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12 Interest Parity and Dynamic Capital Mobility: The Experience of Singapore

Tse Yiu Kuen and Tan Kim Song

12.1 Introduction

The questions of international capital mobility and financial market integration have long attracted the attention of both researchers and policymakers, and understandably so. A high degree of capital mobility not only affects the independence of domestic monetary and fiscal policies, it also adds to the complexity of managing saving and investment problems in a country.

The issue is of particular interest to Asia-Pacific countries, many of whom have embarked on large-scale financial market liberalizations since the early 1980s. In Japan, Taiwan, South Korea, as well as ASEAN countries such as Malaysia and Thailand, various capital and exchange controls were dismantled during the past decade. Whether these liberalization measures have resulted in a greater degree of capital mobility, and how they might have affected the implementation of monetary and exchange rate policies in these countries, have been the subject of various studies (see Ito 1988; Glick and Hutchison 1990; Reisen and Yeches 1993; among others).

This paper seeks to shed some light on the extent of international capital mobility in Singapore. On first thought, such a question might appear to be rhetorical. Most of the capital and exchange controls in Singapore were effectively abolished by the late 1970s. There has been virtually no barrier to the flow of foreign currency funds held either by domestic or foreign residents. Neither is there any substantive restriction on the movement of funds between the domestic banking system and the offshore Asian dollar market. Singa-

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poreans (and foreigners), if they so desire, can hold any well-diversified portfolio of assets denominated in Singapore and foreign currencies. Indeed, in the few empirical studies that have been conducted on the subject so far, the evidence generally points to a high degree of international capital mobility in Singapore (see Edwards and Khan 1985; Frankel 1991; Faruqee 1992; among others).

It is also this belief in high capital mobility that underlies the focus of the Monetary Authority of Singapore (MAS) on the management of exchange rate, rather than that of interest rate or some monetary aggregate, when pursuing its objective of domestic price stability. As Teh and Shanmugaratnam (1992) pointed out, the lack of control on capital flows had resulted in quick, cross-country movements of capital whenever there were small changes in the differential between domestic and foreign (especially U.S.) interest rates. Such capital mobility, they added, "makes it difficult to target either money supply or interest rates in Singapore" (see Teh and Shanmugaratnam 1992, 291–92).

The purpose of this paper is not to question the openness of Singapore's capital market and its integration with the rest of the financial world. Rather, we hope to achieve a better understanding of how the linkage has changed over time. A study of dynamic capital mobility, we believe, can serve several useful purposes. First, even in the absence of capital and exchange controls, there are presumably periods when capital flows more smoothly than others. An analysis of these changes will add to our understanding of the underlying forces that drive the movement of capital across borders. Second, from a policy perspective, it pays to know whether the Singapore capital market has indeed, over time, become more closely linked with those of other countries. An increase in capital mobility not only reflects on the impact of the various liberalization measures taken to promote Singapore as a financial center, it also has obvious implications for the management of exchange rate. The tremendous problems faced over the last two years by some Southeast Asian central banks, such as Bank Negara in Malaysia, in sterilizing their capital inflows point to the policy dilemma in a financially open economy.

The basic benchmark used to measure international capital mobility in this paper will be the deviation from interest rate parity. Deviations from both covered and uncovered interest parities will be discussed, although covered interest parity, as we shall see later, is considered by many economists to be a more generic test of capital mobility.

The paper is organized as follows: Section 12.2 provides a brief discussion of some of the works on capital mobility, with particular focus on studies about Singapore. Section 12.3 explains the methodology followed in this paper. Section 12.4 presents and interprets the results of our findings. Section 12.5 concludes.

12.2 Interest Parity and International Capital Mobility

Feldstein and Horioka (1980) created a stir among economists more than a decade ago when they argued that, based on the close correlation between domestic saving and investment rates that they observed in many countries, international capital might not be as mobile as economists typically assumed.

Since then, research on this issue has developed in two directions: one that follows the Feldstein-Horioka approach, focusing on the link between domestic savings and investment, and another that looks at the parity between domestic and foreign interest rates.[1] But as some economists have pointed out, the Feldstein-Horioka approach is really more suited to the study of how efficiently savings and capital are allocated globally, rather than how closely integrated capital markets are. To equate a zero correlation between domestic saving and investment with perfect capital mobility, a number of preconditions must first be satisfied. Not only must there be parity of real interest rates, but investment behavior must also respond in a particular way to interest rate changes. In practice, neither of these two conditions can be easily met (see Frankel 1991; Obstfeld 1994).

Even for tests of interest rate parity, opinions differ on the correct yardstick to be used. Of the two most commonly used parity concepts, covered interest parity (CIP) is often deemed to be a better indicator of financial openness than uncovered interest parity (UIP). Deviations from CIP suggest that there exist some risk-free arbitrage opportunities that might have arisen from capital and exchange controls, differential tax treatments for capital returns in different countries, the possibility of future controls and regulations, and other country-specific transaction costs such as differences in languages and business practices. These are generally considered barriers to capital movement in a generic sense.

Deviations from UIP, on the other hand, can occur even if CIP holds—that is, even if the forward market is efficient and there is no hindrance to the arbitrage process—as long as a certain exchange risk premium exists. In fact, it is well known that a test of UIP amounts to a joint test of CIP and zero risk premium. But risk premium, as Frankel (1991) pointed out, has more to do with the currency in which the interest rate is denominated than the institutional restrictions on capital flow imposed by individual governments. In other words, while an adherence to UIP would suggest a capital market well integrated with the international economy, the failure of UIP need not necessarily imply a lack of capital mobility.[2]

1. Obstfeld provides a simple definition of international capital mobility. Capital is freely mobile, he said, if "residents face no official obstacles to the negotiation and execution of financial trades anywhere and with anyone in the world, and face transaction costs that are no greater for parties residing in different countries than for parties residing in the same country" (1994, 2).

2. Ito (1988) argued that it was possible for UIP to hold without CIP, as was the case for the Japanese market in the late 1970s.

The different implications of CIP and UIP on international capital mobility were brought out clearly in Frankel's own study of 25 developed and developing countries. Frankel found that, when measured by the size and variability of the *covered* interest differentials, most industrial countries (including Canada, Germany, the Netherlands, Switzerland, the United Kingdom, Austria, Belgium, Sweden, and Japan) and certain Asia-Pacific economies such as Hong Kong and Singapore displayed few barriers to capital movement during the 1980s (1982–88).[3] However, the picture looked very different when *uncovered* interest parity was used as the benchmark for capital mobility instead. Few of these supposedly "open" economies attained any form of UIP. A significant amount of currency risk (including exchange risk premium and expected real depreciation) was observed in almost all the economies.

