Behavioural Heterogeneity and Shift-Contagion: Evidence from the Asian Crisis

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Keywords: heterogeneous expectations; contagion; Asian crisis; dynamic models

JEL-classification: G12, G15

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Abstract
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1. Introduction

The observation that an extreme financial event in a certain country can cause a chain of events in other, not only closely related, countries, has triggered a vast new line of research starting in the end of the 1990’s, see Claessens and Forbes (2001) and Kaminsky et al. (2003) for a review. Although the literature is diverse concerning the exact definition, the term used to describe this observation, is contagion. The commonly used definitions can be split in two broad groups. The first group considers the spread of crises across countries a result of the linkages that exist between countries, such as trade linkages, financial linkages, and common shocks. Forbes and Rigobon (2002) label this interdependence; the underlying assumption is that there are no structural changes during extreme events. The second type of definition is narrower in the sense that it states that the spread of shocks is not only the result of the every day linkages, but that a crisis-contingent mechanism comes into play. That is, linkages between assets change during crisis periods. Forbes and Rigobon (2002) refer to this type of contagion as shift-contagion. Crisis-contingent mechanisms can be based on multiple equilibria, endogenous liquidity shocks, and a political transmission mechanism. The underlying assumption is that the typical conduct of markets changes. The behaviour of agents changes during crises given that the degree of co-movement between assets changes during crisis periods and the price of assets is, in the end, determined by agents trading in a financial market.

The early empirical papers on contagion are unanimous in their conclusions concerning the existence of contagion. Irrespective of the method and definition they employ, contagion is found to be significant. For instance, King and Wadhwani (1990) find increased cross-market correlations between the U.S., U.K., and Japan after the U.S. stock market crash. Lee and Kim (1993) extend this analysis and find similar results. Increased co-movement is also found after the 1994 Tequila crisis and 1997 Asian crisis by Calvo and Reinhart (1995) and Baig and Goldfajn (1998). Using a limited dependent variable setup, Eichengreen et al. (1996) and Kaminsky and Reinhart (2000) find increased probability of a crisis after another country has been hit by a crisis.

Forbes and Rigobon (2002) however, find evidence for interdependence, not shift-contagion. That is, adjusted for the increased volatility in asset returns during crises, the correlation between markets did not increase during the Asian and Mexican crisis and the U.S. stock market crash. Using the same correction method as Forbes and Rigobon (2002), Lomakin and Paiz (1999) conclude that most shocks are transmitted through non-crisis-contingent channels. Likewise, Candelon et al. (2005) reject the null hypothesis of shift-

A second strand of literature assuming that agents condition their behaviour on the state of the market, comparable to the crisis-contingent theories, is the heterogeneous expectations literature; see for instance Day and Huang (1990), Brock and Hommes (1998), Lux (1998), and Hommes (2006) for an extensive overview. In this boundedly rational setting, there are groups of agents who condition their expectations on different sources of information. The resulting market price is the weighted average of the expectations of the different groups. Usually there are two groups, fundamentalists and chartists, who base their expectations on economic fundamentals and technical analysis, respectively. Behaviour is state dependent as agents can change their strategy as how to form their expectations conditional on past strategy performance. Consequently, the distribution of weights given to the various strategies in determining the market price varies through time, conditional on goodness of fit of the strategies. The interaction of different groups of traders combined with the switching of strategies gives a non-linear dynamic asset pricing model capable of replicating the stylized facts of financial markets.

The heterogeneous expectations literature is focused on three issues. The first topic is the dynamic properties of the nonlinear models. Given the nonlinear setup, the behaviour of the model depends heavily on the magnitude of coefficients and the starting values in a simulation setup. Chiarella et al. (2002) and Chiarella and He (2002) characterize the parameter space of the models according to the local stability or instability of the equilibrium point. The second topic is the stylized facts of financial markets. By using simulations combined with time-series techniques, Lux (1996), LeBaron et al. (1999) and De Grauwe and Grimaldi (2005, 2006) show that models with heterogeneous interacting agents are capable of replicating the stylized facts of financial markets (i.e., extreme values, volatility clustering, disconnection from the fundamental, excess volatility). The third topic comprehends the estimation of models with heterogeneous interacting agents. This is a relatively new and unexplored topic since the estimation of the non-linear switching mechanism proofed to be difficult. Vigfusson (1997) and Ahrens and Reitz (2005) have circumvented the problem of estimating the non-linear switching mechanism by replacing it by a Markov regime-switching approach. Baak (1999) and Chavas (2000) find significant evidence of agent heterogeneity in the beef market. Winker and Gilli (2001) estimate a heterogeneous agents model by minimizing a loss function consisting of the kurtosis and ARCH-estimates of the simulated
data by adjusting the coefficients of the model. Reitz and Westerhoff (2003) directly estimate a model of chartists and fundamentalists with switching mechanism for daily exchange rates from 1980 to 1996. Boswijk et al. (2005) rewrite the model of Brock and Hommes (1997) and estimate it directly for the S&P500 using a non-linear least squares technique. All papers find evidence in favor of the heterogeneous agents models; both trader heterogeneity and switching beliefs are found.

The combination between the shift-contagion and heterogeneous agents literature has, to our best knowledge, never been explored. In this paper we develop a dynamic heterogeneous agents model with multiple asset markets. The relation between the markets is established by introducing a third group of agents, next to fundamentalists and chartists, that is forming expectations conditional on past returns in the foreign market. By doing so, we incorporate the existence of real linkages between the economies, while staying in the line of reasoning of the model that the market price is determined by traders. Like the other groups, the weight (so the relative magnitude) of the internationalist group in determining the market price changes through time. Our model therefore combines the two definitions of contagion; there is interdependence because of the fundamental relation between markets, and there is shift-contagion because this relation has the possibility to change over time. By explicitly modelling the behaviour of market participants, we can determine whether the focus on the foreign market changes during the crisis, so whether shift-contagion was present or not. If we observe that the behaviour of market participants changes significantly during the crisis, it can be interpreted as evidence of shift-contagion.

We estimate the model for two countries during the Asian crisis. By doing so, we attempt to shed some light on the (changing) mutual dependence between asset markets during the Asian crisis. This paper therefore adds to the third topic studied in heterogeneous agents modeling, the estimation of heterogeneous agents models, by using a comparable setup as Boswijk et al. (2005). The added value lies in the fact that we have a model with multiple asset markets and a third group of agents. By applying a SUR-method, we estimate the two-country heterogeneous interacting agents model with fundamental linkages between the countries. We explicitly account for the increase in variance during the crisis, and the endogeneity and identification problems described in Forbes and Rigobon (2002). The model is estimated with monthly data for the Hang Seng index and Bankok S.E.T. index for a period surrounding the Asian crisis, 1990 – 1999.

In accordance with the results of Reitz and Westerhoff (2003) and Boswijk et al. (2005), we find evidence of trader heterogeneity, and switching between strategies. All three
groups are found to be present simultaneously, and the magnitude of the groups is found to be
time-variant. Our results do not corroborate the results concerning shift-contagion after
correcting for heteroskedasticity of e.g. Forbes and Rigobon (2002) and Candelon et al.
(2005). We find evidence of shift-contagion of the rapid growth in the Hong Kong market to
the Thai market in the pre-crisis period, and shift-contagion of the crisis in the Thai market to
the Hong Kong market during the crisis period. Furthermore, we find evidence of shift-
contagion in the strictest definition that the structural parameters of the model change during
the crisis. Finally, we show that the model is able to predict the occurrence of the crisis itself
out-of-sample, but not the timing of the crash or the shift-contagion to Hong Kong.

