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Abstract: The Currency Board System in Hong Kong and the monitoring band system in Singapore are important benchmarks for two different exchange-rate systems. In this paper we consider the implications of the two exchange-rate systems on the interest-rate behaviour of the two economies. We examine the domestic-US interest differentials under the two exchange-rate regimes during the Asian Financial Crisis as well as the pre- and post-crisis periods. Using a bivariate generalized autoregressive conditional heteroscedasticity model, we also investigate whether there is any change in the correlation between the domestic and US interest rates due to the Asian Financial Crisis.

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1 Introduction

Hong Kong (HK) and Singapore (SP) are two Asian economies with many similarities. Both economies are small and open (in terms of trade and capital flows), with relatively well developed financial sectors. They have, however, rather different monetary systems and exchange-rate regimes. HK has a currency board system (CBS) under which the HK dollar is pegged to the US dollar at a fixed exchange rate. On the other hand, SP has evolved from a classical sterling-based CBS into a managed-float monitoring band system under which the value of the SP dollar is managed against an undisclosed trade-weighted basket of foreign currencies. In this paper we consider the implications of the two exchange-rate systems on the interest-rate behaviour of the two economies. We examine the domestic-US interest differentials under the two exchange-rate regimes. Using a bi-variate GARCH model, we also investigate whether there is any change in the correlation between the domestic and US interest rates due to the Asian Financial Crisis (AFC).

HK's and SP's exchange-rate systems are each by itself an important and interesting benchmark. Among the economies with a CBS, HK is the one with the most developed financial sector and the highest capital mobility. Kwan and Lui (1996) argued that the economic health of the HK economy has made HK's modern CBS an important benchmark for international comparisons, evaluations and theoretical developments of the CBS. As pointed out by Miller (1998), Chan and Chen (1999), Tsang (1999) and Yip (1999), the substantial surge in HK's interest rate during the AFC was the main cause of the subsequent plunge in asset price. Thus, studying the behavior of interest rate under HK's modern CBS will throw light on the merits and de-merits of the CBS against financial disturbance. On the other hand, the SP government allowed the SP dollar to depreciate by about 20% vis-à-vis the US dollar during the crisis and post-crisis periods. How this flexibility in the SP dollar exchange rate affects the level and volatility of her domestic interest rate is an interesting topic to pursue.

Both the monitoring band and the crawling band are adjustable band systems around a parity that are periodically revised in relatively small steps in a way intended to keep the bands in line with the fundamentals (see Williamson (2000)). Compared with the fixed exchange-rate system or Krugman's (1991) type of target zone, the adjustable band systems can reduce the possibility of a collapse or disruptive change in the domestic exchange rate arising from prolonged differences between the home and foreign countries' fundamentals. In addition, the adjustable band systems allow higher independence in the domestic interest-rate (monetary) policy (see Yip (2003)). However, a monitoring band, as opposed to a crawling band, does not involve an obligation to defend the edge of the band. The obligation is only to avoid intervening within the band.

Williamson (2000) argued that "if a country intends to pursue a fixed exchange rate policy, then it ought to do it properly by employing a currency board," and that "the debate on exchange rate policy ought not to concern fixed versus floating rates, but rather currency boards versus crawling (monitoring) bands." These comments provide strong motivations for studies on various aspects of the two exchange-rate systems. In this paper, we focus on one particular aspect, namely, the implication of the two exchange-rate systems on the interest-rate behaviour of the two economies. As explained above, the surge in HK's interest rate in the crisis period brought about significant adjustment problems to her economy. Thus, an investigation of the interest-rate behaviour under the two regimes has important implications for a comparison of the two regimes. We provide an empirical examination of this issue.

The main objectives of this paper are as follows. First, we investigate whether the monitoring band system in SP is associated with a higher flexibility of the interest-rate policy. Second, we examine whether the SP interbank market, as compared to that in HK, has exhibited a lower interest volatility during the non-crisis period. Third, we compare the levels and the volatilities of domestic-US interest premium during the crisis period. Finally, we examine whether greater flexibility in the exchange-rate target in SP is associated with (a) a wider range of domestic-US interest differential, and (b) a lower correlation between the changes in the domestic and US interest rates.

The plan of this paper is as follows. In section 2, we discuss the exchange-rate systems in the two economies, with special emphasis on their implications for interest-rate movements and policies. Subsequently, we outline the hypotheses to be tested. The data and the econometric methodology are described in section 3. We report the empirical results in section 4. Finally, section 5 provides the conclusion.

2 The Exchange-Rate Systems and Interest-Rate Behaviour in HK and SP: Some Testable Hypotheses

2.1 Implications of HK's Currency Board System on Her Interest Rate

Since October 1983, HK has adopted the CBS in which the money supply is fully backed up by the US dollar held at the Exchange Fund of the Currency Board,[1] and the HK dollar is effectively fixed at the rate of US$1 to HK$7.75-7.80.[2] Because of the high capital mobility and the fixed exchange-rate system, uncovered interest arbitrage ensures that HK's interest rate follows the US interest rate fairly closely during normal periods. In other words, with the high capital mobility and the CBS, HK has little independence in fixing her domestic interest rate.

Our econometric model of HK's interest-rate behaviour resembles the basic features in Tse and Yip (2003). However, to enable comparison with SP, we nest the discussion of

[1]Under the system, any one of the three note-issuing banks wishing to print HK dollar notes need to surrender an equivalent amount of US dollar (at the official rate) to the Exchange Fund in exchange for the Certificate of Indebtedness (CI), which entitles the note-issuing bank to print that amount of HK dollar. On the other hand, the note-issuing banks can always use their holdings of CIs and HK dollar notes to redeem an equivalent amount of US dollar from the Exchange Fund. However, before the introduction of the seven technical measures in September 1998, the HKMA could manipulate interbank liquidity and interest rates to 'defend' the self-imposed line of defence: HK$7.75/US$. Thus, some researchers question whether the HK system could be classified as a genuine CBS.

