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The Robustness of Hong Kong's Linked Exchange Rate System as a Currency Board Arrangement

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Abstract

The Hong Kong currency board arrangement (CBA) is reviewed historically and tested empirically, in terms of its ability to "fix" the officially announced exchange rate of HK$7.80/US$ since October 1983. We confine our attention to the CBA's technical viability. Keeping track of all major documents and reports, the historical review is based on a detailed account of the institutional changes in the system while the empirical part relies on econometric techniques. The key theoretical and institutional hypothesis of ours is that the system behaved like a narrow target zone, before the seven technical measures implemented by the Hong Kong Monetary Authority (HKMA) in September 1998 that turned the system into a more self-adjusting entity with an effective currency arbitrage mechanism. Credibility tests and mean-reversion tests are applied to historical data. The findings point to a Hong Kong CBA that suffered periodic shocks and attacks, yet showing an ability to return to a mean, with the notable exception of the several months following the speculative attack in 1997. While elements of the defense mechanism of a classical CBA contributed partly to this relative robustness, it was also a result of the HKMA's intervention in the foreign exchange and the money markets.

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Shu-ki Tsang, Chor-yiu Sin and Yuk-shing Cheng

1. Introduction

The East Asian economic crisis started out as a currency crisis. Heavy pressures on major currencies in the region began with the Thai baht in mid-1997. Troubles then spread to the Indonesian rupiah, the Malaysian ringgit, the Philippine peso, and the usually robust Singapore dollar. From October 1997 onwards, pressures spilt over to Taiwan, Hong Kong, South Korea, Japan and even outside Asia.

Before the crisis, all the above-mentioned economies other than Japan adopted a variety of fixed exchange rate systems, with their currencies pegged to the U.S. dollar either explicitly or implicitly. It turns out that only the Hong Kong dollar has succeeded in resisting devaluation. Apart from other dissimilarities, Hong Kong differs from its neighbors in that it is the only major economy that adopts a currency board system, other than Brunei and Macau, both very small in size.[1] Like the gold standard (Officer, 1989, 1993), "currency boards" were an ingenious invention which in theory relies on the arbitrage activities of self-interested market participants to hold the exchange rate, instead of resorting to government manipulation either through (1) foreign exchange controls, or (2) market intervention in the form of direct buying or selling of foreign currencies by the central bank. Dozens of economies (many former colonies of Britain) adopted the system before the Second World War. There are now over a dozen countries and territories in the world employing variations of currency board arrangements (CBAs) (Schwartz, 1993; Hanke and Schuler, 1994; Williamson, 1995).

We do not intend to argue that Hong Kong's CBA is a perfect one. Nor do we believe that it is the sole factor that has enabled Hong Kong to defend its currency. Indeed, the Hong Kong dollar was defended at a considerable cost: 1998 saw the deepest recession (at –5.1% in real terms) in the territory since reliable GDP statistics became available in the early 1960s.

In this paper, our concern is not the optimality of a fixed exchange rate system, nor a daring appraisal of discretionary versus rule-based policies. It is never easy to define these policies precisely. We confine our attention to the technical viability of Hong Kong's CBA. The starting point of this paper is precisely that Hong Kong's exchange rate has not been firmly fixed. While the official exchange rate was set at HK$7.8/US$ in October 1983 and applied to notes issuance, the exchange rate in the foreign exchange market has strayed time and again from the official rate (see Figure 1). The key problem was that Hong Kong's CBA failed to successfully harness the market force of self-interested arbitrage activities.

The Hong Kong government until rather recently resorted to various ways of intervention

[1] Nominally, Singapore has a currency board that issues notes. However, the board does not fix the Singapore dollar against any single foreign currency; nor does it use cash-based or other forms of arbitrage to protect that exchange rate. See below for the functioning mechanisms of "genuine" currency boards.

in the market to defend the exchange rate. The Hong Kong Monetary Authority (HKMA) used to argue that it should retain discretion on when and at what level, albeit near to 7.80, to intervene in the market. However, in response to repeated speculative attacks of escalating ferocity at the Hong Kong dollar since October 1997, the HKMA chose, in September 1998, to modify the CBA through a convertibility undertaking at a fixed exchange rate on the Hong Kong dollar balances of banks with it (HKMA, 1998). That reform was in line with the recommendation by Tsang (1996a; 1998b) that Hong Kong should adopt the convertible reserves system of the AEL (Argentina, Estonia, Lithuania) model of modernized CBAs, under which the central bank provides an explicit convertibility guarantee not just for the cash base, as in the classical case, but for the whole monetary base, i.e. the liabilities of the central bank.

In the setting before September 1998, Hong Kong's linked exchange rate system (the link) somewhat resembled an exchange rate target zone, although the government never admitted the existence of such a zone. This paper attempts to evaluate how well the link worked. Empirical tests are conducted to examine whether the exchange rate itself was stationary (in the sense of mean reversion) and whether it was credible from the perspective of market players (as revealed by the differentials in the rate of return between holding domestic and foreign currencies).

Section 2 looks at the history of the link, situating it as a peculiar CBA through its evolution since 1983. Section 3 reviews the various methodologies of testing the robustness of an exchange rate target zone. Section 4 presents the empirical results, and Section 5 concludes.

2. The historical evolution of Hong Kong’s CBA

We start this section with a general historical discussion of CBAs, which is followed by a summary of the institutional changes in the Hong Kong’s monetary system in different time periods from 1983 to 1998. The institutional evolution reflects the changes in the defense mechanism of Hong Kong's CBA, as depicted in Diagrams 1-3.

Currency boards actually have a long history, dating back to the 19th century when they were largely adopted in British colonies. In the post-war era, they were out of fashion as newly independent territories sought monetary autonomy by setting up their own central banks, and then floating exchange regimes replaced the Bretton Woods system (Schwartz, 1993; Williamson, 1995). In recent years, currency board economics seems to be enjoying a revival. Hong Kong resurrected it in 1983. Then Argentina established a currency-board type scheme in 1991, Estonia in 1992, Lithuania in 1994, Bosnia-Herzegovina and Bulgaria in 1997. Because of the emerging varieties, the term “currency board arrangements” (CBAs) has gained wide acceptance.

A currency board issues cash (notes and coins) with 100% foreign exchange reserves backing at a fixed exchange rate against a designated currency (Schwartz, 1993; Williamson, 1995). This supposedly fosters "economic discipline" in monetary and fiscal policies, which would instill confidence and lead to exchange rate stability.

It is far-fetched to argue that an exchange rate can be “fixed” by discipline-generated

confidence alone, without practical mechanisms that bind the exchange rate. Technically, a CBA differs from a fixed rate regime based on market intervention. Like the gold standard, it depends on two "automatic stabilizers" to anchor the exchange rate: (1) specie flow and (2) currency arbitrage.

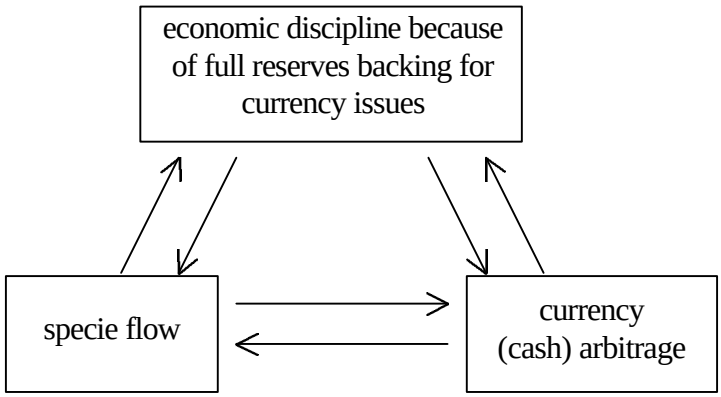
Under the specie flow process, an outflow of capital, as a result of doubts about the exchange rate, would lead to a contraction of the money supply. Interest rates then go up, and a counter-flow of funds is induced. The series of event would take place automatically and speedily, so that the exchange rate can be "fixed" without government intervention. Such logic seems a bit shaky. Under normal circumstances, interest rate hikes may contribute towards the stabilization of a currency. But if the exchange rate is itself fluctuating and looks insecure, higher interest rates will *not* necessarily induce a counter-flow of capital. In this sense, the specie flow process is not a reliable mechanism in fixing an exchange rate.