The remainder of the paper is organized as follows. In Section 2 we develop the two-
country heterogeneous interacting agents model. Section 3 describes the estimation and data
issues involved in estimating the model. In Section 4 we describe the estimation results and in
Section 5 the forecasting results. Section 6 concludes.

2. The Model
In this Section we describe the simple non-linear dynamic model with multiple asset markets,
which we will estimate for two equity indices during the Asian crisis. Our model is a direct
In this type of model, the market price is formed by the weighted average expectation of a
number of heterogeneous beliefs. The weights are determined by the past performance of the
different groups, so agents can change their strategy of how to form price expectations.
Another way of interpreting this setup is as a representative agent, who puts time-varying
weights on the different pieces of (potentially) relevant information. Relevance is determined
by the extent to which the actual price process reacts to a certain piece of information. In this
manner the model also touches upon the scapegoat-literature (see Bachetta and Wincoop
2004), which states that the attention of traders shifts between potentially informative
variables, thereby causing the weight of variables in the price forming process to be time
variant.

The basic heterogeneous expectations model, described in Brock and Hommes (1997,
1998), assumes that agents can invest in a risk-free asset and one risky asset. Westerhoff and
Dieci (2006) and Chiarella et al. (2005) set up a model with interacting heterogeneous agents,
who are able to invest in a risk-free asset and two risky assets. Westerhoff (2004) assumes
that only chartists can switch between markets based on an information-cost argument.
Westerhoff and Dieci (2006) show that the properties of two otherwise unrelated markets with
common traders are related; Westerhoff (2004) and Chiarella et al. (2005) show that the existence of common investors can cause co-movement in markets.

Contrary to models with multiple asset markets of Westerhoff and Dieci (2006), Chiarella et al. (2005) and Westerhoff (2004), we do not assume that individual agents can invest in multiple markets, but we introduce a third group of market participants, next to the chartists and fundamentalists, labelled internationalists, which conditions their expectations on (past) movements of foreign markets. In this way we incorporate the existence of real and/or fundamental linkages between asset markets, while remaining in the logic of the model.

As mentioned above, we assume that the market expectation is equal to the average expectation of different groups

\[ E_t r_{t+1} = \sum_{i=1}^{H} w_{i,t} E_t r_{t+1} \]  

(1)

in which \( r_t \) is the return in period \( t \) defined as \( P_{t+y_t} - P_{t-1} \) with \( P_t \) the log real price in period \( t \) and \( y_t \) log real dividends in period \( t \); \( w_{i,t} \) is the relative weight of group \( i \) with \( \sum_{i=1}^{H} w_{i,t} = 1 \) and \( E \) is the expectation operator. Furthermore, as proposed in De Grauwe and Grimaldi (2005), the realised return in period \( t+1 \) equals the average or market expectation plus a random shock

\[ r_{t+1} = E_t r_{t+1} + \epsilon_t = \sum_{i=1}^{H} w_{i,t} E_t r_{t+1} + \epsilon_t \]  

(2)

Agents are assumed to be homogeneous in their expectation concerning future dividends; all agents expect dividends to follow a random walk with drift, i.e. \( E_t y_{t+1} = dy_t \), with \( d \) the drift equal to one plus the average growth rate of dividends. Equation (2) can be rewritten as

\[ \Delta P_{t+1} = \sum_{i=1}^{H} w_{i,t} E_t \Delta P_{t+1} - (y_{t+1} - dy_t) + \epsilon_t \]  

(3)

Given that \( d \) is the average growth rate, the \((y_{t+1} - dy_t)\) term is equal to zero on average. As indicated before, the weights \( w_{i,t} \) are conditional on past performance of the forecasting rules.
We use the procedure first proposed by Brock and Hommes (1997), which models the fractions as a function of past fitness in a discrete choice model with multinomial logit probabilities

\[
 w_{h,t} = \frac{\exp[\gamma \pi_{h,t-1}]}{\sum_{i=1}^{H} \exp[\gamma \pi_{i,t-1}]} = \frac{1}{1 + \sum_{i\neq h} \exp[\gamma (\pi_{i,t-1} - \pi_{h,t-1})]} \tag{4}
\]

in which \( \pi_{h,t} \) is the fitness of strategy \( h \) in period \( t \) and \( \gamma \) is the intensity of choice. The latter is (one of the) features of the model that illustrates the boundedly rational behavioural setup. In a neo-classical setting, all agents would change to the strategy that most accurately predicts the actual price change. This strategy would always have a weight \( w_{h} \) equal to one. In our setup this can only occur as \( \gamma=\infty \), such that agents are infinitely sensitive to differences in forecasting accuracy. At the other extreme, so as \( \gamma=0 \), agents would not change strategy at all; the weight of all strategies would be uniformly distributed and equal to \( 1/H \), with \( H \) the total number of strategies. The fitness of the strategies \( \pi_{i,t+1} \) is modelled as \((E_{i,t}r_{it})r_{it+1}\), as in Westerhoff and Dieci (2006)\(^1\). If both expected and realized returns have the same sign, the fitness is positive; furthermore, the absolute magnitude of the expectation works multiplicative. In other words, taking risks by having a large expectation in absolute sense can return in a large profit if the realized return is of the proper sign, but also in a large loss if the realized return is of the opposite sign.

The final step is to define the forecasting rules of the heterogeneous groups. We assume that there are three different groups active in the market. The first group, labelled as fundamentalists, condition their expectation on the level of the market price compared to what they see as the level of the fundamental price (which is perfectly visible to all agents in the market)

\[
 E_{f,t} \Delta P_{t+1} = \sum_{i=1}^{k} \theta_i (P_{t+1-i} - P^*_{t+1-i}) + \rho_i (P_{t+1-i} - P^*_{t+1-i})^2 \tag{5}
\]

\(^1\) In fact, Westerhoff and Dieci model the fitness as \( D_{it}(\exp(P_t) - \exp(P_{t+1})) \) in which \( D_{it} \) is demand for the asset. However, their demand is modelled as our forecasting rules are modelled. Furthermore, \( \exp(P_t) - \exp(P_{t+1}) \) is a variation to our log price difference.
in which \( P_t^f \) is the fundamental price in period \( t \). The behaviour of the fundamentalists depends on the sign and magnitude of \( \theta \). If \(-1<\theta<0\), fundamentalist expectations are mean-reverting and thus stabilizing; however, as \( \theta>0 \) fundamentalists are destabilizing as they drive the price away from the fundamental price. The second term represents the sensitivity of fundamentalists’ expectation to fundamental uncertainty. That is, if the misalignment between fundamental and market price is volatile, the expectations of fundamentalists are also volatile, thus taking possible large fluctuations of the market price into account.

The second group, labelled chartists, conditions their expectation on past price movements

\[
E_{c,t} \Delta P_{t+1} = \sum_{i=1}^{K} \alpha_i \Delta P_{t+1-i} + \beta_i \Delta P_{t+1-i} (P_{t+1-i} - P_t^f)
\]  

(6)

Again depending on the sign and magnitude of \( \alpha_i \) chartist behaviour is either stabilizing or destabilizing. Values of \(-1<\alpha_i<0\) imply stabilizing behaviour since previous periods’ price movements are (partly) reversed. If \( \alpha_i > 0 \), behaviour is destabilizing since past movements are (partly) extrapolated; \( |\alpha_i| > 1 \) implies explosive expectations. The second term in Equation (6) states that the extrapolation is dependent on the distance of the market price to the fundamental price. Extrapolation might become more or less stabilizing as price moves further away from the fundamental price. The reasoning could be that the probability of a correction towards the fundamental price increases as the distance to the fundamental price increases (\( \beta_i < 0 \)); on the other hand, the probability of a correction could decrease as the distance between the market and fundamental price increases since fundamentalists could be driven out of the market when the market price moves away from the fundamental price, and price movements become completely self-fulfilling (\( \beta_i > 0 \)).