[2]The market exchange rate for HK$ was around 7.75 HK$/US$ until April 1999 when the monetary authority started to move it gradually to 7.80 HK$/US$ in order to unify it with the rate used to back banknotes.

the two interest-rate regimes in the following equation:

$$i_t - i_t^{US} \equiv y_t = \mathrm{E}_t(\Delta s_{t+k}) + rp_t \tag{1}$$

where i_t is the domestic interest rate in HK or SP, i_t^{US} is the interest rate in the US, y_t is the domestic-US interest differential, $\mathrm{E}_t(\Delta s_{t+k})$ is the expected depreciation of the domestic currency between the current period t and the maturity period at $t+k$; and rp_t is the risk and liquidity premium between the domestic and the US rates. Thus, the variation in the domestic-US interest-rate differential depends on the expected depreciation of the domestic currency and the risk premium. In the following discussion, we examine the hypothesized effects of these determining factors on the interest-rate differential during the crisis and non-crisis periods.

During the non-crisis periods, when the credibility of HK's currency board system is not in question, $\mathrm{E}_t(\Delta s_{t+k})$ is expected to be close to zero. On top of this, the well developed and liquid interbank market in HK implies a fairly small risk and liquidity premium rp_t during these periods. However, the weakened market confidence on the continuation of the peg during a crisis period may lead to a rise in $\mathrm{E}_t(\Delta s_{t+k})$ (see Yip (1999)) and rp_t.[3] As a result, the mean of the domestic-US interest differential during the crisis may be higher than that in the non-crisis period. In addition, the uncertainty in the crisis period implies that the volatility of the interest-rate differential during this period may be higher than that in the non-crisis period, as was found in Tse and Yip (2003).

Although Tse and Yip (2003) examine the changes in the volatility structure they do not take account of the possible difference in the dynamic response of the interest-rate differential between the crisis and non-crisis periods. In this paper, we extend their work and allow the dynamic response (as determined by the regime changes in the AR processes driving the conditional mean) to differ in the crisis and non-crisis periods.[4] With the extended framework, we investigate the following hypotheses arising from the above

[3]Yip (1999) noted that percieved possiblity of a collapse of the peg and a loophole in the CBS had discouraged banks from performing uncovered interest arbitrage, despite the emergence of a huge interest differential between the HK and US interest rates during the crisis period.

[4]See section 3 for the details.

discussion. First, during the non-crisis periods, the absence of an independent interest-rate (monetary) policy in HK results in (a) a small range within which the HK-US interest differential can fluctuate, and (b) a strong correlation between the changes in the HK and US interest rates. Second, during the crisis period (a) the range of the HK-US interest differential widens (although this does not imply a greater independence in HK's interest-rate policy), and (b) there is a decline in the correlation between the changes in the HK and US interest rates. Furthermore, we compare the above interest-rate behaviour in HK with that in SP, which will throw light on the reactions of the two exchange-rate systems to the AFC.

2.2 Implications of SP's Monitoring Band System on Her Interest Rate

Unlike HK, SP has an undisclosed exchange-rate band targeting system with credibility and strong policy instruments (see Teh and Shanmagaratnum (1992) and Yip (2002)). Rajan and Siregar (2002) pointed out that SP's exchange rate system is basically a monitoring band system in which the Monetary Authority of Singapore (MAS) in general (except for tactical reasons) refrains from intervening so long as the SP dollar lies within the undisclosed and adjustable target band. Yip (2003) also noted that (a) during the normal period in our study, the MAS targeted an undisclosed but gradually appreciating band of Singapore dollar, and the average appreciation turned out to be 2 to 3 percent per annum (the actual figure depends on the specific period selected for computation), and (b) when there is evidence that a major depreciation or appreciation is necessary (such as in the case of the AFC),[5] the MAS revises the mean and width of the exchange-rate band.

The above suggests that during the pre-crisis period, the expected appreciation of the SP dollar as well as the relatively low risk and liquidity premium (due to the efficiency

[5]During the crisis, the SP government announced its intention to let the market force decide the level of SP's exchange rate, thus giving the market the greenlight to push the SP dollar down by about 20% against the US dollar.

of the interbank market) imply that the average SP-US interest differential should be at a discount. However, during the crisis period, the discount falls or even reverses to a premium because (a) the usual expected appreciation of the SP dollar diminishes, disappears or even reverses during the crisis period, and (b) there may be an increase in the risk and liquidity premium during the crisis period. During the post-crisis period, the SP-US interest-rate differential is expected to be lower than that during the crisis. Whether the differential is negative, zero or positive depends mainly on the expected depreciation (and partly on the perceived risk and liquidity premium) during the post-crisis period. Finally, the volatility of the interest differential in the crisis period is expected to be higher than that in the non-crisis periods.

We also hypothesize that the greater flexibility in SP's exchange-rate determination implies higher independence in its interest-rate policy,[6] which in turn implies (a) the range of the SP-US interest differential should be bigger than the range of the HK-US interest differential, and (b) the correlation between the changes in the SP and US interest rates should be lower than that between HK and the US.