Therefore, there is the need for the second mechanism of the CBA: currency arbitrage (alternatively known as exchange rate arbitrage) that directly binds the exchange rate. Given the board's 100% foreign reserves for cash in circulation, cash arbitrage can be carried out. In case the market exchange rate weakens from the official rate, people can convert their bank deposits into cash, go to the currency board to exchange the cash into foreign currency at the stronger official rate, and then sell the foreign currency in the market. This arbitrage activity will yield a risk-free profit, and the selling pressure on the foreign currency will bring the market exchange rate back to the official level (Tsang, 1984).

In general, there are three anchors for a CBA: (1) economic discipline because of the 100% foreign reserves requirement for the issuance of currency; (2) specie flow in the form of interest arbitrage; and (3) exchange rate (cash) arbitrage that binds the spot exchange rate.

As illustrated in Diagram 1, these three anchors reinforce one another.

Diagram 1
The "tripod" for a classical CBA to fix the exchange Rate



(I) The Initial Period (1983-1988)

Hong Kong's CBA has evolved over the years since October 1983. The CBA was then adopted as a rescue to save a currency crisis that arose because of the Sino-British dispute over the political future of Hong Kong beyond 1997, when the territory would be resumed under Chinese sovereignty. What is interesting is that the CBA has not functioned in accordance with the theory. There has actually been no currency board in Hong Kong. While coins are made by the government, notes are issued by a few designated note-issuing banks (NIBs), which alone, until very recently, could deal with the monetary authority at the fixed exchange rate of HK$7.80/US$. Notes-based arbitrage opportunities, the core mechanism of the classical CBA, were therefore highly restricted in Hong Kong, rendering one of the two stabilizers almost totally inoperative (Tsang, 1996a; 1996b). It is not surprising that the market exchange rate has strayed from the official rate of 7.80 by an average of slightly less than 1%. In the 1990s, the market rate has been on the strong side of 7.80, which is not necessarily a "good" phenomenon for a "fixed" exchange rate regime (Figure 1).

In the initial period after the launch of Hong Kong's CBA (late 1983-1987), neither economic discipline nor specie flow were depended upon, given the shaky economic and political situation. The presumed bank notes arbitrage process also did not work (FSB, 1998). The linked rate of 7.80 was held imperfectly, thanks to a combination of government intervention in the foreign exchange market, manipulation of interest rates, and administrative measures (including the legal incorporation of "negative interest rates", when the HK dollar faced the speculative pressure of revaluation in 1987-88). See Nugée (1995) for an official admission. See also sub-section VI.1 in Schwartz (1993), which describes the arrangements from October 1983 to July 1988 as "flawed" due to the deficiencies in the mechanisms for both cash arbitrage and interest rate arbitrage.

(II) The New Accounting Arrangements (1988) and the Launching of Exchange Fund Bills and Liquidity Adjustment Facilities (1990)

During the period of 1983-1988, the government could not even define the monetary base as banks did not settle transactions through it. Instead, they settled through the Hong Kong and Shanghai Banking Corporation, the largest commercial bank in the territory. In 1988, the Accounting Arrangements were imposed, which required the Hong Kong and Shanghai Banking Corporation to keep a balance with the government that was equal to the net clearing balance of the whole banking system. The two-tier system gave the government an indirect handle on the monetary base (notes in circulation plus the clearing balance of the banking system). Furthermore, in the early 1990s, the launching of the Exchange Fund Bills and Notes, as well as the setting up of the "Liquidity Adjustment Facility" (LAF) as a kind of "discount window" (but with penalties against frequent users), strengthened the ability of the authority in affecting interbank liquidity in the two-tier system (Nugée, 1995; Tsang, 1996a, 1996b).

As can be observed from Figure 1, the market exchange rate fluctuated around the level of 7.80 in the 1980s. From mid-1991 onwards, however, it stayed persistently on the strong side of the linked rate. What happened was a combination of policy moves and changing economic environment. Inflation in April 1991 went up to 13.9%. In a bid to arrest price rises, the government decided to squeeze liquidity by borrowing HK$100 million in the interbank market. The Hong Kong Association of Banks (HKAB) responded by raising deposit interest rates by 1% across the board on 24 May 1991, while major banks also pushed up their prime lending rates by the same magnitude (Hong Kong Standard, 1991. See also Section 3.5 in

ESB, 1992 for an official description).

The move was criticized by quite a number of commentators (e.g. Bowring, 1991), because activist monetary policy in a small open economy with a fixed exchange rate regime could not possibly work. In any case, the market exchange rate of the Hong Kong strengthened markedly, rising to 7.715 by the close of 21 June. The government had to reverse course, and the HKAB had to slash interest rates by the same 1% on 28 June.

Subsequent to that episode, the market exchange rate never returned to 7.80. A shift in the "mean" rate apparently occurred. Although inflation rates in Hong Kong were high, so were interest rates. There were strong capital inflows in the following years, particularly after the "Deng whirlwind" of mid-1992, when the paramount Chinese leader Deng Xiaoping made a trip to Southern China to urge a speeding up of economic growth and reforms. Investors from all over the world rushed into China, and Hong Kong as the most important "window" benefitted significantly.

In the light of these developments, the Hong Kong government showed little intention of forcing the market exchange rate back to any level near 7.80. Indeed, a view emerged from the official circle that 7.75 might be a good "first line of defence" against any speculative attack on the Hong Kong dollar. This is an important point and has crucial influence on the specifications of our empirical tests. We will revert to it in Section 4.

(III) The Establishment of the Hong Kong Monetary Authority (1993)

On 1 April 1993, a central bank, the Hong Kong Monetary Authority (HKMA) was formally established by putting all the pieces of reforms under one roof and managed by one powerful institution. Since the 1980s the government had also been successful in accumulating huge fiscal and foreign exchange reserves. These developments and evolving mechanisms enabled the HKMA to modify its stance. Officials were proud to present the link as a currency board system (Latter, 1993; HKMA, 1994). Adequate reserves and economic discipline were emphasized.

Nevertheless, the HKMA made it known that it would defend the Hong Kong dollar by having flexible ways to manipulate the monetary base and to influence interest rates. Andrew Sheng, then the Deputy Chief Executive of the HKMA, said on the heel of the Mexican crisis, " .... in recent years the HKMA has introduced various reforms to its monetary management tools, or more aptly, our monetary armoury, to maintain exchange rate stability. ..... As was seen in January (1995), our determination to use the interest rate tool was sufficient to deter further speculation against the HK dollar. In fact, currently, the HK dollar is at a stronger level than it was at 1994 year end." (Sheng, 1995, p.60) "To the extent that the HKMA intervenes through the use of foreign exchange swaps, any increase in the monetary base is fully backed by foreign exchange. We use a whole range of instruments in influencing the level of interbank liquidity to manage interbank interest rates, and consequently, maintain exchange rate stability." (p.61)

However, under the two-tier Accounting Arrangements, the clearing balance of the banks showed wide fluctuations "because banks on the odd occasion miscalculate their own liquidity position. That is why we need and are developing a new RTGS payment system to manage

funds flow more efficiently." (Sheng, 1995, p.61)

(IV) The Real Time Gross Settlement (1996) and The Report on Financial Market Review (1998)

The RTGS (Real Time Gross Settlement) system was installed in December 1996, replacing the previous two-tier structure. The government could then directly manage the clearing balance of the whole banking system (HKMA, 1995, 1997). The HKMA did not make any pronouncements that the link's mode had undergone any significant changes.