The third and final group of traders is labelled internationalists and conditions their expectation on past returns in foreign markets. The underlying reason is the existence of real linkages.

\[
E_{t,t} \Delta P_{t+1} = \sum_{i=1}^{K} \phi_i \Delta \tilde{P} + \lambda_i \left( \Delta \tilde{P} \right)^2
\]  

(7)
in which \( \bar{P}_t \) is the price in the foreign market. The correlation between the markets is positive if one country benefits from e.g. another countries’ growth by increased exports \( (\phi_i > 0) \). A negative correlation is also possible as two countries are e.g. competing on the world market \( (\phi_i < 0) \). The second term represents the sensitivity of expected returns to uncertainty in the foreign market, so a risk premium, implying that \( \lambda_i > 0 \).

Equations (3) to (7) can be combined to form one equation representing the change in the asset price as a function of lagged price changes and fundamental prices. As we focus on the interaction between two specific markets in this paper, we write the model as a system of two interacting equations, in which each equation represents a local version of the model.

\[
\begin{align*}
\Delta P^A_{t+1} &= F^A(P^A_{t+1}, \Delta P^A_{t+1}, \Delta P^B_{t+1}) + \epsilon^A_{t+1} \\
\Delta P^B_{t+1} &= F^B(P^B_{t+1}, \Delta P^B_{t+1}, \Delta P^A_{t+1}) + \epsilon^B_{t+1}
\end{align*}
\]

Both the functions \( F^A \) and \( F^B \) are formed by Equations (3) to (7), \( F^A \) with coefficients from market \( A \) (which is the Hang Seng in the empirical section) and \( F^B \) with coefficients from market \( B \) (the Bangkok S.E.T); \( \epsilon^A_{t+1} \sim N(0, \sigma^2_A) \), \( \epsilon^B_{t+1} \sim N(0, \sigma^2_B) \) and \( E(\epsilon^A_{t+1} \epsilon^B_{t+1}) \neq 0 \).

3. Data and Methodology
This Section handles the data and methodological issues concerned with estimating the model described in Section 2. The determination of the fundamental price is treated first, followed by estimation issues concerning the model.

We have chosen to focus on the Asian crisis as it is more widespread than previous crises in the sense of both the geographical scope and the impact on the real side of the economies involved. Given the central role of the fundamental price in our model, the Asian crisis provides an appropriate case study. The Thai stock exchange, Bangkok S.E.T., and the Hong Kong stock exchange, the Hang Seng, have been chosen because the first is the country in which Asian crisis “officially” started with the attack on the Thai Baht in July 1997. The latter is chosen as Hong Kong, together with Singapore, is the financial centre of the south-east Asian region, a leading stock exchange. Furthermore, Forbes and Rigobon (2002) note that it was not until the crash of the Hong Kong market in October 1997 that the press started to focus on Asia and that the words “crisis” and “contagion” appeared. Corsetti et al. (2005) follow Forbes and Rigobon (2002) in this respect. All raw data used in this paper are taken
from DataStream. We use monthly data from January 1990 to December 1999, which are 120 observations. This sample is chosen because we want to focus specifically on the potentially changing behaviour of agents during the build-up of the crisis, the crisis, and the aftermath.

3.1 Fundamental Price
In order to construct a fundamental price, which is used in determining the expectation of fundamentalists, we consider a dynamic version of the classical Gordon growth model for equity valuation. Gordon (1962) states that the price of equity $P_t$ is equal to

$$P_t = \frac{1 + g_y}{r - g} Y_t$$

(9)

in which $g$ is the growth rate of dividend, $r$ the discount rate and $Y_t$ dividends. One of the issues concerning this model is the period over which to consider the growth and discount rates. In our boundedly rational setup, agents cannot use future information in order to determine the current fundamental value; that is, $g$ and $r$ in period $t$ can only contain information up to period $t$. Therefore, we make the model dynamic by assuming that $g$ and $r$ are time-varying. To be more specific, the growth rate $g$ in period $t$ is the average over all available past values until period $t$ and the discount rate $r$ is the expected (i.e. average) return in period $t$, determined from past values until period $t$. Thus, $g_t$ and $r_t$ are rolling averages of the growth rates of dividend and returns, respectively.

Fama and French (2002) state that the average stock return $r_t$ is the sum of the average dividend yield, $Y_t / P_{t-1}$, plus the average rate of capital gain, $(P_t - P_{t-1})/P_{t-1}$. The Gordon model implies that the average rate of capital gain is equal to the average growth rate of $Y_t$ ($=g$). Therefore, Equation (9) simplifies to

$$P_t = \frac{1 + g_t}{Y_t / P_{t-1}} Y_t$$

(10)

in which $g_t$ is the average growth rate of dividend and $Y_t / P_{t-1}$ is the average dividend yield (both averages up to period $t$).

In order to create a fundamental price for our two markets, we applied Equation (10) to the stock price indices of Thailand, the Bangkok S.E.T. and Hong Kong, the Hang Seng.
For $Y_t$, we use earnings instead of dividends since we believe that earnings are less affected by management choices compared to dividends\(^2\). This is especially the case in recent years with respect to the increasing importance of firms who enter the stock market on the basis of expected future dividends (i.e. IT-firms). Nominal data is discounted using CPI. To create the rolling averages of the growth rate $g$ and earnings yield $\frac{Y_t}{P_{t-1}}$, we used as much data as was available to us, so assuming that agents have equal access to information. For Thailand the starting point is 1975; for Hong Kong 1973. The sample we concentrate on when estimating is 1990 – 1999, so the averages used in our sample are based on a relatively large number of observations. The earnings growth numbers are annual growth rates divided by twelve.

Figure 1 displays the log real market price and fundamental price determined using the dynamic Gordon model as described above for 1990 - 1999. The Hang Seng market price oscillates around the fundamental price during the entire sample. Clearly recognizable is the Asian crisis in 1997 and 1998, when the index loses 58% of its value, starting in October 1997 with the attack on the Hong Kong Dollar and the accompanying interest rate hikes in Hong Kong to defend the currency board. Remarkable is that only 28% of the drop is a correction to the fundamental price. As a result of the sharp drop, the fundamental price itself also decreases in 1998, while the market price is rising again.

The picture for Thailand differs considerably. We find that the market is highly overvalued until 1996, reflecting the immense capital inflows into the country at that time. Just before the decline in May 1996, the market is 85% overvalued relative to our Gordon-based fundamental. During the decline, from May 1996 until August 1998, the market loses 85% of its value. Also in the case of Thailand does the immense drop in stock value cause the fundamental value to drop. After the correction, the market value remains close to the fundamental.

\(^2\) Fama and French (2002) note that one can use any variable that is cointegrated with the stock price.
Both the Thai and Hong Kong market start climbing again halfway 1998. Note that the decline in the stock market in Thailand (May 1996) commences well before the attack on the pegged exchange rate (July 1997).

In Table 1 we present the summery statistics of the realized (log real) market prices and their first differences (so the return in the model), the constructed fundamental price, and the misalignment (i.e. the difference between market and fundamental price). The descriptive statistics confirm the image from the graphs. For Hong Kong we find that the means and medians of the market and fundamental price are not significantly different from each other, but that both the range and standard deviation are. This implies that the market price is more volatile than the fundamental, but that they are closely linked. Both series are integrated of order one, but they are not cointegrated. The fact that the Thai market price is overvalued during a large part of our sample period results in the fact that the mean and median of the market price are significantly larger than those of the fundamental price. Range and standard deviation are also significantly higher for the market price. The market and fundamental prices for Thailand are both integrated of order one, but as in the case of Hong Kong also not cointegrated.