On the other hand, as the MAS usually refrains from intervention as long as SP dollar lies within the target band, this implies that SP has the flexibility of using exchange rate to absorb the impact of any exogenous shocks.[7] This would mitigate the burden of the domestic interest rate as an adjusting variable and hence reduce the volatility of SP's interest rate. Thus, compared with the case of a rigid peg/targeting, the characteristic

[6]For example, if the economy is overheated (slowing down), the MAS may opt for a greater (lower or negative) appreciation of the SP dollar by re-injecting less (more) liquidity into the economy through its foreign exchange market operation. The reduction (increase) in money supply will in turn bid up (down) the interest rate and further help cooling (stimulating) the overheated (slowing) economy. For the details of SP's institutional set up related to her exchange-rate system and MAS's liquidity re-injection operation, see Yip and Wang (2001).

[7]For example, consider the case of an exogenous capital inflow (outflow). Without any change in the SP's exchange rate, the exogenous capital inflow (outflow) will cause a decline (increase) in the SP interest rate. However, with the SP dollar being allowed to fluctuate within the band, the capital inflow (outflow) will cause an appreciation (depreciation) of the SP dollar. This will in turn mitigate the capital flow and hence induce a smaller fall (rise) in the SP interest rate. This is particularly obvious during the AFC in which the speculative pressure on the Asian currencies spilled over to SP and exerted an upward pressure on the SP interest rate. By widening the target band and announcing the intention to let the market force determine (i.e., depreciate) the value of the SP dollar, the SP government allowed the SP dollar to fall to a lower level, which in turn mitigated the upward pressure on SP's interest rate.

of allowing the SP dollar to fluctuate within a band implies a lower volatility in the SP interest rate.

Before summarizing the hypotheses to be tested, we highlight that a lower volatility of SP's interest rate is not contradictory with a larger range over the sample. The former is due to the existence of a band within which the SP dollar is free to fluctuate, while the latter is more related to the greater flexibility in revising the target band of the SP dollar according to the prevailing economic conditions.

2.3 Hypotheses to be Tested

Summarizing the discussions in the above subsections, we consider the following testable hypotheses:

(1) During the pre-crisis period, the expected appreciation of the SP dollar implies that the average SP-US interest differential should be at a discount.[8]

(2) During the non-crisis period, the greater independence of interest-rate policy in SP implies that (a) the range of the SP-US interest differential should be wider than the range of the HK-US interest differential, and (b) the correlation between the changes in the HK and the US interest rates should be higher than that between SP and the US.

(3) The monitoring band system in SP implies that there is an extra policy variable (exchange rate) to absorb the impact of exogenous shocks. This is, however, not the case for HK's CBS. Thus, we expect the volatility of the SP-US differential to be lower than that of the HK-US differential during both the crisis and non-crisis periods.

(4) The crisis leads to (a) an increase in both the HK-US and SP-US interest differentials. This also means (b) a breakdown of the HK-US and SP-US interest links (i.e., a reduction in the correlation between the changes in the HK and the US interest rates as well as the correlation between the changes in the SP and US interest rates). As there was a discount in the SP-US differential but no (or limited) discount in the HK-US differential

[8]This result says that the appreciation of the SP dollar causes a lower interest rate in SP. As Yip and Wang (2001) showed that the appreciation has also caused a proportionate reduction in SP's inflation, SP's real interest rate may not be lower than that in HK during the non-crisis period.

before the crisis, there is (c) a premium in the HK-US differential during the crisis period. The SP-US differential, however, may be positive, zero or negative.

(5) The changes highlighted in (4) is reversed during the post-crisis period.

3 The Data and the Methodology

Our data consist of daily observations of the HK, SP and US three-month interbank rates. The data were obtained from the Datastream, and cover the period 1 April 1986 through 28 February 2002, with 4153 observations in total.[9]

Figure 1 plots the three-month interbank rates of the three economies, and figure 2 presents the three-month interest-rate differentials of HK-US and SP-US. Table 1 provides some summary statistics of the data, as well as the tests for unit root using the Augmented Dickey-Fuller (ADF) test. The ADF statistics show that the hypothesis that the SP and US interbank interest rates are nonstationary cannot be rejected at the 10 percent level, while the hypothesis that the HK interbank interest rates are nonstationary cannot be rejected at the 5 percent level.[10] In contrast, the hypotheses that the differenced interest rates are nonstationary are rejected at the 1 percent level for all economies. Thus, the results indicate that all interbank interest rate series contain a unit root. Next we check the stationarity of the HK-US and SP-US interest-rate differentials. The ADF of the HK-US and SP-US interest-rate differentials are, respectively, -6.081 and -3.727. Thus, the evidence is in support of the interest-rate differentials being stationary. Furthermore, in the system of three interest rates Johansen's trace statistics for the null hypotheses of at most one cointegrating equation and at most two cointegrating equations are, respectively, 17.137 and 0.037, providing additional evidence for two cointegrating equations.

As documented in Tse and Yip (2003), the CBS in HK went through several reforms in the last two decades. Also, the AFC was an external shock that had significant impact on

[9]Although the CBS in HK came into effect in 1983, the data we collected from Datastream were only available from 1986.

[10]The results of these tests are based on the critical values given by MacKinnon (1991).

the economy. To capture the possible structural breaks in the data due to the CBS reforms and the AFC we divide the sample period into seven subperiods, which are summarized as follows:

Subperiods (No. of obs.)	Events
P_1: 86/4/1 – 88/6/30 (588)	No monetary reform
P_2: 88/7/1 – 92/5/31 (1021)	Accounting Arrangements
P_3: 92/6/1 – 94/3/15 (467)	Liquidity Adjustment Facility
P_4: 94/3/16 – 97/10/22 (941)	Revised Mode of Operations, without AFC
P_5: 97/10/23 – 98/9/04 (227)	Revised Mode of Operations, with AFC
P_6: 98/9/5 – 98/12/18 (75)	Technical Measures, with AFC
P_7: 98/12/19 – 02/2/28 (834)	Technical Measures, without AFC

For the SP data, the only major external shock is the AFC. To capture the possible structural break in the data we partition the sample period into three subperiods of crisis and non-crisis as follows: (a) P_1: 86/4/1 – 97/10/22 (pre-crisis), (b) P_2: 97/10/23 – 98/10/9 (crisis), and (c) P_3: 98/10/10 – 02/2/28 (post-crisis).

