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# One - way arbitrage with transaction costs: an evidence from the Hong Kong foreign exchange market

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## ABSTRACT

This paper deals with the effects of transaction costs on the efficacy of one-way arbitrage under the linked exchange rate system during the period of January to April 1990 in the Hong Kong foreign exchange market. Empirical findings have confirmed the co-integration of the forward premium and the interest rate differential in the long run. There exists small and short-lived profits for one-way arbitrage in the Hong Kong swap market. Our findings do give support to some of the findings by Deardorff and Clinton that the validity of the one-way arbitrage help reducing deviations from the covered interest parity.

## 1. Introduction

In the conventional analysis of the spot and the forward markets for foreign exchange, it is usually the covered interest arbitrage that will be examined. Covered interest parity holds well in international markets, such as the Eurocurrency markets where securities are traded that differ only in their currency denomination. However, interest parity is often violated between domestic and foreign securities markets. This result comes on the one hand from obstacles to free flow of capital between countries and on the other hand from the transactions costs involved. Transactions costs include costs of transacting in the securities markets—brokerage (purchases and sales), stamp duties and bid-ask spread in both spot and forward foreign exchange markets. The impact of transactions costs on interest parity had been explored by Frenkel and Levich (1975), Deardorff (1979), Callier (1981), and recently by Clinton (1988). It is interesting not just that transactions costs have a negative effect on market participants, but that a very small increase in transactions costs can cause the market to dry up completely. Clinton, elaborating on Deardorff's arguments, claimed the deviations from the covered interest parity that attributed to transactions costs had been exaggerated because the swap market in foreign exchange has been ignored. It is shown that it should be no greater than the lowest of the transactions costs in the swap market and the two relevant securities markets.

Since market participants choose the least-cost method of exchanging currencies in these markets, they would engage in one-way arbitrage if that is preferable to a direct transaction in the other exchange market. One-way arbitrage, instead of simultaneously being transacted on four markets—the spot

and forward markets for foreign exchange and the domestic and foreign securities markets—consists of using one exchange market and the two securities markets. It is shown that the one-way arbitrage would prevent rates from ever departing enough from interest parity for the conventional covered interest arbitrage to break even.

Since the introduction of the linked exchange rate system in Hong Kong in October 1983, the Hong Kong dollar has been linked to a fixed parity (HK\$7.8 per US\$1). In theory, the spot as well as the forward rate of the Hong Kong dollar against US dollar should be close to the parity. However, there still exists speculation on the change of the fixed parity.<sup>1</sup> The maintenance of the parity relies upon the Hong Kong monetary authorities to manipulate the interest rate so as to affect the covered interest arbitrage between the spot and the forward market. Based on the argument of Deardorff (1979), the one-way arbitrage will help in reducing the deviations of forward premium from the covered interest parity, and thus would help in maintaining the fixed parity of the Hong Kong dollar.

Our interest is to investigate the one-way arbitrage in Hong Kong under the linked exchange rate system, allowing for transactions costs.<sup>2</sup> In this paper, we first examine the one-way arbitrage equilibrium conditions as suggested by Deardorff (1979) and Clinton (1988) for different maturity periods by means of calculating some statistics and plotting frequency distributions. Then we test for unit roots among the variables

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1 During January and February of 1988, there existed great speculation on the Hong Kong dollar realignment against the US Dollar.

2 The covered interest arbitrage and the linked exchange rate system were discussed in Chan and Cheung (1991).

of interest. Lastly, we apply the co-integration regression model (Engle and Granger, 1987) to investigate whether or not there exists some long-run equilibrium relationships between the swap rate,  $W$  and parity forward premium,  $W_0$ . In other words, we would like to see if the parity forward premium,  $W_0$ , and the swap rate,  $W$ , converge to each other under the interest rate parity. The factor leading to convergence between  $W$  and  $W_0$  will be the one-way arbitrage activities.

The structure of the paper is as follows: *section 2* dwells on the theory of the one-way arbitrage with transactions costs, particularly with reference to the swap market of the US dollar against the Hong Kong dollar and the US dollar interbank markets. *Section 3* gives a brief discussion of data and methods, while *section 4* presents the empirical findings. Lastly, our conclusion is summarised in *section 5*.

