The Impacts of Hong Kong's Currency Board Reforms on the Interbank Market

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First draft: July 2001
Revised: January 2002

Abstract: Among the economies with a Currency Board System (CBS), Hong Kong (HK) is probably the one with (i) the largest and most developed financial sector, and (ii) the highest capital mobility. Hence, studying HK's CBS is not only crucial to HK, but also important for the understanding of the modern CBS. This paper outlines the major monetary reforms in HK since the late 1980s. The impacts of these reforms and the 1997-98 Asian Financial Crisis are then examined empirically. We focus on the differentials between the US and HK interbank interest rates. We assume the conditional-mean equation follows an autoregressive process and the conditional-variance equation follows a generalized autoregressive conditional heteroscedasticity (GARCH) process. This model captures the time-varying level and volatility of the differentials. In light of the empirical results we provide an assessment of the reforms in HK.

JEL Classification: E42, E58

Acknowledgment: The authors are indebted to two anonymous referees for many helpful comments and suggestions. They would also like to express their gratitude to Professors Charles Goodhart and C.Y. Sin for their advice on an earlier version of the paper. The usual disclaimer applies.

1 Introduction

Among the economies with a Currency Board System (CBS), Hong Kong (HK) is the one with the highest daily turnover in the interbank market, in the foreign exchange market, in the stock market as well as in the stock index futures market.[1] Capital is allowed to flow freely in and out of the economy. Thus, among the economies with a CBS, HK is probably the one with (i) the largest and most developed financial sector, and (ii) the highest capital mobility. Hence, studying HK's CBS and money market is not only crucial to HK, but also important to the understanding of the modern CBS.

Until recently empirical studies on the CBS were in general favourable to the system. McCarthy and Zanalda (1996) compared the inflation and growth performances of the Caribbean countries and found that the subgroup of countries operating under a CBS had lower inflation and higher growth than other Caribbean economies, though they attributed part of this to the greater concessionary flows to the currency board members. Kwan and Lui (1996) compared the performance of the CBS in HK since October 1983 to the previous floating-rate regime during 1974-83. Based on a simulation study, they concluded that inflation and output growth, and volatility of the two, would have been lower during the floating-rate period had HK operated under a CBS. Ghosh et al (1998) compared inflation and output growth in countries with currency boards to countries with other less extreme forms of exchange-rate peg. They found that the average inflation rate under currency boards is about 4 percentage points lower than that of other pegged exchange-rate systems. They also showed that while some of this might be attributed to

[1] The average daily turnover in the HK dollar interbank market and swap market in 2000 were HK$87 billion (US$11 billion) and HK$106 billion (US$14 billion), respectively. According to a recent survey the average daily turnover in HK's foreign exchange market was the seventh largest in the world. The average daily turnover in HK's stock market in 2000 was HK$12.3 billion. The average daily turnover in the Hang Seng Stock Index Futures in 2000 was 16,292 contracts, equivalent to a contract value of HK$13 billion. Among the economies with a CBS, HK has the largest number of foreign (123) and local (31) banks. In addition to the above, HK ranks well within the world's top ten in its foreign exchange holdings (US$108 billion at end 2000), external trade (US$415 billion in 2000), and stock market capitalisation (US$604 billion in 2000).

the greater monetary discipline under the CBS, the bulk of the difference was explained by the greater confidence engendered by adopting a CBS. Such effects resulted in higher money demand and hence lower inflation for a given monetary growth rate. They also showed that the result was qualitatively the same even if one controls for the regime choice endogeneity (i.e., countries with a greater proclivity toward low inflation may be more likely to adopt a CBS). Regarding the growth performance, they also found that countries with a CBS on average grew faster than countries with either pegged exchange rates or floating exchange rates. While recognizing that it is unlikely that this growth performance can be explained by exchange-rate regimes alone, they highlighted that the opposite proposition – the CBS leads to more sluggish growth – receives no support from the data.

Ghosh et al admitted that currency boards are more constraining on credit policy and on the ability of the authorities to alter the exchange-rate parity. This is important in case of crisis where there could be misalignment of exchange rate and credit crunch. Along this line, Yip and Wang (2002) showed that the fixed exchange rate implied by the CBS plus the sluggish adjustment speed of the export price in HK played an important role in explaining the poor export performance of HK's total export during the post-Asian Financial Crisis (AFC) period. They also believed that the fixed exchange rate implicit in the CBS plus the sluggish adjustment of the gross domestic product (GDP) deflator, consumer price index and wage rate in HK was one of the main reasons for the long and on-going deflation, recession and high unemployment rate after the AFC. Parallel with this, Yip and Wang (2001) showed that Singapore's use of exchange-rate depreciation has helped mitigate the adverse impact of the crisis on its export. As a result, Singapore was less affected by the crisis, despite the fact that Singapore's economic relationships with the crisis-affected economies were closer than those of HK. Using the surge in interest rates as a proxy for financial dis-intermediation caused by the crisis, they argued that the difference in the exchange-rate system in HK caused a more

severe liquidity crunch in HK than in Singapore, which in turn was shown to contribute to a weaker export (and deeper recession) in HK.

While the above literature has focused their evaluation of the CBS on broader economic measures like inflation, export growth and GDP growth, there is so far no rigorous empirical study on the behaviour of interest rates under the CBS. As highlighted by Chen and Chan (1998), Tsang (1999), Miller (1998) and Yip (1999), the substantial surge in HK's interest rate during the crisis period was the main cause of the subsequent plunge in asset price and recession, and hence the source of pain in HK during the crisis and post-crisis period. The interest-rate hikes in Argentina in the 2001 debt crisis and the 1998 Brazilian crisis were probably other examples of similar incidences. Thus, the behaviour of interest rates under the CBS is a very important issue. This paper attempts to examine this issue empirically. HK is probably the best choice for such an empirical study because it has a CBS with a well developed financial sector and high capital mobility. This makes HK's modern CBS an important benchmark for international comparisons, evaluations and theoretical developments of the CBS. As noted by Kwan and Lui (1996), " ... the economic health and significant strength of Hong Kong provide an almost ideal situation to test the vulnerability of a currency board system when it is confronted with a crisis. ... if ... Hong Kong's currency board has to face a crisis when it is subject to shocks of specified magnitude, then it is hard to imagine that the currency board in a country with poorer economic health can survive under the same scenario."

Since the late 1980s, HK has adopted a few monetary reforms that may have substantial impacts on the interbank market. In this paper we examine the effectiveness of these monetary reforms empirically. In particular, we investigate (i) whether the monopoly and special position of HK's largest colonial bank in creating money (without foreign exchange backup) before the reform in 1988 led to a downward bias in HK's interest rate relative to the US, which may have in turn contributed to unnecessary inflation, (ii) whether the reform introduced in 1988 rectified the above problem, (iii) whether the

introduction of HK's version of discount window in 1992 helped reduce the volatility of HK's interest rates relative to the US, (iv) whether the misguided reform in 1994, which could have fueled the excessive initial public offer (IPO) over-subscriptions, also led to a downward bias in HK's interest rate. Finally, we investigate to what extend the AFC in 1997-98 destabilized the interbank market, and whether the reform in the anti-crisis package introduced in September 1998 succeeded in rectifying the loophole in HK's CBS.

It has been suggested that, before the AFC, HK's CBS was in general highly credible among market participants, despite the fact that HK had slightly violated the foreign exchange backup rule (of a CBS) on money supply before the reform in 1988 and during the misguided reform between 1994 and 1997 (see the explanations in subsequent sections). As a result, a small premium (and at times even a downward bias) in HK's interest rates relative to the US was found. However, with the outbreak of the AFC, public confidence in and credibility of the system were greatly reduced among the market participants. This was translated into devaluation expectations and risk premium, which in turn created a substantial surge in the HK-US interest-rate differential. With the introduction of the anti-crisis package and the eventual fading out of the crisis, credibility of HK's CBS seems to have come back despite a very bleak economic outlook induced by the recession, asset deflation and surge in unemployment. As a result, the HK-US interest-rate differential reverted back to the pre-crisis level despite a very poor macroeconomic environment. These incidences provide an excellent opportunity to study the impacts of the CBS credibility on the level and volatility of the interest rates.

The plan of this paper is as follows. In Section 2 we outline the characteristics of the CBS in HK and some of its monetary reforms that may have impacts on the interbank market. We also discuss the impacts of the speculative attack on the HK interest rate, and the subsequent reforms. In Section 3 we specify the empirical model and the econometric methodology for analyzing the interest-rate data. Section 4 summarizes the

empirical results and assesses the impacts of the monetary reforms. Section 5 provides the conclusion.

2 A Review of HK's CBS and Its Monetary Reforms

Prior to its present CBS, HK adopted the floating exchange rate system between 1974 and 1983. With the 1983 Sino-Anglo dispute on the return of HK's sovereignty to China after 1997, a confidence crisis quickly emerged. The HK dollar was under severe pressure (the HK dollar fell from US$1 to HK$5.13 in 1981 to US$1 to HK$9.8 in 1983). To pre-empt the weakening of confidence from deteriorating into a full blown economic crisis, the HK government adopted the CBS on 17 October 1983. Under this system, the money supply in HK is fully backed up by US dollar held at the Exchange Fund (of the Currency Board),[2] and the HK dollar is effectively fixed at the official rate of US$1 to HK$7.8. Because of the high capital mobility and the fixed exchange rate system, HK's interest rate has then tended to follow the US interest rate fairly closely. Nevertheless, there have been moderate differences between the HK and US interest rates from time to time due to various reasons, such as the differences in the economic and political environments, and the occurrence of the AFC in 1997-1998.