As in Tse and Yip (2003), the interest-rate differentials of HK/SP versus US are modelled using a model with time-varying conditional mean and conditional variance. We denote the HK/SP three-month interbank rate at time t by i_t and the three-month US interbank rate by i_t^{US}. Let $y_t = i_t - i_t^{US}$ denote the interest-rate differential of HK/SP versus US. As i_t and i_t^{US} are found to be nonstationary while y_t is found to be stationary (see the discussions above), we model the dynamics of the interest-rate differential y_t using an autoregressive process.[11] Furthermore, we allow the volatility of the interest-rate differentials to be time-varying. In addition, dummy variables are introduced in the conditional-mean and conditional-variance equations to capture the effects of the reforms (for HK) and the AFC (for both HK and SP). For example, for the HK-US interest differential, we define D_i, $i = 1, ..., 7$, as a dummy variable such that $D_{it} = 1$ if t belongs to the subperiod P_i, and zero otherwise. Thus, the conditional-mean equation for the

[11] For simplicity in estimation we use autoregressive process to model the stationary series y_t.

interest-rate differential is given by

$$y_t = \sum_{i=1}^{M} \delta_i D_{it} + \sum_{j=1}^{p} \phi_j y_{t-j} + \varepsilon_t \tag{2}$$

so that y_t follows an autoregressive (AR) process of order p. The time-varying intercept δ_i determines the average interest-rate differential in each subperiod. For the HK-US differential, $M = 7$; for the SP-US differential, $M = 3$.

In equation (2) the speed of adjustment of the interest-rate differential is determined by the AR coefficients ϕ_j. This model was used by Tse and Yip (2003) for the HK data, with the assumption that the adjustment process is the same during or outside the AFC. In this paper, we relax this restriction in the empirical model and allow ϕ_j to vary in the crisis and non-crisis subperiods. This extension will be applied to the SP data as well. Further details will be given in section 4.

We assume the conditional-variance of the residual ε_t follows a generalized autoregressive conditional heteroscedasticity (GARCH) process. The GARCH model was first suggested by Bollerslev (1986) following the earlier work of Engle (1982), and has since been applied extensively in the empirical finance literature.[12] Thus, by assumption $\varepsilon_t \mid \Phi_{t-1} \sim N(0, \sigma_t^2)$, such that conditional on the information set Φ_{t-1} at time $t-1$ the residual ε_t is distributed as a normal variable with mean zero and variance σ_t^2. In particular, we assume a GARCH(1, 1) model such that

$$\sigma_t^2 = \sum_{i=1}^{M} \gamma_i D_{it} + \alpha \varepsilon_{t-1}^2 + \beta \sigma_{t-1}^2.$$

In this equation the conditional-variance is allowed to shift according to the subperiod. The parameter γ_i determines the shift in the volatility of the interest-rate differential in subperiod P_i.[13]

We estimate the parameters of the conditional-mean and conditional-variance equations jointly using the quasi-MLE (QMLE) method (see Bollerslev and Wooldridge, 1992).

[12]See, for example, Bollerslev, Chou and Kroner (1992) for a survey.

[13]Note that we could allow the persistence of the volatility (as determined by α and β) to vary in the crisis and non-crisis subperiods. However, we believe this extension is of second order.

Restrictions on model parameters are tested using the likelihood ratio (LR) statistic. LR is distributed approximately as a χ^2_R when the restrictions are valid, where R denotes the number of restrictions on the parameters.

To examine the comovements of the changes of the HK/SP interest rates versus the US, we consider a bivariate model. The conditional-mean structures are again assumed to follow autoregressive schemes. We denote $\triangle i_t = i_t - i_{t-1}$ and $\triangle i_t^{US} = i_t^{US} - i_{t-1}^{US}$. The following bivariate process is assumed

$$\triangle i_t = \delta_D + \sum_{j=1}^{p_D} \phi_{Dj} \triangle i_{t-j} + \theta_D (i_{t-1} - i_{t-1}^{US}) + \xi_{1t},$$

$$\triangle i_t^{US} = \delta_U + \sum_{j=1}^{p_U} \phi_{Uj} \triangle i_{t-j}^{US} + \theta_U (i_{t-1} - i_{t-1}^{US}) + \xi_{2t},$$

which incorporate the error correction term $i_{t-1} - i_{t-1}^{US}$.[14]

For the conditional-variance process, we adopt a multivariate GARCH model in which $\xi_t \mid \Phi_{t-1} \sim N(0, \Omega_t)$. The conditional-variance matrix is assumed to follow the BEKK(1,1) structure given by[15]

$$\begin{aligned} \Omega_t &= \begin{pmatrix} c_{11} & c_{12} \\ 0 & c_{22} \end{pmatrix}' \begin{pmatrix} c_{11} & c_{12} \\ 0 & c_{22} \end{pmatrix} + \begin{pmatrix} g_{11} & g_{12} \\ g_{21} & g_{22} \end{pmatrix}' \Omega_{t-1} \begin{pmatrix} g_{11} & g_{12} \\ g_{21} & g_{22} \end{pmatrix} \\ &\quad + \begin{pmatrix} a_{11} & a_{12} \\ a_{21} & a_{22} \end{pmatrix}' \xi_{t-1}\xi_{t-1}' \begin{pmatrix} a_{11} & a_{12} \\ a_{21} & a_{22} \end{pmatrix}. \end{aligned} \quad (3)$$

For the conditional-variance of $\triangle r_t$ (for HK or SP), a dummy variable is added to allow for a shift (increase) in the volatility during the AFC. The estimated equations are used to compute the (daily) conditional correlations over the whole sample period, from which the average correlations over the subperiods of pre-crisis, crisis and post-crisis are calculated.