In October 1997, the Hong Kong dollar suffered a strong speculative attack. Doubts were cast on the nature and the robustness of Hong Kong's CBA. A controversy arose concerning whether and to what extent the HKMA did intervene in the markets on 23 October 1997, and was therefore responsible for the unprecedented high interest rates---with overnight interbank rates going up to 280% at one point.

The HKMA later argued that the Authority was just "sitting there passively", allowing the system to go on "auto-pilot" (Yam, 1998a). But critics pointed out that the HKMA openly warned banks in the morning of 23 October that those who repeatedly borrowed HK dollars from the LAF would be penalized. This presumably touched off a strong "announcement effect" and banks just scrambled for funds (Cheng, Wong and Findlay, 1998). There were reports that the HKMA also sold US dollars in the market to defend the spot exchange rate of the HK dollar. The result was a further drain in HK dollar liquidity.

In reaction, the Hong Kong government took a major step in defining the link as an automatic CBA. On 23 April 1998, the Hong Kong government published its report on the October 1997 financial storm: *Report on Financial Market Review* (FSB, 1998). The key change was that the HKMA announced a commitment not to actively manage the clearing balance of the banking system to defend the exchange rate (FSB, 1998, paras. 3.36-3.41; Annex 3.5), the HKMA would keep to the rule of automatic adjustment.

Nevertheless, the HKMA maintained the option to sterilize the monetary effect of several types of "exceptional circumstances".[2] This option provided a certain degree of discretion to the HKMA in influencing the market. In early August 1998, when speculators sold short of Hong Kong dollars heavily, the HKMA arranged to use Hong Kong's fiscal reserves in US dollars to buy in Hong Kong dollars for the expected fiscal deficit for this year, thus offsetting the speculative force.[3]

In terms of the "tripod" on which a classical CBA relies in fixing its exchange rate (see

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[2] According to the HKMA (1998), the "exceptional circumstances" include: (a) occasions when Initial Public Offerings (IPOs) of shares and other large scale Hong Kong dollar transactions risk creating extreme conditions in the interbank market; (b) the necessity of entering into intraday Repos and overnight Repos (through the LAF) to "smooth the settlement of interbank transactions"; (c) activities which may have the unintended effects of affecting the clearing balance, such as a transfer of fiscal surpluses by the government to the HKMA.

[3] This was confirmed by the Financial Secretary's Briefing on 7 August 1998. The Briefing can be read on web site http://www.info.gov.hk/gia/general/199808/07/0807223.htm and it is available from the authors upon request.

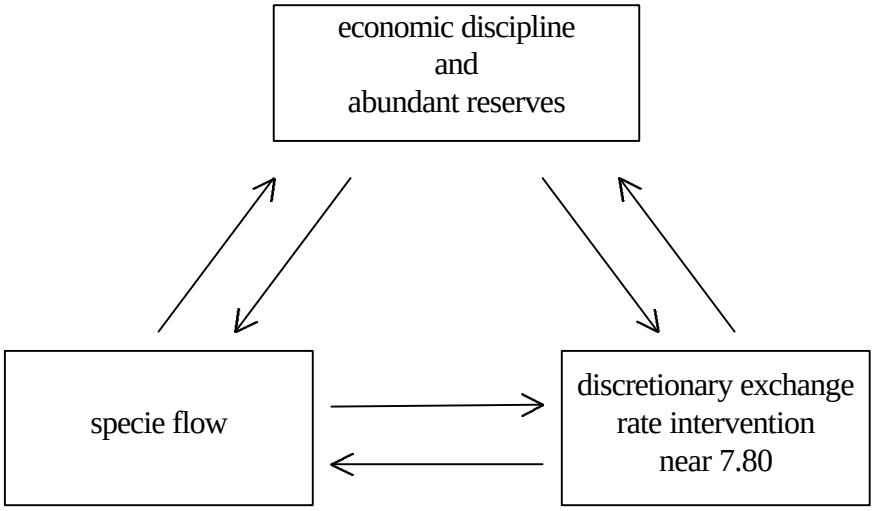
Diagram 1), the HKMA arrived at a situation where two of three anchors could be effectively used: (1) economic discipline on the basis of adequate reserves; and (2) automatic specie flow. The problem then lied with the third anchor---exchange rate arbitrage.

In the *Report on Financial Market Review*, the Hong Kong government admitted the implausibility of bank notes arbitrage---a key pillar of the classical CBA---as an effective mechanism to bind the exchange rate (FSB, 1998, para. 3.34). Tsang (1997, 1998b) had tried to drive home this point for quite some time: in a modern financial economy with a diminishing cash base, notes arbitrage is a non-starter. To compensate for this deficiency, however, the government did not put in place an alternative arbitrage mechanism, and rejected in the *Report* his proposal (Tsang, 1996a, 1996b, 1997) of adopting the AEL (Argentina, Estonia, Lithuania) model of convertible reserves (FSB, paras. 3.64-3.65; Tsang, 1998a). Under that model, the monetary authority guarantees the convertibility of not just the cash base, but the whole monetary base, i.e. including also banks' reserves and balances with it. Currency arbitrage can then be performed electronically, through interbank settlement at the monetary authority. While no movement of bank notes is necessary, the spot exchange rate will be firmly fixed.

Rejecting the AEL model, the HKMA opted for a tactic of "constructive ambiguity" (Yam, 1998a, p.24), under which it would manipulate a "surprise element" and choose the level of exchange rate at which it intervened directly in the foreign exchange market. At the end of 1997, Hong Kong's international reserves covered more than six times of the currency in circulation. In fact, including the Land Fund, which was transferred to the management of the HKMA in September 1997, Hong Kong had the *third* largest foreign exchange reserves in the world, which represented over 40% of HK$M3. Hence, the HKMA could afford discretionary market intervention. It should be emphasized that nothing about regime switching in Hong Kong's CBA has been officially documented.

Essentially the *Report on Financial Market Review*, among other things, outlined a new version of CBA, as depicted in Diagram 2. Compared with Diagram 1 of the classical system, one can see that it was a unique CBA, with the arbitrage anchor replaced by discretionary foreign exchange market intervention to underpin an officially sanctioned exchange rate. Some would even call it "central banking in disguise".

Diagram 2
The tripod for Hong Kong's CBA in April 1998



In August 1998, the Hong Kong government intervened in the stock and futures markets, touching off a huge controversy. The major objective of the intervention, according to the Chief Executive of the HKMA, was to protect the integrity of the Hong Kong dollar and the stability of Hong Kong's monetary and financial system. Speculators were alleged to have sold short of stocks and futures, before attacking the Hong Kong dollar. The latter move aimed at pushing up interest rates, which in turn would trigger a "planned" fall in the prices in the stock and futures markets, completing the circle. (Yam, 1998c). Hong Kong is perhaps the only international financial centre where the opportunity to make profits by engaging in this kind of "double-market play" emerges. Under such circumstances, defending the currency by pushing up interest rates would be costly.

(V) The Seven Technical Measures and the 500-Day Plan

On 5 September 1998, the HKMA announced seven technical measures to strengthen the link.[4] These measures can actually be grouped into two categories: (1) the convertibility undertaking that banks could exchange their Hong Kong dollar balances with the HKMA into US dollars at the fixed exchange rate of 7.75; and (2) the replacement of the Liquidity Adjustment Facility (LAF) by a formal Discount Window.

