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On the Interaction of Taiwan Stock Market and the Currency Market of US Dollar

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Abstract

In this paper, we measured the relationship between the stock market and the currency market in Taiwan through a simultaneous equation system. We found that the stock price in Taiwan is negatively related to the exchange rate of the NT dollar per US dollar. The NT dollar appreciates when the Taiwanese stock market is hot. On the other hand, the Taiwan stock market recesses when the NT dollar depreciates. Since the Johansen test indicates that the stock index and the US dollar exchange rates are co-integrated, we concluded that there exists a connection between theTaiwanese stock market and the US dollar currency market over the long run.

Keywords: Stock Market, Currency Market, Simultaneous Equation System.

Introduction

Certain macroeconomic variables may cause stock prices to change. A major determinant of the stock price, introduced by Pearce and Roley (1983) and Wong (1986), is the money supply. They argue that if there is an amount of money in the market, the demand for capital assets will be high and thus stock prices would soar. Pearce and Roley (1985) point out that another determinant of the stock price is the discount rate. When the discount rate is low, the cost of investments in the stock market is also low and thus stock prices will increase. However, few studies ever investigate the relationship between stock prices and foreign exchange rates. Further, most of the previous studies such as Aggarwal (1981) and Soenen and Hennigar (1988), working on the relationship between stock indices and the foreign exchange rate, emphasize on the leading relationship or uni-directional relationship of foreign exchange rate on the stock price, i.e. the currency market is a "leading" indicator of the stock market. Nevertheless, based on the portfolio model of exchange rates proposed by Branson, Halttunen and Masson (1977), we hypothesize that the relationship between the stock market and the currency market is not simply a uni-directional causality. Rather, there exists a bi-directional causality relationship between stock prices and foreign exchange rates.

Bahmani-Oskooee and Sohrabian (1992) employ the Granger (1969) concept of causality, and use the Chow test (1960) to show that there does exist a bi-directional causality relation between the stock prices measured by S&P's 500 index and the exchange rate of the US dollar. Further, Mok (1993) uses an ARIMA approach to test the causality of daily interest rates, exchange rates and stock prices in Hong Kong from 1986 to 1991. He shows that stock prices cause the interest rate to fluctuate, but the interest rate does not cause stock price to fluctuate. However, Mok also finds a weak bi-directional causality between stock prices and exchange rates. Kang and Chu (1996) establish a simultaneous equation model to check the relationship between stock prices and foreign exchange rate and find no significant relationship between the stock market and the foreign exchange market in Taiwan.

In this paper, we measure the interaction of the stock market and the foreign exchange market in Taiwan through a simultaneous equation model similar to that proposed by Kang and Chu. Furthermore, other than the short-run relationship between the stock market and the exchange rate market, we also investigate the long-run relationship between stock prices and exchange rates through unit root tests and co-integration tests. Typically, if two series are co-integrated, there exists a long-run relationship between these two variables, which means that we can set up a connection between these two variables. On the other hand, if the variables are not co-integrated, we cannot establish a long-run relationship between the variables.

The remainder of the paper is organized as follows. Section 2 describes empirical models such as ordinary least square (OLS) regression, simultaneous equation system, unit root test and co-integration test. In section 3, we present the data source and the descriptive statistics. The empirical results are reported in section 4. Finally, section 5 states the conclusion.

Empirical Models

The Granger causality test is typically employed to investigate the causality relationship between two data series. Previous studies emphasize on the Granger causality concept to examine the leading effect of foreign exchange rates on stock prices. That is, the past and present information about foreign exchange rates helps us forecast stock prices. In this paper, we argue that the relationship between the stock market and the currency market is not a simple leading effect of one on the other. Nevertheless, we hypothesize that there might exist a bi-directional causality relationship between the stock market and the currency market. Besides the short-run relationship between stock prices and the foreign exchange rates, we also investigate the long run relationship between stock prices and the foreign exchange rate through co-integration tests.

