model 2)

	Drift term	Auto regressive term	Foreign exchange parameter	Transition probabilities		Volatility S_x	Log Likelihood
	h_1	j_1	z_1	w_1	J_1		
	(h_2)	(j_2)	(z_2)	(w_2)	(J_2)		
Thailand	0.016 (-0.071)	0.812 ^a (-0.155 ^a)	-1.123 ^a (-0.018 ^a)	-1.227 ^a (0.403 ^c)	-0.275 (-0.008)	2.474 ^a	-2821.2
Indonesia	-0.007 (0.109 ^c)	0.754 ^a (-0.082 ^a)	-0.345 ^a (0.124 ^a)	-0.219 (0.043)	-0.045 (-0.023)	1.562 ^a	-2475.0
Philippines	-0.007 (0.122)	0.071 ^a (1.438 ^a)	-0.290 ^a (0.777 ^a)	2.274 ^a (-1.736 ^a)	-0.377 ^c (0.012)	2.086 ^a	-2663.7
Malaysia	1.659 ^a (-0.045)	0.880 ^a (-0.061 ^a)	-8.173 ^a (-0.486 ^a)	-0.828 (4.040 ^a)	0.084 (0.369 ^a)	2.881 ^a	-2870.4
Singapore	0.060 (-0.001)	1.005 ^a (-0.163 ^a)	-0.756 ^a (-0.101)	-0.614 ^a (1.224 ^a)	0.665 ^a (0.231)	1.078 ^a	-2241.6
Korea	-0.081 (0.020)	0.497 ^a (-0.212 ^a)	0.147 ^a (-0.757 ^a)	-0.965 ^a (-0.043)	-0.506 (0.029)	2.616 ^a	-2831.3
Hong Kong	-0.381 ^b (0.133 ^b)	1.241 ^a (-0.160 ^a)	0.803 (-0.246)	-1.802 ^a (1.444 ^a)	-1.561 (0.901)	2.560 ^a	-2850.2
Japan	0.039 (-0.091)	-0.510 ^a (0.213 ^a)	-0.383 ^a (0.259 ^a)	-0.902 ^c (0.087)	-0.240 (0.305)	1.851 ^a	-2570.7

See notes for Table 2. The model estimates refer for regime 1 and regime 2 (reported between parentheses) to the mean equations $r_t = h_1 + j_1 r_{t-1} + z_1 z_{t-1} + x_{1t}$ and $r_t = h_2 + j_2 r_{t-1} + z_2 z_{t-1} + x_{2t}$, respectively where z denotes foreign exchange returns. Also, $w_1 + J_1 z_{t-1}$ and $w_2 + J_2 z_{t-1}$ represent the respective probabilities that regime 1 and 2 will occur next period given that the same regime is prevailing this period.

Table 4. State-dependent quadratic effects (Model 3)

	Drift term	Auto regressive term	Foreign exchange parameters		Transition probabilities		Volatility s_u	Log Likelihood
	h_1	j_1	z_1	l_1	w_1	J_1		
	(h_2)	(j_2)	(z_2)	(l_2)	(w_2)	(J_2)		
Thailand	-0.077 (0.046)	-0.148 ^a (0.825 ^a)	-0.200 ^a (-0.161 ^a)	0.003 (-0.039 ^c)	0.448 ^b (-1.316 ^a)	0.026 (-0.247)	2.476 ^a	-2820.7
Indonesia	0.100 (-0.043)	-0.098 ^a (0.804 ^a)	0.131 ^a (-0.259 ^a)	0.000 (-0.008 ^a)	-0.060 (0.200)	-0.037 (-0.052)	1.531 ^a	-2464.1
Philippines	-0.249 ^c (0.035)	1.279 ^a (0.030)	-0.319 ^c (-0.197 ^a)	0.096 ^c (-0.007)	2.172 ^a (1.550 ^a)	-0.074 (0.452 ^b)	2.002 ^a	-2652.2
Malaysia	0.046 (-0.273)	0.187 ^a (-0.754 ^a)	-0.482 ^a (-7.466 ^a)	-0.064 ^a (0.437)	3.835 ^a (-1.399)	-0.054 (-0.543)	2.738 ^a	-2826.5
Singapore	0.022 (-0.017)	0.962 ^a (-0.141 ^a)	-1.066 ^a (-0.044)	0.111 (-0.135 ^a)	-0.590 ^b (1.412 ^a)	0.356 (-0.549 ^c)	1.080 ^a	-2237.3
Korea	-0.097 (-0.002)	0.502 ^a (-0.202 ^a)	0.194 ^a (-0.821 ^a)	-0.020 (0.018 ^a)	-0.944 ^a (-0.016)	-0.502 ^c (-0.014)	2.585 ^a	-2827.1
Hong Kong	0.206 (-0.023)	-0.826 ^a (0.264 ^a)	-0.141 (-0.090)	-0.038 (-0.323)	-2.134 ^a (1.948 ^a)	1.911 (-0.637)	2.808 ^a	-2854.2
Japan	0.035 (-0.089)	-0.341 ^a (0.305 ^a)	-0.165 ^b (0.167 ^c)	0.070 ^b (-0.225 ^a)	-0.388 (-1.737 ^a)	-0.310 (0.771 ^b)	1.866 ^a	-2569.1

See notes for Tables 2 and 3. The estimated coefficients for regime 1 and regime 2 (reported between parentheses) refer to the mean equations $r_t = h_1 + j_1 r_{t-1} + z_1 z_{t-1} + l_1 z_{t-1}^2 + u_{1t}$ and $r_t = h_2 + j_2 r_{t-1} + z_2 z_{t-1} + l_2 z_{t-1}^2 + u_{2t}$, respectively.