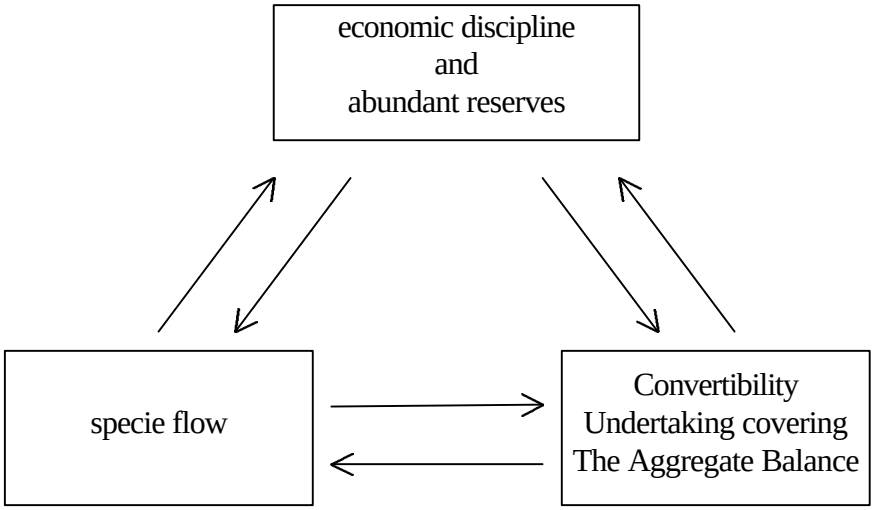
The first move means that the coverage of convertibility is effectively extended from bank notes to the whole monetary base. The Discount Window, on the other hand, enlarges the monetary base. This arrangement will reduce interest rate pressures when there are speculative attacks. As said above, a system of convertible reserves is the core mechanism in the AEL (Argentina, Estonia and Lithuania) model of modernized currency board arrangements. The new tripod of CBA that the HKMA instituted in September 1998 is depicted in Diagram 3.

There were some remaining problems with regard to the seven technical measures, which

[4] These measures started to take effect from 7 September 1998.

represented a late conversion to the AEL model. They included the one-sided nature of the convertibility undertaking (that guaranteed only conversion from Hong Kong dollars to US dollars, not the other way round), the need to move from the rate of 7.75 to 7.80, and the determination of the base rate in the discount window, etc. See Tsang (1998c) for a preliminary discussion of these problems.

Diagram 3
The tripod for Hong Kong's CBA after September 1998



Some of these issues were rectified after September 1998 by the HKMA. The base rate was fixed as a premium (150 basis points for the time being) to the US Fed Fund Target Rate. Starting from 1 April 1999, the one-way convertibility rate was to shift by "one pip a day" from 7.75 to 7.80 through 500 calendar days, reaching the latter on 12 August 2000. Moreover, in a bid to increase transparency of Hong Kong's reborn CBA, the HKMA started to publish monthly the Currency Board Account from March 1999, which spelt out clearly the Backing Portfolio (reserves in US dollars) behind the monetary base. Various technical changes to tidy up the convertibility of and transferability among different components of the monetary base were also implemented. (Yam, 1998b; HKMA, 1999)

Financial calm has apparently returned to Hong Kong with these reforms. The SAR has not suffered any large-scale speculative attack again after the seven technical measures settled in, despite serious problems in Russia and Brazil. Local interest rates have come down significantly, with volatility much reduced. It is difficult to say whether the reforms alone could have achieved it. Changes in the external environment did help. The Asian crisis showed signs of bottoming out. The LTCM incidence in the US finally woke the elite up for the need of a "new international financial architecture". Powerful speculators apparently decided to take a

rest.

3. Investigation of the robustness of the Hong Kong CBA as a "target zone"

The discussion in the previous section points to the fact that the exchange rate of the Hong Kong dollar had not been firmly fixed since its inception and before the introduction of the seven technical measures in September 1998. In the setting before April 1998, the government intervened in the market with a view to affect interest rates and the exchange rate whenever the market exchange rate deviated "too much" from the official rate. In the short period of April - August 1998, the HKMA promised to withhold from interest rate manipulation other than specified needs for sterilization. Nevertheless, it reserved the right for discretionary intervention in the foreign exchange market.

In this regard, Hong Kong's CBA before September 1998 resembled an exchange rate target zoning system, although the government never announced a zone to defend. As for any target zone, one issue at stake is whether the system is credible. Market players from time to time evaluate whether the government will realign (or re-peg in the case of Hong Kong) the exchange rate or not. Suppose that there is significant selling pressure on the exchange rate. If it is believed that the government will maintain the current rate, the government is expected to intervene in the market to defend the rate and engineer a rebound. If the government's intention or ability to defend the current rate is in doubt, the existing exchange rate loses credibility. Market players will act accordingly to avoid loss or even to fetch a gain.

Two inter-related empirical issues concerning the Hong Kong link arise here. One is how credible the linked rate system has been from the perspective of market players since its inception in 1983. This would have been reflected by the data of the exchange rate and the interest rate differential between domestic and foreign interest rates. Specifically, Svensson's (1991) "simplest credibility test" of target zone can be applied to the data. Another issue is whether Hong Kong's exchange rate exhibits a mean-reversion property – that is, the exchange rate reverts to the mean level after it has deviated from the latter. There are at least two ways of testing the existence of such a property, namely, the variance ratio test and the unit root test.

Conceptually, the two sets of tests are complementary to each other. Svensson's "simplest test" enables us to detect specific episodes in which the target zone lacked credibility, when the interest and exchange rates strayed significantly. Mean-reversion tests, on the other hand, investigate the tendency of an exchange rate to gravitate towards an average level. At one extreme, an exchange rate system can fail both sets of tests. It may be a potential disaster when a financial turmoil unfolds. At the other extreme, the system passes both of them: then it is indeed very robust as a target zone. The more interesting case is that of a mixed result. There may be a system that shows signs of non-credibility at different time points, by failing Svensson's test, and yet demonstrates an ability to revert to a mean, by passing the mean-reversion tests. The implication is that while it is not perfect, by succumbing to various shocks and speculative attacks, it is still strong enough to regain its posture and maintain the integrity of the target zone, or indeed a peg.

Given the historical analysis of the Hong Kong link as a peculiar CBA, which we sketched above, it is in our view a useful exercise to determine to which category of robustness it actually belongs. Let us first discuss the technicalities of the two sets of tests.

(I) Svensson's simplest credibility test on the interest differential:

Svensson's (1991) "simplest test" of target zone credibility is performed on Hong Kong's linked exchange rate system. The rationale is that, because of arbitrage imperfection, the market rate would deviate to a certain extent from the official rate of *HK$7.80/US$*. Nevertheless, the system still holds as market participants do not doubt its ability to continue, albeit at some cost. Svensson's test starts by computing the rate of return of a foreign currency investment for t months, R_t^t, given a band within which the central bank defends the exchange rate. Hence there will be an upper bound ($\overline{R}_t^t$) and a lower bound ($\underline{R}_t^t$) of the rate of return. The upper bound is calculated as:

$$\overline{R}_t^t = (1 + i_t^{*t})(\overline{S}/S_t)^{12/t} - 1,$$

where i_t^{*t} represents the foreign interest rate in time t for a t-month loan or investment, S_t the spot exchange rate (expressed as the ratio of the domestic currency per unit of foreign currency), and $\overline{S}$ the upper bound of the exchange rate (that is, the limit of depreciation allowed). Likewise, the lower bound of the rate of return is given by:

$$\underline{R}_t^t = (1 + i_t^{*t})(\underline{S}/S_t)^{12/t} - 1.$$

Under the assumption of there being no arbitrage, a completely credible exchange rate implies that the domestic interest rate i_t^t must lie within the band of R_t^t, that is,

$$\underline{R}_t^t \leq i_t^t \leq \overline{R}_t^t .$$

If the domestic interest rate moves above the upper bound, the no-arbitrage assumption implies that the exchange rate regime cannot be completely credible as investors perceive a risk of devaluation.