While the relevance of UIP as a measure of capital mobility may be limited in static analysis, the situation is somewhat different in a dynamic setting. Here changes in the extent of deviation from UIP do provide some information about changing capital mobility. As capital markets become more integrated, one possible outcome is that assets denominated in different currencies become more substitutable. This will reduce the risk premium and narrow the uncovered interest differentials. In other words, a sustained narrowing of uncovered interest differentials over time could itself indicate an increased level of capital mobility.

Faruqee (1992) applied such an argument in his study of dynamic capital mobility in four Asian economies, including Singapore.[4] He first examined the differentials between the LIBOR rate on yen deposits and some domestic interest rates in Singapore, Malaysia, Thailand, and South Korea from 1978 to 1990. A generalized autoregressive conditional heteroskedasticity (GARCH) structure was then fitted on these differentials. Both the size of the differential bands and the conditional variances of the differentials in these countries were used to illustrate the dynamic changes of capital mobility in these countries. A smaller band and a reduced variability of the differentials are said to reflect more financial openness.

For Singapore, a declining variability of uncovered interest differentials throughout the sample period was observed, pointing to a consistent trend toward greater capital mobility. Such a trend contrasted sharply with the "epi-

3. On the other hand, substantial barriers to capital flow appeared to remain in countries like France, Italy, Ireland, and EC members that adopted a timetable for capital account liberalization in accordance with the single European program set out in the Single European Act of 1987 (see Obstfeld 1994, 11).

4. Faruqee's study is the only one that provides a detailed analysis of dynamic interest parity in Singapore. Previous studies, including that of Frankel (1991), examined the issue from a static perspective. Edwards and Khan (1985), e.g., reached the same conclusion of high capital mobility by comparing the relative importance of interest parity and domestic monetary conditions in determining the domestic interest rates in Singapore. They found that the Singapore interest rates during the period from 1976 to 1983 were largely influenced by their parity with the prevailing Eurodollar rates.

sodic" developments in the other three countries, which oscillated between periods of high and low financial openness. Simulation of impulse responses to domestic monetary shocks were also conducted for all four countries. The results showed that the Singapore interest rate returned to its parity condition within a much shorter time than those in other countries. This again was evidence of greater capital mobility in Singapore.

In this paper, we shall provide another perspective on dynamic capital mobility in Singapore. The time-series properties of the interest differentials from 1977 to 1993 will be examined. Unlike Faruqee, however, both covered and uncovered interest differentials will be studied, in order to give better insight into the various forms of barriers to capital movement. A GARCH model is then fitted to the residuals. The parameters of the model are estimated simultaneously using the maximum likelihood estimation (MLE) method, instead of the (less efficient) two-stage method used by Faruqee. We then offer some explanation for the particular trends taken by deviations from CIP and UIP and try to relate them to the prevailing monetary and financial conditions. We also discuss briefly the efficient market hypothesis in the context of Singapore.

12.3 Methodology

To examine the interest rate and exchange rate relationships, the following notation is used:

F_1 = one-month forward exchange rate (S$ per U.S.$)
F_3 = three-month forward exchange rate (S$ per U.S.$)
S = spot exchange rate (S$ per U.S.$)
f_1 = logarithm of one-month forward exchange rate (S$ per U.S.$)
f_3 = logarithm of three-month forward exchange rate (S$ per U.S.$)
s = logarithm of spot exchange rate (S$ per U.S.$)
R_1^S = one-month yield of Singapore dollar
R_3^S = three-month yield of Singapore dollar
R_1^U = one-month yield of U.S. dollar
R_3^U = three-month yield of U.S. dollar

Consider investments over a one-month horizon. Lack of risk-free arbitrage opportunities requires that the principal plus interest for a unit U.S. dollar investment is equal to the principal plus interest on an equivalent amount of Singapore dollar investment, when the latter is converted to U.S. currency at the forward rate of exchange. Using continuous compounding, the following relationship holds at time *t:*

(1) $$\exp R_{1,t}^U = \frac{S_t \exp R_{1,t}^S}{F_{1,t}},$$

which implies

(2) $$R^{U}_{1,t} + f_{1,t} - s_t - R^{S}_{1,t} = 0$$

Equation (2) is known as CIP. A similar argument for the three-month investment horizon implies

(3) $$R^{U}_{3,t} + f_{3,t} - s_t - R^{S}_{3,t} = 0 \, .$$

We denote the left-hand sides of equations (2) and (3) by $C_{1,t}/1200$ and $C_{3,t}/400$, respectively. Thus, C_1 and C_3 represent deviations from CIP in annualized percentage terms. Note that if $C_i > 0$ for $i = 1, 3$, a risk-free opportunity is available by selling Singapore dollars for U.S. dollars, with a synchronized long forward contract to buy Singapore dollars.

As pointed out by Ito (1988), CIP is an arbitrage condition without any theoretical hypothesis about the financial market. In an economy with free capital mobility, the validity of CIP is a matter of fact. On the other hand, UIP is a hypothesis that can be tested irrespective of capital mobility. It states that the interest rate spread between two currencies is equal to the difference between the expected future (logarithmic) exchange rate and the current (logarithmic) exchange rate.[5] Using the above notation, UIP is defined as the hypothesis that

(4) $$\mathrm{E}_t\,(s_{t+i}) = s_t + R^{S}_{i,t} - R^{U}_{i,t},$$

where $i = 1, 3$ denotes the horizon of the yield and E_t denotes the expectation conditional on information at time t.

A direct test of UIP is difficult because the hypothesis involves the unobservable expectation of the future spot exchange rate. Analysis may be simplified, however, with additional assumptions. For example, under the hypothesis that the spot exchange rate follows a random walk (RW) that is, $\mathrm{E}_t(s_{t+i}) = s_t$, equation (4) can be written as $R^{S}_{i,t} - R^{U}_{i,t} = 0$. Thus, denoting $U_{1,t} = (R^{S}_{1,t} - R^{U}_{1,t}) \times 1200$ and $U_{3,t} = (R^{S}_{3,t} - R^{U}_{3,t}) \times 400$ as deviations from UIP(RW) in annualized percentage terms, a test of UIP may be constructed by examining whether U_1 and U_3 are significantly different from zero.

An alternative approach to modeling the expected future spot rate is to assume rational expectations (RE). If we assume expectation is formulated rationally with perfect foresight, that is, $\mathrm{E}_t(s_{t+i}) = s_{t+i}$, deviations from UIP(RE) may be calculated as $U^{*}_{1,t} = (R^{S}_{1,t} - R^{U}_{1,t} + s_t - s_{t+1}) \times 1200$ and $U^{*}_{3,t} = (R^{S}_{3,t} - R^{U}_{3,t} + s_t - s_{t+3}) \times 400$. Both UIP(RW) and UIP(RE) will be examined in this paper.

Using equations (2) and (3), equation (4) can be written as

(5) $$\mathrm{E}_t\,(s_{t+i}) = f_{i,t} \, .$$

Thus, UIP and CIP together imply that the forward exchange rate is an unbiased predictor of the future spot rate. This is referred to as the efficient market hypothesis without risk premium.