[14] As we are not considering interest differentials, dummy variables are not incorporated into the model. Thus, daily interest-rate changes are assumed to follow the same process regardless of CBS reforms and/or AFC. Although not reported in the next section, the error correction term is found to be statistically significant in at least one of the equations in each system, thus supporting the cointegration of the interest rate processes.

[15] The BEKK model is named after Baba, Engle, Kraft and Kroner (see Engle and Kroner (1985)). It has the advantage of ensuring the conditional-variance matrix to be theoretically positive semi-definite. This model has been widely used in the financial econometrics literature.

4 The Empirical Results

4.1 Univariate Models

The estimation results of the univariate GARCH models of the interest-rate differential of HK-US and SP-US are summarized in tables 2 and 3, respectively. Model 1 in table 2 is a replication of the estimation results in Tse and Yip (2003), with the time span of the data expanded. As explained in section 2, Model 1 does not allow for a difference in the interest-rate response (i.e., the AR coefficients) during the crisis and non-crisis periods. In contrast, the AR coefficients in Model 2 allow for differential response in the following periods: (a) the non-crisis (NC) period prior to and after the AFC, (b) the crisis period prior to the anti-crisis package (C1), and (c) the crisis period after the anti-crisis package (C2). Using the penalized likelihood approach as given by the Aikaike Information Criterion (AIC), Model 2 is preferred to Model 1 for the HK-US differentials. Similarly, in table 3 Model 2 allows the AR coefficients to vary in the crisis (C) and non-crisis (NC) subperiods.[16] Based on the AIC, Model 2 is preferred to Model 1.

By allowing the AR scheme to differ during the crisis, we can investigate whether there is any evidence of over-reaction response in the interbank markets. From Model 2 in table 2, we note that $\hat{\phi}_1^{C1} = 1.17$, providing evidence that there was an over-reaction response in the HK interbank market during subperiod P_5 (i.e., the crisis period before the anti-crisis package). The estimate implies that there was not only a tendency for the impact of the shock to persist, but also a tendency for the differential to widen the next day.[17] However, the estimate $\hat{\phi}_2^{C1} = -0.24$ suggests that the impact of the shock would start to narrow down from the second day. With the imposition of the convertibility undertaking measure within the anti-crisis package, $\hat{\phi}_1^{C2}$ is no longer greater than 1, confirming that the revitalisation of interest arbitrage has removed the over-reaction response in the interest rate. As SP allowed substantial depreciation of its currency vis-à-vis the US dollar to

[16] Unlike the case of HK, there is no further breakdown in the crisis period.

[17] During this period, the US interest rate was rather stable. Most of the changes in the differential was due to the change in HK interest rate.

absorb the shocks during the crisis period, the estimate $\hat{\phi}_1^C = 0.86$ in table 3 shows that there was no over-reaction in SP's interest-rate response.[18] It is noted that the sum of $\hat{\phi}_i$ (for both the HK and SP equations) during the crisis period are less than that of the non-crisis period, reflecting the fact that the shocks during the crisis are temporary in nature.

A comparison of Model 1 and Model 2 suggests that the $\hat{\delta}_i$ are very close to each other during the pre-crisis and post-crisis periods (i.e., subperiods P_1, P_2, P_3, P_4 and P_7). A comparison of $\hat{\delta}_5$ in Model 1 and Model 2 shows that the failure to take into account the possibility of different interest-rate responses in the crisis and non-crisis periods have led to a downward bias in the estimated interest differential between HK and the US in subperiod P_5. The results in Model 2 show that the estimated average interest differential is 2.01% and the average surge in the differential is 2.15% (i.e., 2.01 + 0.14), larger than the corresponding estimates in Model 1 and in Tse and Yip (2003). In addition, the estimate $\hat{\delta}_6$ suggested that there was a similar downward bias in subperiod P_6.

We now compare $\hat{\delta}_i$ and the implied range of the SP and HK interest differentials during the pre-crisis and post-crisis periods.[19] During the pre-crisis period, $\hat{\delta}_1$ in Model 2 of table 3 shows that there was a 2.27% discount in the SP-US three-month interest differential arising from the expected appreciation of the SP dollar vis-à-vis the US dollar. Meanwhile, the estimated standard error of $\hat{\delta}_1$ shows that the implied four standard-error range of the SP-US interest differential is 3.31%.[20] Similarly, $\hat{\delta}_3$ and its estimated standard error suggests that: (a) during the post-crisis period, there was a 2.39% discount in SP's three-month rate relative to the US rate, reflecting that the market was expecting similar appreciation of the SP dollar vis-à-vis the US dollar, and (b) the implied four standard-

[18] As the sum of the AR coefficients ($\hat{\phi}_2^{C1} + \hat{\phi}_2^{C2} = 1.17 - 0.24 = 0.93$) for HK is greater than that for SP ($\hat{\phi}_1^C = 0.86$), the rise in the interbank rate in HK is also more persistent than that in SP during the AFC.

[19] Because of the monetary reforms in HK, the time span for the pre-crisis and the post-crisis periods in HK are different from those of SP. We have chosen to report the results with the longest time span for each economy. Nevertheless, the results with the same over-lapping time span for the two economies are qualitatively the same.