Since the late 1980s HK has adopted several monetary reforms to strengthen the CBS. In this section we review the major reforms and their targeted objectives. The effectiveness of these reforms will then be examined empirically in Section 4.

2.1 The Accounting Arrangements

When the linked exchange-rate system was first put into place in October 1983, the interbank clearing system was not run by the Currency Board, but by HK's largest

[2]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 the CIs and HK dollar notes to redeem an equivalent amount of US dollar from the Exchange Fund.

commercial bank, namely, the Hongkong and Shanghai Banking Corporation Limited (HSBC). Under the arrangement, all licensed banks in HK maintained a clearing account directly with the HSBC or indirectly through another settlement bank. HSBC was the controller of the aggregate balance (net clearing balance) of the whole banking system and was therefore in a position to create money. The aggregate balance was determined by the commercial activities of HSBC in the money market and foreign exchange market, as well as by the activities of its customers. When HSBC lent to other banks or bought assets (including foreign exchange), or when HSBC's customers drew cheques and paid them to customers of other banks, the aggregate balance increased. There was no requirement and no need for HSBC to back up this monetary base by foreign exchange. Consequently, there was no arrangement imposed upon HSBC to subject the aggregate balance to the Monetary Rule (foreign exchange backup rule) of the CBS.

Control over the aggregate balance was eventually brought under the Currency Board in July 1988 through the so called Accounting Arrangements. These arrangements reversed the customer-banker relationship between the Currency Board and HSBC in that HSBC was required to operate a clearing account with the Currency Board. As HSBC was still the management bank of the Clearing House and all other licensed banks still maintained clearing accounts directly or indirectly with it, HSBC was further required to conduct its interbank activities so that the net clearing balance of the rest of the banking system was not bigger than the balance in its account at the Currency Board. The aggregate balance thus operated as a cap on HSBC's ability to create money, beyond which the Accounting Arrangements imposed a penal rate of interest on the excess. Given that the aggregate balance can only be altered when transactions were conducted with the Currency Board, this balance was then defined and subject to the indirect control of the Currency Board.

The Hong Kong Monetary Authority (HKMA) (see HKMA, 1994) argued that

> Before the introduction of Accounting Arrangements, there tended to be a downward bias in local interest rates relative to the US dollar interest rates, as there was a lack of effective control over the extension of credits in the interbank market. The Accounting Arrangements built in such control and has therefore helped to narrow the gap between HK dollar and US dollar interest rates. In terms of the three-month rates, for instance, the differential was about 100 basis points in favor of the US dollar during the period November 1983 to June 1988. During the period July 1988 to October 1994, the differential was a mere 23 basis points.

We will examine in Section 4 whether HSBC's special position (in creating money without foreign exchange backup) during the period before the Accounting Arrangements had on average reduced the local interest rates relative to the US interest rates. We will also investigate whether the HSBC's position contributed to a higher or lower volatility of the interest-rate differential.

Before proceeding to the next monetary reform, a point of interest is that the downward bias could be beneficial or harmful to the HK economy, depending on the boom and bust conditions of the economy at the time. If the economy is close to the full-employment level, the downward bias is probably harmful by adding unnecessary inflationary pressure. On the other hand, if the aggregate demand is weak, the downward bias is beneficial in stimulating aggregate demand.

2.2 The Liquidity Adjustment Facility

The Liquidity Adjustment Facility (LAF) introduced on 1 July 1992 is the HK version of discount window.[3] Under the facility, licensed banks can borrow over-night funds from the HKMA through repurchase agreements of eligible securities at the offer rate

[3]In general, as the LAF is directly related to the over-night rate and only indirectly related to the three-month rate, the impact of the LAF on the over-night rate is more significant and pronounced than that on the three-month rate.

and can place surplus funds over-night with the HKMA at the bid rate. The HKMA argued that this facility has effectively set the floor and ceiling of the over-night interest rate. Through the licensed banks' demand for and utilization of the facility, the HKMA can also supply additional liquidity or mob up excess liquidity from the whole banking system.

According to the HKMA, the facility helped reduce the volatility of the over-night rate during periods of transitory tight liquidity such as substantial over-subscription of IPO (see HKMA, 1994):

> There were a total of 63 IPOs in 1993, involving enormous amounts of subscription monies. The most notable example was the IPO of Denway which was about 600 times over-subscribed. Subscription monies involving $240 billion had to be recycled through the interbank market on the closing date. Over-night rate firmed up 50 basis points above the LAF offer rate as many banks were aggressively bidding for funds. In response, the HKMA increased the level of interbank liquidity to provide some relief to the market. On the whole, the intraday volatility in the interbank market was much lower compared with the situation before the introduction of the Accounting Arrangements and LAF. For example, the Cathay Pacific IPO in 1986 and the Oriental Press IPO in 1987 resulted in a rise of 12.75 percentage points and 6 percentage points respectively in HIBOR.

It is interesting to note that the facility could have in fact fuelled the already high over-subscription rates of the IPOs in HK. We will examine in Section 4 whether the LAF did in fact reduce the volatility of the over-night interbank rate and reduce the gap between the HK and US over-night interbank rates. As the lending rate is more related to longer-term (e.g., three-month) interbank rates instead of over-night interbank rate, reducing the volatility of over-night rate may not have strong impacts on the economy

if the volatility of the longer-term rates remains unchanged. Therefore, we will also investigate whether the LAF had any impacts on the three-month interbank rate.

2.3 The Revised Mode of Monetary Operations

Realizing that the over-night rate may still breach the range set by the LAF, the HKMA adopted a Revised Mode of Monetary Operations from mid-March 1994. Under the Revised Mode, the HKMA targeted the short-term interbank interest rate instead of the level of interbank liquidity in its money-market operations (see HKMA, 1994):

> This entails the injection or withdrawal of liquidity to prevent the over-night HIBOR from breaching the range set by the LAF Bid and Offer Rates. The actual amount will therefore be determined by the prevailing market conditions.

Thereafter, the HKMA made far more active short-term interventions during both the IPOs and seasonal (month-end or quarter-end) period (see HKMA, 1994):

> For example, towards the end of March (1994), money market conditions tightened considerably as banks became cautious in lending before the quarter-end which coincided with a long weekend. The HKMA injected (HK)$3.8 billion into the interbank market, thereby preventing the over-night HIBOR from breaching the LAF Offer Rate. The excess liquidity was withdrawn in early April when market conditions started to ease.

In Section 4 we will examine whether the revised mode of monetary operations helped reduce the level and volatility of the HK-US interest-rate differential. We will also investigate whether the impacts of the reform on the over-night rate are different from those on the three-month interbank rate.

Before turning to the next reform, we shall make some comments on the reforms discussed so far. According to the classical CBS, the monetary authority should let the

market demand determine the local quantity of money supply and refrain from creating liquidity – whether short-term or long-term – without a parallel increase in the foreign exchange backup (see Schwartz (1993) and Tsang and Ma (2002)). In such a system, interest rates and money supply should be determined by market forces. Nevertheless, in the reforms discussed above we observe that the HKMA had a tendency of introducing and justifying the freedom in monetary operations (i.e., a tendency to deviate from the classical CBS). In addition to arguing that the provision of short-term liquidity to finance the huge over-subscription of IPOs and seasonal demands may or may not be desirable, we believe that a shift towards the Revised Mode of Monetary Operations may represent a dangerous step away from the monetary rule (foreign exchange backup rule) of the CBS (i.e., the local money supply is also affected by the HKMA intervention). For example, suppose some speculators borrow a large amount of HK dollar through the foreign exchange swap market. According to the mechanism inherent in the CBS, this will tend to bid up the HK interest rate, which would in turn attract capital inflows through interest arbitrage. Under the Revised Mode of Monetary Operations, the HKMA supplies short-term liquidity when they see a rise in the HK interest rate. By the same token, some fundamental changes could create an upward/downward pressure on interest rate, which would in turn change the local money supply through the standard mechanism. If this is not recognized, the HKMA may supply additional liquidity without a parallel increase in foreign exchange backup. It is noted, however, that HKMA's interventions have been so far short-term in nature.