Despite the crash in the Hong Kong market, the average return is 1.1% positive over the total sample; for Thailand this is 1.1% negative. The variability of the Bangkok S.E.T. return is also significantly higher than of the Hang Seng return given the range and standard deviation. The positive trend for Hong Kong and the negative trend for Thailand are reflected in the signs of the skewness. The large monthly returns of especially Thailand show in the excess kurtosis. Given the significant autocorrelation in the returns for both countries, we expect that chartism as we defined it in our model can be profitable. Volatility clustering does not seem to be clearly present, especially for Thailand, which can be expected at this frequency. The return series are stationary.

The mean misalignment is not significantly different from zero for Hong Kong, implying that the market is, on average, not over- or under-priced. The Bangkok market is significantly overpriced on average during our sample; the maximum overvaluation and variability in the misalignment is also larger compared to Hong Kong. Because the market
and fundamental prices are not cointegrated, their difference should not be stationary. The ADF test indicates that the Thai misalignment is stationary on the five-percent level, while the Hong Kong misalignment is not. However, given the percentages and the small sample properties of the ADF test, we consider both series to be stationary.

3.2 Estimation Issues

Forbes and Rigobon (2002) state that the propagation mechanisms between markets can be modelled using two frameworks; a single equation setup,

\[ x_{i,t} = \alpha_i + \beta_i X_t + \gamma_i a_i + \epsilon_{i,t} \]  

(11)

and a multiple equation setup

\[
\begin{align*}
    x_i &= \alpha_x + \beta_x y_i + \gamma_x a_i + \epsilon_x \\
y_i &= \alpha_y + \beta_y x_i + \gamma_y a_i + \epsilon_y
\end{align*}
\]  

(12)

(c.f. Equations (1), (2) and (3) from Forbes and Rigobon (2002)). The problem with the single equation setup, with \( X_t \) containing the returns of multiple markets, is endogeneity. By assuming cross-market linkages, \( X_t \) causes \( x_{i,t} \) but \( x_{i,t} \) also causes \( X_t \). By using a system with \( N \) equations, \( N \) the number of markets, the endogeneity problem can be solved by estimating the equations as a system. The issue with a multiple equations setup, however, is that the \( \beta \) parameters might not be identified. For \( \beta \) to be identified, one needs market-specific shocks in each line of the system; the \( a_t \) variables cannot be perfectly correlated; see Forbes and Rigobon (2002).

Our model is of the \( N \)-equations type; the timing, however, is different compared to the multiple equation setup described in Forbes and Rigobon (2002). The equations in the system are not contemporaneous; agents form their expectations based on past returns. Furthermore, fundamental shocks between the countries are correlated because of the real and financial linkages, but not perfectly so such that the coefficients in Equation (8) are identified anyhow.

The literature on contagion stresses the importance of correcting for the increased volatility during a crisis when investigating potentially increased correlation; see Forbes and Rigobon (2002), Candelon et al. (2005). Without this correction, one might conclude that the
correlation has indeed increased, while this result is solely driven by increased volatility. By including the squared returns in the expectation formation function of internationalists and the squared misalignment in the expectation formation function of the fundamentalists, we explicitly take the potential changing variance of the returns of both the Thai and the Hong Kong market into account.

In order to control for common shocks to the markets, so for the correlation between the error terms in Equation (8), we estimate the system using a Seemingly UnRelated (SUR) estimation procedure. The SUR setup takes the non-zero covariance between the error terms into account and thereby returns consistent estimates of the variances. The starting values used in the SUR procedure are the coefficients estimated by a non-linear least squares estimation on the individual elements of Equation (8). Experiments were performed with alternative starting values in order to assure ourselves of the fact that the optimization procedure produced a global minimum.

The correlation matrix (not shown in the paper) indicates a relatively high correlation between a number of explanatory variables; especially between the returns of Thailand and Hong Kong (0.60). When estimating the system without taking this into account, we obtain a typical collinearity result for Thailand\(^3\), i.e., a relatively high \(R^2\) without any significant coefficients. In order to control for the multicollinearity, we propose the following alternative instrumental variable procedure. The following equation is estimated, which extracts all possible correlating information from the Thai returns

\[
\Delta P_{t}^{Th} = \alpha + \beta \Delta P_{t-1}^{HK} + \gamma(P_{t-1}^{Th} - P_{t-1}^{Th}) + \xi_t \tag{13}
\]

Next, we use the residuals \(\xi_t\) as input for the chartist expectation formation in Thailand. In other words, we replace \(\Delta P_{t-1}^{Th}\) with \(\xi_{t-1}\) in Equation (6) for the Thai case. The advantage of this method is that it eliminates all collinearity from the explanatory variables without having to undergo the difficult task of finding appropriate external instrumental variables. The disadvantage, on the other hand, is the fact that the interpretation of the coefficients \(\alpha_i\) and \(\beta_i\) in Equation (6) becomes difficult. Given that chartists in the Bangkok market no longer base their expectations for future returns on actual past returns but on the residuals from Equation (13), the coefficients \(\alpha_i\) and \(\beta_i\) can no longer be interpreted directly. A value of \(\alpha_i\) of 0.5 does not imply that chartists expect that next period’s return is half of previous period’s return.

\(^3\) For Hong Kong this is not the case.
The number of lags used in the expectation formation Equations (5), (6), and (7) is one \((K=1)\) for Thailand and two \((K=2)\) for Hong Kong for all three groups. These numbers are sufficient to remove all autocorrelation from the residuals; serial correlation in the squared returns and normality of the distribution of returns are no significant issues at the monthly frequency, see the descriptive statistics in Table 1.

4. Empirical Results

The results of estimating the model described in Section 2 using the fundamental price and estimation procedure developed in Section 3 are presented in this Section. We first focus on the estimated coefficients in two cases: with and without switching mechanism. By doing so, we attempt to stress the importance of the non-linear structure of the model, i.e. the possibility of agents to change their forecasting strategy. Second, we examine the development of weights \(w_{i,t}\) attached to the different strategies in price determination, and third we examine the stability of the expectation formation functions through time.

4.1 Estimation

Table 2 presents the estimation results of the model described by Equation (8) with and without switching mechanism. In terms of the model, without switching implies that \(\gamma=0\); the distribution of agents over the different strategies is uniform and constant through time, i.e. \(w_{i,t}=1/3\ \forall i,t\). With switching implies we estimate the switching parameter \(\gamma\) simultaneously with the expectation formation functions of the three groups.

Concentrating on the linear case first, we observe that fundamentalists are stabilizing for both Hong Kong and Thailand on the first lag, given the negative \(\theta_i\) coefficients. The misalignment in Hong Kong is expected to be eliminated almost completely at the first lag, given that the coefficient is close to -1, while for Thailand this is 18.3%. For Hong Kong the mean reversion increases as fundamental uncertainty increases, \(\rho_i < 0\), for Thailand it decreases, \(\rho_i > 0\). This strong mean reversion for Hong Kong is compensated in the second lag, where both coefficients are positive. All fundamentalist coefficients are significantly different from zero.
The fact that the mean reversion, so the correction of the over- or under valuation of the stock market, is stronger for Hong Kong than for Thailand can be explained by the fact that the market price fluctuates around the fundamental price in Hong Kong, while the market price is severely detached from the fundamental price without moving towards it for the majority of the sample period in Thailand. Because of this, fundamentalists do not expect a quick reversion towards the fundamental price in Thailand, which is translated in a relatively small mean-reversion coefficient $\theta_1$, while investors in Hong Kong anticipate on a quick reversal towards the fundamental price.