[20] This is measured by 4 × standard error of $\hat{\delta}_1 \div (1 - \hat{\phi}_1^{NC} - \hat{\phi}_3^{NC})$, which is approximately the 95% interval of the interest-rate differential.

error range of the SP-US interest differential is 4.88%. In fact, a test for $H_0 : \delta_1 = \delta_3$ gives a LR statistic of 0.0374, suggesting that there was no change in the SP-US interest discount before and after the crisis. Similarly, the LR statistic for $H_0 : \gamma_1 = \gamma_3$ is 0.4828, suggesting that there was no change in SP's interest rate volatility between the pre-crisis and post-crisis periods. Imposing these restrictions gives an estimate of 2.32% interest discount and an implied four standard-error range of 3.29% for the non-crisis period.

On the other hand, due to the fixed exchange rate between the HK dollar and the US dollar, there was no interest discount in HK during the pre-crisis (i.e., subperiods P_3 and P_4) and post-crisis (i.e., subperiod P_7) periods. Besides, the implied four standard-error range of the HK-US interest differential was only 0.24%, 0.21% and 0.23% for subperiods P_3, P_4 and P_7, respectively. Such small ranges imply that the HK-US interest-rate differential did not vary much during the non-crisis periods. Thus, we have found some supporting evidence for the argument that: (a) the expected appreciation of the SP dollar vis-à-vis the US dollar led to a SP-US interest discount during the non-crisis period, and (b) when compared with HK, greater flexibility of exchange rate target in SP allowed the economy greater independence in its interest-rate policies.

In addition to the results of more independent interest-rate policies in SP, it is also interesting to note that $\hat{\gamma}_i$ in Model 2 of tables 2 and 3 imply that the volatility of SP's interest rate relative to the US was lower than that of HK during the non-crisis period. As shown in Model 2 of table 3, $\hat{\gamma}_1$ and $\hat{\gamma}_3$ imply that the unconditional standard deviations of SP's interest rate during the pre-crisis and post-crisis periods are 14.4 basis points and 13.9 basis points, respectively. These are lower than the corresponding figures of 24.9 basis points and 25.3 basis points in HK (i.e., in subperiods P_4 and P_7), confirming that the possibility of exchange-rate changes in SP during the normal period helped absorb the impact of external shocks on SP's interest rate.

The outbreak of the AFC caused an increase in SP's interest rate. In fact, the crisis virtually removed SP's usual interest rate discount relative to the US, leaving $\hat{\delta}_2$ in Model

2 of table 3 insignificantly different from zero. Yet, the effect of the crisis on SP was much smaller when compared to HK's 2.01% interest premium relative to the US (i.e., $\hat{\delta}_5$ in Model 2 of table 2). In summary, the flexibility of SP's exchange rate caused a lower interest premium relative to the US and a lower volatility. According to Model 2 of tables 2 and 3, the implied unconditional standard deviation of HK's interest rate was 144.5 basis points, much higher than the 86.4 basis points in SP. Thus, with higher interest rate premium and volatility, HK experienced a more severe plunge in asset price and economic pains during the crisis.

4.2 Bivariate Models

In section 2 we have argued that due to the use of exchange-rate adjustments to absorb external shocks in SP during the non-crisis periods, the correlation between the interest-rate changes in SP and US should be smaller than that between HK and US. We now consider a bivariate GARCH model to test this hypothesis.

Table 4 reports the average correlation coefficients between the changes in the interest rates in HK, SP and US during the pre-crisis, crisis, and post-crisis periods.[21] As we can see, the SP-US correlation during the pre-crisis period (0.0687) was smaller than the HK-US correlation (0.2061), supporting the hypothesis that the greater flexibility of exchange rate allowed for a more independent interest-rate policy in SP. During the crisis, the HK-US correlation coefficient plunged to a low level (0.0023), reflecting a breakdown in the HK-US interest link arising from speculative attacks and the loophole in the CBS (failure of uncovered interest arbitrage amid the confidence shock). Nevertheless, with the introduction of the convertibility undertaking (anti-crisis package) and the eventual fading out of the crisis, the HK-US interest link is re-established, as reflected in a rebound of the correlation back to the pre-crisis level (0.1851). For SP, the lower correlation during the

[21] As the crisis ended at different dates in HK and SP, we define the pre-crisis, crisis and post-crisis periods, respectively, as: (a) 92/06/01 – 97/10/22, 97/10/23 – 98/09/04, 98/12/19 – 02/02/28 for HK versus US, (b) 86/04/01 – 97/10/22, 97/10/23 – 98/10/06, 98/10/07 – 02/02/28 for SP versus US, and (c) 92/06/01 – 97/10/22, 97/10/23 – 98/09/04, 98/12/19 – 02/02/28 for HK versus SP.

crisis (0.0102) reflected a breakdown in the SP-US interest link during the crisis period. Nevertheless, the reduction of the correlation in SP was smaller than that in HK, reflecting that the effect created by the crisis is much smaller in SP. With the fading out of the crisis, the SP-US correlation bounced back to 0.0391. Despite the above differences between SP and HK, it is interesting to note that the HK-SP correlation (0.1753) remained high during the crisis. One reason is that both economies were subjected to the same contagion crisis among the Asian economies. It is noted that the correlation (0.1977) went up further during the post-crisis period.