2.4 The Crisis and Subsequent Reforms

HK's financial market was under severe speculative attack during the AFC in October 1997. The strategy of the speculators was to bid up HK's interbank rate and subsequently benefit from the huge short positions they had built up in the stock futures

market prior to the launch of their attack.[4]

In view of the surge in interest rate, the plunge in asset prices and hence the harm done to the HK economy, Chen and Chan (1998), Tsang (1999),[5] Miller (1998) and Yip (1999)[6] made proposals to bring down the interest rate and hence the economic pain. Of particular interest are the proposals by Tsang and Yip. Tsang first argued that because of institutional imperfection, cash arbitrage (between the market exchange rate and the official linked rate) was never operative in HK's linked exchange rate system. He proposed to modernize HK's Currency Board by adopting the "convertible reserves mechanism" of Argentina, Estonia and Lithuania (the AEL model), under which arbitrage could be done electronically without moving cash around. In the design, each bank will have an account with the central bank, in which deposit reserves as well as other balances are kept. The central bank guarantees the full convertibility of these bank balances at the official exchange rate. Tsang believed this would correct the institutional imperfection and make cash arbitrage operative. He also mentioned the possibility of interest arbitrage under this system. However, Tsang did not explicitly elaborate the mechanism to remove the exchange-rate risk of interest arbitrage, which some researchers (see Yip, 1999) believe is the main reason that stops the HK interest rate from falling to the US level during the crisis.

In addition to Tsang's suggested set-up, Yip proposed to use the electronic Certificate of Indebtedness as a guarantee to remove the exchange-rate risk of interest arbitrage.[7] With the guarantee, banks would be interested in earning the interest differential by borrowing US dollar (from aboard) at the low US interest rate and lending HK dollar

[4]The Appendix provides an account of the speculators' strategy.

[5]The proposal was first made in 1997, and was subsequently included in Tsang (1999).

[6]The proposal was first made in an internal report in the Bank of China (Hong Kong-Macau Regional Office) in 1997, and was released in a local newspaper (Hong Kong Economic Journal) on 24 February 1998. It was then subsequently included in Yip (1999).

[7]Under the colonial CBS, Certificates of Indebtedness (CIs) are certificates that guarantee the holders can always use the CIs and domestic currency to exchange for an equivalent amount of foreign currency specified in the CIs.

at the high HK interest rate. Thus, with the guarantee, interest arbitrage will continue until the HK interest rate falls back to the US level.

The HKMA modified and adopted these proposals into its anti-crisis package in September 1998. Meanwhile, speculators were able to repeat their October 1997 speculative strategy (see the details in the Appendix) in January, April, June and August 1998. While speculators earned substantial profits from these attacks, Yip (1999) reported that the harm done to the HK economy far exceeded the speculators' profits. In the speculative attack during August 1998, the HKMA opted for stock market interventions. Nevertheless, with the weak market sentiment, traditional funds dumped about HK$100 billion HK shares on 31 August 1998, and the HKMA was forced to purchase all these shares.

To avoid the development in the stock market from deteriorating into a deeper crisis, the HKMA modified the recommendations of the researchers and came up with its own reform package (or modern CBS) on 5 September 1998, highlighted under seven Technical Measures. Of the seven measures, the most important measures are: (i) an exchange rate guarantee (convertibility undertaking) for the banks' net balance in the account with the HKMA, and (ii) a modification of previous practice to a discount window which allows banks substantial freedom to use their holdings of Exchange Fund debts as a collateral for over-night liquidity borrowing from the HKMA (see Yam, 1998).

Measure (i) removes the exchange-rate risk of banks' interest arbitrage activities and hence brings the HK interest rate in line with the US interest rate. Measure (ii) aims at allowing an increase in interbank liquidity in case of speculative attack, so that the impacts of the attack on the interbank rate can be mitigated. Before this reform, HK banks' clearing balance and interbank liquidity were relatively small.[8] Thus, allowing the interbank liquidity to expand when deemed necessary may stop the speculators from

[8]As a result, it took only US$1-2 billion spot selling of the HK dollar in the foreign exchange market to create a substantial shortage of interbank liquidity on 23 October 1997.

squeezing the interbank liquidity (and hence interbank rate) with a relatively small amount of spot selling of the HK dollar. To justify this arrangement, the HKMA re-defined its monetary base to cover the currency issued, the banks' net clearing balance with the HKMA and the debts issued by the Exchange Fund. The HKMA justified their definition of monetary base by arguing that all the three components are fully backed up by their holdings of foreign reserve.[9]

After the introduction of the Technical Measures, the interest rate in HK began to fall gradually towards the US level in the fourth quarter of 1998. By mid-October 1998, the three-month interbank rate was only 6%, as compared to 11.8% on 14 September 1998. With further cuts in the US interest rate and a continued reduction in the interest-rate differential, the HK three-month interbank rate fell further to 5.63% on 28 December 1998, which was only 0.4 percentage point higher than the US rate. In Section 4 we will examine the impacts of the AFC and the Technical Measures on HK's interbank market.

2.5 Summary of the Hypotheses to be tested

Summarizing the previous discussions, we present our synopsis for the level and volatility of the HK-US over-night and three-month interest-rate differentials in Table 1.[10] Of particular interests are Remarks 5b, 6c and 7c. As noted in Remark 5c, whenever there was any shortage in liquidity in the over-night interbank market during the AFC, the HKMA could have provided additional liquidity through the LAF, money market activities or other channels,[11] causing a quick reversal of the over-night rate back to the

[9]No doubt, such definition and arrangement did help discourage speculative attacks. It is, however, interesting to note that HK is probably the only economy in the world that includes long-term bonds as a component of the monetary base.

[10]See Section 3 below for the starting and ending dates of the seven subperiods.

[11]For example, with the shortage in over-night liquidity in the interbank market on 23 October 1997, the LAF borrowings surged from HK$2.082 billions on 23 October to HK$9.578 billions on 24 October. Meanwhile, the HKMA injected, through its money market activities, HK$1.982 billions on 23 October and another HK$4.444 billions on 24 October into the banking system. As another example, to offset the speculators' liquidity squeeze during the early August 1998, the HKMA injected liquidity into the system using the opportunity (or excuse) of the "usual deficit season" for the Treasury in which there would be a sizable drawdown from the Exchange Fund by the Treasury to pay for government expenses.

normal level. If this is the case, there may not be a significant surge in the average level of the over-night rate, although the surge in the first day of an individual shock may be substantial. Remarks 6c and 7c discuss how changes in the HKMA liquidity injection behaviour may affect the behaviour of the over-night rate during the second phase of the crisis period and the post-crisis period.

3 The Data and the Methodology

Our data consist of daily observations of the HK and US interbank interest rates, namely, the HIBOR and LIBOR.[12] The over-night and three-month interbank interest rates were obtained from the Datastream. The data cover the period 2 February 1987 through 30 March 2001, with 3695 observations in total.[13]

Figures 1 and 2 plot the over-night interbank rates and their first differences, respectively. Similarly, Figures 3 and 4 plot the three-month interbank rates. In these figures the dashed lines indicate the changes in the monetary regimes (reforms) and the dashed-dotted lines define the period of the AFC.[14] Table 2 provides some summary statistics for 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 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 1 percent level.[15] In contrast, the hypothesis that the differenced interest rates of both maturities

Thus, after explaining the need to fund the actual and anticipated drawdown by the Treasury, the HKMA justified switching some of its foreign currency reserves into HK dollar. The latter in turn counteracted some of the selling pressures on the HK dollar, leaving the aggregate balance of the banking system unchanged. For more details, see the Operation of Monetary Policy in the November 1998 issue of the HKMA Quarterly Bulletin.

[12] These stand for the HK Interbank Offer Rate and the London Interbank Offer Rate, respectively.

[13] Although the CBS in HK came into effect in 1983, the data we collected from Datastream were only available from 1987.

[14] See the discussion below for the definition of the AFC period. The dashed and dashed-dotted lines divide the sample into seven nonoverlapping subperiods. These subperiods are also presented in Figures 5 and 6 below.

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

are nonstationary are rejected at the 1 percent level. Thus, the results indicate that the interbank interest rate series contain a unit root.

Figures 5 and 6 plot the differentials between the HK and US interbank rates. We can see that for the period prior to the first reform (Accounting Arrangements) and during the AFC, there were signs of regime shift. Johansen's likelihood ratio trace statistics for the null hypothesis of no cointegrated relationship among the HK and US series are 130.721 and 34.098, respectively, for the over-night and three-month rates.[16] Also, the likelihood ratio trace statistics for the null hypothesis of at most one cointegrated equation are 3.178 and 1.169, respectively, for the over-night and three-month rates. Thus, there is evidence in support of the hypothesis that the HK and US interbank rates are cointegrated, both for the over-night and three-month interest-rate data.

As discussed in the last section, we will examine the impacts of the monetary reforms introduced since the late 1980s and the effects of the AFC on the level and volatility of HK's interbank rates relative to their US counterparts. While the identification of various regime changes due to the currency board reforms are aided by policy announcements, the demarcation of the AFC is not clear-cut. Nonetheless, the AFC represents an enormous external impact and may cause a structural break in the econometric model. Model misspecification occurs if the structural break is not recognized. At the peril of over-simplification we define the AFC as the period from 23 October 1997 through 18 December 1998. The dates are so chosen because (i) 23 October 1997 is well known to be the day when HK's interbank rates made substantial surge due to speculators' selling of HK dollar in the foreign exchange market, and (ii) 18 December 1998 is the day when the HK Association of Bank (HKAB) reduced its deposit saving rate, not because of any reduction in the US interest rate but because the HKAB perceived the crisis was probably over.