1.Classical regression approach

The classical regression approach is typically used to check the relationship rather than causality between variables. Since we argue that there exists a bi-directional relationship between stock prices and the exchange rates, we can employ the classical regression approach with stock prices or exchange rates as the dependent variables to check their relationship. However, stock prices are not the only determinants of foreign exchange rates. On the other hand, the foreign exchange is not the only factor affecting stock prices. Consequently, when setting the regression model, we also need to add some other control variables to obtain efficient estimates. Soenen and Hennigar (1988) and Mok (1992) show that money supply, interest rates, price index and trade deficit may affect the stock market. On the other hand, purchasing power party, balance of payment and monetary approach imply that the differences of interest rates, price levels, money supply and production levels between two countries and the trade amount will influence the exchange rate. Therefore, we form the following regression models.

$$STOCK = \beta_0 + \beta_1 DOLLAR + \beta_2 X_1 + \beta_3 X_2 + \beta_4 X_3 + \beta_5 X_4 + \varepsilon_1 \quad (1)$$

$$DOLLAR = \beta_0 + \beta_1 STOCK + \beta_2 X_5 + \beta_3 X_6 + \beta_4 X_7 + \beta_5 X_8 + \beta_6 X_9 + \varepsilon_2 \quad (2)$$

where,

STOCK: the stock index in Taiwan,

DOLLAR: the exchange rate of NT dollars per US dollar,

X_1: money supply in Taiwan,

X_2: the short-term interest rate,

X_3: consumer price index of Taiwan,

X_4: trade deficit of Taiwan,

X_5: relative interest rate, Taiwan rate / US rate,

X_6: relative consumer price index, Taiwan index / US index,

X_7: relative money supply, money of Taiwan / money of US,

X_8: relative industrial production index, Taiwan index / US index,

X_9: relative export to import of Taiwan.

With the time series data, the error terms of regressions (1) and (2) may be auto-correlated. With the auto-correlated error terms, the OLS regression results might be inefficient. In this paper, when the error term of regressions are auto-correlated, we employ the Yule-Walker estimate to adjust for the auto-correlated error terms.[1]

2.Simultaneous equation system

If we regress (1) and (2) separately to investigate the relationship between the stock market and the currency market, the estimated coefficients may be biased. Since we argue that the stock price and the exchange rate are cross interacted, we set up a simultaneous equation model with the stock price and the foreign exchange rate as the endogenous variables and the remaining as the exogenous variables. We find

[1] Please refer to Anderson (1971) and Gallant and Goebel (1976) for more discussion about Yule-Walker estimators.

that the exogenous variables in regressions (1) and (2) are not identical. Consequently, we should be able to estimate the coefficients of regressions (1) and (2)through the two-stage least square method (2SLS).

In 2SLS, we regress stock

ssions.

$$STOCK = \beta_0 + \beta_1 \text{predicted } DOLLAR + \beta_2 X_1 + \beta_3 X_2 + \beta_4 X_3 + \beta_5 X_4 + \varepsilon_1 \quad (3)$$

$$DOLLAR = \beta_0 + \beta_1 \text{predicted} STOCK + \beta_2 X_5 + \beta_3 X_6 + \beta_4 X_7 + \beta_5 X_8 + \beta_6 X_9 + \varepsilon_2 \quad (4)$$

As we mentioned earlier, the error terms of regressions (3) and (4) may be auto-correlated. Therefore, we employ the Yule-Walker estimates besides OLS estimates to measure the relationship between the stock market and the currency market in Taiwan.

3.Unit root test

In addition to the short-run relationship between the stock price and the foreign exchange rate, we are also curious about the long-run relationship between these two variables. In this paper, co-integration tests are employed to check if there exists a long-run relationship between the stock market and the currency market.

To check if two data series are co-integrated, first of all we need to test whether these series are integrated of the same order. In other words, we need to figure out the integrated order of data series.

If the level series of a variable (y_t) is stationary, the data series is denoted as $y_t \sim I(0)$. Further, if the first order difference (Δy_t) of a data series is stationary, the data series is denoted as $y_t \sim I(1)$. Generally, Engle and Granger (1987) define that a series y_t, which has a stationary, invertible, ARMA representation after differencing d times, is said to be integration of order d, denoted as $y_t \sim I(d)$.