To further examine the relationship between the changes in the US versus the changes in the HK interbank rates in various periods of the HK CBS reforms and AFC, we calculate the average correlation coefficient in each of the seven subperiods partitioned according to the CBS reforms and AFC as described in section 3. The following results are obtained: (a) the average correlation in sub-period P_1 is relatively low (0.0926), reflecting HSBC's special position in fixing the interest rate,[22] (b) the average correlation increased in subperiods P_2 to P_4 to between 0.1849 and 0.2123. This suggests that the reforms succeeded in bringing the HK interest rate more in line with that of the US, (c) after a substantial fall in the average correlation in the crisis (subperiod P_5) to 0.0023, the average correlation rose to 0.0228 in sub-period P_6 due to the introduction of the convertibility undertaking. Finally, with the fading out of the crisis (subperiod P_7), the average correlation (0.1798) rose back to the pre-crisis level .

5 Conclusions

In this paper, we consider empirically the effects of the currency board and monitoring band systems on interest-rate behavior. We find that the monitoring band system in SP has allowed a greater flexibility in the exchange rate policy, thus mitigating the effects of

[22]Before the first CBS reform in July 1988, HSBC was the only commercial bank in charge of the interbank clearing system. This special role endowed the HSBC some freedom in creating money supply without a parallel increase in the US dollar holding (Tse and Yip (2003)).

the financial crisis on the level and volatility of the SP interest rate. There is empirical support for the hypothesis that greater flexibility in the exchange-rate target in SP is associated with (a) a wider range of SP-US interest differential, and (b) a lower correlation between the changes in the SP and US interest rates. On the other hand, there was a higher HK-US interest premium during the crisis.

We also find that there is an over-reaction response during the financial crisis in HK's interbank market but not in SP's. The over-reaction response, however, has disappeared with the adoption of the anti-crisis package. In the bivariate model, we find a breakdown of the HK-US and SP-US interest links during the crisis. After the crisis, the links were somewhat restored. Meanwhile, the correlation between the changes in HK's and SP's interest rates rose during the crisis period, reflecting the fact that both were affected by the contagious shocks at that time.

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Table 1: Summary statistics of three-month interbank rates

Statistic	HK	SP	US
Mean	6.043	3.607	5.862
Median	5.875	3.310	5.750
Maximum	25.188	12.940	10.500
Minimum	0.625	0.625	1.641
Std Dev	2.183	1.571	1.750
Std Skewness	0.798	0.832	0.109
Std Kurtosis	5.369	3.865	2.820
ADF statistics			
Interest rates	–2.734	–2.192	–0.160
Differenced interest rates	–32.122	–30.600	–70.412

Note: ADF statistic is the augmented Dickey-Fuller statistic of test for unit root.

Table 2: Estimation results of the HK-US three-month interest-rate differential

Model 1				Model 2			
Parameter	Estimate	s.e.	Implied mean/s.d.	Parameter	Estimate	s.e.	Implied mean/s.d.
ϕ_1	0.7427***	0.0185		ϕ_1^{NC}	0.7208***	0.0187	
ϕ_2	0.0867***	0.0249		ϕ_2^{NC}	0.0952***	0.0258	
ϕ_3	0.0579***	0.0217		ϕ_3^{NC}	0.0777***	0.0224	
ϕ_4	0.0666***	0.0140		ϕ_4^{NC}	0.0642***	0.0148	
				ϕ_1^{C1}	1.1734***	0.0660	
				ϕ_2^{C1}	–0.2376***	0.0678	
				ϕ_1^{C2}	0.9179***	0.0342	
δ_1	–0.0454***	0.0074	–0.983	δ_1	–0.0415***	0.0076	–0.986
δ_2	0.0164***	0.0043	0.354	δ_2	0.0148***	0.0044	0.353
δ_3	0.0070***	0.0025	0.152	δ_3	0.0065***	0.0025	0.155
δ_4	–0.0057**	0.0021	–0.124	δ_4	–0.0060***	0.0022	–0.142
δ_5	0.0385	0.0317	0.833	δ_5	0.1292*	0.0680	2.011
δ_6	0.0135	0.0175	0.293	δ_6	0.0674	0.0614	1.049
δ_7	0.0002	0.0025	0.004	δ_7	0.0002	0.0025	0.002
γ_1	0.0067***	0.0005	0.629	γ_1	0.0066***	0.0005	0.549
γ_2	0.0060***	0.0002	0.597	γ_2	0.0060***	0.0002	0.524
γ_3	0.0015***	0.0001	0.296	γ_3	0.0015***	0.0001	0.261
γ_4	0.0014***	0.0001	0.285	γ_4	0.0013***	0.0001	0.249
γ_5	0.0528***	0.0080	1.766	γ_5	0.0454***	0.0085	1.445
γ_6	0.0059***	0.0023	0.592	γ_6	0.0064*	0.0037	0.544
γ_7	0.0014***	0.0001	0.290	γ_7	0.0014***	0.0001	0.253
α	0.4355***	0.0110		α	0.4228***	0.0115	
β	0.5475***	0.0079		β	0.5555***	0.0083	
Log-likelihood: 2342.1520				Log-likelihood: 2358.9059			

Note: For Model 1, the mean interest-rate differential in sub-period P_i is calculated by $\hat{\delta}_i/(1-\sum_j \hat{\phi}_j)$. For Model 2, it is calculated by $\hat{\delta}_i/(1-\sum_j \hat{\phi}_j^{NC})$ for i = 1, 2, 3, 4, 7; $\hat{\delta}_i/(1-\sum_j \hat{\phi}_j^{C1})$ for i = 5; and $\hat{\delta}_i/(1-\sum_j \hat{\phi}_j^{C2})$ for i = 6. For both models, the unconditional standard deviation of the interest-rate differential in sub-period P_i is calculated by $\sqrt{\hat{\gamma}_i/(1-\hat{\alpha}-\hat{\beta})}$. The asterisks *, ** and *** denote statistical significance at the 10%, 5% and 1% levels, respectively.