5. From here onward we shall simply refer to the logarithmic data as exchange rate.

Recently, Faruqee (1992) examined the changing degree of capital mobility by capturing the time-varying structure of UIP deviations. He argued that a sustained narrowing in deviations of interest rate differentials from an appropriate measure of interest rate parity indicates an increased level of capital mobility. The banding structure of deviations is examined using a GARCH framework. If we denote y generically as deviations from either UIP or CIP, a time-series model that captures autoregressive (AR) structure in both mean and variance can be written as follows:

$$y_t = \alpha_0 + \alpha_1 y_{t-1} + \ldots + \alpha_p y_{t-p} + \varepsilon_t,$$

(6) $$\varepsilon_t \sim N(0, h_t^2),$$

$$h_t^2 = \beta_0^2 + \beta_1 h_{t-1}^2 + \beta_2 \varepsilon_{t-1}^2.$$

Thus, y_t follows an AR (p) process with a conditional variance equation described by a GARCH (1, 1) process. Parameters of the model can be estimated simultaneously using the MLE method. The estimated conditional standard deviation $\hat{h}_t$ gives an indication of the changing conditions of capital mobility.

12.4 Empirical Results

The data used in this paper were extracted from various issues of the *Business Times*. For interest rate data, we use interbank offer rates of one-month and three-month duration on both the Singapore dollar and the U.S. dollar. The foreign (U.S.) interest rates, referred to as SIBOR, are quotes from the Asian Currency Units.[6] End-of-month data were compiled from January 1977 through September 1993, totaling 201 observations.

Table 12.1 summarizes some statistics of the unconditional distributions of the exchange rate and interest rate data. Two sets of autocorrelation statistics are presented: $\hat{\rho}_{1,i}$ is the i^{th} sample autocorrelation coefficient of the series, and $\hat{\rho}_{2,i}$ is the i^{th} sample autocorrelation coefficient of the square of the deviation from mean of the series; Q_j (24), j = 1,2, are the Box-Pierce portmanteau statistics based on autocorrelation coefficients of order up to 24. On the null hypothesis of white noise, Q is approximately distributed as a χ^2 with 24 degrees of freedom. To the extent that these statistics may be affected by nonnormality we also calculate the nonparametric runs tests. Thus, R_1 is the runs test statistic for the series, and R_2 is the runs test statistic for the square of the series. On the null hypothesis of white noise, R_1 and R_2 are approximately distributed as standard normal.

It can be seen that all seven series exhibit high autocorrelation in mean as well as in variance. The autocorrelation functions of the raw data decline very

6. SIBOR is used in preference to LIBOR as the data can be conveniently extracted from a single source. Also, synchronous trading in domestic and foreign interbank markets facilitates arbitrage activities.

Table 12.1 **Summary Statistics of Exchange Rate and Interest Rate Data**

Statistic	f_1	f_3	s	R_1^S	R_3^S	R_1^U	R_3^U
Mean	0.709	0.706	0.711	0.005	0.015	0.007	0.023
S.D.	0.113	0.111	0.112	0.002	0.007	0.003	0.009
Minimum	0.462	0.462	0.462	0.001	0.004	0.002	0.006
Maximum	0.901	0.904	0.902	0.011	0.034	0.017	0.049
Skewness	−0.779	−0.746	−0.785	0.899	0.851	0.866	0.746
Kurtosis	2.774	2.768	2.772	3.625	3.510	3.737	3.283
$\hat{\rho}_{1,1}$	0.977	0.977	0.977	0.956	0.967	0.950	0.957
$\hat{\rho}_{1,2}$	0.956	0.956	0.956	0.907	0.923	0.901	0.909
$\hat{\rho}_{1,3}$	0.934	0.933	0.934	0.855	0.871	0.855	0.863
$\hat{\rho}_{1,4}$	0.913	0.911	0.914	0.817	0.830	0.815	0.828
Q_1 (24)	3072	3052	3082	2054	2193	2076	2156
R_1	−13.7	−13.4	−13.7	−12.2	−12.8	−12.5	−12.4
$\hat{\rho}_{2,1}$	0.964	0.964	0.964	0.888	0.902	0.820	0.850
$\hat{\rho}_{2,2}$	0.931	0.930	0.931	0.753	0.765	0.657	0.713
$\hat{\rho}_{2,3}$	0.898	0.896	0.899	0.600	0.602	0.550	0.619
$\hat{\rho}_{2,4}$	0.865	0.861	0.867	0.509	0.487	0.490	0.546
Q_2 (24)	2052	2009	2069	844	873	786	925
R_2	−13.9	−13.9	−13.9	−11.7	−12.0	−12.5	−12.8

slowly with the lag order, suggesting strongly that the series may be nonstationary and integrated. Table 12.2 summarizes similar statistics for the first difference of the data. For the exchange rate data, autocorrelations in mean and variance seem to have been eliminated.[7] Thus, there is evidence to support the hypothesis that both forward and spot exchange rates may be treated as random walks. For the interest rate data, all Q statistics are significant, indicating that there is autocorrelation in mean as well as in variance. Thus, it may be appropriate to model the differenced interest rate data as an autocorrelated time series with time-varying conditional variance. Table 12.2 also presents the standardized statistics of skewness and kurtosis.[8] It is found that both exchange rate and interest rate data exhibit higher kurtosis than that of a normal distribution. This result, however, may be due to autocorrelation in variance. To ascertain the nonstationarity of the raw data, we calculate the Dickey-Fuller (DF) and augmented Dickey-Fuller (ADF) tests. Results are summarized in table 12.3. It can be observed that the null hypothesis of nonstationarity cannot be rejected for all cases.

Deviations from CIP, C_1 and C_3, are calculated, and their summary statistics

7. For Δf_3, Q_1 is marginally significant at the 5 percent level. Otherwise, all other Q statistics are insignificant at the 5 percent level.

8. These statistics are approximately standard normal if the data are normally distributed. Their validity, however, depends on the assumption that the data come from a random sample. Thus, these statistics are not presented in table 12.1, as the exchange rate and interest rate data are highly autocorrelated.