[16]See Johansen (1988) for the use of the likelihood ratio test for cointegration. The critical values of the tests can be found in Osterwald-Lenum (1990).

Thus, the AFC overlaps the periods of Revised Mode of Monetary Operations and Technical Measures. To allow for the interaction of the AFC with the regime changes, we partition the periods of these two regime changes into distinct sub-periods with or without the AFC. In sum, the sample period is divided into the following seven nonoverlapping sub-periods:

Sub-periods (No. of obs.)	Events
P_1: 87/2/2 – 88/6/30 (369)	No monetary reform
P_2: 88/7/1 – 92/5/31 (1022)	Accounting Arrangements
P_3: 92/6/1 – 94/3/15 (466)	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 – 01/3/30 (595)	Technical Measures, without AFC

We denote the HK interbank rate (over-night or three-month) at time t by r_{Ht} and the corresponding US interbank rate (over-night or three-month) by r_{Ut}. Let $y_t = r_{Ht} - r_{Ut}$ denote the interest-rate differential. As r_{Ht} and r_{Ut} 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.[17] 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 and the AFC. We define D_i, $i = 1, ..., 7$, as a dummy variable such that $D_{it} = 1$ if t belongs to the sub-period P_i. Thus, the conditional-mean equation is given by

$$y_t = \sum_{i=1}^{7} \delta_i D_{it} + \sum_{j=1}^{p} \phi_j y_{t-j} + \varepsilon_t$$

so that y_t follows an autoregressive process of order p. The time-varying intercept δ_i determines the average interest-rate differential in each sub-period.

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

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.[18] 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

$$\sigma_t^2 = \sum_{i=1}^{7} \gamma_i D_{it} + \alpha \varepsilon_{t-1}^2 + \beta \sigma_{t-1}^2$$

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

We estimate the parameters of the conditional-mean and conditional-variance equations jointly using the quasi-MLE (QMLE) method (see Bollerslev and Wooldridge, 1992), and adopt a general-to-specific approach by testing the restrictions on the dummy variables, which are tests of the impacts of the reforms and the AFC. Restrictions on model parameters are tested using the likelihood ratio (LR) statistic. LR is distributed approximately as a χ_R^2 when the restrictions are valid, where R denotes the number of restrictions on the parameters.

4 The Empirical Results

Tables 3 and 4 summarize the estimated general models for the over-night and three-month interbank interest-rate differentials, respectively. As can be seen from $\hat{\delta}_1$, HK's over-night and three-month interbank rates were statistically significantly lower than their US counterparts prior to the Accounting Arrangements (i.e., in sub-period P_1). Thus, there is support for HKMA's claim that during this period the HSBC was able to

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

exploit its position as a clearing bank by creating money without an appropriate increase in the US dollar backup, causing a downward bias in the differential between the HK and US interest rates. Of particular interest is that the downward bias for the over-night rate (302 basis points) was markedly larger than that for the three-month rate (89 basis points). This suggests a very interesting behavior of the HSBC: The HSBC was more willing to create money for very short-term (over-night) loans/transactions rather than longer-term (three-month) loans/transactions. The HSBC's lower (higher) willingness to take risk in the longer (shorter) term in turn led to a larger downward bias in the over-night rate.

With the introduction of the Accounting Arrangements in July 1988, the HSBC was no longer capable of creating HK dollar as mentioned. As a result, the HK-US interest-rate differential returned to positive under the Accounting Arrangements (i.e., in sub-period P_2). HK's over-night and three-month interbank rates were on average 18.2 basis points and 32.7 basis points above their US counterparts, respectively. If we take the differential during this period as a "normal" reflection of the political and economic risk premium between HK and the US, we can infer that HSBC's special position during the pre-Accounting-Arrangements period led to a downward bias of HK's over-night and three-month interbank rates of 3.20 percentage points and 1.22 percentage points, respectively. The LR statistic for $H_0 : \delta_1 = \delta_2$ are 57.2602 and 18.4132, respectively, for the over-night and three-month rates. Thus, the null hypothesis of no change in the differential is convincingly rejected for both cases. A comparison of the estimates of γ_2 and γ_1 also shows that the HSBC's special position led to a higher volatility in HK's interbank rates. The LR statistics for $H_0 : \gamma_1 = \gamma_2$ are 153.1784 and 5.1374, respectively, for the over-night and three-month rates. Thus, the volatility of HK's interest rate during the pre-Accounting-Arrangements sub-period P_1 was significantly higher than that in sub-period P_2. This shows that HSBC's special position in sub-period P_1 did not only cause downward bias in HK's interest rate, but also higher volatility in the interest-rate

differentials. Again, because of HSBC's higher risk aversion over the longer end, the change in the volatility of the over-night rate was markedly higher than that of the three-month rate.

For the effect of the introduction of the LAF in sub-period P_3, Tables 3 and 4 show that $\hat{\gamma}_3$ is lower than $\hat{\gamma}_2$ for both the over-night and three-month rates. The LR statistics for $H_0 : \gamma_2 = \gamma_3$ are 3.5934 and 114.0080, respectively, for the over-night and three-month rates, supporting the hypotheses listed in Table 1. That is, in addition to supporting the HKMA's claim that the introduction of the LAF reduced the volatility of the over-night rate, we also find that the LAF reduced the volatility of the three-month rate. The estimates of δ_3 for HK's over-night and three-month rates are lower than $\hat{\delta}_2$, providing a mild evidence that the introduction of the LAF may have also reduced the average level of HK's over-night and three-month rates. Nevertheless, the LR statistics for $H_0 : \delta_2 = \delta_3$ are only 1.3084 and 2.3556, respectively, implying that the impacts of the LAF on the levels of HK's interest rates are not statistically significant.

We now come to the Revised Mode of Monetary Operations introduced since March 1994. As explained in Section 2, under this regime, the HKMA became more active in injecting short-term liquidity to finance IPO over-subscriptions and seasonal demands. Tables 3 and 4 show that $\hat{\gamma}_4$ for HK's over-night and three-month rates are lower than $\hat{\gamma}_2$, providing some support for the hypotheses listed in Table 1. The LR statistics for $H_0 : \gamma_2 = \gamma_4$ are 85.0286 and 184.6124 for the over-night and three-month rates, respectively. In comparison, the LR statistics for $H_0 : \gamma_3 = \gamma_4$ are, respectively, 35.6182 and 0.3156 for the over-night and three-month rates. Thus, there is empirical evidence that the Revised Mode of Monetary Operations reduced the volatility of HK's over-night interbank rates. Perhaps more interesting is the impact of the Revised Mode on the levels of HK's interest rates. Tables 3 and 4 show that the estimates of δ_4 are negative, suggesting that the Revised Mode re-established a downward bias in HK's over-night and three-month interest differentials by 35.3 basis points and 9.9 basis points, respectively.

A comparison between $\hat{\delta}_4$ with $\hat{\delta}_3$ and $\hat{\delta}_2$ shows that the Revised Mode reduced the level of HK's interbank rate – a consequence that has never been addressed or recognized by the HKMA. Tests for $H_0 : \delta_2 = \delta_4$ and $H_0 : \delta_3 = \delta_4$ confirm that the impacts are statistically significant. The LR statistic for the former hypothesis are 21.4522 and 14.6878 for the over-night and three-month rates, respectively, while the LR statistics for the latter test are 7.7313 and 7.6674 for the over-night and three-month rates, respectively.

Regarding the impacts of the AFC on the three-month interbank rate, the results in Table 4 show that $\hat{\delta}_5 = 0.0583$, implying that the AFC created an average interest-rate differential of 1.18 percentage points between the HK and US three-month rates. Meanwhile, the LR statistic is 2.8746 for $H_0 : \delta_4 = \delta_5$ and 66.6002 for $H_0 : \gamma_4 = \gamma_5$, confirming that the AFC did cause not only a rise in the level, but also a rise in the volatility of HK's three-month interbank rate.[19] The impact of the AFC on the over-night rate is, however, very different from that on the three-month rate. As explained in Remark 5c of Table 1, whenever there was any shortage in the liquidity of the over-night interbank market, the HKMA soon provided additional liquidity through the LAF (or other channels such as money market activities), causing a quick reversal of the over-night rate back to the normal level. In this case, there might not be a significant surge in the average level of the over-night rate, although the surge in the first day of an individual shock might be substantial. From the results reported in Table 3, $\hat{\delta}_5$ is in fact lower than $\hat{\delta}_4$ and the LR statistic for $H_0 : \delta_4 = \delta_5$ is 0.9026, which is not statistically significant. Besides, the LR statistic for $H_0 : \gamma_4 = \gamma_5$ is 0.8822, suggesting that the effects of the AFC on the volatility of the over-night rate may have been nullified by the huge injection of short-term liquidity by the HKMA.