## 2. One-Way Arbitrage

Given the transaction costs in both the foreign exchange markets and securities markets, transactions among profit-maximisation (or the cost-minimisation) arbitrageurs would determine the maximum limits on divergence of price from parity that are created by the above costs. Deardorff (1979) and Callier (1981) argued that there exists two minimal conditions for which the one-way arbitrage would have equilibrium in the foreign exchange market. Clinton (1988) brought the swap market and the securities market into the model and restructured the conditions. In this paper, we will mostly follow Clinton's work and the notation used will be the same as that defined in Clinton (1988):  $t_s$  is the transaction cost in the spot exchange,  $t_w$  that in forward swaps,  $t$  that in domestic currency assets, and  $t^*$  that in foreign currency assets. Again  $S$  is the spot price of the foreign currency and  $W$  is the swap rate



(forward premium) of a given term on foreign currency. The costs  $t_w$ ,  $t$ ,  $t^*$ , and the swap rate  $W$  are expressed in the same units as the interest rates on domestic ( $i$ ) and foreign ( $i^*$ ) currencies.

The estimates of transactions costs in foreign exchange markets are taken directly from bid-ask spreads<sup>3</sup>, while those in the interbank rates are bid-ask spreads plus commission cost. Following Clinton's assumption, the transactions cost parameter is equal to one-half of the posted bid-ask spread since the spread is given in the two transactions of a 'round trip'.

The swap rate  $W$  is calculated as

$$W = (36,000/n) * (W_a + W_b) / (S_a + S_b),$$

where  $W_a$  and  $W_b$  are the ask and bid swap rates,  $S_a$  and  $S_b$  are the ask and bid spot rates, and  $n$  is the number of days in the contract.

The swap transactions cost is computed as

$$t_w = (36,000/n) * (W_a - W_b) / (S_a + S_b)$$

The parity forward premium,  $W_0$ , that would exactly equate covered interest rates in the absence of transactions costs is approximately equal to the interest differential on short-term assets, so that  $W_0 = i - i^*$ .

According to Deardorff, one-way arbitrage equilibrium is possible only if:

$$|W - W_0| < t + t^* + t_w \quad (1)$$

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3 From Table 2, we find that the brokerage fees are negligible in wholesale exchange markets relative to foreign exchange spreads.

However, it is quite possible for such an equilibrium to occur with no transactions taking place in any of the markets. In such a case, the corresponding exchange rate does not represent a price at which currencies actually traded but, rather, a price at which supply and demand are both zero. Because there exists no real transactions in demanding or supplying of funds in either the spot or forward market, this, in fact, becomes the regular covered interested arbitrage. To rule out such a 'no-trade' equilibrium, a much stronger condition that (1) is needed.

One-way arbitrage equilibrium with transactions in the spot and forward markets as well as securities markets are:

$$|W - W_0| < t + t^* - t_w \quad (2)$$

$$|W - W_0| < t_w - |t - t^*| \quad (3)$$

Taken together, (2) and (3) imply

$$|W - W_0| < \min(t + t^* - t_w, t_w - |t - t^*|). \quad (4)$$

In fact, inequality (4) already implies inequality (1). Thus, one-way arbitrage transactions will help reduce the deviations of the forward premium or discount from the covered interest parity condition.

### 3. Data and Methods

The data used in this article were confined to the period from 9 January 1990 to 19 April 1990. This is due to the lack of data for the other time period. Daily spot and forward swap US\$ rates (vs Hong Kong dollar), as well as interbank rates for the Hong Kong and US dollars (bid and offer rates) with respect to maturity of one, three and six months were recorded

simultaneously in the Hong Kong Financial markets during the time period between 10:45 and 11:15 a.m.<sup>4</sup> of each reference day. Rates quotations of these were obtained from Tokyo Forex & Tullett and Hua Chiao Commercial Bank Limited.