Table 12.2 **Summary Statistics of Differenced Exchange Rate and Interest Rate**

Statistic	Δf_1	Δf_3	Δs	ΔR_1^S	ΔR_3^S	ΔR_1^U	ΔR_3^U
Mean	−0.002	−0.002	−0.002	0.000	0.000	0.000	0.000
S.D.	0.014	0.014	0.014	0.001	0.002	0.001	0.002
Minimum	−0.063	−0.067	−0.062	−0.003	−0.008	−0.005	−0.014
Maximum	0.045	0.045	0.045	0.003	0.007	0.003	0.008
Skewness	−0.305	−0.358	−0.407	0.314	0.356	−0.926	−0.901
St. skewness	−1.763	−2.066	−2.347	1.812	2.056	−5.348	−5.199
Kurtosis	5.999	6.423	6.454	6.683	8.762	12.119	10.557
St. kurtosis	8.659	9.882	9.972	10.633	16.633	26.324	21.816
$\hat{\rho}_{1,1}$	−0.036	−0.061	−0.036	0.045	0.165	0.068	0.157
$\hat{\rho}_{1,2}$	0.028	0.082	0.020	0.039	0.110	−0.053	−0.046
$\hat{\rho}_{1,3}$	−0.030	−0.021	−0.051	−0.180	−0.177	−0.064	−0.134
$\hat{\rho}_{1,4}$	−0.108	−0.134	−0.068	−0.106	0.220	−0.217	−0.224
Q_1 (24)	32.60	36.51	28.38	77.95	110.60	80.15	72.69
R_1	−2.13	−1.84	−1.84	0.12	−1.56	0.50	−0.52
$\hat{\rho}_{2,1}$	0.289	0.282	0.282	0.281	0.215	0.473	0.486
$\hat{\rho}_{2,2}$	−0.036	−0.031	−0.010	0.100	0.084	0.167	0.221
$\hat{\rho}_{2,3}$	−0.057	−0.055	−0.040	0.105	−0.023	0.066	0.108
$\hat{\rho}_{2,4}$	−0.048	−0.035	−0.054	0.191	0.217	0.070	0.160
Q_2 (24)	34.06	31.83	32.47	108.27	127.42	139.14	158.38
R_2	−0.57	−0.55	−0.97	−2.44	−1.78	−5.91	−5.20

Notes: St. skewness = standardized skewness, and St. kurtosis = standardized kurtosis. Skewness is standardized with respect to mean zero and standard deviation $\sqrt{6/n}$, while kurtosis is standardized with respect to mean 3 and standard deviation $\sqrt{24/n}$.

Table 12.3 **Unit Root Tests**

Variable	DF	D-W	ADF	χ_1^2
f_1	−0.3052	2.065	−0.2895	0.0376
f_3	−0.3764	2.113	−0.3139	1.1134
s	−0.2945	2.065	−0.2672	0.0195
R_1^S	−1.9857	1.869	−2.0889	0.5471
R_3^S	−1.6541	1.646	−2.0292	2.3948
R_1^U	−2.1224	1.798	−2.0119	0.1053
R_3^U	−1.9800	1.618	−1.9726	1.0271

Notes: DF = Dickey-Fuller statistic, D-W = Durbin-Watson statistic of the associated regression of the DF test, ADF = augmented Dickey-Fuller statistic, χ_1^2 = Lagrange multiplier test for residual correlation of the ADF regression. The (lower-tail) critical values of the DF and ADF tests at 5 and 1 percent levels are, respectively, approximately −2.88 and −3.46.

are presented in table 12.4. We can see that C_1 has larger volatility than C_3. The Q-statistics show that C_1 is a white noise, while C_3 is an autocorrelated series. This agrees with the well-known result that if the sampling interval is shorter than the length of the forward contract, serial correlation is induced. The covered interest differential for the whole period was 1.045 percent for the one-month interest rate, while that for the three-month interest rate was

Table 12.4 **Summary Statistics of CIP and UIP Deviations**

Statistic	C_1	C_3	U_1	U_3	ΔU_1	ΔU_3
Mean	1.045	0.944	−2.876	−2.902	−0.011	−0.012
S.D.	2.569	1.120	1.751	1.679	1.170	0.998
Minimum	−6.135	−4.374	−9.375	−8.500	−4.563	−3.875
Maximum	16.988	6.175	1.729	1.794	5.750	4.688
$\hat{\rho}_{1,1}$	0.083	0.249	0.759	0.804	−0.118	−0.065
$\hat{\rho}_{1,2}$	−0.034	0.136	0.585	0.652	−0.211	−0.161
$\hat{\rho}_{1,3}$	−0.017	0.135	0.507	0.555	−0.134	−0.266
$\hat{\rho}_{1,4}$	−0.054	0.074	0.490	0.553	0.041	0.060
Q_1 (24)	31.51	116.66	563.18	713.83	60.24	79.40
R_1	−2.00	−4.71	−8.83	−9.68	1.95	0.58
$\hat{\rho}_{2,1}$	−0.039	−0.023	0.422	0.509	0.434	0.391
$\hat{\rho}_{2,2}$	−0.034	−0.029	0.287	0.317	0.145	0.182
$\hat{\rho}_{2,3}$	0.195	0.111	0.127	0.200	0.106	0.137
$\hat{\rho}_{2,4}$	0.046	0.020	0.198	0.226	0.073	0.175
Q_2 (24)	17.78	14.59	170.60	175.81	160.05	169.51
R_2	0.65	−0.77	−7.89	−9.19	−2.22	−4.62

Note: Deviations from CIP and UIP are measured in annualized percentages.

smaller, at 0.944 percent. Taking account of the usual bid-offer spread and thus the transaction costs in the market, these figures represent mild deviations from CIP.[9]

Figure 12.1 presents C_1 and C_3 graphically, from which the higher fluctuations in C_1 are evident. Note that deviations from CIP were mostly positive in the sample period. This indicates that if there was any transaction cost limiting the flow of capital, it was in the form of outward "restrictions," that is, restrictions on Singapore residents' purchase of foreign assets. The restriction has, however, become less and less important over the years. By late 1991, they had nearly all disappeared, as can be seen by the near-zero deviations.

The higher covered interest differential from late 1980 to the end of 1981 might have to do with the additional adjustment cost that arose from the change in the monetary and exchange rate regime. Until then, the MAS had focused on the management of domestic interest rates and money supply to ensure price stability. In 1981, however, it decided to switch its focus to exchange rate man-

9. These deviations, however, may be large compared to studies on other countries (see, e.g., the post-1981 results for the Japanese market in Ito [1988]). It should be pointed out that to capture the effects of transaction costs adequately, it may be more appropriate to consider *one-way arbitrage*. Thus, using the subscripts B to denote bid price and O to denote offer price, arbitrage opportunity exists if

$$R^{U}_{B,t} + f_{B,t} - s_{O,t} - R^{S}_{O,t} > 0 \quad \text{or} \quad R^{U}_{O,t} + f_{O,t} - s_{B,t} - R^{S}_{B,t} < 0.$$

This approach was used by Ito (1986) in his study on the yen-dollar relationship. Although it explicitly takes transaction costs into account, it requires bid-offer data that are exactly synchronized. Research following this approach will be left to future studies.