How can we know whether or not a data series is stationary? The unit root test proposed by Dickey and Fuller (1979) provides us an easy way to check the stationarity of a series. Suppose there is a series, y_t.

$$y_t = \alpha + \rho y_{t-1} + \varepsilon_t, \tag{5}$$

where $\varepsilon_t \sim iid(0,\sigma^2)$. If $\rho = 1$, then $y_t = \alpha + y_{t-1} + \varepsilon_t$, i.e. $\Delta y_t = \alpha + \varepsilon_t$. Obviously, y_t is a random walk series with a drift term α. Hence, y_t is not a stationary series. The Dickey-Fuller test suggests that $H_0 : \rho = 1$ versus $H_1 : \rho \leq 1$ for testing non-stationarity against stationarity. Now equation (5) minus y_{t-1} at both sides yields:

$$\Delta y_t = \alpha + (\rho - 1) y_{t-1} + \varepsilon_t. \tag{6}$$

From equation (6), if y_t is not stationary, the coefficient of y_{t-1} should be greater than or equal to zero. Reparameterizing regression (6) yields:

$$\Delta y_t = \alpha + \lambda y_{t-1} + \varepsilon_t. \tag{7}$$

If $H_0 : \lambda \geq 0$ is rejected i.e. λ is negative and significant, we conclude that the series is stationary.

Furthermore, based on augmented Dickey-Fuller test, we can extend regression (7) by adding a deterministic trend, *t*:

$$\Delta y_t = \alpha + \beta t + \lambda y_{t-1} + \varepsilon_t. \tag{8}$$

Testing the stationarity of a series, we specify the statistics $\tau_{\tau 1}$ for H_0:$\lambda \geq 0$ under regression (7), $\tau_{\tau 2}$ for $H_0 : \lambda \geq 0$ under regression (8), Φ_2 for $H_0 : \alpha = 0$, $\beta = 0$, $\lambda = 0$, and Φ_3 for $H_0 : \beta = 0$, $\lambda = 0$. Note that $\tau_{\tau 1}$ and $\tau_{\tau 2}$ are not *t* statistics and Φ_2 and Φ_3 are not *F* statictics. To check if $\tau_{\tau 1}$ and $\tau_{\tau 2}$ are significant, we need to consult the tables constructed by Dickey (1975) using the Monte Carlo method. For the significance of Φ_2 and Φ_3, we have to consult Dickey and Fuller (1981).

4.Co-integration and error correction

Granger (1981) and Granger and Weiss (1983) define co-integration as follows.

x_t and y_t are said to co-integrated of order *b,d* denoted by $x_t, y_t \sim CI(d,b)$ if (i) $x_t \sim I(d)$ and $y_t \sim I(d)$ and (ii) $z_t = x_t + a y_t \sim I(d-b), b > 0, a \in \Re^1$.

If the stock price and the exchange rate are integrated of the same order, say *d*, and if we can find a linear combination of the stock price and the exchange rate to be integrated of order less than *d*, then we can argue that the stock price and the exchange rate are co-integrated.

Engle and Yoo (1987) suggest that the null hypothesis of no co-integration is rejected if the residual series from the regression of the stock price on the exchange rate or the exchange rate on the stock price is integrated of order less than *d*. Obviously, we can simply employ the unit root test again to check if the residual series is integrated of order less than *d*.

In addition to Engle and Yoo (1987), Engle and Granger (1987) argue that if x_t and y_t are co-integrated, then Δx_t and Δy_t have an error correction representation. The error correction mechanism is:

$$\Delta x_t = \beta_0 + \beta_1 \Delta y_t + \beta_2 e_{t-1} + \varepsilon_t, \tag{9}$$

where e_t is the residual series of the regression of x_t on y_t. Hence, if $\beta 2$ is significantly different from zero, x_t and y_t are co-integrated.

5.Johansen co-integration test

Johansen (1988, 1991) proposes a full-information maximum likelihood analysis of co-integrated systems. Consider the following unrestricted vector autoregression (VAR) involving up to K-lags of Z_t.

$$Z_t = A_1 Z_{t-1} + \ldots\ldots + A\ Z_{t-k} + u_t,$$

$$u_t \sim in(0, \varepsilon),$$

where Z_t is a n×1 vector;[2] A_i is a n×n matrix of parameters.

The equation above can be rewritten as a vector error-correction (VECM) form：

[2] In the case of PPP, Z_t is a 2×1 vector, and Z_t=[$s_t, p_t - p_t^*$]'; in the case of IRP, Z_t is also a 2×1 vector, and Z_t=[$\Delta s_t, r_t - r_t^*$]'.

$$\Delta Z_t = \Gamma_1 \Delta Z_{t-1} + ... + \Gamma_{k-1} \Delta Z_{t-k+1} + \pi Z_{t-k} + u_t ,$$

where, $\Gamma_i = -(I - A_1 - .... - A_i)$, $(i = 1, 2, ..., k-1)$; $\pi = -(I - A_1 - .... - A_k)$.

