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Offshore Money Market Integration –Evidence of the U.S. Dollar Yields in Taiwan, Singapore, and the United Kingdom

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Abstract

The purpose of this paper is to extend the money market integration study by including Taiwan's offshore money market to provide a more global perspective and to examine Taiwan's progress in entering the international financial arena. The results indicate that three offshore money markets examined are not fully cointegrated. For the overnight yields, only the pairs of Taipei and London and London and Singapore show significant long-run equilibrium relationships. Singapore and London are the only pair of markets displaying cointegration relationship for the one-month maturity yield series. In addition, based on the estimated error correction models, the hypothesis that these offshore money markets are perfectly linked cannot be supported.

Keywords: Offshore money market, Integration, Cointegration, Error correction model, Banking liberalization,

1. Introduction

Close financial interdependencies between countries and the evolution of national financial markets into global financial markets have been widely recognized and received much attention in the public press and in the academic literature. Especially, money market integration evidenced by linkages and comovements between money market yields in different geographic markets has been the primary focus of study in recent years.

Hendershott's 1967 study of the international transmission of interest rates launched the rigorous study of the integration of world money markets. Using a stock adjustment model and assuming that the U.S. bill rate was the primary determinant of the equilibrium Eurodollar rate, he concluded that the Eurodollar rate adjusted completely to changes in the U.S. bill rate. Kwack's (1971) study extended Hendershott's model by incorporating foreign rates, including the Canadian and United Kingdom three-month Treasury bill rates and Frankfurt interbank loan rate. His results agreed with Hendershott's finding. Covering the period of 1958 through 1971, Argy and Hodjera (1973) did a similar study exploring financial integration and interest rate linkages in ten industrial countries. Primary finding was that the movement in the Eurodollar rate tended to be dominated by conditions in the United States and that the U.S. and Eurodollar markets were highly integrated.

The first study reporting the presence of feedback effects (causality running from the offshore market to the domestic market) was done by Giddy, Dufey, and Min (1979). Their results supported the view that U.S. rates show greater stickiness than Eurodollar rates and the Eurodollar market is generally more competitive and flexible, implying that Eurodollar rates respond more efficiently to information. The evidence of feedback causality was further documented by Hartman (1984) where he applied a variant of the Sims-Granger methods. Another important issue, whether Eurocurrency and national interest rate changes lead, lag, move together, or jointly determine each other, was investigated by Kaen and Hachey (1983). Their evidence suggested that since the removal of capital controls and the demise of the Bretton Woods system, domestic interest rates generally adjust more quickly to economic and monetary changes than do the external market interest rates.

A significant and thorough study in changing money market integration was conducted by Swanson (1987). By applying Granger techniques, she examined direct and feedback effects and contemporaneous determination between Eurodollar and U.S. domestic yields. Major findings were that the degree of integration between these two money markets had increased throughout the period studied and that the direct causality was found to be stronger than the reverse causality. Subsequently, Swanson (1988) extended the study of money market integration by investigating the relationships between yields on various currency denominated deposits. Results indicated that changes in domestic and offshore yields for the same currency moved closely, and highly significant contemporaneous determination was found between the U.S. dollar and all the included foreign currencies. Furthermore, it appears that the primary direction of causality is from the national to the offshore markets.

In a recent study, utilizing a technique which combines stationarity and cointegration tests as a basis for constructing the error correction model, Lin and Swanson (1993) extended the study of global money market integration by incorporating the Asiancurrency markets, Singapore and Hong Kong, into traditional European and national markets analysis. Major findings were (1) the error correction model is an appropriate technique for identifying causality relationships, (2) major domestic markets and included offshore markets are partially segmented, and (3) domestic markets are not immune from influences from the Singapore offshore market although the Hong Kong market appears to be generally of little consequence. Subsequently, Lin and Swanson (1994) applied traditional Sims and Granger tests on the same data and obtained consistent results.