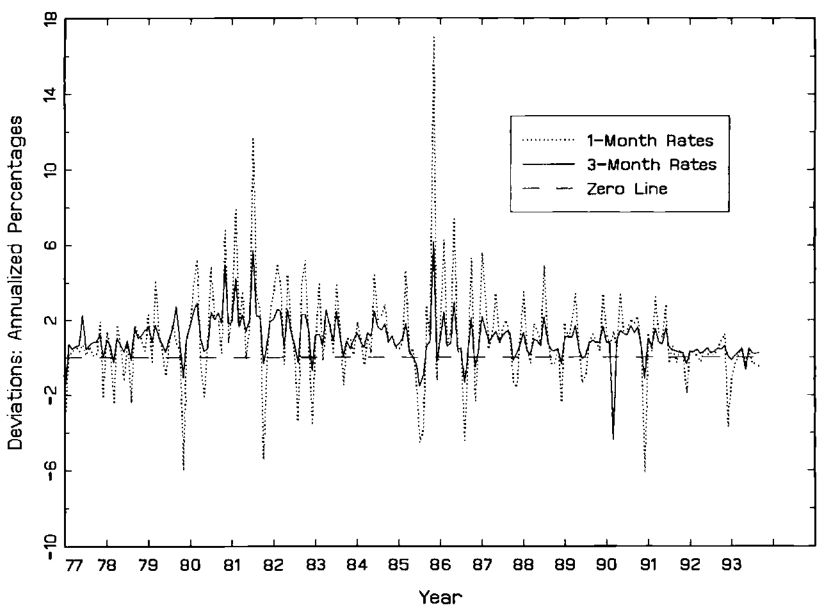

Fig. 12.1 Deviations from CIP

agement, that is, to rely on a strong Singapore dollar to keep the domestic inflation rate low. This change came about as the MAS increasingly recognized the small and open nature of the Singapore economy, and its need to maintain a liberal financial environment, so as to promote the country as a regional financial center. Much of the exchange rate management was carried out through swap operations between the U.S. dollar and Singapore dollar. In fact, there was a substantial increase in the volume of swap transactions in 1981. The need to keep the Singapore currency strong, and hence the emphasis on more capital inflow than outflow, could be one reason why the domestic interest rate seemed to enjoy a greater advantage. This indicates that some arbitrage opportunity was present during this period of regime change.

Table 12.4 also presents summary statistics of the interest rate differentials, U_1 and U_3, as well as their differences, ΔU_1 and ΔU_3.[10] Unlike the C_i, the U_i exhibit autocorrelation in mean and in variance.[11] UIP deviations, as is well known, result from a certain expectation about exchange rate changes as well

10. As pointed out in section 12.3, the interest rate differential measures UIP deviations conditional on the assumption that spot exchange rates follow a random walk, which is an acceptable hypothesis based on results in tables 12.2 and 12.3.

11. The autocorrelations in the U_i are surprisingly high. The DF statistics for U_1 and U_3 are, respectively, −5.3176 and −4.9913. The corresponding D-W statistics are 1.993 and 1.979. Thus interest rate differentials are stationary. This implies that R^U and R^S are cointegrated.

as the presence of risk premium. But, if as we found earlier the exchange rate follows a random walk, then the differential can be interpreted as the time-varying risk premium.

The graphs in figure 12.2 show that the U_t are negative almost throughout the whole sample period. Overall, the uncovered interest differentials exhibit a broad trend similar to covered interest differentials, with the gap becoming negligible from about 1991 onward. The mean values of U_1 and U_3 for the whole period are 2.876 and 2.887 percent, respectively. The risk premium, however, was much larger in the early 1980s, especially from mid-1979 to late 1983. At its height, it reached about 8 percent above the UIP level, notably in the first quarters of 1980 and 1982. Such a high premium was again a result of the changes in monetary and exchange rate conditions in that period. One reason could be the fear of inflation and the tight monetary policy conducted by the U.S. Federal Reserve Board during that period. High interest rates in the United States and the uncertainty surrounding inflation had added to the volatility and hence the riskiness of the U.S. dollar. The uncertainty was compounded by a worsening of the world debt problem and the doubt it cast on the U.S. banking system. The latter was reflected in the slowdown in Asian Dollar Market activities. By 1983, for example, the gross size of the market increased by only 8 percent, which paled in comparison to the 20 and 58 percent increases in 1982 and 1981, respectively. That the SIBOR rate was far higher

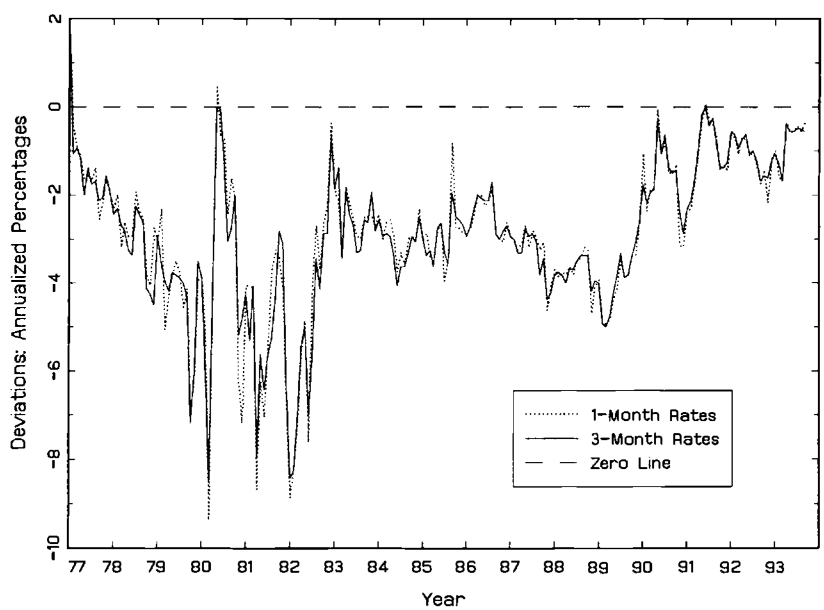

Fig. 12.2 Deviations from UIP(RW)

than the Singapore dollar interest rate was itself an indication of the strong preference for assets denominated in the Singapore dollar.

But as Marston (1993) pointed out, uncovered interest differentials need not be equal to zero even in the absence of any risk premium. The market, for example, might be learning about changes in regimes that have occurred. If so, the forecast error for exchange rate movement might be systematically positive or negative, even though the market might be processing information in a rational manner. This could have been the case in 1981 and 1982, after the MAS switched its modus operandus from interest rate and money supply management to exchange rate management, in its rationalization exercise. Another aspect of the MAS's rationalization process, which might also have added to the adjustment cost, was the policy initiated in 1981 of relying on greater "self-regulation" by financial institutions. This change was intended to maintain a liberal environment. It was felt that anticipations of strict penalties for non-compliance with legislation and administrative guidelines under this freer environment would not only help to ensure the success of the policy but also provide more opportunities for self-improvement by the financial institutions.

The band of interest deviations is not the only indicator of changing capital mobility. As Faruqee (1992) argued, another way to measure such mobility is to look at the conditional variance of such deviations. With greater capital mobility, not only the band but also the variance would decline over time. A preferred model with well-known success in financial research is the GARCH model. For CIP deviation, however, the results in table 12.2 show that there is no significant correlation in conditional variance. To give some indication of the time-varying volatility, we compute standard deviations of CIP deviations over subperiods of 20 observations each. The series of sample standard deviations is plotted in figure 12.3. As we can see, there is no discernible trend in the volatility, although the standard deviation of C_1 is generally greater than that of C_3.