Following the study of the one-way arbitrage conditions, we will test for unit roots among the variables of interest. We then investigate if there exists some long-run equilibrium relationships between the swap rate,  $W$ , and parity forward premium,  $W_0$ . This is done in order to see whether or not they converge to each other under the interest parity in the long run. In a statistical sense, we test to see if  $W$  and  $W_0$  are co-integrated<sup>5</sup>:

$$Y_t = a_1 + a_2 Y_{t-1} + \varepsilon_t \quad (5)$$

and if  $a_2$  is equal to unity (unit root), then  $Y_t$  is non-stationary and is said to be integrated in order  $r$  denoted by  $I(r)$ .<sup>6</sup> In the case of bi-variate, suppose both  $Y_t$  and  $X_t$  are integrated of order 1,  $I(1)$  but the variable  $Z_t = Y_t - K(X_t)$  is stationary, that is,  $I(0)$ , the  $Y_t$  and  $X_t$  are said to be co-integrated and  $K$  is called the co-integrating parameter. The test of co-integration between  $Y$  and  $X$  is done by simply carrying out the OLS regression of  $Y_t$  on  $X_t$  and by testing that the residuals of this regression are stationary.<sup>7</sup> If  $Y$  and  $X$  are not co-integrated, any linear combinations of  $Y$  and  $X$  will not be stationary. Hence, the

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4 During this time period, trading transactions are most active and the spread of rates may actually reflect the real demand and supply situation of finding and foreign exchange at that particular moment.

5 See Engle and Granger (1987) and Hendry (1986).

6 Time series is integrated of order  $r$ ,  $I(r)$  if the  $r$ 'th difference of the time series is stationary. See Granger (1981).

7 See Engle and Granger (1987) and Hendry (1986).

residual,  $e_t$ , will be non-stationary. However, if  $e_t$  has a unit root, then  $E(e_t - e_{t-1}) = 0$ , and accordingly the Durbin-Watson (DW) statistic will be closed to zero. Thus, the test of co-integration between  $Y$  and  $X$  is equivalent to the test to see whether  $DW=0$ . (Engle and Granger, 1987)

Engle and Granger (1987) establish an isomorphism between co-integration and error correction mechanisms. This is relevant to the problem of determination of equilibrium. If  $Y_t$  and  $X_t$  are co-integrated, then there exists an error correction of the form  $Y_t - K(X_t)$ .  $Y_t$  and  $X_t$  will converge to each other and have equilibrium parity,  $Y_t = K(X_t)$ .

Two main approaches are currently used to test for unit roots and co-integration. These are the 'augmented' Dickey and Fuller (ADF) test and the Phillips and Perron (PP) test. Both tests involve estimating the equation

$$Y_t = \gamma + \delta t + \alpha Y_{t-1} + \sum \theta_j \Delta Y_{t-j} + \varepsilon_t \quad (6)$$

and allow lags to whiten the error terms when necessary.

The ADF test was originally developed for autoregressive representations of known order. However, the PP test is a non-parametric test that allows for a wide class of time series models with heterogeneously as well as identically distributed innovations. The PP test seems to have significant advantages when there are moving average components in the time series. In this paper, we employ both the ADF test and PP test for comparison.

#### 4. Empirical Findings

Table 1 shows the number and percentage of positive returns from the covered interest arbitrage. In other words, it is the one-way arbitrage with no real transactions because inequality (1) has been violated. The number of profitable one-way

arbitrage observations increases drastically from 6 for the one-month period to 34 and 43 for the three-month and six-month period respectively. Thus we can conclude that there exists some arbitrage profit opportunities for the longer maturity period. Figure 1 shows the frequency distributions of the positive arbitrage returns. It is evident that the distribution is skewed to the right for longer maturity period. However, 95 per cent of positive returns are less than 0.15 per cent.

The number and percentage of positive returns from one-way arbitrage with real transactions are shown in Table 2. For the one-month case, the number of profitable one-way arbitrage observations is 57 and those for three-month and six-month are both 60. This implies that profit opportunities do exist for one-way arbitrage, especially for longer maturity periods. To investigate the magnitude of the positive arbitrage returns, we plot the frequency distributions. In Figure 2, the distribution is skewed to the right for both the three-month and the six-month period. However, 95 per cent of the positive returns from arbitrage are less than 0.25 per cent.