We now come to the effects of the anti-crisis package on the three-month rate during the second part of the crisis period. As we can see from Table 4, there were (i) a sharp reduction in the HK-US interest-rate differential from 118 basis points in sub-period P_5

[19] The difference between $\hat{\delta}_4$ and $\hat{\delta}_5$ is statistically significant at the 10% level, but not at the 5% level.

to 44 basis points in sub-period P_6, and (ii) a sharp reduction in the volatility coefficient from 0.0558 in sub-period P_5 to 0.0064 in sub-period P_6. Thus, the much lower values of $(\hat{\delta}_6, \hat{\gamma}_6)$, as compared against $(\hat{\delta}_5, \hat{\gamma}_5)$, have at least provided a rudimentary evidence that the anti-crisis package has helped to reduce both the level and volatility of the HK-US three-month interest-rate differential induced by the crisis. A test for $H_0 : \gamma_5 = \gamma_6$ gives a LR statistic of 23.2778, confirming that the impact of the anti-crisis package on the volatility of the three-month rate is statistically significant. Nevertheless, because of the large standard error for $\hat{\delta}_6$ and $\hat{\delta}_5$, the LR statistic for $H_0 : \delta_5 = \delta_6$ is only 0.7830 (not statistically significant). The case for the over-night rate in sub-period P_6 is somewhat different. As the HKMA's provision of short-term liquidity implied no significant rise in the average level of the over-night interest-rate differential in sub-period P_5, the anti-crisis package would most likely have no significant effects on the average level of the over-night interest-rate differential in sub-period P_6. In fact, the LR statistics for $H_0 : \delta_5 = \delta_6$ is 0.6383 and the LR statistics for $H_0 : \gamma_5 = \gamma_6$ is 0.0844**,** confirming the null hypothesis of no significant change in the average level and volatility of the over-night differential between sub-periods P_5 and P_6.

Finally, we come to the three-month interest-rate differential during the post-crisis period (sub-period P_7). As we can see from $\hat{\delta}_7$ and $\hat{\gamma}_7$ in Table 4, the convertibility undertaking within the anti-crisis package and the eventual fading out of the crisis have (i) virtually removed all the risk premium between the HK and US three-month interbank rate (i.e., $\hat{\delta}_7$ is close to zero and its t statistic is low); and (ii) brought the volatility of the three-month interest differential down to more normal level ($\hat{\gamma}_7 = 0.0020$). Besides, the LR statistic for $H_0 : \gamma_6 = \gamma_7$ is 5.1504, confirming that the fading out of the crisis has led to further reduction in the volatility of the three-month interest-rate differential. The large difference in the magnitude of $\hat{\delta}_7$ and $\hat{\delta}_6$ suggests that the fading out of the crisis was associated with a substantial reduction in the differential, although the LR statistic for $H_0 : \delta_6 = \delta_7$ is only 0.8993 (not statistically significant) due to a high standard error

in the estimate of δ_6.

As explained in Remark 7c of Table 1, the very short-term nature of the over-night rate and transaction cost imply that there may be a wide range of over-night differential before uncovered interest arbitrage would take place. Thus, the actual level and volatility of the over-night rate differential in the post-crisis period could be higher or lower than the pre-crisis period, depending on the supply of short-term liquidity and the HKMA's tendency for discretionary liquidity injection. As pointed out in Section 2.5, (i) the amount of short-term liquidity in the discount window facility in the post-crisis period was in fact higher than that in the LAF before the crisis, and (ii) because of the criticism against the HKMA's discretionary liquidity policy, the HKMA became less inclined to short-term liquidity injection and withdrawal. As we can see from Table 3, the former caused a downward bias in HK's over-night rate similar to that in sub-period P_4,[20] and the latter led to an over-night interest-rate volatility significantly higher than that in sub-period P_4 but not much different from that in sub-period P_2.[21]

Finally Table 5 presents the estimated parameters when the zero and equality restrictions are imposed. In addition to the disucssions above, joint restrictions are imposed (as opposed to pairwise restrictions). The LR statistics verify that the restrictions imposed cannot be rejected at the 10 percent level. The long-run mean differentials of the interest rates are then upated based on the new estimates.

5 Conclusion

In this paper, we have outlined the monetary reforms in HK's CBS since the late 1980s. We have estimated the impacts of these reforms and the 1997-98 AFC on the interest-rate differentials between the US and HK, both in terms of the level and the volatility. We find support for the HKMA's claim that, prior to the Accounting Arrangements introduced

[20]The LR statistic for $H_0 : \delta_4 = \delta_7$ is 0.2148.
[21]The LR statistic for $H_0 : \gamma_4 = \gamma_7$ is 56.7460 and the LR statistic for $H_0 : \gamma_2 = \gamma_7$ is 0.8766.

in July 1988, the HSBC was able to exploit its position as a clearing bank by creating money without an appropriate increase in the US dollar backup, causing a downward bias in the differential between the HK and US interest rates. Of particular interest is that the downward bias for the over-night rate was markedly higher than that for the three-month rate. One possible reason for this is that risk consideration has made the HSBC more willing to create money for very short-term (over-night) loans/transactions rather than longer-term (three-month) loans/transactions. With the introduction of the Accounting Arrangements since July 1988, the HSBC was no longer capable of creating HK dollar as mentioned. As a result, the HK-US interest-rate differential returned to positive during the Accounting-Arrangements period. In addition to the downward bias, it is found that the HSBC's special position in the Pre-Accounting-Arrangements period led to higher volatility in the interest-rate differential. Again, because of HSBC's higher risk aversion over the longer end, the rise in the volatility of the over-night rate was significantly higher than that of the three-month rate.

We also find that the LAF introduced in July 1992 reduced both the level and volatility of HK's over-night rate. In fact, the LAF removed the risk premium between the HK and US over-night rates. The impacts of the LAF on the over-night rate were also transmitted to the three-month rate (say through the mechanism described by the liquidity premium theory), leading to a reduction in both the level and volatility of the three-month interest-rate differential. Rather than jumping to the conclusion that the reduction in the interest-rate volatility has benefited the HK economy, we would caution that this could have been achieved at the cost of fueling the already high over-subscription of the IPOs in HK. Our reservation is even stronger when it comes to the Revised Mode of Monetary Operations. In fact, we have found that the Revised Mode led to a downward bias in the HK-US interest-rate differentials – a result that is not recognized or addressed by the HKMA. That is, with the HKMA more inclined to inject short-term liquidity to finance huge over-subscription of IPOs and seasonal demand for

liquidity, the interest rate in HK, especially at the shorter end, tended to be lower than its US counterpart. Given that the HK economy was plagued by high inflation with asset price bubble building up at that time,[22] the downward bias was probably harmful to the economy by adding fuel to inflation and asset bubble.

We have found that the AFC in 1997-98 led to an increase in the level and volatility of HK's three-month rate. The higher medium-term interest rate was widely believed to be the source of HK's economic pain during the crisis. We have also found that the anti-crisis package introduced in September 1998 led to a drastic decline in the level and volatility of HK's three-month rate. In fact, with the convertibility undertaking inherent in the seven Technical Measures, interest rate arbitrage was revitalized, which in turn brought HK's three-month rate down to the US level. While the revised version of discount window in the seven Technical Measures might have also contributed to the reduction of HK's three-month rates from exceptionally high levels towards the US level, it also created a strange monetary definition in which HK is the only economy in the world with long term (Exchange Fund) bonds being included as part of the monetary base. The behavior of HK's over-night rate was, however, more complicated, as it was also affected by HKMA's reaction (reversal) to market changes.

[22]HK's CPI inflation rate in 1994 was 8.7%, substantially higher than the 2.6% in the US. Meanwhile, HK's property price index rose by 37.5%, 40.5%, 10.4% and 25.4%, respectively, in 1991, 1992, 1993 and 1994.

Appendix: Speculative Strategy used by Speculators on the HK Market during the AFC

This appendix provides an account of the strategy used by the speculators on the HK financial markets in September/October 1997. Exploiting the precarious fixed exchange-rate system during the crisis, the speculators adopted a "double-play" strategy in the foreign exchange and stock futures market. Their strategy consists of the following steps.

Step 1: Preparation

The speculators first borrowed, or pre-funded themselves with, substantial amount of medium-term (6-12 months) HK dollar through the swap market (i.e., swapping US dollar for HK dollar). Some speculators also bought HK dollar (and sold US dollar) forward in the forward market. In the stock futures market, the speculators started to build up large short positions. To equip themselves with the ability to create panic selling in the stock market during the formal attack, the speculators also utilized the "loophole" in the stock custodian sector to borrow substantial amount of shares from the custodians and trustees.

Step 2: Formal attack

After the above preparation, the speculators sold their pre-funded HK dollar (and bought US dollar) in the spot market. To maximize the impact of their attack, they sold the HK dollar in the relatively thin offshore markets. When the HKMA attempted to support the HK dollar by purchasing the HK dollar, the interbank liquidity was squeezed. This in turn caused a surge in the interbank rate. In addition to selling in the spot market, the speculators also sold large amount of HK dollar (and bought US dollar) in the forward market. As banks usually did arbitrage between the swap market and the interbank market, the forward selling of HK dollar would also bid up HK's interbank rate. This would create a sentiment that the HK dollar was under attack,

thus attracting more speculators to follow.