All chartist coefficients are positive, indicating that this group extrapolates recent price changes (i.e. $\alpha_i > 0$), and that the extrapolation becomes stronger as the market price is further detached from the fundamental price (i.e. $\beta_i > 0$). The first lag coefficients are significant. These results imply that chartists are destabilizing because a certain shock to the market price is not reversed in the next period, but extended. The fact that the destabilizing effect becomes stronger as the market price moves further away from the market price implies that chartist expectations work self-fulfilling; chartists appear to know that the fraction of fundamentalists becomes small as the market price moves further away from the fundamental price (since a fundamentalist strategy does not provide a good forecasting result). As the market is dominated by chartists, who all expect the price to move in a certain direction, this expectation will come true. Recall that the magnitude of these coefficients cannot be interpreted as a result of the instrumented returns used for Thailand, formed in Equation (13).

The results for the third and final group, the internationalists, indicate that there is significantly positive correlation between the stock exchanges of Thailand and Hong Kong, $\phi_i > 0$ and significant for both countries. A positive return in the foreign market in period $t-1$ results in a positive return in the home market in period $t$. The fact that there is positive correlation between the two stock markets is an indication that there is interdependence between the two markets on average over the total sample period. Given that the internationalist group is significantly present while the other two groups are also in the equation, implies that past returns from the foreign market contain information on returns of the home market. We cannot conclude anything about shift-contagion from these results, because the coefficients are estimated over the total sample period, and are therefore an average effect. Returns in Hong Kong react significantly negative to high volatility in Thailand with a lag of two periods: $\lambda_2 < 0$. This implies that there is no risk-premium effect,
but traders appear to pull funds out of the market as they expect volatility (and thus risk) to spill over from the foreign market.

Concerning the non-linear case, so estimating the system with switching mechanism, we observe in the final two columns on the right hand side of Table 2 that the coefficients for the three groups are not significantly different from the case without switching mechanism; signs and magnitudes remain highly comparable. Only the coefficient for fundamental uncertainty in Thailand, $\rho_1$, changes significantly, from significantly positive to insignificantly negative. Introducing the possibility for agents to switch forecasting strategy thus does not seem to have an impact on the weight they give to certain pieces of information when forming expectations.

The switching parameter $\gamma$ is significant for both Hong Kong and Thailand; the signs, however, are opposite. The negative sign for the Hang Seng implies that the weight attached to a strategy with a relatively good fit in period $t$ is decreased in period $t+1$. In other words, strategies that perform better than competing strategies in a given period, perform worse than the other strategies in the next period, such that agents move away from well performing strategies as they know they will not perform well the next period. For the Bangkok stock exchange this is not the case because of the positive $\gamma$; a strategy that performs well in period $t$ receives more weight in period $t+1$. A strategy that performs well in period $t$ is known to perform well in period $t+1$ as well, such that more agents will follow that particular strategy. The higher absolute magnitude of $\gamma$ in Thailand compared to Hong Kong implies that traders are more sensitive to differences in performance between strategies; they are more inclined to change strategy in response to a difference in forecasting performance. The reason for the higher sensitivity in Thailand is the higher volatility in the market. The probability that a certain strategy performs well for a number of consecutive periods in a volatile market is smaller than in a stable market. Because of the fact that market conditions change more rapidly in a volatile market, optimal forecasting strategies also change more rapidly. As agents know this, they will react instantaneously on a difference in forecasting performance.

The fact that we find significant coefficients for all three strategies simultaneously makes us conclude that there are indeed heterogeneous agents active on the Thai and Hong Kong stock exchanges. If there would be a single, representative agent using one strategy, we would not have found significant coefficients for more than one strategy at the same moment. Furthermore, the fact that the switching parameters are both significant, and that the model fit,
represented by the adjusted $R^2$, is significantly higher in the switching case\(^4\), implies that there are not only heterogeneous groups active on the market, but that the relative magnitude of these groups also changes through time. Agents thus switch between strategies.

These results are consistent with the results of Boswijk et al. (2005) and Reitz and Westerhoff (2003). Both papers find evidence of heterogeneous behaviour in the S&P500 and the major foreign exchange markets, respectively. Boswijk et al. (2005) find two groups of fundamentalists who differ in their mean-reversion coefficients; significant switching, however, is not found. Reitz and Westerhoff (2003) find a group of chartists and a group of fundamentalists, including significant and rapid switching between the groups. Our results are not yet directly comparable to the contagion literature, because the presence of the internationalist groups in both countries does not provide a firm conclusion concerning shift-contagion; it only indicates significant interdependence on average during the sample period. The significant switching is a first indication that the magnitude of the internationalist group is possibly unstable through time, though. This would imply that the correlation between the markets is also unstable, thus pointing towards shift-contagion. However, it could also be the case that agents only switch between chartism and fundamentalism, leaving the correlation between the two stock markets constant.

### 4.2 Weights

The estimation results indicate that there are agents in the market that have time-varying forecasting strategies. In this subsection we will analyze the development and distribution of the weights through time, in order to determine the effect of the crisis. Furthermore, it allows us to draw inferences concerning the potential shift-contagion.

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Insert Figure 2 Here

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Figure 2 displays the evolution of weights $w_{it}$, estimated by the model over the sample period. The monthly weights of Hong Kong (upper left plot) move in a relatively small band, roughly between 0.24 and 0.40, and oscillate around the uniform distribution of 1/3. There is an increase in volatility in 1993/1994, and a built-up in volatility starting in 1996, around the

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\(^4\) F-tests on the difference between the $R^2$'s of the model with and without switching indicates that the model with switching has a significantly better fit for both Hong Kong (p=2.218\%) and Thailand (p=0.021\%).
crisis. Although somewhat difficult to distinguish, but the fundamentalists’ and chartists’ weights move in opposite directions, in a zigzag pattern, while internationalists weight is relatively stable. That is, a positive shock induced by fundamentalists is picked up and extrapolated by chartists in the next period, and reversed again by fundamentalists in the third period etc. This corroborates the results of the negative switching parameter, which implies that agents move away from a strategy with a good fit in the previous period. The monthly weights of Thailand (bottom left plot), show a different picture. The range in which the weights move is much wider than for Hong Kong. This is a direct result of the higher absolute value of the switching parameter, which makes agents move in large groups such that they tend to cluster in one certain strategy per period. Fundamentalists’ weight is close to zero up to 1997, after which it becomes the dominant strategy. This causes the market to correct back towards the fundamental price, i.e. to crash. In Thailand we do not see a high frequency of switching between the two strategies, as we see in Hong Kong, as a result of the positive switching parameter; profitable strategies attract instead of push away people. Chartist and internationalist weight move in opposite directions in the first part of the sample as a result of the fact that the weights sum up to one, and fundamentalist weight is equal to zero.