Table 3 shows the summary statistics of  $|W-W_0|$  and  $|W-W_0| - (t + t^* + t_w)$  under the case of one-way arbitrage with no real transaction (Covered Interest Arbitrage). All the mean values of  $|W-W_0| - (t + t^* + t_w)$  have insignificant t values (less than critical values, 1.65 under the one-tail test at 5 per cent significance level), showing no profitable arbitrage opportunity can be expected at a randomly chosen moment.

Table 4 shows the summary statistics of  $|W-W_0|$  and  $|W-W_0| - \min(t + t^* - t_w, t_w - |t - t^*|)$  under the case of one-way arbitrage with real transactions. The mean values of  $|W - W_0| - \min(t + t^* - t_w, t_w - |t - t^*|)$  for all maturity periods except the one-month period are significantly greater than zero at the 5 per cent significance level, thus showing profitable arbitrage opportunity can be expected at a randomly chosen

moment. This might be due to the fact that the Hong Kong dollar is not as secure as the US dollar in a liquidity and political sense, despite the Joint Declaration between British and China to preserve Hong Kong's "prosperity and stability". Hence, a greater risk premium might be needed to compensate the Hong Kong dollar interbank rates relative to the counterparts of the US dollar. Thus parts of positive arbitrage profits may reflect the risk elements. In general, these profits are small (no more than a few basis points), even though they are not rare.

Table 5 presents the results of unit root tests on the parity forward premium,  $W_0$ , and the swap rate,  $W$ , using two different methods—the 'augmented' Dickey-Fuller (ADF) test and the Phillips-Perron (PP) Test. In both cases, we cannot reject the unit root hypothesis of the two series in question for all maturity periods. In other words, all of them are non-stationary.

Table 6 and 7 show the unit roots results for the linear combination of  $W_0$  and  $W$  for different maturities,  $W_0 + K(W)$ , which is derived through running the OLS regression. Employing the ADF method, we cannot reject the null hypothesis, indicating that there exists no co-integration between the swap rate,  $W$ , and the parity forward premium,  $W_0$ . However, when the more powerful PP approach is used, the test statistics are all statistically significantly greater than the critical value at 5 per cent level. Thus, the null hypothesis is rejected. We can conclude that  $W_0$  and  $W$  are co-integrated and converge to each other. It is of interest to find that  $K$ , the co-integrating parameter, approaches one in co-integrating regressions, showing interest rate parity holds in the long run. This implies that, even though profit opportunities do exist in the short run, in general they are both small and short-lived.

## 6. Conclusions

The one-way arbitrage would prevent high-cost methods of exchanging currencies in doing arbitrage. When transaction costs are taken into consideration, we find that there exists small and short-lived profits for one-way arbitrage in the Hong Kong swap market over the study period. There, however, exists some long-run equilibrium relationships (the cointegration relation) between the swap rate and parity forward premium. Our findings do give support to some of the findings by Deardorff and Clinton that the validity of the one-way arbitrage helps in reducing deviations from the covered interest parity. The reported results, however, should be interpreted with caution. First, with sixty observations, the sample size may not be long enough to reveal the real situation among arbitrageurs in the Hong Kong foreign exchange market. Second, actual transactions may not be conducted at the quoted prices. Third, parts of positive arbitrage profits may reflect the risk element in the Hong Kong dollar.