For the UIP(RW) deviations, the results in table 12.2 show that there is significant serial correlation and conditional heteroskedasticity for both one-month and three-month data. Thus we fit an autoregressive process with GARCH residuals for both U_1 and U_3. The results are summarized in table 12.5. It is found that U_1 is driven by an AR(2) process while U_3 follows an AR(1) process. Parameter estimates of the variance equation are very similar.[12] Residual diagnostics using the Q and R statistics show that the model adequately captures autocorrelations in both mean and variance. To study the changing degree of capital mobility we calculate the conditional standard deviation, $\hat{h}_t$, and plot the series in figure 12.4, which largely confirms our earlier finding. That is, except for the period from late 1979 to late 1983, volatility has been very small, not exceeding 1 percent. At its height in 1980, the conditional

12. As in many other studies of financial data, the values of $\hat{\beta}_1 + \hat{\beta}_2$ in the model are very close to unity, implying that conditional variance is highly persistent.

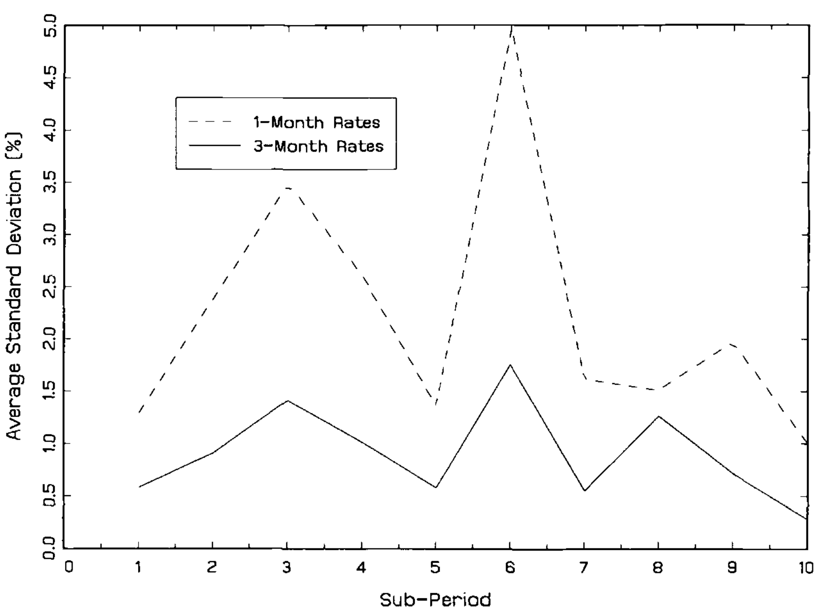

Fig. 12.3 Average standard deviations, CIP

standard deviation reached 2.4 percent. Since then it has been decreasing, indicating an increasingly higher degree of capital mobility.

Comparing our findings with those of Faruqee, we see that Faruqee failed to capture the large volatility in the first few years of the 1980s. This could be explained by the larger sample size used in our study and the fact that we use a more efficient simultaneous estimation method. Furthermore, the slight reversal in increasing volatility in late 1989 found by Faruqee proved to be temporary. The volatility had since then returned to a downward trend until the second half of 1993, when the Singapore stock market was swept by an unprecedented bull run. The bull run, fueled by, among other things, the listing of Singapore Telecom in an effort to encourage Singaporeans to own shares and a series of pro-business policies, had led to a tremendous inflow of capital. This in turn had caused some instability in the domestic interbank market, which was reflected in the volatility of the UIP deviations.

To consider an alternative assumption about the expectation of the future spot rate, we consider UIP(RE). Figure 12.5 plots the deviations from UIP(RE). It can be observed that the deviations are much larger than those of UIP(RW). The fact that some of the deviations from UIP(RE) are exceedingly large, reaching over 60 percent in annualized terms, may be an indication that the perfect foresight assumption is inappropriate. Serial correlation analysis shows that the deviations do not exhibit conditional heteroskedasticity. Similar to CIP, we consider the average standard deviations for the deviations from

Table 12.5 **Estimation Results of GARCH Models for UIP Deviations (eq. [6])**

	Parameters						Residual Diagnostics			
Dependent Variable	α_0	α_1	α_2	β_0	β_1	β_2	Q_1	R_1	Q_2	R_2
U_1	−0.2360	0.7549	0.1698	0.2403	0.7336	0.2277	36.03	0.930	34.53	0.213
	(−1.932)	(8.667)	(2.003)	(5.801)	(27.736)	(6.668)				
U_3	−0.2093	0.9015		0.1718	0.8188	0.1345	24.26	0.359	21.56	0.462
	(−2.012)	(25.224)		(3.605)	(28.973)	(5.664)				

Notes: Numbers in parentheses are t-values. Q_1 and R_1 test for residual serial correlation. Q_2 and R_2 test for conditional heteroskedasticity. If residuals are white noise, Q_1 and Q_2 are approximately distributed as a χ^2_{24}, and R_1 and R_2 are approximately distributed as a standard normal.

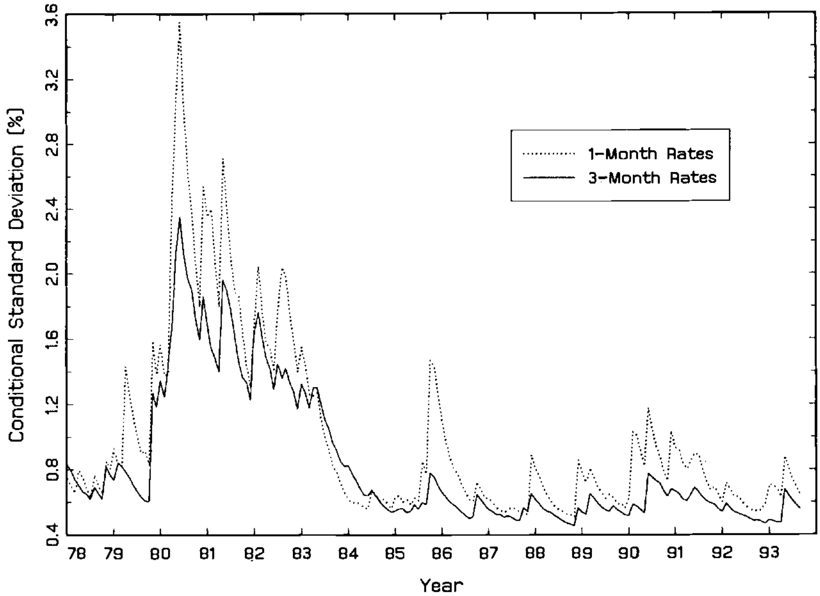

Fig. 12.4 Conditional standard deviations, UIP(RW)