The plots of the yearly weights, on the right hand side, show a clearer image of the market dynamics. For Hong Kong (upper right) we observe again the small band, with weights moving around 1/3 for the first number of years, but during the crisis we see a shift. In 1997 and especially 1998, the two years in which the Hang Seng loses 60% of its value, we see a sharp increase in the internationalist weight, accompanied by a sharp decrease in the weight of the other two strategies. This is a direct sign that there is indeed shift-contagion from the Thai market to the Hong Kong market during the crisis. In the crisis years, investors in the Hang Seng market put a significantly larger weight on past movements of the Thai market than before or after the crisis. As the coefficients in the expectation formation function of internationalists remain constant in this setup, the relation between the markets is strengthened. The yearly weights for the Thai market (bottom right) also show a clear image. Until 1996, the weight given the misalignment is equal to zero. During these years, internationalists dominate the market. That is, more than half of the agents active on the Thai market extrapolate lagged movements from the Hong Kong market (which were backed up by fundamentals); the rest of the agents extrapolate recent national price changes causing the bubble to inflate. This can be interpreted as shift-contagion of the strong fundamental-based

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5 Yearly weights are yearly averages of the monthly weights.
growth in the Hong Kong market to the Thai market during the first half of the 90’s. In 1997, there is a massive turn-around in sentiment and fundamentalists start dominating the market such that the importance given to the Hong Kong market falls. This causes a correction to the fundamental price in the Bangkok S.E.T. Given this extremely large correction, real factors start playing a role and the fundamental price itself also drops (see Figure 1), causing the market to move with it.

Table 3 presents descriptive statistics of the monthly strategy weights. The numbers illustrate the findings from Figure 2 somewhat more.

The mean values of the weights for Hong Kong are close to one-third for all periods, i.e. none of the strategies is dominant or gets driven out of the market for long periods on end. The range and standard deviations increase somewhat in the crisis period due to increased uncertainty. Although it is not possible in this model to follow individual agents, it is possible to examine the switching behaviour of the population of agents by interpreting the correlations between the weights. The correlation coefficients for Hong Kong are all negative, reflecting the fact that the weights sum up to one. The correlation between fundamentalists’ and chartists’ weight is high and negative throughout the sample, which represents the zigzag-pattern we observed in the graphical analysis of the weights. The largest part of switching thus occurs between fundamentalism and chartism. The internationalists’ weight is relatively stable on average; the switching that does occur is between chartism and internationalism. This can be explained by the fact that these strategies are highly comparable in their methodology (both use past price movements), combined with the fact that the average correlation between the markets over the sample period is relatively high.

For Thailand we observe that the fraction of fundamentalists is indeed practically equal to zero until 1996 and dominant afterwards. The mean value of internationalists’ weight is highest until 1996, and drops during and after the crisis. The range of fundamentalists is small for the first part of the sample; for internationalists and chartists we see that they almost vary between zero and one, reflecting the sensitivity and group-behaviour of traders in Thailand. The variability in internationalists’ and chartists’ weight drops during and after the
crisis because the third group becomes active, which decreases the range in which the former two strategies move. While the correlations between the weights were relatively stable through time for Hong Kong, they change dramatically for Thailand during the crisis. Before the crisis, the correlation between internationalists and chartists is practically equal to minus one because fundamentalist influence was equal to zero, and the sum of weights is equal to one per definition. During the second half of the sample, the correlation between \( w_c \) and \( w_i \) diminishes, while the other two correlations rise considerably. Therefore, agents either switch between fundamentalism and chartism or between fundamentalism and internationalism, not between chartism and internationalism in the second half of the sample; this result is the opposite of the result for Hong Kong.

4.3 Stability

Given that the market conditions change dramatically over the course of the sample, it might be possible that the coefficients of the model are also time-dependent. Although the model is dynamic in itself, behaviour of traders can be time-varying. In terms of the model this is especially the case concerning the switching parameter \( \gamma \). As market risk is higher in periods with high volatility, agents might become more sensitive to differences in forecasting ability of the strategies (assuming that risk aversion is constant through time). Especially during the course of the crisis, which, as we have seen in Section 4.2, was triggered by a massive turnaround in trader-sentiment, it is not unlikely that the behaviour of traders has changed.

In order to test this proposition, we estimate the model for a rolling window of observations. The first window is the first 52 observations of the total sample (January 1990 – April 1994); for the second window we add one observation on the right side, and subtract one from the left side, etc. In the end this procedure results in 70 sub-samples and corresponding estimated coefficient vectors.

Figure 3 shows the development of the switching parameter \( \gamma \) and the 95% confidence intervals\(^6\) for the 70 estimated sample windows. The switching parameter for the Hong Kong

\(^6\) Note that the confidence intervals are relatively wide as a result of the small sample size.
market is close to zero until September 1996, when there is a sharp increase making the estimate significantly positive. This is during the time when the correction in the Thai market is most severe. This increase is corrected when the Thai market reaches its fundamental, the Thai Baht reaches its lowest value in ten years and the Thai overnight rates increase sharply in January 1997. The increase in the confidence intervals of the switching parameter in July 1997 coincides with the accession of Hong Kong to the People’s Republic of China, and the attack on the Thai Bath. After the attack on the Hong Kong Dollar in October 1997, the intervals decrease again, and γ becomes significantly negative. The dip at the end of 1998 coincides with the sharp rise of the fundamental price in Thailand and another attack on the currency board in Hong Kong.

For Thailand the switching parameter is stable and insignificant until 1997, when there is a sudden increase to significantly positive values, followed by a sharp decrease to significantly negative values. The increase coincides with a series of measures by the government to tighten international capital inflows, the attack on the Thai Baht, and the beginning of the descend of the Hong Kong market. The parameter becomes significantly negative after the sharp decrease in the Thai fundamental price in the beginning of 1998. This decrease coincides with the decision to dismantle currency controls. By the end of the sample period, the coefficient rises again and becomes significantly positive. This increase coincides with the peak in the Thai fundamental price, and with the sharp decrease of the switching parameter of the Hong Kong market.

In general it seems to be the case that the behaviour of agents in both the Hong Kong and Thai market depends on market conditions and changing government regulation in Thailand and Hong Kong. Note, however, that this is a very rough characterization of events. The high volatility periods were characterized by a number of events. Future research should give more insights into the nature of the changes in behaviour. The crisis in 1997 and 1998 is for both countries the immediate cause for the switching parameter to become instable, and thus for trader behaviour to change.

The development of the other parameters in the model is displayed in Figures A1 and A2 in the Appendix. For all coefficients in the Hong Kong case we observe relatively stable values until 1996, until the Thai markets starts to drop. Between 1996 and 1998 or 1999 the coefficients are more volatile, but stabilize again in 1998 or 1999 as both markets themselves are stabilized again. The post-crisis value of the coefficients is in most cases roughly comparable to the ante-crisis values, or moving towards it. During the crisis period the variance in the estimates is relatively high, and coefficients change sign in six cases. These
shifts in the values of the parameters are generally not significant, though. The same conclusions hold more or less for Thailand. Only concerning the fundamental based coefficients $\theta_1$ and $\rho_1$ do we observe a high volatility in the ante-crisis period. This, however, can be explained by the fact that the market was detached from the fundamental price.

Gravelle et al. (2006) state that the change in co-movement between asset returns should be driven by a change in the structural transmission of shocks in order to be qualified as shift-contagion. Given that the parameters in our model, including the coefficients that define the co-movement between the two indices $\phi$ and $\lambda$, change during the crisis period, our model also leads us to conclude that there was indeed shift-contagion present during the Asian crisis in 1997-1998. So next to the increased proportion of Hong Kong traders that focused on the Thai market during the crisis, the expectation formation functions also changed.

5. Crisis Prediction

Although the model gives interesting insights in the dynamics occurring during the Asian crisis, the more fundamental question is whether the model is also able to predict the crisis out-of-sample. If the model shows to be able to predict crises, one could think of developing an early-warning system for crises. One could e.g. think of the observed overvaluation or the distribution of agents over the different strategies in this respect. The current Section will try to answer this question.