This way of specifying the system contains information on both the short-run and long-run adjustment to changes in Z_t via the estimates of Γ_i and π.

$$\pi = \alpha\beta'$$

where, α : represents the speed of adjustment to disequilibrium; β : matrix of long-run coefficients such that the term $\beta' Z_{t-k}$ embedded in the VECM up to (n-1).

Co-integration relationships in the multivariate model ensure that Z_t converge to their long-run steady-state solutions.

After estimating the eigenvalues of the canonical correlation Analysis, we are ready to find the number of r linearly independent columns in π, which is equivalent to testing that the last *(n-r)* columns of α are insignificantly small (i.e. effectively zero).

Assuming that the Johansen's maximum likelihood approach to solution this problem amounts to a reduced rank regression which provides n eigenvalues $\hat{\lambda}_1 > \hat{\lambda}_2 > .... > \hat{\lambda}_n$ and their corresponding eigenvectors $\hat{v} = (\hat{v}_1, ..., \hat{v}_n)$. Those r elements in $\hat{v}$ which determine the linear combinations of stationary relationships can be denoted $\hat{\beta} = (\hat{v}_1, ... \hat{v}_r)$.

Combinations and theoretically these are uncorrelated with the stationary elements. Consequently, for the eigenvectors corresponding to the non-stationary part of the model, $\hat{\lambda}_i = 0$, for $i = r+1, ..., n$

$$H_0 : \lambda_i = 0, \quad (i = r+1, ..., n)$$

(first r eigenvalues are not zero)

Test the Null Hypothesis using the trace statistics,

$$\lambda_{trace} = -2\log(Q) = -T \sum_{i=r+1}^{n} \log(1 - \hat{\lambda}_i)$$

$$r = 0, 1, 2 ...., n-2, n-1,$$

where, Q=(Restricted maximized likelihood ÷ unrestricted maximized likelihood).

H_0 : Test for r cointegration vectors against

H_1 : r+1 cointegration vectors

$\lambda_{\max} = -T \log(1 - \hat{\lambda}_{r+1})$,

r=0, 1, 2, …, n-2, n-1.

Data and Descriptive Statistics

This paper measures the relationship between the stock market and the currency market. Generally, the stock market and the currency market are dependent on a group of macroeconomic variables, such as the money supply, interest rate, price index, trade amount and production of the countries. Recently, we find that the stock market declines sharply and NT dollar depreciates significantly relative to US dollar simultaneously. These phenomena are similar to the patterns of Taiwan stock index and NT currency before 1993. For the period after 1993, Taiwan experienced a lot of politic issues such as the missile test from mainland China and presidential elections in Taiwan which may significantly influence the movements of the stock index and NT currency. Therefore, we collect the monthly data of macroeconomic variables of Taiwan over the period of 1986 to 1993 from the AREMOS database provided by Taiwan Economic Data Center. The monthly data of macroeconomic variables of US over the same period are collected from IMF International Financial Statistics.

Each variable is explicitly defined as follows.

1. Stock index of Taiwan: weighted average stock price index with 1966 as the base year.
2. Exchange rate: market exchange rate of NT dollars per US dollar.
3. Short-term interest rate in Taiwan: money market rate on 91-day treasury bills.
4. Money supply of Taiwan: M2 (unit: billion NT$).

5. Price index of Taiwan: consumer price index with 1991 as the base year.
6. Production index of Taiwan: industrial production index with 1991 as the base year.
7. Exports and imports of Taiwan: value of exports and imports in terms of US dollars.
8. Short-term interest rate of US: money market rate on 91-day Treasury Bills.
9. Price index of US: consumer price index with 1985 as the base year.
10. Money supply of US: M2 (unit: billion US$.)
11. Production index of US: industrial production index with 1980 base year.

The descriptive statistics of the variables are reported in Table 1. From Table 1, we find that on average the stock price index is 4,630 with a maximum equal to 11,985 and minimum equal to 856. The exchange rate averages at 20.73 with maximum=39.59 and minimum=24.76. Figure 1 indicates that the NT dollar appreciates over time relative to the US dollar and the stock price index fluctuates dramatically over the empirical period. On average, short-term interest rate of Taiwan is higher than that of the US. The export value is 30% higher than the import value on Taiwan. Basically, the univariate descriptive statistics show no particular relationship between the stock index and the dollar exchange rate.