For several years, Taiwan has been strive to establish Taipei as a regional international financial center. Efforts include liberalization of the foreign exchange markets, reopening of the forward exchange market, enacting laws to enhancing banking operational environment, and allowing more foreign capital to invest in Taiwan's financial markets. Another prominent effort is the establishment of the Taipei Offshore Banking Center (TOBC) in 1984. Since its inception, the TOBC has grown at a rapid pace from an initial size of US$4.3 million to approximately US$27 billion at the end of 1993. To foster the growth of the TOBC and to pursue the ultimate goal of establishing the Taipei International Financial Center, the Central Bank of Taiwan took several rigorous actions in showing support. On August 7, 1989, the Taipei Offshore Money Market (or Call Market) began its operations with an initial

US$3 billion capital seeded by the Central Bank. The capital was increased to US$4 billion on October 4, 1989 and further to US$5 billion. On May 1, 1990, 500 million German marks were added to the market and Japanese yen was also listed in the same year. In February, 1991, synchronous transaction linkage of the offshore money markets was established between Taiwan and Singapore. Subsequent linkages were also accomplished between Taiwan and Hong Kong and Japan.

It is believed that the synchronous transaction linkages between Taiwan and three well-developed Asian financial markets symbols the success of Taiwan in joining the global banking transaction network, implying offshore money market integration between Taiwan and the global banking society. Therefore, it is of great importance to examine if interest rates in Taiwan's offshore money market fully integrate with yields in other offshore money markets, especially major well-developed markets such as Singapore and London.[1.] The purpose of this paper is to extend the money market integration study by including Taipei Offshore Money Market to provide a more global perspective of money market integration and to examine Taiwan's progress in entering the international financial arena.

The remainder of this paper is structured into three major sections. The next section discusses the methodology used in testing integration. The third section presents data and empirical results. Finally, the investigated issues are concluded and implications drawn from empirical results are also addressed.

2. Methodology

Previous studies relied upon stock adjustment models or methodologies focusing on the lead and lag structure of interest rate changes such as Granger causality or Modified Sims tests. In this paper, a relatively new methodology which combines cointegration concept and the error correction model is used. This methodology which has more causality detecting power had been proved by Lin and Swanson (1993) to be an appropriate method in examining the issue of money market integration.[2.]

Cointegration is a statistical concept developed by Granger and Weiss (1983), Granger (1986), and Engle and Granger (1987). It has been applied in testing the validity of various theories and models. Lucey (1988), Hakkio and Rush (1989), Baillie and Bollerslev (1989), Leddin (1989), Coleman (1990), MacDonald and Taylor (1989), and Ho and Shen (1993) used the concept to examine foreign exchange market efficiency. Taylor (1988), Thom (1989), Layton and Stark (1990), McNown and Wallace (1989), Heri and Theurillat (1990), Canarella, Pollard, and Lai (1990), and Kim (1990) applied cointegration in testing the purchasing power parity. Other applications include Rose and Yellen (1989), Baillie and Selover (1987), Bergstrand and Bundt (1990), Miller and Russek (1990), Koch and Koch (1991), and Miller (1991).

Cointegration becomes relevant when time series being examined are nonstationary. A time series is integrated of order d, denoted I(d), if the series can achieve stationarity only after differencing d times. For $d = 0$, an interest rate series, Y_t, will be stationary and for $d = 1$, the first differencing of Y_t, will be stationary.[3.] The test of stationarity is primarily a test of unit roots.

A common approach for testing unit roots is to apply the Augmented Dickey-Fuller test (ADF) with a time trend. In the ADF test, the first difference of the variable is regressed on a time trend, T, on its own level lagged one period, and on lagged first differences of the variable.

$$\Delta Y_t = \alpha + \rho T + \beta Y_{t-1} + \sum_{i=1}^{p} \gamma_i \Delta Y_{t-i} + \epsilon_t \tag{1}$$

where p is chosen so that the residual series ϵ_t is white noise. The null hypothesis is that the level of the series, Y_t, contains a unit root. If it does, then the estimated coefficient, β, should be zero, suggesting non- stationary. The conventional calculated t statistic for β is used. However, the t statistic does not follow the usual t distribution so that the critical value has to be taken from Fuller (1976). To test white noise on the residual series, the Box-Pierce Q-statistic with 24 lags specified, which follows the x^2 distribution, is computed.