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## TABLES

**Table 1 Profitable One-Way Arbitrage Observations with No Real Transactions**

$$|W - W_0| > t + t^* + t_w$$

<i>Maturity Period</i>	<i>Observations</i>	<i>Percentage of All Observations</i>
One-Month	6	10.00
Three-Month	34	56.67
Six-Month	43	71.66

**Table 2 Profitable One-Way Arbitrage Observations with Real Transactions**

$$|W - W_0| > \min(t + t^* - t_w, t_w - |t - t^*|)$$

<i>Maturity Period</i>	<i>Observation</i>	<i>Percentage of All Observations</i>
One-Month	57	95
Three-Month	60	100
Six-Month	60	100

**Table 3 Mean Statistics For One-Way Arbitrage with No Real Transaction**

<i>Maturity Period</i>	$ W - W_0 $	$ W - W_0  - t - t^* - t_w$
One-Month	0.0981 (0.0619)	-0.2205 (0.2531)
Three-Month	0.1417 (0.0610)	0.0231 (0.0641)
Six-Month	0.1506 (0.0685)	0.0479 (0.0702)

Note: Standard errors are in parentheses.

**Table 4 Mean Statistics For One-Way Arbitrage with Real Transactions**

<i>Maturity Period</i>	$ W - W_0 $	$ W - W_0  - \min(t + t^* - t_w, t_w -  t - t^* )$
One-Month	0.0981 (0.0619)	0.0827@ (0.0588)
Three-Month	0.1417 (0.0610)	0.1373@ (0.0604)
Six-Month	0.1506 (0.0685)	0.1542@ (0.0692)

Note: Standard errors are in parentheses.  
@ significant at 1% level.

**Table 5 Unit Root Tests**

Variable	Augmented Dickey-Fuller Method			Phillips-Perron Method		
	ADF Test Statistics			PP Test Statistics		
	Lag	Without Trend	With Trend	Lag	Without Trend	With Trend
One-Month $W_0$	7	0.366	-1.167	7	-1.877	-2.885
Three-Month $W_0$	7	0.778	-1.197	7	-0.755	-2.568
Six-Month $W_0$	6	0.819	-1.252	6	-1.093	-3.013
One-Month $W$	7	0.068	-1.412	7	-1.428	-2.454
Three-Month $W$	0	-0.422	-2.04	0	-0.422	-2.040
Six-Month $W$	0	-0.296	-2.056	0	-0.296	-2.056
Critical Value at 5% level		-2.91	-3.49		-2.91	-3.49

Note: The regression for both approaches are as follows

$$\Delta Y_t = \alpha + \phi T + b Y_{t-1} + \sum_{k=1}^m C_k \Delta Y_{t-k} + u_t$$

where  $u_t$  is a white noise and  $T$  denotes the time trend.  $m$  is the optimal augmented lags where  $c_k$  is significantly different from zero.

The null hypothesis of a unit root is  $H_0: b = 0$  while alternative hypothesis is  $H_1: b < 0$ .

**Table 6 Unit Root Tests for Co-integrating Regression Residuals**

<i>Variable</i>	<i>Augmented Dickey-Fuller Method</i>			<i>Phillips-Perron Method</i>		
	<i>ADF Test Statistics</i>			<i>PP Test Statistics</i>		
	<i>Lag</i>	<i>Without Trend</i>	<i>With Trend</i>	<i>Lag</i>	<i>Without Trend</i>	<i>With Trend</i>
One-Month Case	3	-3.020*	-2.961	3	-5.383*	-5.374*
Three-Month Case	4	-1.731	-2.516	4	-4.054*	-4.470*
Six-Month Case	7	-1.660	-1.714	7	-6.234*	-6.205*
Critical Value at 5% level		-2.87	-3.45		-2.88	-3.44

Note: \* denotes significant at 5% level.