Another variant of Svensson's (1991) test based on the uncovered interest parity is also performed. It uses following equation:

$$E_t S_{t+t} = S_t[(1 + i_t^t)/(1 + i_t^{*t})]^{t/12},$$

where $E_t S_{t+t}$ is the expected value in time t of the ruling exchange rate in month $t+t$. The right-hand side of the equation is the (annualized) interest differential (between the domestic and foreign interest rates) adjusted for the maturity period of t months. It can be checked whether the expected exchange rate (determined by interest differential) ever moved outside

the "target zone", that is, $\overline{S}$ and $\underline{S}$.

(II) Testing the mean-reversion of the exchange rate:

One way of testing whether the exchange rate exhibits mean-reverting properties is to perform the *variance ratio test*, which has been introduced to the analysis of time series data by Cochrane (1988) and has been frequently applied to test the efficiency of financial markets. Let s_t represent the exchange rate in natural logarithm. Suppose s_t follows a random walk model with a drift:

$$s_t - s_{t-1} = m + e_t, \qquad t = 1, \ldots, T$$

where e_t's are i.i.d with mean zero and variance s^2. An unbiased estimator of s^2 is:

$$\hat{s}_1^2 \equiv \frac{1}{(T-1)} \sum_{t=1}^{T} \left[s_t - s_{t-1} - \hat{m} \right]^2,$$

where $(T+1)$ is the number of observations and $\hat{m} \equiv (s_T - s_0)/T$ is an unbiased estimator of m. On the other hand, the sample variance of the kth difference of s_t will also be an unbiased estimator of s^2:

$$\hat{s}_k^2 \equiv \frac{T}{k(T-k)(T-k+1)} \sum_{t=k}^{T} \left[s_t - s_{t-k} - k\hat{m} \right]^2.$$

To test whether s_t follows a random walk, we can simply look at the ratio of the two estimators (*the variance ratio*):

$$\hat{V}(k) \equiv \frac{\hat{s}_k^2}{\hat{s}_1^2}.$$

We can reject the random walk hypothesis if $\hat{V}(k)$ is significantly greater than or smaller than one and signifies the ignored covariance. Lo and MacKinlay (1988) defined the test statistics:

$$z_1(k) \equiv (\hat{V}(k) - 1) \left(\frac{2(2k-1)(k-1)}{3Tk} \right)^{-1/2},$$

which is asymptotically $N(0, 1)$ under the null of a random walk. Lo and MacKinlay (1988) also derived the test statistic, with the same asymptotic distribution which allows for heteroskedasticity:

$$z_2(k) \equiv (\hat{V}(k) - 1) W^{-1/2}(k),$$

where $W(k) \equiv 4\sum_{j=1}^{k-1}\left(\frac{k-j}{k}\right)^2 d_j$, $d_j \equiv \frac{\sum_{t=j+1}^{T} a_{0t}a_{jt}}{\left(\sum_{t=1}^{T} a_{0t}\right)^2}$, $a_{jt} \equiv \left(s_{t-j} - s_{t-j-1} - \hat{m}\right)^2$.

One shortcoming of the variance ratio test is that it is only applicable to time series data with autoregression of order 1. Another method to test the existence of mean-reverting property is the unit root test. The standard way of testing the null hypothesis is to estimate:

$$Ds_t = g + (b_0 - 1)s_{t-1} + \sum_{j=1}^{q} b_j \, Ds_{t-j} + e_t,$$

where e_t's are i.i.d with mean zero and variance s^2, as before.

The unit root test amounts to examining whether $(b_0 - 1) = 0$, which can be done by using a non-standard t-test proposed by Dickey and Fuller (1979).

4. Empirical Results

(I) Svensson's simplest credibility test on the interest rate differential:

With *daily closing data* figures[5], Figure 2 and Figure 3 show the results of the interest rate and those of the expected exchange rate respectively. The three-month Hong Kong Interbank Offered Rate (HIBOR) is used as i_t^3 while the three-month London Interbank Offered Rate (LIBOR) is employed as a proxy for i_t^{*3}. A *1%* limit on either side of *7.80* as the range of the "target zone" for the linked rate system is used, on the basis that the government did seem alarmed when the deviation from the official rate approached *1%* in the past. Hence $\overline{S}$ is *7.878* and $\underline{S}$ is *7.722* for the zone. But it should be pointed out that the HKMA has never explicitly defined any “target zone”.

Several observations are in order:

1. From the end of 1984 to the end of 1988, doubt about the credibility of the link persisted. Initially, it was due to a lack of confidence about whether the link as a rescue measure could hold. Then in the second half of 1987, speculation about a possible revaluation of the Hong Kong dollar became rife. Hong Kong's interest rate stayed significantly below $\underline{R}_t^t$. The market expectation was due to the relatively good political atmosphere after the Sino-British accord on Hong Kong’s post-1997 future, as well as the economic recovery from 1986 onwards.

2. The performance in the period of late 1988 to early 1997 seemed to be better. Hong Kong's interest rate was by and large close to $\underline{R}_t^t$. Yet, credibility was not established for

[5] The data, which are originated from *Datastream* and *Bloomberg*, as well as the computer codes, are available from the authors upon request.

certain, as the interest rate still fell below $\underline{R}_t^t$ marginally in many occasions.

3. Since the second half of 1997, that is, when the Asian financial crisis spread to Hong Kong, the link was clearly not credible. Apparently, market participants at that time suspected that the Hong Kong dollar would devalue. In particular, the domestic interest rate deviated from the band most dramatically during the powerful attack in October 1997. Three more sub-attacks occurred in January 1998 (due to the Indonesian crisis), June and August 1998 (as a result of the pressure on the Japanese Yen). In all these three occasions, the credibility of the link was breached, albeit to a much lesser extent than the first attack.

4. After the adoption the seven technical measures in early September 1998, credibility of the link was strengthened. The interest rate fell within the bounds of rate of returns.

5. Not surprisingly, the three-month expected exchange rate plotted in Figure 2 shows similar patterns. The credibility of the target zone of 1% was upheld or breached in the same direction in the three periods since the end of 1984.

(II) Testing the mean-reversion of the exchange rate:

As seen from Figure 1, the market exchange rate did not deviate from the official rate permanently. This indicates that there may have been mean-reversion, with a possibly different mean after May 1991. We have performed two tests, the first assuming the same mean for the whole period, the second taking 24 May 1991 (the date on which the interest rate was raised and the market exchange rate strengthened significantly thereafter; see the discussion in sub-section 2(II)) as the break point for two different means. Furthermore, we have adjusted the data after 1 April 1999. Since that day, as discussed in sub-section 2(V), the HKMA has been moving the rate for convertibility undertaking by one pip a day. In the context of this paper, this 500-day programme is equivalent to edging the target zone upwards gradually and continuously. The continuous upward movement of the exchange rate does not necessarily imply a failure of the system to keep the exchange rate in check. Thus, a mechanical application of the mean-reversion tests may give rise to misleading results. To overcome this problem, we have deducted the corresponding pips from the actual market exchange rate, so that its relative position to the convertibility undertaking remains at the previous level (i.e. at that of 31 March 1999). The results of the *Variance Ratio Test* and the *Augmented Dickey-Fuller Test* are reported in Table 1 and Table 2 respectively.

Table 1

K	2	4	6	8	10	12	16	20	24
Same mean									
$\hat{V}(k)$	0.641	0.381	0.319	0.262	0.234	0.212	0.185	0.167	0.152
$z_1(k)$	-22.590	-20.823	-17.361	-15.706	-14.294	-13.244	-11.666	-10.552	-9.740
$z_2(k)$	-1.619	-1.841	-1.797	-1.825	-1.822	-1.825	-1.823	-1.822	-1.827
Different means									
$\hat{V}(k)$	0.641	0.382	0.319	0.263	0.234	0.212	0.186	0.169	0.154
$z_1(k)$	-22.590	-20.818	-17.353	-15.696	-14.283	-13.231	-11.651	-10.534	-9.721
$z_2(k)$	-1.619	-1.840	-1.797	-1.824	-1.820	-1.823	-1.821	-1.819	-1.823

Table 2

Sample period	Dummy	s_{t-1}	No. of lags	Sample size
29 Oct 83-4 Aug 99	-	-0.0109 (-3.467)***	3	3962
29 Oct 83-4 Aug 99	-0.469×10^{-3}(-7.211)***	-0.0602 (-8.009)***	3	3962

(*), (**) and (***) indicate significance at 10%, 5% and 1% respectively.