Table 1 Descriptive statistics

Descriptive statistics for the stock index, money supply, interest rate, price index, trade deficit, export and import in Taiwan, the exchange rate of US dollar, the relative interest rate, relative price level, relative money supply between Taiwan and US. The monthly data are collected from AREMOS database and IMF International Financial Statistics over the period of 1986 to 1993. For each variable series, there are 96 observations.

Variable	Mean	Standard deviation	Minimum	Median	Maximum
Stock index	4,630.47	2,700.99	856.16	4,419.12	11,983.46
Exchange rate (NT $ per US $)	28.73	4.05	24.76	27.18	39.59
Money supply in Taiwan (unit: billion NT$)	5,744.57	2,151.58	2,658.12	5,627.43	10,170.20
Short-term interest rate in Taiwan	7.22	2.36	4.27	6.81	14.67

Consumer price index in Taiwan	95.60	7.51	86.07	93.94	109.34
Trade deficit of Taiwan (unit: million US$)[a]	1,069.61	461.34	-317.98	1,148.15	2,183.16
Relative interest rate between US and Taiwan[b]	1.15	0.48	0.47	0.98	2.17
Relative price level between US and Taiwan[c]	0.81	0.02	0.78	0.80	0.87
Relative money supply between US and Taiwan[d]	1.775	0.520	1.031	1.734	2.837
Relative production index between US and Taiwan[e]	0.74	0.07	0.50	0.73	0.87
Export relative to import in Taiwan[f]	1.30	0.20	0.94	1.25	1.79

[a] The monthly export in US dollar minus the monthly import in US dollar.

[b] One plus the interest rate in Taiwan divided by one plus US interest rate.

[c] Consumer price index in Taiwan divided by the consumer price index in US.

[d] Money supply (M2) of Taiwan divided by the money supply of US.

[e] Industrial production index of Taiwan divided by the industrial production index of US.

[f] The monthly export in US dollar divided by the monthly import in US dollar.

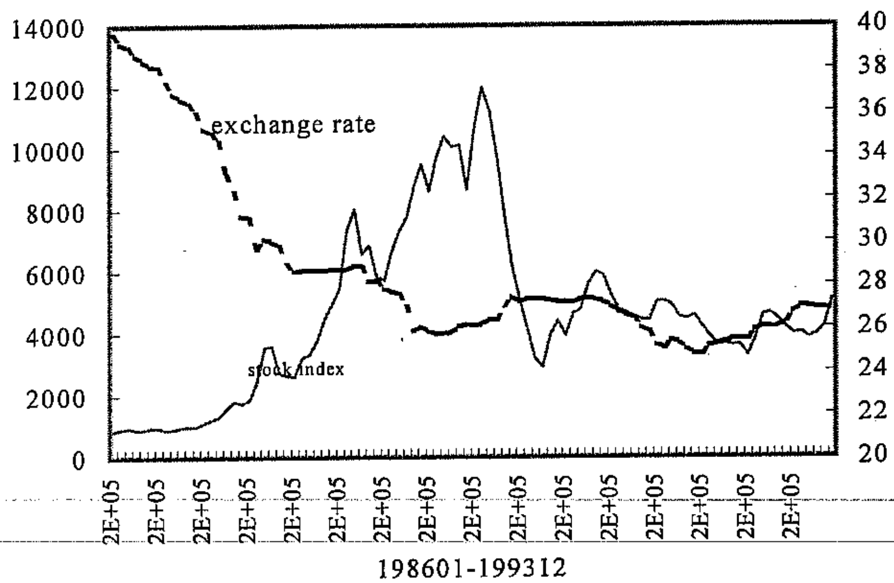

Figure 1 The time series patterns of the exchange rate of NT dollars per US dollar and the stock index of Taiwan over the period of 1986 to 1993.

Empirical Results

Based on the empirical models described in section 2, we report our empirical results in this section. Basically, the empirical study emphasizes on the relationship between the stock market and the currency market both in the short run and in the long run.