If two interest rate series, X_t and Y_t, are non-stationary, in general, the linear combination of X_t and Y_t will also be non-stationary. However, there may exist a number d such that

$$X_t - dY_t = U_t \tag{2}$$

will be stationary. In this case, X_t and Y_t are said to be cointegrated with a cointegrating vector of d and $X_t = dY_t$ is considered to be an equilibrium relationship, implying a long-run comovement relationship.

One widely used method of detecting cointegration is to employ the Augmented Dickey-Fuller test.[4] Given Equation (2), the ADF test is implemented as the following regression

$$\Delta U_t = -\rho U_{t-1} + \beta_1 \Delta U_{t-1} + \cdots\cdots + \beta_k \Delta U_{t-k} + \nu_t \tag{3}$$

K lags of ΔU is to ensure that the residuals are serially uncorrelated. The test statistic is the t statistic for ρ. The critical values can be obtained from Engle and Yoo (1987). A large t statistic will confirm cointegration.

However, the Augmented Dickey-Fuller test has been criticized to have numerically too small critical values, leading to a rejection of a unit root, i.e., finding cointegration too often.[5] To verify results obtained from the ADF, the Johansen maximum likelihood procedure (or called the Johansen procedure) developed by Johansen (1988) and Johansen and Juselius (1990, 1992) is also applied.[6] The Johansen procedure which implements the trace test (or the likelihood ratio test) takes into account the error structure of the underlying process and imposes no restriction on the simultaneous structure of the model dynamics, providing a more powerful test for cointegration than the ADF test. To perform the trace test, a computer package called SHAZAM is utilized.[7] The SHAZAM is an Econometrices computer package which provides the Johansen trace test procedure for cointegration. The critical values of the trace test are given in Johansen and Juselius (1990, Table 3).

If X_t and Y_t are nonstationary and are cointegrated with a cointegrating vector d, then they can be expressed as an error correction model (ECM)

$$\Delta X_t = a + bU_{t-1} + \sum_{i=1}^{n} c_i \Delta X_{t-i} + \sum_{j=0}^{m} f_j \Delta Y_{t-j} + e_t \tag{4}$$

where the lagged changes of X and Y may be needed to induce white noise in e_t.

In constructing the error correction model, an important step is to select the optimal lag lengths, n and m. A frequently applied method is to use the Akaike's minimum final prediction error criterion (FPE) as recommended by Hsiao.[8.] Following Hsiao, the FPE can be calculated as

$$\text{Final Prediction Error} = [(T+G+1)/(T-G-1)] * (SEE/T) \tag{5}$$

where T is the number of observations and $G = n + m$ is the number of lags in the autoregression.[9.]

The error correction model, Equation (4), provides a basis for the test of money market integration. If two money market yield series are nonstationary and are cointegrated, then they can be expressed as an error correction model similar to Equation (4). Therefore, changes of one yield series, ΔX_t , can be related to the last period's deviation from equilibrium, U_{t-1}, to its own past changes, ΔX_{t-i}, and to the current and lagged changes of another yield series, ΔY_{t-j}. If some of the f_j are statistically significant, then the change of one yield series can be explained by past changes of another yield series, implying the existence of causality and incomplete integration between these two money markets.

3. Data and Empirical Results

Three offshore money markets are included in this study: Taipei, Singapore, and London. Daily observations of U.S. dollar denominated overnight, one-week, and one-month maturity yields during the period May 19, 1993 through February 28, 1994 were collected from the Taipei Foreign Exchange Market Development Foundation. Data prior to May 19, 1993 are not available. Table 1 presents descriptive statistics of these yield series. It is obvious that Taiwan's one-week and one-month maturity markets are thinner with only one third and one half recorded trading days, respectively, as compared with Singapore and London. However, the overnight money market in Taiwan is comparable.