Table 1 shows that the variance ratio tests with or without different means deliver virtually the same results. By and large the random walk model is rejected by the significant test statistics with different k. In the unit root test that follows, 3 lags are chosen under the specific-to-general approach, thus confirming that autoregression of order 1 as assumed in the variance ratio tests is an insufficient model.

From Table 2, it can be observed that the Augmented Dickey-Fuller tests with or without a dummy lead to the conclusion that there was mean-reversion in the exchange rate. The significant dummy suggests that there is a change in the mean. Next we have divided the whole period into three sub-periods (see the discussion in the historical review) and performed the tests for each of them. Specifically, the starting dates of the three sub-periods are:

(1) the inception of the linked rate system on 17 October 1983;
(2) the introduction of the new accounting arrangement on 15 July 1988;
and
(3) the HKMA's implementation of the seven technical measures after 5 September 1998.

It should be emphasized that we divided the entire sample into three sub-periods to check the robustness of our empirical results on the basis of observed behavioural changes, regardless of whether policy shifts were officially announced or not.

Figures 4 to 6 plot the exchange rates in the three periods respectively. The first period clearly shows mean-reversion, despite a couple of outliers. Figure 5 represents a downward sloping curve in the initial phrase, which levels off at a lower point (around 7.73). This figure may suggest a change in the target point at which the government intervened in the foreign

exchange market. Figure 6 shows the situation after the introduction of the seven technical measures. The exchange rate looked unstable in the initial phase, yet showed a tendency to stabilize at the level of 7.75 in early 1999. The exchange rate started to go up notably but slowly in April 1999. This was the result of the upward adjustment of the rate for the Convertibility Undertaking, which has been scheduled at one pip per calendar day.

The results of the variance ratio tests and the Augmented Dickey-Fuller tests for different sub-periods are reported in Table 3 and Table 4.

Table 3

K	2	4	6	8	10	12	16	20	24
17 Oct 83-14 July 88 $\hat{V}(k)$	0.62	0.34	0.27	0.22	0.19	0.17	0.14	0.13	0.11
$z_1(k)$	-13.27	-12.25	-10.14	-9.11	-8.25	-7.64	-6.71	-6.06	-5.57
$z_2(k)$	-1.56	-1.78	-1.73	-1.74	-1.73	-1.73	-1.73	-1.72	-1.72
15 July 88-4 Sept 98 $\hat{V}(k)$	0.89	0.82	0.75	0.68	0.64	0.62	0.59	0.58	0.54
$z_1(k)$	-5.72	-4.92	-5.01	-5.40	-5.37	-5.13	-4.66	-4.30	-4.20
$z_2(k)$	-1.67	-1.68	-1.91	-2.23	-2.37	-2.38	-2.35	-2.30	-2.36
5 Sept 98-4 Aug 99 $\hat{V}(k)$	0.85	0.75	0.66	0.62	0.58	0.54	0.45	0.44	0.40
$z_1(k)$	-2.29	-1.99	-2.05	-1.94	-1.86	-1.86	-1.89	-1.69	-1.64
$z_2(k)$	-1.92	-1.62	-1.72	-1.66	-1.61	-1.63	-1.67	-1.51	-1.48

Table 4

Sample period	Dummy	s_{t-1}	No. of lags	Sample size
(1) 21 Oct 83-14 July 88	-	-0.0907 (-5.178)***	3	1185
(2) 15 July 88-4 Sept 98	-0.205×10^{-3}(-4.907)***	-0.0288 (-5.652)***	1	2550
(3) 5 Sept 98-4 Aug 99	-	-0.1468 (-4.110)***	1	227

(*), (**) and (***) indicate significance at 10%, 5% and 1% respectively.

The random walk model is rejected by the $z_1(k)$ for all k, for all the sub-periods. For the first sub-period, the $z_2(k)$ is marginally significant, possibly due to the outliers, the effect of which is magnified by the heteroskedasticity-consistent variance estimator. For the second sub-periods, the random walk model is rejected for all k. For the third period, that is, after the introduction of the seven technical measures, the random walk model is not rejected only for some k's (for mainly k≥10). Anyway, in all sub-periods, one or more lags are chosen with the specific-to-general approach and it is confirmed that autoregression of order 1 is an insufficient model. The Augmented Dickey-Fuller tests essentially find mean-reversion in all periods.[6] As the result for the whole period, the dummy for Period (2) is significant.

[6] Even if we use the general-to-specific approach to select the number of lags, mean reversion is found in the

5. Conclusion

In this paper, we present the results of applying target zone robustness tests to Hong Kong's linked exchange rate system. While a fixed exchange rate system, in particular a currency board system, is in theory different from a target zone, in terms of rigidity, we justify our exercise with a detailed historical analysis of the link since its inception, as presented in section 2. As a CBA, the link has been neither classical nor modernized (if the AEL model of Argentina, Estonia and Lithuania is taken as the latter's benchmark).

The crux of the problem was the absence of an effective currency arbitrage mechanism that directly mobilized self-interested market force, like the old gold standard or the classical currency board system, before September 1998. The market exchange rate and interest rates did not behave exactly according to the theory of currency board economics. At the same time, though, Hong Kong possessed, and possesses huge foreign exchange reserves and the government has shown an extraordinary commitment to the rate of 7.80. The evolution of Hong Kong's CBA can be treated as one of targetting an exchange rate with various means.

As we said in section 3, the Svensson's simplest credibility test and the mean-reversion test are complementary. The former enables us to detect specific episodes of breach of credibility, in which the domestic interest and exchange rates stray significantly from the zone. The latter investigate whether an exchange rate, despite various shocks, gravitates towards a mean.

Our empirical results are mixed. The link showed signs of non-credibility at different time points since its inception, by failing Svensson's test and reflecting the lack of firmness against revaluation or devaluation expectations. During the East Asian economic crisis, the stress was particularly pronounced. Yet the exchange rate of the Hong Kong dollar has also demonstrated an ability to gravitate towards a mean, by passing the two varieties of mean-reversion tests. More importantly, after Hong Kong moved in September 1998 towards a more self-adjusting CBA with an effective currency arbitrage mechanism, akin to the AEL model, the system passed both the Svensson's test and the unit root test.

Overall, the empirical results suggest that while the link was not perfect, by falling victim to various shocks and speculative attacks, it was still strong enough to subsequently regain its posture and to maintain the integrity of the target zone, or indeed the peg.

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first two sub-periods. In the case of Period 3, as many as 18 lags are chosen. This is rather dubious given the small number of data points. We also detect that the fifth to the seventeenth lags are all insignificant. The results are shown in the following table:

Sample period	Dummy	s_{t-1}	No. of lags	Sample size
21 Oct 83-14 July 88	-	-0.0907 (-5.178)***	3	1185
15 July 88-4 Sept 98	-0.176×10^{-3}(-4.112)***	-0.0249 (-4.769)***	7	2550
5 Sept 98-4 Aug 99	-	-0.1137 (-2.388)	18	227

(*), (**) and (***) indicate significance at 10%, 5% and 1% respectively.