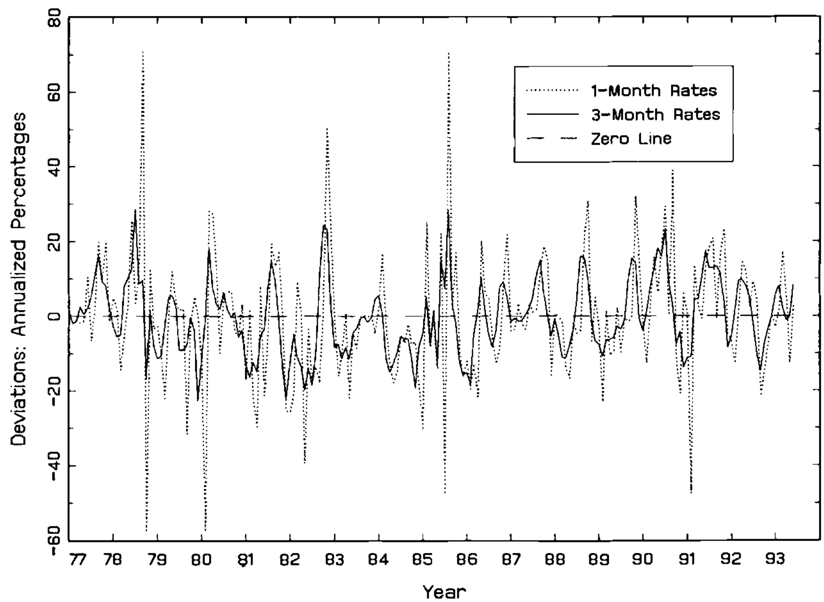

Fig. 12.5 Deviations from UIP(RE)

UIP(RE) over 10 subperiods. Results are plotted in figure 12.6. Although there is no obvious trend in the volatility, the standard deviations of the one-month data show a slight declining tendency.

Finally, we follow the Hansen-Hodrick (Hansen and Hodrick 1980) approach to examine the orthogonality of the prediction error of the spot exchange rate (using the forward exchange rate) on some information variables, including past prediction errors and forward premium. If the market is efficient, these information variables should be orthogonal to future forecast errors. To avoid the problem of serial autocorrelation in residual errors, we rely on quarterly data when three-month forward rates are used. The results of the tests are summarized in table 12.6.

For the monthly data, we notice that the F statistics in all three equations in table 12.6 suggest that the forward rate is statistically no different from the (ex post) actual spot rate, whether we use forward premium or past prediction errors (both for the immediate past month and past two months) as the information variable. This implies that there is no evidence of inefficiency in the market.

For the quarterly data, the results are less clear-cut. The market passes the efficiency test when past forecast errors are used as the information variable but fails when forward premium is used. This, together with the fact that the marginal significance level is higher when forward premium is used as the information variable in the quarterly data equation, may be a reflection more

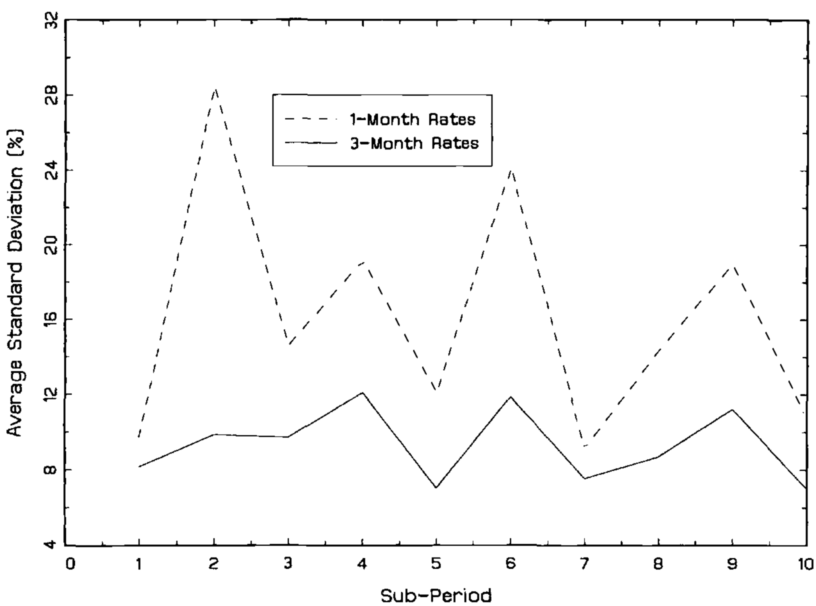

Fig. 12.6 Average standard deviations, UIP(RE)

Table 12.6 **Tests of UIP Using Hansen-Hodrick Approach**

			Regression Parameters					Residual Diagnostics		
Dependent Variable	Sampling Interval	Sample Size	Constant	Lag−1 Dependent Variable	Lag−2 Dependent Variable	Forward Premium	F (p-value)	D-W	Q_1	Q_2
$s_t - f_{3,t-1}$	Quarterly	65	−0.0019	−0.0530			0.178	2.022	35.63	30.74
			(−0.5963)	(−0.4215)			(0.675)			
$s_t - f_{3,t-1}$	Quarterly	65	−0.0128			2.3584	10.406	2.248	40.87	31.73
			(−2.8463)			(3.2259)	(0.002)			
$s_t - f_{1,t-1}$	Monthly	199	−0.0007	−0.0154			0.047	1.996	32.02	34.04
			(−0.6713)	(−0.2159)			(0.829)			
$s_t - f_{1,t-1}$	Monthly	198	−0.0007	−0.0146	0.0521		0.288	1.996	31.41	33.66
			(−0.6480)	(−0.2046)	(0.7275)		(0.750)			
$s_t - f_{1,t-1}$	Monthly	200	−0.0017			0.6986	2.586	2.060	29.43	33.80
			(−1.4400)			(1.6082)	(0.109)			

Notes: Numbers in parentheses are t-values. The F-statistic tests that all regression parameters, apart from the constant, are jointly zero.

of the existence of some risk premium than of the inability of the market to exploit possible arbitrage opportunity.

12.5 Conclusion

This paper examines the dynamic changes in the degree of international capital mobility in the context of Singapore. Our concern here is not so much with the financial openness in Singapore relative to other countries, but with the changes in this openness over time. The issue is important not only because it reflects the impact of various liberalization measures taken over the years but also because of its relevance to the conduct of independent domestic monetary policy.

Both the band and the variability of deviations from covered and uncovered interest parities are used to measure changing capital mobility. We have found that, except for a brief period in the early 1980s, both the band and the variability of the deviations have been declining over time, implying that capital has indeed become increasingly mobile. In the 1990s, the deviations have virtually disappeared, suggesting almost perfect capital mobility. In addition, we found that, for the sample period as a whole, there is no reason to reject the efficient market hypothesis.