Table 3: Estimation results of the SP-US three-month interest-rate differential

Model 1				Model 2			
Parameter	Estimate	s.e.	Implied mean/s.d.	Parameter	Estimate	s.e.	Implied mean/s.d.
ϕ_1	0.9121***	0.0187		ϕ_1^{NC}	0.9048***	0.0194	
ϕ_3	0.0819***	0.0188		ϕ_3^{NC}	0.0897***	0.0194	
				ϕ_1^{C}	0.8561***	0.0374	
δ_1	–0.0133***	0.0045	–2.216	δ_1	–0.0124***	0.0045	–2.265
δ_2	–0.0009	0.0432	0.144	δ_2	0.0261	0.0554	0.181
δ_3	–0.0146**	0.0066	–2.437	δ_3	–0.0131***	0.0067	–2.393
γ_1	0.0031***	0.0002	0.143	γ_1	0.0030***	0.0002	0.144
γ_2	0.1265***	0.0056	0.919	γ_2	0.1094***	0.0092	0.864
γ_3	0.0029***	0.0002	0.138	γ_3	0.0028***	0.0002	0.139
α	0.3681***	0.0196		α	0.3685***	0.0196	
β	0.4820***	0.0173		β	0.4847***	0.0180	
Log-likelihood: 1568.2682				Log-likelihood: 1581.3584			

Note: For Model 1, the mean interest-rate differential in sub-period P_i is calculated by $\hat{\delta}_i/(1-\sum_j \hat{\phi}_j)$. For Model 2, it is calculated by $\hat{\delta}_i/(1-\sum_j \hat{\phi}_j^{NC})$ for i = 1 and 3; and $\hat{\delta}_i/(1-\sum_j \hat{\phi}_j^{C})$ for i = 2. For both models, the unconditional standard deviation of the interest-rate differential in sub-period P_i is calculated by $\sqrt{\hat{\gamma}_i/(1-\hat{\alpha}-\hat{\beta})}$. The asterisks *, ** and *** denote statistical significance at the 10%, 5% and 1% levels of significance, respectively.

Table 4: Average correlation in different subperiods

Subperiod	HK-US	SP-US	HK-SP
Pre-crisis	0.2061	0.0687	0.1620
Crisis	0.0023	0.0102	0.1753
Post-crisis	0.1851	0.0391	0.1977

Figure 1: Three-month Interbank Rates of HK, SP and US

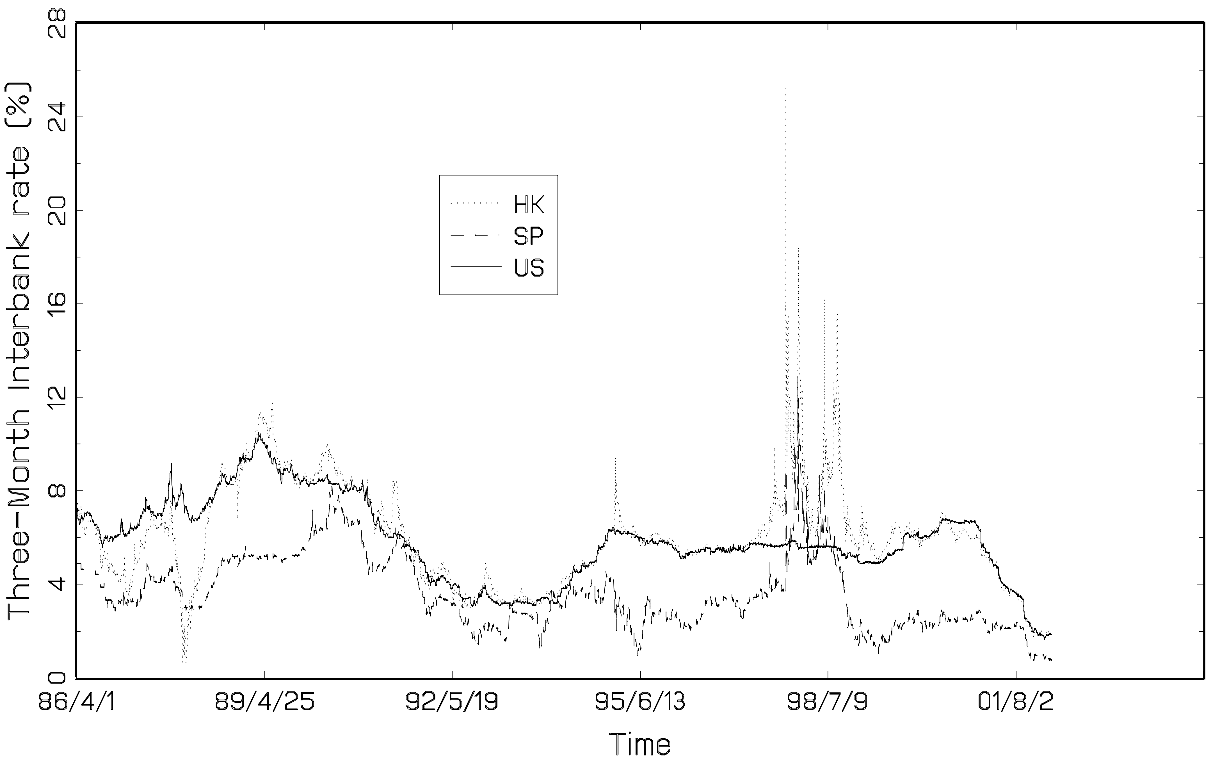

Figure 2: Three-month Interbank-Rate Differential: HK-US and SP-US