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Figure 1 Daily movement of the market exchange rate (HKD/USD), 17 October 1983 to 4 August 1999

Figure 2 Svensson's "simplest test" on the linked rate system (no arbitrage)

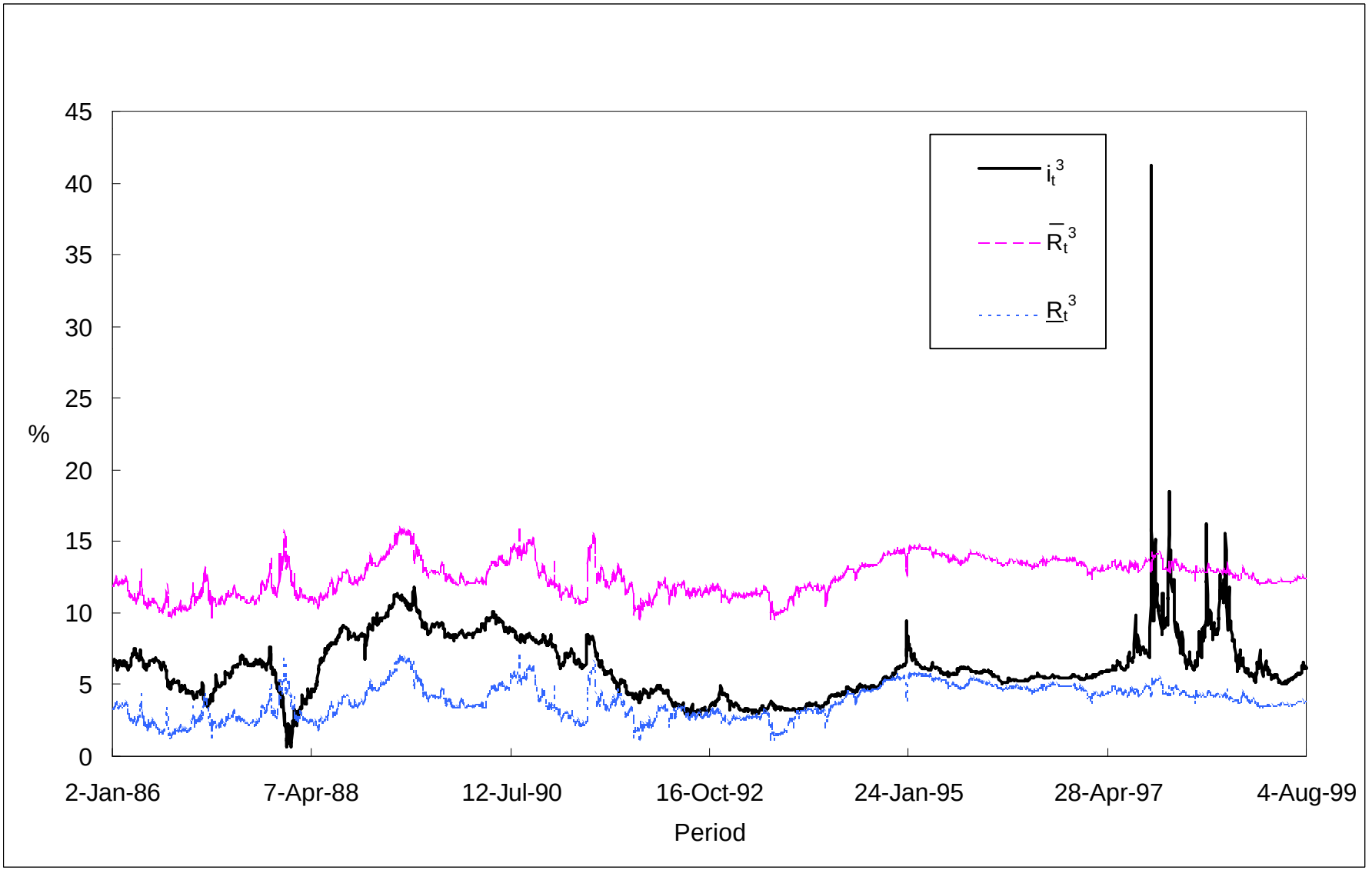

Figure 3 Svensson's "simple test" on the linked rate system (uncovered interest parity)

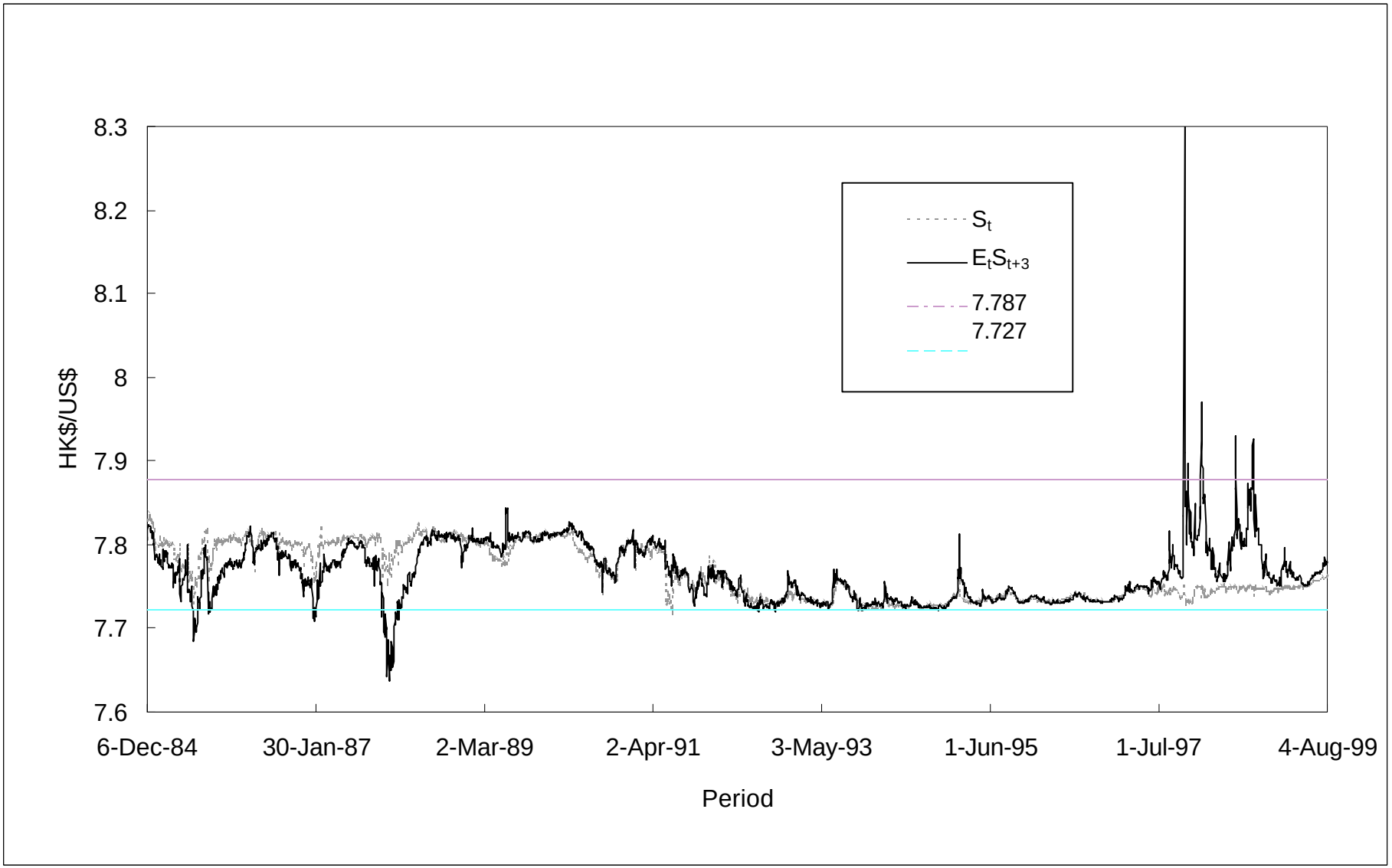

Figure 4 Daily movement of the market exchange rate (HKD/USD), 17 October 1983 to 14 July 1988