1.Classical regression

We employ regression approaches to examine the relationship between two variables. However, the stock price index and the exchange rate may also be related to some other variables. Hence, to avoid spurious effect and to avoid bias, we need to include several control variables in the regression. Nevertheless, with our time series data, we conjecture that the error terms of the regressions might be auto-correlated to make the OLS results inefficient. Therefore, beside OLS estimates, we also provide Yule-Walker estimates to investigate the relationship between the stock price index and the exchange rate. The regression results with stock price and exchange rate as dependent variables are listed in tables 2 and 3, respectively.

Table 2 Regression result with stock index as the dependent variable

Regressions of stock index on the exchange rate, money supply, interest rate, price index, and trade deficit. Yule-Walker estimates are employed for the time series data with autocorrelated errors. 96 monthly data series are collected from AREMOS database and IMF International Financial Statistics over the period of 1986 to 1993. In the parentheses are the p-values. ***, **, and * represent the significance levels of 1%, 5% and 10%, respectively.

Model: Stock index=f(exchange rate, money supply, interest rate, price index,trade deficit)

	OLS estimates	Yule-Walker estimates
Intercept	42994	24531
	(0.000)***	(0.001)***
Exchange rate	-471.409	-488.886
	(0.000)***	(0.000)***
Money supply	0.557	-0.230
	(0.239)	(0.488)
Interest rate	496.874	134.552

	(0.000)***	(0.015)**
Price index	-331.078	-54.709
	(0.007)***	(0.471)
Trade deficit[a]	0.040	-0.187
	(0.923)	(0.259)
R-square	68.49%	30.70%
Estimate of the lag 1 autoregressive parameter: -0.812 (t-ratio=-13.142)		

[a] The monthly export in US dollar minus the monthly import in US dollar.

Table 3 Regression result with exchange rate as the dependent variable

Regressions of the exchange rate on stock index, money supply, interest rate, price index, production and trade. Yule-Walker estimates are employed for the time series data with autocorrelated errors. 96 monthly data series are collected from AREMOS database and IMF International Financial Statistics over the period of 1986 to 1993. In the parentheses are the p-values. ***, **, and * represent the significance levels of 1%, 5% and 10%, respectively.

Model: Exchange rate=f(stock index, interest rate, price level, money supply, production, trade)

	OLS estimates	Yule-Walker estimates
Intercept	-23.676	13.173
	(0.044)**	(0.125)
Stock index	-0.000	-0.000
	(-0.000)***	(0.000)***
Relative interest rate[a]	-0.017	-0.056
	(0.980)	(0.905)
Relative price level[b]	71.469	30.033
	(0.000)***	(0.003)***
Relative money supply[c]	-1.678	-3.975
	(0.050)*	(0.000)***
Relative production[d]	-6.812	-0.108
	(0.047)**	(0.939)
Export relative to import[e]	3.440	0.572
	(0.032)**	(0.472)
R-square	87.12%	68.90%

Estimate of the lag 1 autoregressive parameter: -0.717(t-ratio=-9.658)

[a] One plus the interest rate in Taiwan divided by one plus US interest rate.

[b] Consumer price index in Taiwan divided by the consumer price index in US.

[c] Money supply (M2) of Taiwan divided by the money supply of US.

[d] Industrial production index of Taiwan divided by the industrial production index of US.

[e] The monthly export in US dollar divided by the monthly import in US dollar.

Tables 2 and 3 indicate that the lag one autoregressive parameter of the regression error terms are significant (t-ratio = -13.142 and t = -9.658), which means that Yule-Walker estimates are more efficient than OLS estimates. However, OLS estimates and Yule-Walker estimates reach similar results. That is, even though OLS estimates are less efficient, OLS estimates are still reliable. From Table 2, we find that the stock price is significantly negatively related to the exchange rate, which implies that when the NT dollar appreciates, the Taiwanese stock market booms. Furthermore, table 2 also shows that stock price is positively related to the interest rate. Obviously, when the stock market is hot, the demand of bonds is lower and thus the price of bonds declines, and then the interest rate goes up.

In table 3, we find that the NT dollar depreciates when the stock market declines, when the price level of Taiwan is relatively higher than that of US, and when money supply of Taiwan is relatively lower than that of US. The positive relationship between the exchange rate and the price level is consistent with the concept of purchasing power parity. Further, we argue that when the NT dollar appreciates, import cost should be relative lower than export costs and thus money supply in Taiwan should decline. Hence, the exchange rate is negatively related to the relative money supply.