Like Frankel and other researchers, we found that, whatever barriers to capital movement exist seem to take the form of currency-related risks, as shown by the larger deviations from uncovered interest parity. Country-specific transaction costs, which deviations from covered interest parity are supposed to capture, are rather negligible. This finding is consistent with the fact that, since the late 1970s, all capital and exchange controls have effectively been abolished, even though the system is not immune to external economic shocks. It also implies that the effort to promote Singapore as an international financial center by removing unnecessary restrictions is indeed bearing fruit.

The results nevertheless suggest that the central bank's ability to conduct independent domestic monetary operations will be severely hampered. Any attempt to fix the domestic interest rate at a level different from the world interest rate (the U.S. rate in particular) is likely to be foiled. Exchange rate management, rather than domestic monetary policy tools, will more than ever be the key to maintaining domestic price stability.

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Comment Ngiam Kee Jin

The paper by Tse and Tan examines whether there were deviations from covered and uncovered interest parity in Singapore during the period 1977–93. Deviations from covered interest parity (CIP) were found to be generally small during the sample period but large during the early 1980s. Similarly, deviations from uncovered interest parity (UIP) were found but became smaller and less variable over time. Based on these findings, it is then claimed that capital has tended to be more mobile in Singapore over time because of the various liberalization measures taken by the authorities over the years.

One way to test whether CIP holds is to find out whether the following inequality is satisfied:

$$|R^U + F - S - R^S| < C, \tag{1}$$

where C is the cost of carrying out the transaction, and the left-hand side is the absolute value (ignoring the sign) of the gap between the Eurodollar rate (R^U) and the onshore Singapore interest rate (R^S), adjusted for the forward premium or discount ($F - S$). Hence, contrary to the claim made in the paper, deviations from CIP do not necessarily imply that risk-free arbitrage opportunity is avail-

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able. Arbitrage profits arise only if the deviations are greater than the transaction costs.

In testing whether CIP holds for the Singapore and U.S. dollars, the biggest problem is deciding what Singapore interest rate should be used. There is no problem with the U.S. interest rate because the LIBOR (or SIBOR) can be used. As for the Singapore interest rate, the domestic interbank rate is commonly used. This paper is no exception. In the Singaporean context, the correct domestic interest rate is the effective cost of funds (EC) because it is used by foreign exchange traders to calculate the Singapore-U.S. dollar forward exchange rate or the swap points. The EC can be obtained by adding the reserve cost to the nominal cost of borrowing (NC). In the simplest form, the EC is expressed by the following:

$$(2) \qquad x\,\mathrm{CR} + (1 - x)\,\mathrm{EC} = \mathrm{NC}\,,$$

where CR represents the interest on cash reserves held by the bank (which, for simplicity, are assumed to earn zero interest) and x is the ratio of cash reserves against the liabilities base.

Rearranging equation (2) gives

$$(3) \qquad \mathrm{EC} = \frac{\mathrm{NC} - x\,\mathrm{CR}}{1 - x}\,.$$

It is clear that the EC is always greater than the NC, which is actually the weighted average of the CR and EC. Moreover, a given change in the NC will lead to a more than proportionate change in the EC. This merely shows that the reserve cost is higher (lower) when the interest rate is higher (lower). For many banks in Singapore, especially foreign banks, which normally have a low deposit base, the domestic interbank rate is their nominal cost of funds. However, the minimum rate at which they can lend is not NC but EC, which takes into account the reserve cost.

Tse and Tan find that the left-hand side of equation (1) is always positive and that in the early 1980s the positive deviations were larger than usual. It should be noted that during the early 1980s, the domestic interbank rate soared to a yearly average of 11.48 percent in response to the surge in the U.S. interest rate. Consequently, the increase in EC would have been greater than the rise in NC. If EC rather than NC were used to proxy the Singapore interest rate, most of the positive deviations in the sample period, including the early 1980s, would be substantially reduced in size and may even disappear altogether. The argument in the paper that the smaller deviations from CIP in subsequent years is due to the various liberalization measures taken by the Singapore government is not convincing. This is because Singapore had completely liberalized its exchange control as early as June 1978. Since then, Singaporeans have been allowed to borrow and lend freely in all currencies as well as to deal freely in foreign exchange.

The test for UIP is more fruitful and interesting and may involve testing the following equation:

$$S^e - S = a + b(F - S) + u, \tag{4}$$

where S^e is the expected spot rate in the ith period ahead, $F - S$ is the forward premium or discount, and u is the error term. The problem with testing equation (4) is that S^e is unobservable and has to be estimated. There are several ways to solve this problem. One approach is to use survey data on the expectations of the Singapore-U.S. dollar exchange rate, which fortunately can be obtained from the *Currency Forecaster's Digest.* Another way is to use an exchange rate model to generate the exchange rate expectations. Last, but not least, the actual exchange rate movements that occur over time can be used if there is perfect foresight. However, the paper tests for UIP by simply assuming that the Singapore-U.S. dollar exchange rate follows a random walk, which means that $S^e = S$. Thus, the UIP holds only if

$$R^U - R^S = 0 . \tag{5}$$

Moreover, if the CIP holds, then

$$S^e = F , \tag{6}$$

which implies that there is no risk premium in the case of the Singapore-U.S. dollar exchange rate.

The assumptions made in the paper for testing UIP are arbitrary and tend to oversimplify. Figure 12.2 shows that the Singapore interest rate has been consistently below the U.S. interest rate and that there has been significant deviation between the two rates. Can one then conclude that UIP is not supported? The answer is obviously no. The failure of the data to accord with equation (5) above can be explained by the fact that UIP does not hold (probably because of the existence of a risk premium) or that the assumptions about exchange rate expectations are at fault, or both. This is really a test of the joint hypothesis.

Suppose that the Singapore-U.S. interest rate differential can be decomposed into two parts as follows:

$$R^U - R^S = (S^e - S) + \text{RP}, \tag{7}$$

where $S^e - S$ is the expected change of the exchange rate and RP is the risk premium. In order to test adequately whether UIP holds, one must be able to measure anticipated exchange rate changes. Otherwise, how can one tell whether a risk premium or discount exists? The existence of a risk premium cannot be easily dismissed in the case of Singapore. Over the entire decade of the 1980s, the Singapore-U.S. interest rate differential averaged 3.5 percent. During the same period, the Singapore dollar appreciated against the U.S. dollar by 2.3 percent on average. This difference might suggest that the market perceived Singapore dollar deposits to be less risky than U.S. dollar deposits and therefore would require a risk premium in order to induce investors to hold the U.S. dollar–denominated assets. Finally, it is useful to remember that the test of UIP is not a test of the degree of capital mobility. Failure of UIP may simply reflect the fact that Singapore and U.S. assets are not perfect substitutes but move freely. The question of capital mobility can only be deduced from CIP which, I believe, is valid in the case of Singapore.