Table 2 sets forth the results of the Augmented Dickey-Fuller tests. The results show that overnight and one-month maturity yield series in three markets are all nonstationary in levels and stationary after being differenced once, fulfilling the condition for further cointegration testing. However, one-week maturity yield series presents a different picture showing significance toward stationarity in levels.

Results of the Augmented Dickey-Fuller cointegration tests are shown on Table 3. For all maturities and in all pairs of geographic markets the test statistics are highly significant, rejecting noncointegration in all instances. The lags needed to induce white noise in residuals are all 1 except the first pairing, overnight yields in Singapore and Taiwan, in which 2 lags are required.

Table 1
Descriptive Statistics of U.S. Dollar Yields in
Taipei, Singapore, and London Offshore Money Markets
May 19, 1993 - February 28, 1994

Market	Maturity	# of Obs.	Average	Std. Dev.	Max.	Min.
	Overnight	182	3.107%	0.116%	3.47%	2.94%
Taipei	1 - Week	63	3.173%	0.119%	3.63%	3.03%
	1 - Month	94	3.212%	0.098%	3.59%	3.11%
	Overnight	181	3.123%	0.107%	3.50%	2.94%
Singapore	1 - Week	188	3.208%	0.100%	3.63%	3.00%
	1 - Month	189	3.254%	0.110%	3.69%	3.06%
	Overnight	179	3.082%	0.119%	3.44%	2.81%
London	1 - Week	186	3.127%	0.096%	3.44%	3.00%
	1 - Month	185	3.202%	0.105%	3.56%	3.06%

Based on Table 3, since three markets are studied, cointegration in all market pairs implies three cointegrating vectors, showing the ADF "over-identifying" problem argued by Baillie and Bollerslev (1989) and Ho and Shen (1993).

To verify cointegration relationships, the Johansen trace test procedure is employed using the SHAZAM computer package.[10.] The results are presented on Table 4. For overnight yields, two market pairs, Taipei and London and Singapore and London, demonstrate one percent significance of cointegration relationships with 25.807 and 21.881 trace test statistics, respectively. For one-month maturity yields, only the pair of Singapore and London observes a cointegration relationship with a test statistic of 33.424 highly significant at the one percent level. For the purpose of further confirming the actual number of cointegrating vectors, the multivariate Johansen trace test procedure is performed. Results are displayed on Table 5. Two cointegrating vectors in three markets are confirmed for the overnight yields and one for the one-month yield series. These results are consistent with those on Table 4. Therefore, only three pairs of markets, overnight yields in Taipei and London and Singapore and London and one-month yields in Singapore and London, meet the criteria for the error correction model construction.

Table 6 sets forth the error correction models based on the three cointegration relationships on Table 4. Both the F and Wald statistics, together with optimal lag lengths (n and m), are reported. The Wald test is included to confirm the results of the F test because of the potential biasedness due to the inclusion of lagged values of the dependent variable on the right hand side.[11.] For all pairs, including overnight and one-month yields, the error correction terms are highly significant at the one percent level, suggesting long-term trend relationships and adjustments in yield series of these offshore markets. Both the Wald and F statistics show consistent results of bi-directional causality in all instances. In terms of the adjustment speed of the dependent yield variable

Table 2

Results of Augmented Dickey-Fuller Stationarity Tests

$$\Delta Y_t = \alpha + \rho T + \beta Y_{t-1} + \sum_{i=1}^{p} \gamma_i \Delta Y_{t-i} + \epsilon_t$$

Market	Maturity	*t* Test Statistic of β^a			
		Level	Lag Length	1st-Differ.	Lag Length
Taipei	Overnight	-3.04	3	-11.08***	3
	1 - Week	-5.19*	1	-8.18***	2
	1 - Month	-3.11	1	-6.82***	1
Singapore	Overnight	-2.28	4	-8.04***	5
	1 - Week	-4.52*	2	-7.30***	3
	1 - Month	-2.53	1	-10.26***	1
London	Overnight	-3.06	3	-13.97***	2
	1 - Week	-3.71**	1	-14.15***	1
	1 - Month	-2.64	1	-13.02***	1

a: Critical values for the ADF tests are from Fuller (1976).