Generally speaking, the regression results in tables 2 and 3 show that when the NT dollar is expected to appreciate, an amount of foreign currency such as US dollars will flow into Taiwan to invest in the capital market or money market, leading to a "hot" stock market. On the other hand, if Taiwan stock market prices decrease, it is not wise for the foreign investors to invest in the Taiwanese stock market. Since the investments in the Taiwanese stock market decline, the demand for NT dollars shrinks leading to the depreciation of the NT dollar.

2.Simultaneous equation system

When both the stock price and the foreign exchange rate are endogenously determined, they should be estimated simultaneously. Therefore, we challenge that the empirical results in tables 2 and 3 should be biased. To overcome the bias, we also design a simultaneous equation system to measure the relationship between the stock price and the exchange rate through the 2SLS method.

The results of 2SLS are reported in tables 4 and 5. Roughly speaking, we find that the 2SLS results are consistent with those by classical regression approach.

Table 4 Simultaneous regression result with stock index as the dependent variable

2SLS regressions of stock index on the exchange rate, money supply, interest rate, price index, and trade deficit. Yule-Walker estimates are employed for the time series data with autocorrelated errors. 96 monthly data series are collected from AREMOS database and IMF International Financial Statistics over the period of 1986 to 1993. In the parentheses are the p-values. ***, **, and * represent the significance levels of 1%, 5% and 10%, respectively.

Model: Stock index=f(exchange rate, money supply, interest rate, price index, trade deficit)

	OLS estimates	Yule-Walker estimates
Intercept	46127	15080
	(0.000)***	(0.034)**
Exchange rate	-573.609	-289.684
	(0.000)***	(0.002)***
Money supply	0.397	-0.041
	(0.416)	(0.914)
Interest rate	442.480	175.457
	(0.000)***	(0.007)***
Price index	-320.149	-31.180
	(0.010)**	(0.732)
Trade deficit[a]	0.121	-0.192
	(0.770)	(0.333)
R-square	68.23%	25.56%
Estimate of the lag 1 autoregressive parameter: -0.752 (t-ratio=-10.750)		

[a] The monthly export in US dollar minus the monthly import in US dollar.

Table 5 Simultaneous egression result with exchange rate as the dependent variable

2SLS regressions of the exchange rate on stock index, money supply, interest rate, price index, production and trade. Yule-Walker estimates are employed for the time series data with autocorrelated errors. 96 monthly data series are collected from AREMOS database and IMF International Financial Statistics over the period of 1986 to 1993. In the parentheses are the p-values. ***, **, and * represent the significance levels of 1%, 5% and 10%, respectively.

Model: Exchange rate=f(stock index, interest rate, price level, money supply, production, trade)

	OLS estimates	Yule-Walker estimates
Intercept	-22.716	9.771
	(0.072)*	(0.320)
Stock index	-0.000	-0.000
	(0.000)***	(0.000)***
Relative interest rate[a]	0.015	-0.032
	(0.983)	(0.951)
Relative price level[b]	69.842	34.017
	(0.000)***	(0.003)***
Relative money supply[c]	-1.587	-4.051
	(0.072)*	(0.000)***
Relative production[d]	-7.017	0.095
	(0.048)**	(0.952)
Export relative to import[e]	3.768	0.500
	(0.023)**	(0.582)
R-square	86.30%	67.02%
Estimate of the lag 1 autoregressive parameter: -0.689 (t-ratio=-8.929)		

[a] One plus the interest rate in Taiwan divided by one plus US interest rate.

[b] Consumer price index in Taiwan divided by the consumer price index in US.

[c] Money supply (M2) of Taiwan divided by the money supply of US.

[d] Industrial production index of Taiwan divided by the industrial production index of US.

[e] The monthly export in US dollar divided by the monthly import in US dollar.

The stock price index is negatively related to the exchange rate and positively correlated to the relative price level. Moreover, the exchange rate is positively related to the relative price level and negatively related to the relative money supply.

In general, the regression results indicate that the foreign exchange rate of NT dollars per US dollar is negatively correlated with the stock price in Taiwan at least in the short run.

3.Unit root test

Even though there is a relationship between the stock market and the currency market in the short run, we are not sure about their long run relationship. Therefore, we would like to figure out if the stock price index series and the dollar exchange rate series are co-integrated.