In the analysis of the log real market price and log real fundamental price, it became clear that the market price in Thailand was severely overvalued with a maximum in 1995, after which prices fell back to the fundamental price (and beyond). We examine whether our model also predicts this decline by iterating the model forward using the estimated coefficients. That is, we take the estimated coefficients from Section 4 as given, and iterate the system of two equations forward starting from the point where the market starts declining (June 1996). Note that the forecasted value of Hong Kong in period $t$ is used to forecast the Thai market in period $t+1$ and vice-versa, implying that it is a dynamic interactive iteration process. This methodology does not use unknown information in forecasting; that is, we keep the level of the fundamental price and dividend constant at June 1996 levels. The model does not use more information than the standard random walk in forecasting. Figure 4 presents the forecasted and realized prices, starting in June 1996.
The forecasted price for the Hong Kong market shows a slowly increasing price level starting in the first months of 1997. It does not follow the realized price level, but the realized price level appears to oscillate around the forecasted price. The model does not predict a crisis in the Hong Kong market; price gradually moves away from the (constant) fundamental price. The forecasted price for Thailand, though, does follow the realized price level. The forecast follows the decline of the realized price until it reaches the fundamental price. After that, the market price declines further (following the actual fundamental price), while the forecast remains close to the June 1996 fundamental price. In fact, the forecasted market price stabilizes somewhat below the June 1996 fundamental price; this occurs as a result of the counterweight of chartists and internationalists. Forecasting prices while assuming that agents can observe the contemporaneous fundamental price and dividend yield gives a comparable picture for Hong Kong. For Thailand the forecasted price continues to follow the fundamental price, as does the realized market price, also after the correction (results now shown in the paper). In general it thus seems that the forecasted market prices follow the fundamental price relatively close; if the price is detached from the fundamental, the model brings it back to the fundamental price.

In Figure 5 we present the monthly and yearly weights forecasted by the model. The first issue is the striking difference in volatility between forecasted and realized weights for both countries. The model converges to a stable equilibrium when it does not receive exogenous shocks (i.e. fundamental shocks). Concerning Hong Kong we notice that the internationalists’ weight does not increase as we have seen in Figure 2. This explains why we do not observe the contagion of the crisis in the forecasted price level from Thailand to Hong Kong in Figure 4. Instead, the fundamentalists gain momentum. However, even though fundamentalism is the dominant strategy, chartists and internationalists push the market price away from the fundamental price. The development of forecasted weights in Thailand does roughly resemble the realized development of weights. Internationalists’ and chartists’ weights drop, while fundamentalists’ weight increases.
From the results described above we conclude that the model does forecast the correction of the Thai market to its fundamental. However, it does not foresee the contagion effect to the Hong Kong market, and, second, we started the forecasting procedure at the same moment the realized market price started to decline. Experiments with this starting date illustrate that the model predicts a return to the fundamental price regardless of the date at which we start the iteration process. That is, if we iterate the model forward starting form any point between 1990 and 1996, the model always predicts a sharp drop in price until it reaches the fundamental price. Therefore, the model does forecast the Asian crisis, but it does not forecast the timing of the crisis. In terms of early-warning-systems, the model puts forward that (large) over- or under- valuations of the market price versus the fundamental price will need to be corrected. Therefore, if one observes an excessive misalignment, this serves as an early-warning in the logic of the model. In reality, of course, it is always the question which fundamental to look at, on what horizon, and to determine what is excessive.

6. Conclusions and Suggestions
The purpose of this paper was to combine insights from the (shift-) contagion literature and the heterogeneous expectations literature in order to get a better view on market-dynamics during crises. For this end, we set up and estimated a dynamic model with boundedly rational heterogeneous interacting agents for the asset market. The contagion issue is incorporated by assuming that there are two markets for risky assets and by modelling a third group of market participants, internationalists, next to fundamentalists and chartists, who condition their expectations on past returns of the foreign market. The model is estimated for the Hang Seng and Bangkok S.E.T. indices for the period surrounding the Asian crisis, 1990-1999.

We find that the Thai market was highly overvalued in the period leading to the crisis as a result of the fact that more than half of the traders active in the Thai market conditioned their expectations on the Hang Seng index while the other half used destabilizing technical analyses, and none of the traders considered the fundamental price. The Hang Seng market was relatively close to its fundamental in this period and the traders were equally spread across forecasting strategies. The crisis is triggered by the fact that Thai traders started focusing on the fundamental price instead of the Hang Seng index. As a result, the balance
shifted and traders in the Hong Kong market started focusing predominantly on the Thai market, causing the Hang Seng to drop as well.

From these findings we conclude that traders in the Asian stock markets are heterogeneous, and that they change strategy. Furthermore, we conclude that there was indeed shift-contagion in the Asian markets during the 1990’s; first from the Hang Seng to the Bangkok S.E.T., then from the Bangkok S.E.T. to the Hang Seng. Traders appear to focus on the news item that is most extreme. Next to shifting strategy weights during the crisis, we also find that the expectation formation functions themselves change during the crisis. Therefore, we also find shift-contagion in its most stringent definition. The model is also capable of predicting the occurrence of the crisis, but it is not able to predict the timing.

Future research in this field can spread into different directions. First of all, theoretical knowledge of the behaviour of heterogeneous interacting agents models with multiple asset markets is relatively limited. The focus thus far has been primarily on single asset markets, while global financial markets are becoming more and more interrelated. In the application of heterogeneous expectations models to the contagion issue, one can think of enhancing the two-market model to a multi-market model. In this way, it might be possible to distinguish the exact spread of a crisis across different countries. Finally it will be interesting to determine the exact triggers of changing behaviour. In this paper we have mainly focused on the behaviour of market participants, and matched turning points in an ad-hoc fashion with economic events. Knowing that behaviour of agents changes resulting from certain shocks is one, the next step is to determine why it changes.
References

Appendix
Figure A1: Stability Parameters Hong Kong

Figure A1 presents the evolution of the coefficients of the expectation formation functions (Equations (5), (6) and (7)) estimated by a rolling regression technique for Hong Kong. The dates in the x-axis represent the final date in the rolling sample of 52 observations. Dotted lines represent the 95% confidence intervals.

Notes:
Notes: Figure A2 presents the evolution of the coefficients of the expectation formation functions (Equations (5), (6) and (7)) estimated by a rolling regression technique for Thailand. The dates in the x-axis represent the final date in the rolling sample of 52 observations. Dotted lines represent the 95% confidence intervals.
Tables and Figures

Figure 1: Market and Fundamental Prices

Notes: Figure 1 presents the (log real) market and fundamental prices of the Hang Seng and Bangkok S.E.T. The fundamental prices are determined by the dynamic Gordon model, Equation (10).
Figure 2: Weights

Notes: Figure 2 represents the weights of the three groups $w_{i,t}$ as estimated by the model. Upper two plots for Hong Kong lower for Thailand. The two left plots are monthly observations; the right plots are yearly averages. $W_f$ represents fundamentalist weight; $W_c$ chartist weight and $W_i$ internationalist weight.
Figure 3: Switching Parameters

Notes: Figure 3 presents the evolution through time of the switching parameter $\gamma$ estimated by a rolling regression technique. The dates on the X-axis represent the final date of the 52 observation interval. Dotted lines are 95% confidence intervals.
Figure 4: Forecasted Prices

Notes: Figure 4 depicts the by the model forecasted price evolution (solid lines) and realized price evolution (dotted line) for Hong Kong (left) and Thailand (right). Forecasts are made by iterating the realized price forward starting in June 1996 using the estimated coefficients, without adding new information.