***: 1% significance level *:10% significance level

** : 5% significance level

Table 3

Results of the Augmented Dickey-Fuller Cointegration Tests

$$\Delta U_t = -\rho U_{t-1} + \beta_1 \Delta U_{t-1} + \cdots\cdots + \beta_k \Delta U_{t-k} + \nu_t$$

Dependent Variable	Independent Variable	t Test Statistic of ρ^a	Lag Length[b]
Overnight Yields:			
Singapore	Taipei	-5.73***	2
Taipei	Singapore	-6.89***	1
London	Taipei	-8.18***	1
Taipei	London	-7.07***	1
London	Singapore	-7.68***	1
Singapore	London	-6.56***	1
One-Month Yields:			
Singapore	Taipei	-5.94***	1
Taipei	Singapore	-5.47***	1
London	Taipei	-6.47***	1
Taipei	London	-6.18***	1
London	Singapore	-6.61***	1
Singapore	London	-6.78***	1

a : Critical values for the ADF tests are based on Engle and Yoo (1987).

b : The number of lags needed to induce white noise in residual series in the ADF test.

***: 1% significance level

Table 4
Results of the Johansen Trace Tests
(Bivariate Cointegration)

Variables Included	Trace Test[a]	
	r≤0	r≤1
Overnight Yields:		
Taipei & Singapore	17.554	0.276
Taipei & London	25.807***	0.297
Singapore & London	21.881***	0.384
One-Month Yields:		
Taipei & Singapore	13.038	0.231
Taipei & London	17.097	0.193
Singapore & London	33.424***	0.471

a:Critical values are from Johansen and Juselius (1990, p.209, Table 3).
r ≤ 0 : at most one cointegrating vector
r ≤ 1 : at most two cointegrating vectors
***: 1% Significance level

Table 5
Results of the Johansen Trace Tests
(Multivariate Cointegration)

Variables Included	Trace Test[a]		
	$r \leq 0$	$r \leq 1$	$r \leq 2$
Overnight Yields:			
Taipei, Singapore, & London	45.73***	20.55**	0.291
One-Month Yields:			
Taipei, Singapore, & London	32.79*	12.45	0.358

a: Critical values are from Johansen and Juselius (1990, p.209, Table 3).
$r \leq 0$ at most one cointegrating vector
$r \leq 1$ at most two cointegrating vectors
$r \leq 2$ at most three cointegrating vectors
*** : 1% Significance level
** : 5% significance level
* : 10% significance level

Table 6
Estimation of Error Correction Models
$\Delta X_t = a + bU_{t-1} + \sum_{i=1}^{n} c_i \Delta X_{t-i} + \sum_{j=0}^{m} f_j \Delta Y_{t-j} + e_t$

Dependent Variable	Independence Variable	F Test Statistics for H_0: $b=0$	$\Sigma c_i = 0$	n	$\Sigma f_i = 0$	m	Wald Test
Overnight Yields:							
London	Taiwan	95.5***	2.0	3	125.9***	0	133.5***
Taiwan	London	17.4***	2.3	5	65.5***	1	156.2***
London	Singapore	18.9***	8.3***	3	22.2***	3	137.5***
Singapore	London	16.8***	8.6***	3	69.0***	1	160.2***
One-Month Yields:							
London	Singapore	22.1***	5.6**	1	11.9***	0	12.3***
Singapore	London	62.3***	3.4*	2	11.2***	0	11.7***

*** : 1% significance level
** : 5% significance level
* : 10% significance level

in reflecting changes of the independent variable, only contemporaneous and lagged one terms are required [m in Equation (4)], except the impact of the Singapore overnight yield on London of which three lags are shown. Therefore, the studied offshore money markets are rather efficient, being consistent with the general expectation.