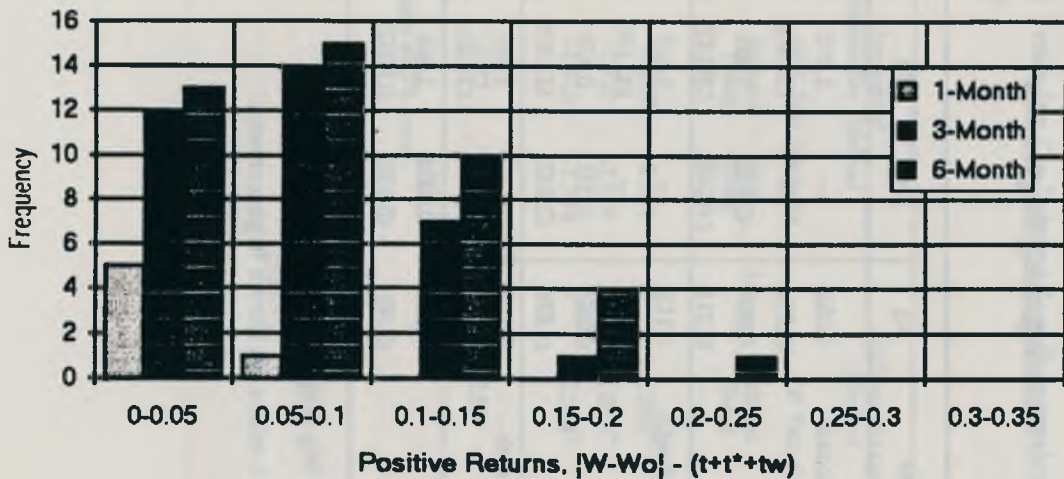
**Table 7** Co-integrating Regression

<i>Case</i>	$\beta_0$	$\beta_1$	$\beta_2$	$R^2$	<i>D W</i>
One-Month	0.052	—	1.072	0.9353	1.351
	(2.73)	—	(28.95)		
	0.057	-0.0003	1.083	0.9354	1.346
	(2.21)	(-0.295)	(20.142)		
Three-Month	0.115	—	1.067	0.9683	0.898
	(9.73)	—	(42.09)		
	0.082	0.002	0.978	0.9715	1.051
	(4.83)	(2.532)	(22.89)		
Six-Month	0.114	—	1.089	0.9129	1.588
	(6.66)	—	(24.65)		
	0.106	0.0004	1.066	0.913	1.590
	(3.90)	(0.338)	(13.052)		

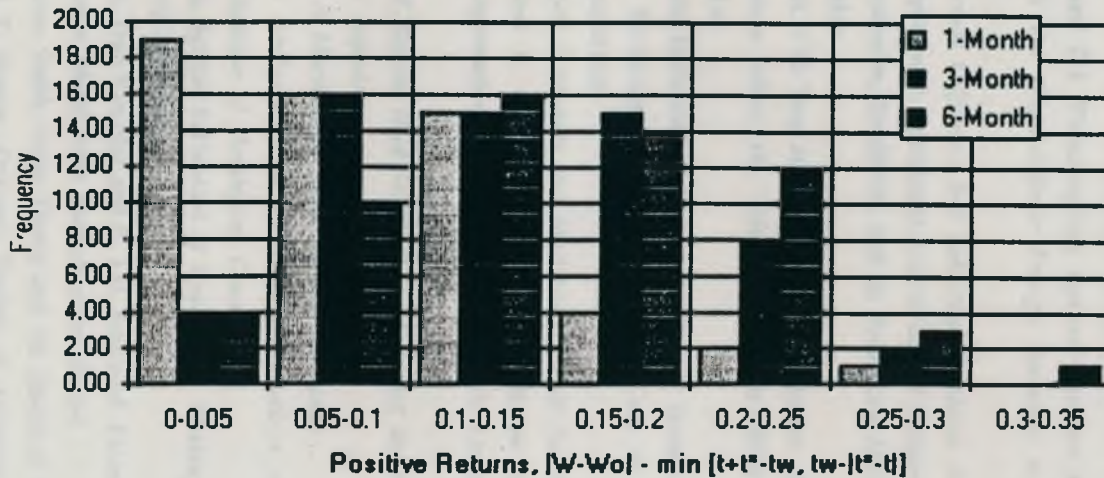
Note:  $W_0 = \beta_0 + \beta_1 T + \beta_2 W + u_t$

t values are shown in parentheses.

Figure 1: Distribution of Positive Returns for the Covered Interest Arbitrage



**Figure 2: Distribution of Positive Returns for One-Way Arbitrage**





APPENDIX

The first part of the report, which is the most important, is devoted to a description of the various types of work done by the various departments of the Government. It is a very interesting and useful book, and one which every citizen should read. It is a very good example of the work of the various departments of the Government, and it is a very good example of the work of the various departments of the Government.

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