Concurrently, the speculators attacked the stock market by (i) selling their shares originally borrowed from the custodians, and (ii) accelerating their selling in the stock futures market with a high profile (arbitrage would ensure that a fall in the stock futures also caused a fall in the spot stock market). These actions would create panic selling of shares. In fact, these strategies turned out to be very successful and there was substantial fall in HK's stock index during the attack.

Step 3: Profit taking

Having bid up the interbank rate and pushed down the spot and futures stock indices, the speculators took their profits by closing the short positions in the stock futures market. The also bought back the shares (at much lower prices) and returned them to the custodian. In the foreign exchange market, they closed their short position in forward HK dollar (and made profit from the lower forward rate), and lent out any surplus HK dollar (at a shorter maturity) earlier borrowed from the swap market.

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Table 1: Summary of the Probable Impacts of the Reforms in HK's CBS on the Interbank Rates

Period/Event	Over-night rate		Three-month rate	
	Level	Volatility	Level	Volatility
P_1: Before the Accounting Arrangements	Downward biased	Unspecified	Downward biased	Unspecified
	Remark 1a: Before the introduction of the Accounting Arrangements, there tended to be a downward bias in the local interest rates relative to the US interest rates. **Remark 1b**: If the HSBC was more risk averse in creating money at the longer end, the downward bias in the over-night rate would be greater than that of the three-month rate.			
P_2: Introduction of the Accounting Arrangements starting 1 July 1988	Remove bias, positive premium	Unspecified	Remove bias, positive premium	Unspecified
	Remark 2: The Accounting Arrangements would remove the downward bias and cause a positive but moderate over-night and three-month interest-rate differential between HK and the US.			
P_3: Introduction of the LAF Starting 1 June 1992	Unspecified	Reduce	Unspecified	Reduce
	Remark 3a: The introduction of the LAF would cause a reduction in the volatility of HK's over-night and three-month rates relative to the US dollar rates. **Remark 3b**: As the process involves injection of liquidity, the level of HK's over-night and three-month interest-rate differentials in this sub-period may be lower than the previous sub-period.			
P_4: Introduction of the Revised Mode of Monetary Operations starting 16 March 1994	Reduce, possibly downward bias	Reduce	Reduce, possibly downward bias	Reduce
	Remark 4a: Relative to sub-period P_2, the introduction of the Revised Mode of Monetary Operations would reduce the volatility of HK's over-night and three-month interest-rate differentials. **Remark 4b**: In case the HKMA injected short-term liquidity to finance the huge over-subscription of IPOs, it could reduce the level of HK's interbank rates and re-establish a downward bias in HK's interbank rates.			
P_5: Asian Financial Crisis before anti-crisis measures	Unspecified	Unspecified	Increase	Increase
	Remark 5a: The crisis would increase the level and volatility of HK's three-month rate. **Remark 5b**: If the HKMA soon provided additional short-term liquidity through the LAF, money market activities or other channels whenever there was a shortage of liquidity in the over-night market, there could be a quick reversal of the over-night rate so that there might or might not be a significant surge in the average level and volatility of over-night rate even though the surge in the first day of each shock could be substantial.			
P_6: Asian Financial Crisis with anti-crisis package	Unspecified	Unspecified	Reduce	Reduce
	Remark 6a: The anti-crisis package would bring HK's three-month rate back towards the US level. **Remark 6b**: It would also reduce the volatility of HK's three-month rate. **Remark 6c**: Its effect on the over-night rate would be unknown if the HKMA did provide additional short-term liquidity immediately after each individual shock during the crisis.			
P_7: Post-crisis period starting 19 December 1988	Unspecified	Unspecified	Zero premium	Low
	Remark 7a: The convertibility undertaking within the anti-crisis package would encourage uncovered interest arbitrage, which would in turn remove the risk premium between the HK and US three-month rates. **Remark 7b**: Uncovered interest arbitrage would ensure a low volatility in the three-month interest-rate differential. **Remark 7c**: Because of the very short-term nature of the over-night rate, and the transaction costs, a wide range of over-night interest-rate differential may be required before uncovered interest arbitrage would take place. In such case, the actual level and volatility of the over-night differential may be lower or higher than the pre-crisis period, depending on the supply of the over-night liquidity and HKMA's tendency for discretionary liquidity injection. For example, if the amount of short-term liquidity in the discount window facility in the post-crisis period was larger than that in the LAF before the crisis, the downward bias in the post-crisis period could be larger than that in sub-period P_4. On the other hand, if public criticism on HKMA's discretionary liquidity policy suceeded in making the HKMA more hesitant in repeating their actions in sub-periods P_3 and P_4, the over-night rate volatility in the post-crisis period could be higher.			

Table 2: Summary statistics of the interbank rates

Statistic	Over-night rate		Three-month rate	
	HK	US	HK	US
Mean	5.489	5.790	6.276	6.019
Median	5.250	5.563	5.977	5.750
Maximum	23.500	10.750	18.438	10.500
Minimum	0.155	2.813	0.625	3.063
Std Dev	2.159	1.656	2.108	1.668
Std Skewness	0.812	0.331	0.773	0.308
Std Kurtosis	5.390	2.799	4.309	2.671
ADF statistics				
Interest rates	–3.210	–0.943	–3.038	–0.994
Differenced interest rates	–20.465	–14.723	–30.248	–66.69

Note: ADF statistic is the augmented Dickey-Fuller statistic of test for unit root. Four lags are implemented in the regression.

Table 3: Estimation results of the over-night interbank interest-rate differentials of HK versus US

Parameter	Estimate	Standard error	Mean differential
ϕ_1	0.7059***	0.0191	
ϕ_2	0.0974***	0.0208	
ϕ_4	0.0447***	0.0134	
δ_1	–0.4591***	0.0348	–3.021
δ_2	0.0277**	0.0129	0.182
δ_3	0.0006	0.0159	0.004
δ_4	–0.0537***	0.0073	–0.353
δ_5	–0.0766***	0.0212	–0.504
δ_6	–0.0216	0.0453	–0.142
δ_7	–0.0628***	0.0145	–0.413
γ_1	0.4098***	0.0237	
γ_2	0.0756***	0.0041	
γ_3	0.0605***	0.0034	
γ_4	0.0292***	0.0013	
γ_5	0.0358***	0.0047	
γ_6	0.0397***	0.0106	
γ_7	0.0847***	0.0067	
α	0.4399***	0.0162	
β	0.4047***	0.0173	

Likelihood ratio (LR) statistics for parameter restrictions

Restriction	LR	Restriction	LR
$\delta_1 = \delta_2$	57.2602***	$\gamma_1 = \gamma_2$	153.1784***
$\delta_2 = \delta_3$	1.3084	$\gamma_2 = \gamma_3$	3.5934*
$\delta_2 = \delta_4$	21.4522***	$\gamma_2 = \gamma_4$	85.0286***
$\delta_3 = \delta_4$	7.7313***	$\gamma_3 = \gamma_4$	35.6182***
$\delta_4 = \delta_5$	0.9026	$\gamma_4 = \gamma_5$	0.8822
$\delta_5 = \delta_6$	0.6383	$\gamma_5 = \gamma_6$	0.0844
$\delta_6 = \delta_7$	0.7732	$\gamma_6 = \gamma_7$	6.1952***

Note: The mean interest-rate differential in sub-period P_i is calculated by $\hat{\delta}_i/(1-\sum_j \hat{\phi}_j)$. The asterisks *, ** and *** denote rejection of the null hypothesis (restriction) at the 10%, 5% and 1% levels of significance, respectively.

Table 4: Estimation results of the three-month interbank interest-rate differentials of HK versus US

Parameter	Estimate	Standard error	Mean differential
ϕ_1	0.7687***	0.0197	
ϕ_2	0.1820***	0.0191	
δ_1	–0.0440***	0.0104	–0.892
δ_2	0.0161***	0.0048	0.327
δ_3	0.0069***	0.0026	0.140
δ_4	–0.0049**	0.0024	–0.099
δ_5	0.0583*	0.0332	1.183
δ_6	0.0216	0.0198	0.438
δ_7	–0.0001	0.0034	0.020
γ_1	0.0092***	0.0007	
γ_2	0.0063***	0.0002	
γ_3	0.0015***	0.0001	
γ_4	0.0014***	0.0001	
γ_5	0.0558***	0.0080	
γ_6	0.0064***	0.0022	
γ_7	0.0020**	0.0001	
α	0.4114***	0.0121	
β	0.5522***	0.0087	

Likelihood ratio (LR) statistics for parameter restrictions

Restriction	LR	Restriction	LR
$\delta_1 = \delta_2$	18.4132***	$\gamma_1 = \gamma_2$	5.1374***
$\delta_2 = \delta_3$	2.3556	$\gamma_2 = \gamma_3$	114.0080***
$\delta_2 = \delta_4$	14.6878***	$\gamma_2 = \gamma_4$	184.6124***
$\delta_3 = \delta_4$	7.6674***	$\gamma_3 = \gamma_4$	0.3156
$\delta_4 = \delta_5$	2.8746*	$\gamma_4 = \gamma_5$	66.6002***
$\delta_5 = \delta_6$	0.7830	$\gamma_5 = \gamma_6$	23.2778***
$\delta_6 = \delta_7$	0.8993	$\gamma_6 = \gamma_7$	5.1504***

Note: The mean interest-rate differential in sub-period P_i is calculated by $\hat{\delta}_i/(1-\sum_j \hat{\phi}_j)$. The asterisks *, ** and *** denote rejection of the null hypothesis (restriction) at the 10%, 5% and 1% levels of significance, respectively.