4. Conclusion and Implications

The purpose of this paper has been to extend the money market integration study by including Taiwan offshore money market to provide a more global perspective of money market integration and to examine Taiwan's progress in entering the international financial arena. Daily observations of overnight and one-month maturity U.S. dollar yields in Taipei, Singapore, and London offshore money markets are examined. A technique which combines stationarity and cointegration concepts as a basis to construct the error correction models is applied to assess the existence of long-run equilibrium relationships.

The results indicate that three offshore money markets are not fully cointegrated. For the overnight yields, only the pairs of Taipei and London and London and Singapore show significant long-run equilibrium relationships. Singapore and London are the only pair of markets displaying cointegration relationship for the one-month maturity yield series. With regard to the one-week maturity yields, none fulfills, statistically, the necessary conditions of establishing a cointegration relationship. Furthermore, based on the estimated error correction models, the hypothesis that these offshore money markets are perfectly linked cannot be supported. Strong bi-directional causality suggests that three offshore money markets are at least partially segmented. These findings are consistent with those obtained by Lin and Swanson (1993).

Several implications can be deduced from these results. First of all, Taiwan's financial and banking liberalization actions seem not enough even after accomplishing synchronous transaction linkages with other offshore markets. Taiwan's degree of integration with well-developed offshore markets is still weak, implying that more aggressive actions toward liberalization are needed if to pursue the ultimate goal of establishing Taipei as an international financial market. Second, although significant bi-directional causal relationships exist, the speed of reflecting changes in the counterpart market is rather fast. In most instances, the adjustment is simultaneous or is completed in one day, indicating that interest rate arbitrages may not be profitable. Third, the over-identifying problem of the Augmented Dickey- Fuller cointegration test is explicitly demonstrated in this study. Therefore, it is strongly recommended that future cointegration tests should be conducted by implementing the Johansen maximum likelihood procedure or other more powerful techniques.

Due to data unavailability, the other well-developed offshore markets, such as Hong Kong and Japan, are not included in the study. Future efforts should be steered into this direction to provide a complete perspective of global offshore money market integration. Given the fact that Hong Kong will be returned to China in 1997, how this political change will influence the interrelationships among Asian offshore markets will also be an interesting and important issue of future studies.

Notes

1. Logically, a study of integration relationships among Taiwan, Hong Kong, Japan, and Singapore would provide a better picture regarding Taiwan's progress in banking internationalization and liberalization. However, call market yields data are not available for Hong Kong and Japan.
2. However, the error correction model was first proposed by Engle and Yoo (1987).
3. There are substantial differences between a series which is I(0) and another which is I(1). These characteristics are discussed thoroughly by Engle and Granger (1987).
4. Seven tests for examining cointegration have been proposed by Engle and Granger (1987). According to them, the Augmented Dickey-Fuller is the most powerful one. Lin and Swanson (1993) also adopted this test as their primary method in examining cointegration.
5. See Baillie and Bollerslev (1989) and Ho and Shen (1993) for detailed discussion on this aspect.
6. Please see Johansen (1988), Johansen and Juselius (1990, 1992), or Baillie and Bollerslev (1989) for thorough discussion and derivation of this testing procedure.
7. The SHAZAM is an Econometrices computer package which provides the Johansen trace test procedure for cointegration.
8. See Hsiao (1981) for more discussion regarding this criterion and FPE calculation.

9. To construct the error correction model, the FPE procedure involves several steps. See Lin and Swanson (1993, Note 9) for these steps.
10. Different lag structures from 2 to 6 had been implemented. It is found that the test with 4 lags is more stable with various data sizes. In addition, 4 lags plus the level contributes one week trading.
11. Wald statistic is computed as $W = T(\sigma_r{}^2 - \sigma_u{}^2)/\sigma_u{}^2$ where T is the number of observations, $\sigma_r{}^2$ is the maximum likelihood of estimate of variance of the error term for the restricted model [Equation (4) without $\Sigma f_j \Delta Y_{t-j}$], $\sigma_u{}^2$ is for the unrestricted equation [Equation (4)].

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