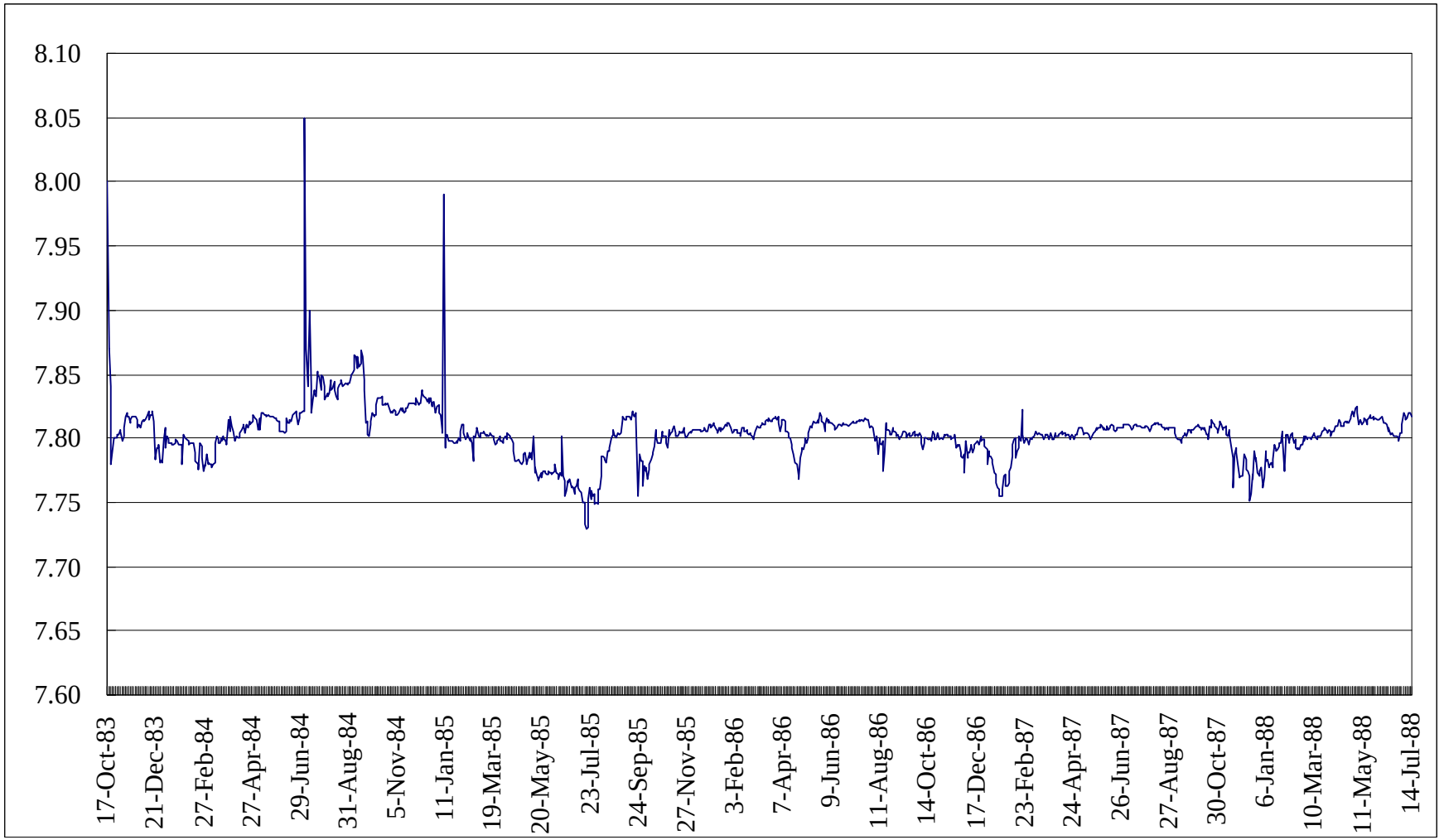

Figure 5 Daily movement of the market exchange rate (HKD/USD), 15 July 1988 to 4 September 1998

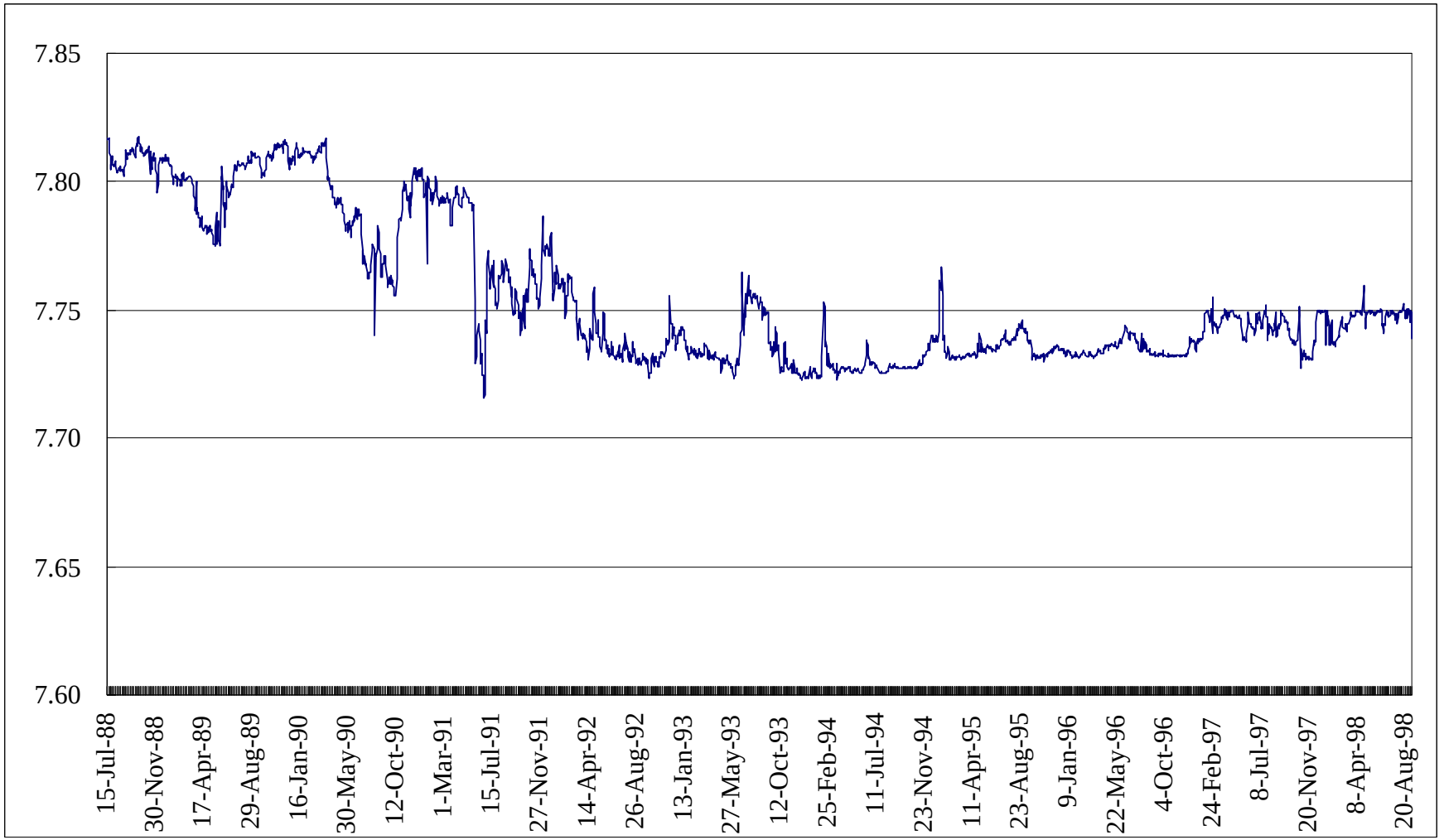

Figure 6 Daily movement of the market exchange rate (HKD/USD), 5 September 1998 to 4 August 1999