Table 5: Estimation results of the restricted models of the interbank interest-rate differentials of HK versus US

Parameter	Over-night rate			Parameter	Three-month rate		
	Estimate	Standard error	Mean differential		Estimate	Standard error	Mean differential
ϕ_1	0.7059	0.0190		ϕ_1	0.7693	0.0196	
ϕ_2	0.0964	0.0206		ϕ_2	0.1825	0.0190	
ϕ_4	0.0460	0.0134					
δ_1	–0.4571	0.0347	–3.013	δ_1	–0.0428	0.0102	–0.888
δ_2	0.0275	0.0132	0.181	δ_2	0.0157	0.0048	0.326
$\delta_4 = \delta_5 = \delta_7$	–0.0578	0.0065	–0.381	δ_3	0.0068	0.0025	0.141
				δ_4	–0.0050	0.0024	–0.104
				δ_5	0.0556	0.0327	1.154
γ_1	0.3856	0.0218		γ_1	0.0091	0.0007	
$\gamma_2 = \gamma_7$	0.0736	0.0038		$\gamma_2 = \gamma_6$	0.0063	0.0002	
γ_3	0.0573	0.0031		$\gamma_3 = \gamma_4$	0.0014	0.0001	
$\gamma_4 = \gamma_5 = \gamma_6$	0.0288	0.0012		γ_5	0.0559	0.0001	
				γ_7	0.0020	0.0001	
α	0.4283	0.0154		α	0.4104	0.0121	
β	0.4288	0.0164		β	0.5528	0.0087	
LR statistic	4.0314			LR statistic	1.3232		

Note: The mean interest-rate differential in sub-period P_i is calculated by $\hat{\delta}_i/(1-\sum_j \hat{\phi}_j)$. LR statistic is the likelihood ratio statistic for testing the constrained models versus the unconstrained models reported in Tables 2 and 3. For the over-night rate, the constraints are: $\delta_3 = 0, \delta_6 = 0, \delta_4 = \delta_5 = \delta_7, \gamma_4 = \gamma_5 = \gamma_6, \gamma_2 = \gamma_7$. The LR statistic is approximately distributed as a χ^2_7 when the constraints hold. For the three-month rate, the constraints are: $\delta_6 = 0, \delta_7 = 0, \gamma_2 = \gamma_6, \gamma_3 = \gamma_4$. The LR statistic is approximately distributed as a χ^2_4 when the constraints hold.