Figure 5: Forecasted Weights

Notes: Figure 5 depicts the evolution of forecasted weights. $W_f$ represents chartist weight; $W_i$ internationalist and $W_c$ chartist.
Table 1: Descriptive Statistics

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Notes: Table 1 presents the descriptive statistics of the (log real) prices \( P_i \), fundamental prices \( P'_i \), returns \( r_i \) and misalignments \( P_i - P'_i \) of the Hang Seng and Bangkok S.E.T. stock markets. St.Dev. represents the standard deviation; Prob AC the probability of autocorrelation at the first lag; Prob AC Sq the probability of autocorrelation in the squares at the first lag and Prob U.Rt. the probability of a unit root.
Table 2: Estimation Results

This table reports the estimated coefficients and standard errors of the system formed by the Thai and Hong Kong versions of the following equations (c.f. Equation (8)), for the linear ($\gamma=0$) and nonlinear ($\gamma$ is estimated) case:

Fundamentalists:  
$$E_t \Delta P_{it} = \sum_{i=1}^{k} \theta_i (P_{it} - P_{it-1}) + \rho_i (P_{it} - P_{it-1})^2$$

Chartists:  
$$E_t \Delta P_{it} = \sum_{i=1}^{k} \alpha_i \Delta P_{it-1} + \beta_i \Delta P_{it-1} (P_{it-1} - P_{it-1})$$

Internationalists:  
$$E_t \Delta P_{it} = \sum_{i=1}^{k} \phi_i \Delta P_{it} + \lambda (\Delta P_{it})^2$$

Switching:  
$$w_{st} = \frac{1}{1 + \sum_{i=1}^{k} \exp[\gamma (P_{s,t-i} - P_{t-i})]}$$

<table>
<thead>
<tr>
<th></th>
<th>Without Switching</th>
<th></th>
<th>With Switching</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Hong Kong</td>
<td>Thailand</td>
<td>Hong Kong</td>
</tr>
<tr>
<td>Fundamentalists</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\theta_1$</td>
<td>-0.987**</td>
<td>-0.183**</td>
<td>-0.850**</td>
</tr>
<tr>
<td></td>
<td>(0.446)</td>
<td>(0.073)</td>
<td>(0.399)</td>
</tr>
<tr>
<td>$\rho_1$</td>
<td>-2.755***</td>
<td>0.174*</td>
<td>-3.505***</td>
</tr>
<tr>
<td></td>
<td>(1.028)</td>
<td>(0.094)</td>
<td>(1.048)</td>
</tr>
<tr>
<td>$\theta_2$</td>
<td>0.819*</td>
<td>0.675*</td>
<td>3.167***</td>
</tr>
<tr>
<td></td>
<td>(0.441)</td>
<td>(0.401)</td>
<td>(1.032)</td>
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<tr>
<td>$\rho_2$</td>
<td>3.167***</td>
<td>3.772***</td>
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</tr>
<tr>
<td></td>
<td>(1.032)</td>
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</tr>
<tr>
<td>Chartists</td>
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<tr>
<td>$\alpha_1$</td>
<td>1.697***</td>
<td>4.944***</td>
<td>1.394***</td>
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<tr>
<td></td>
<td>(0.555)</td>
<td>(2.043)</td>
<td>(0.487)</td>
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<tr>
<td>$\beta_1$</td>
<td>8.638***</td>
<td>10.626**</td>
<td>10.754***</td>
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<tr>
<td></td>
<td>(2.208)</td>
<td>(4.614)</td>
<td>(2.248)</td>
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<tr>
<td>$\alpha_2$</td>
<td>0.030</td>
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<td>(0.273)</td>
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<td>$\beta_2$</td>
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<td>(1.110)</td>
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<td>Internationalists</td>
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<tr>
<td>$\phi_1$</td>
<td>0.492***</td>
<td>1.023***</td>
<td>0.656***</td>
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<td>(0.224)</td>
<td>(0.346)</td>
<td>(0.204)</td>
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<tr>
<td>$\lambda_1$</td>
<td>-1.410</td>
<td>2.042</td>
<td>-1.619</td>
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<td>(1.168)</td>
<td>(3.290)</td>
<td>(1.061)</td>
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<td>$\phi_2$</td>
<td>0.128</td>
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<td>(0.206)</td>
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<tr>
<td>$\lambda_2$</td>
<td>-3.655***</td>
<td>-3.306***</td>
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<tr>
<td></td>
<td>(1.072)</td>
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<td>Switching</td>
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<tr>
<td>$\gamma$</td>
<td>-0.073*</td>
<td>3.249***</td>
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<td></td>
<td>(0.041)</td>
<td>(0.886)</td>
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<tr>
<td>Adjusted $R^2$</td>
<td>0.239</td>
<td>0.215</td>
<td>0.270</td>
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Notes: Table 2 presents the estimated coefficients and standard errors (in parenthesis) of the system in Equation (8), without (left two columns) and with (right two columns) switching mechanism, for Hong Kong and Thailand. The subscripts of the coefficients denote the number of lags. *, **, *** represents significance at the 10, 5 and 1% level, respectively.
### Table 3: Weights Characteristics

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<tr>
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<tr>
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<td>'90-'99</td>
<td>'90-'96</td>
<td>'97-'99</td>
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<td></td>
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<tr>
<td>$w_f$</td>
<td>0.333</td>
<td>0.333</td>
<td>0.333</td>
<td>0.005</td>
<td>0.363</td>
<td>0.116</td>
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<tr>
<td>$w_c$</td>
<td>0.329</td>
<td>0.321</td>
<td>0.326</td>
<td>0.467</td>
<td>0.292</td>
<td>0.412</td>
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<tr>
<td>$w_i$</td>
<td>0.338</td>
<td>0.347</td>
<td>0.341</td>
<td>0.528</td>
<td>0.345</td>
<td>0.471</td>
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<td>Max</td>
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<tr>
<td>$w_f$</td>
<td>0.394</td>
<td>0.434</td>
<td>0.434</td>
<td>0.062</td>
<td>0.818</td>
<td>0.818</td>
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<tr>
<td>$w_c$</td>
<td>0.407</td>
<td>0.396</td>
<td>0.407</td>
<td>0.868</td>
<td>0.666</td>
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<tr>
<td>$w_i$</td>
<td>0.365</td>
<td>0.389</td>
<td>0.389</td>
<td>0.960</td>
<td>0.644</td>
<td>0.960</td>
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<tr>
<td>Min</td>
<td></td>
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<tr>
<td>$w_f$</td>
<td>0.251</td>
<td>0.263</td>
<td>0.251</td>
<td>4.72E-7</td>
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<td>$w_c$</td>
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<td>0.241</td>
<td>0.037</td>
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<tr>
<td>$w_i$</td>
<td>0.328</td>
<td>0.325</td>
<td>0.325</td>
<td>0.132</td>
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<tr>
<td>$w_f$</td>
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<td>0.022</td>
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<tr>
<td>$w_c$</td>
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<tr>
<td>$w_i$</td>
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<td>0.013</td>
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<td>0.143</td>
<td>0.204</td>
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<td>$w_f - w_c$</td>
<td>-0.934</td>
<td>-0.915</td>
<td>-0.910</td>
<td>-0.351</td>
<td>-0.630</td>
<td>-0.469</td>
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<tr>
<td>$w_c - w_i$</td>
<td>-0.348</td>
<td>-0.310</td>
<td>-0.361</td>
<td>-0.999</td>
<td>-0.073</td>
<td>-0.539</td>
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<tr>
<td>$w_f - w_i$</td>
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<td>-0.100</td>
<td>-0.059</td>
<td>0.309</td>
<td>-0.729</td>
<td>-0.491</td>
</tr>
</tbody>
</table>

**Notes:** Table 2 presents the characteristics of the estimated weights for the ante-crisis period (1990-1996), the crisis/post-crisis period (1997-1999) and the total sample. $w_f$, $w_c$, $w_i$ represents fundamentalist, chartist and internationalist weight, respectively.