Figure 1: Over-night Interbank Rates of Hong Kong and US

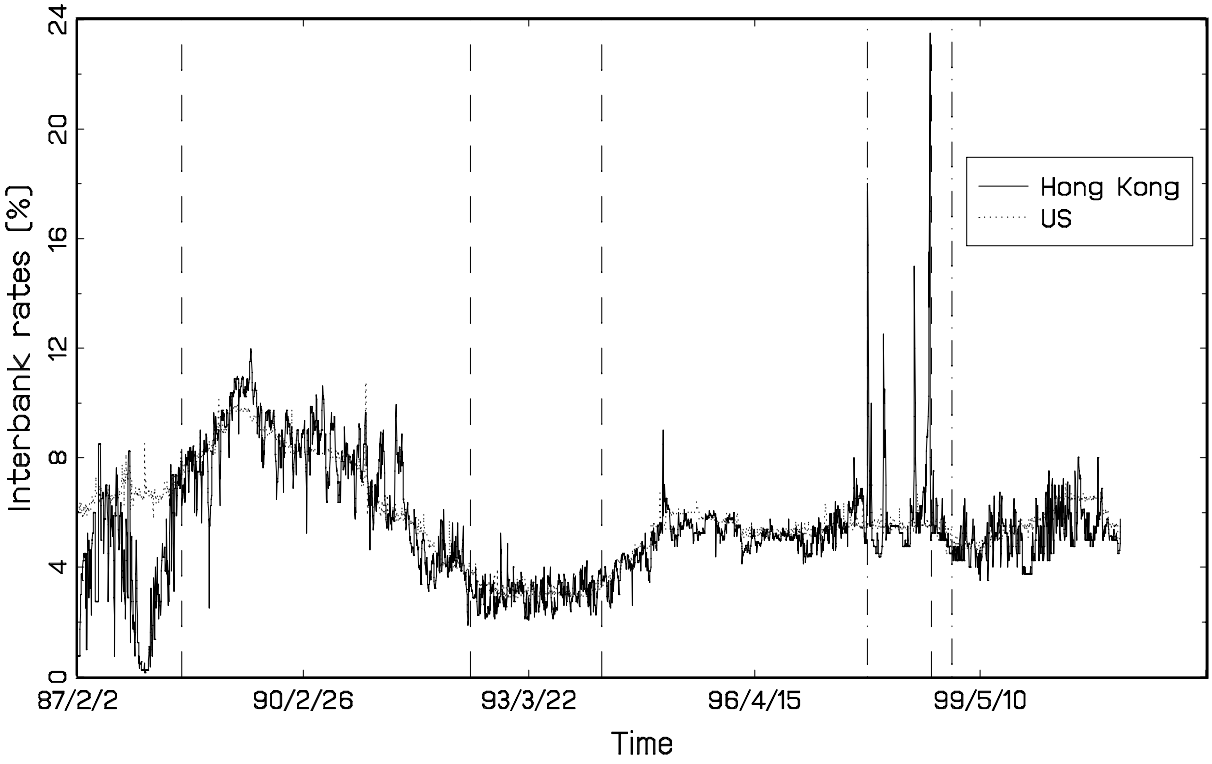

Figure 2: Differenced Over-night Interbank Rates of Hong Kong and US

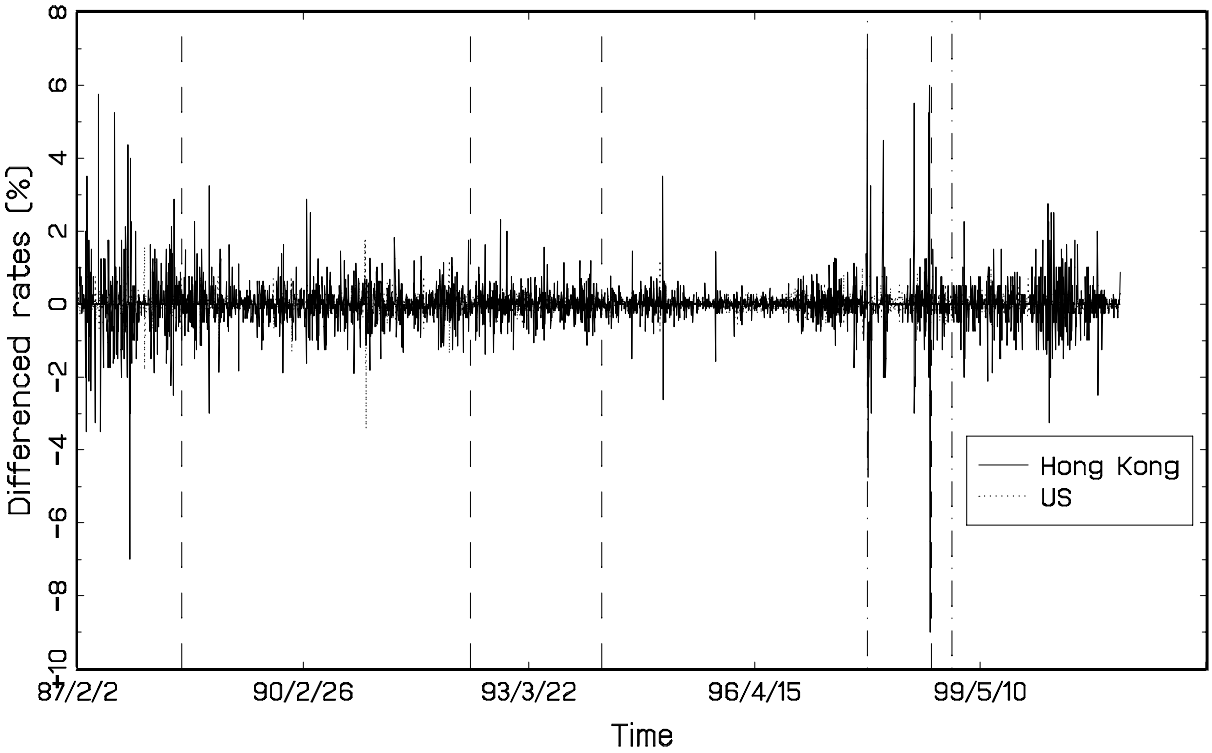

Figure 3: Three-month Interbank Rates of Hong Kong and US

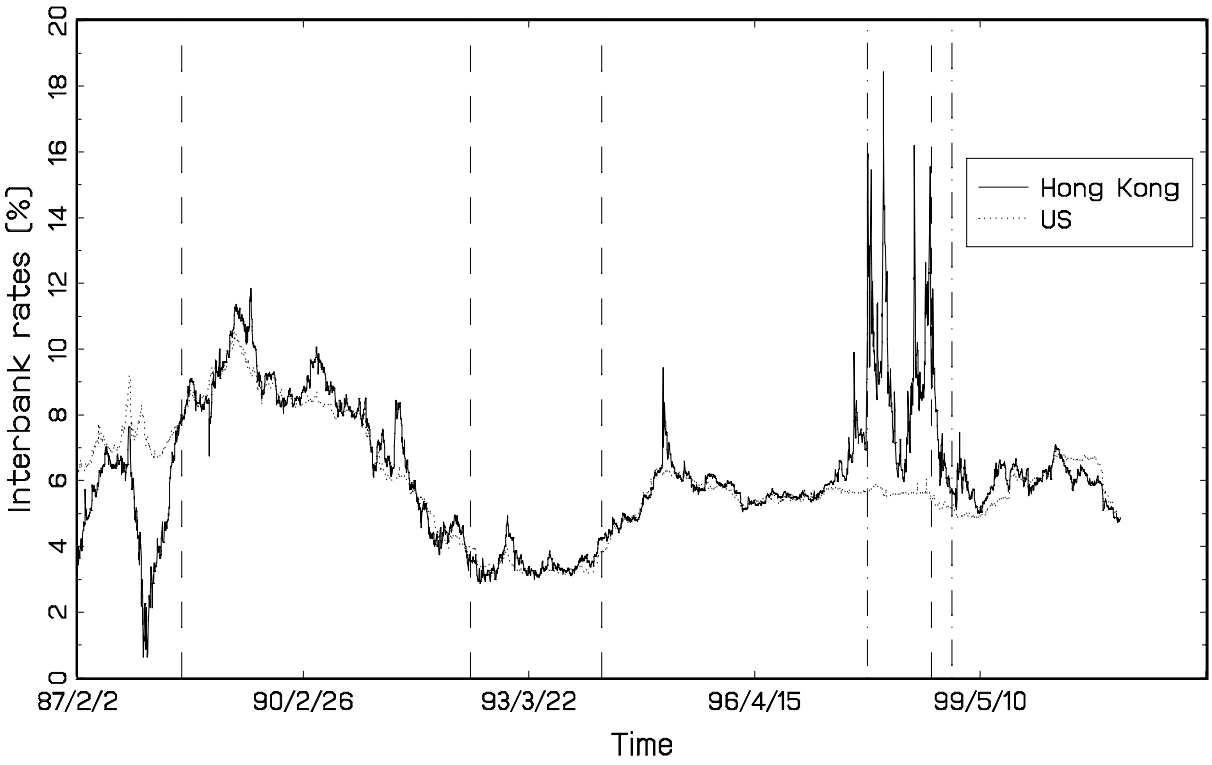

Figure 4: Differenced Three-month Interbank Rates of Hong Kong and US

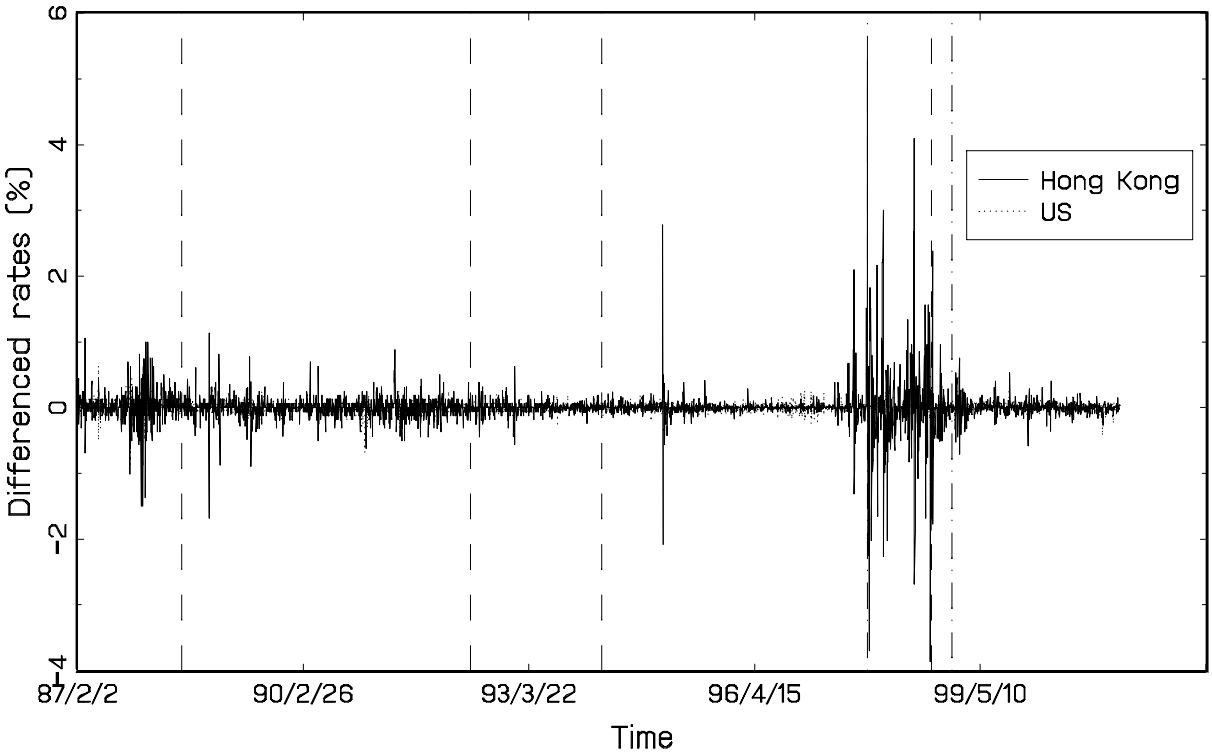

Figure 5: Differentials of Over-night Interbank Rates: HK versus US

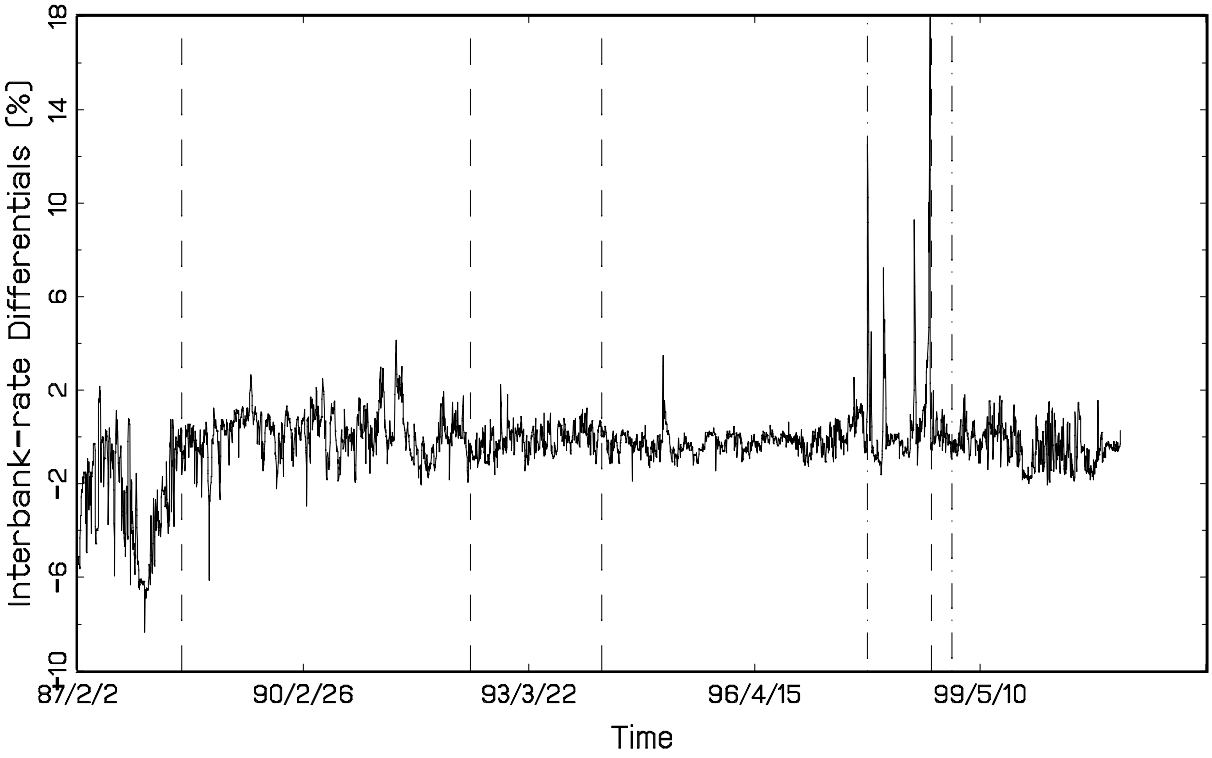

Figure 6: Differentials of Three-month Interbank Rates: HK versus US