Table 6 shows that the level stock index series is definitely not stationary based on all the statistics, $\tau_{\tau 1}$, $\tau_{\tau 2}$, Φ_2 and Φ_3. However, the statistics of $\tau_{\tau 1}$, Φ_2 and Φ_3 indicate that the level series of foreign exchange rate is stationary at the 5% level of significance. Nevertheless, the statistic of $\tau_{\tau 2}$ ($\tau_{\tau 2}$=-1.707) points out that the level series of foreign exchange rate is non-stationary. Therefore, we argue that both the level series of the stock price index and the dollar exchange rate are not stationary.

Table 6 Unit root tests

Unit root tests of the level series and the first order difference series of stock index and exchange rate by Dickey-Fuller test and Augmented Dickey-Fuller test. 96 monthly data series are collected from AREMOS database and IMF International Financial Statistics over the period of 1986 to 1993.

	$\tau_{\tau 1}$ [a]	$\tau_{\tau 2}$ [b]	Φ_2 [c]	Φ_3 [d]
Panel A: Level series				
Stock index	-1.623	-1.413	1.385	1.061
Exchange rate	-4.910	-1.707	13.302	14.215
Panel B: First order difference series				
Δ (Stock index)	-6.704	-6.696	22.445	14.967
Δ (Exchange rate)	-6.825	-8.050	32.411	21.610

[a] The statistic for $\lambda \geq 0$ under $\Delta y_t = \alpha + \lambda y_{t-1} + \varepsilon_t$, where y is the data series of stock index or exchange rate.

[b] The statistic for $\lambda \geq 0$ under $\Delta y_t = \alpha + \beta t + \lambda y_{t-1} + \varepsilon_t$.

[c] The statistic for $\alpha = 0, \beta = 0, \lambda = 0$ under $\Delta y_t = \alpha + \beta t + \lambda y_{t-1} + \varepsilon_t$.

[d] The statistic for $\beta = 0, \lambda = 0$ under $\Delta y_t = \alpha + \beta t + \lambda y_{t-1} + \varepsilon_t$

Since the level series are not stationary, we further difference the level series to examine whether the first order difference series are stationary. Table 6 also reports the results of the unit root tests of the first order difference series of the stock index and the dollar exchange rate. From table 6, we find that all the statistics of $\tau_{\tau 1}$, $\tau_{\tau 2}$, Φ_2 and Φ_3 indicate that the first order difference series of the stock index and the dollar exchange rate are both stationary. Therefore, both the stock index and the dollar exchange rate series are integrated of order one; i.e., stock index ~ *I(1)*, dollar exchange rate ~ *I(1)*.

4.Co-integration

Through the unit root tests, we find that both the stock index series and the dollar exchange rate series are integrated of the same order. Hence, they are possibly co-integrated. Based on Engle and Yoo's argument, we run the regressions of the stock index on the exchange rate and the exchange rate on the stock price index. If the residual series of the regressions are integrated of order less than those of the level series, we can say that the stock price index and the exchange rate series are co-integrated. Since stock index series and dollar exchange rate series are both integrated of order one, we need to check if the residual series of the regressions are integrated of order zero. The results of unit root tests of the residual series are listed in table 7.

In table 7, all the statistics of $\tau_{\tau 1}$, $\tau_{\tau 2}$, Φ_2 and Φ_3 indicate that the residual series of regressions of stock index on dollar exchange rate and dollar exchange rate on stock price index are not stationary. Therefore, the stock price index and dollar exchange rate are not co-integrated according to Engle and Yoo's co-integration test.

Table 7 Engle and Yoo's co-integration test

Engle and Yoo co-integration tests of stock index and exchange rate by testing the stationarity of the residual terms of the regressions of stock index on exchange rate and of exchange rate on stock index. 96 monthly data series are collected from AREMOS database and IMF International Financial Statistics over the period of 1986 to 1993.

	$\tau_{\tau 1}$ [a]	$\tau_{\tau 2}$ [b]	Φ_2 [c]	Φ_3 [d]
	Panel A: Stock index as the dependent variable			
	Model: Stock index= $\alpha_1 + \beta_1$ (exchange rate)+ e_1			
Residual term	-1.620	-1.638	1.353	0.916
	Panel B: Exchange rate as the dependent variable			
	Model: Exchange rate= $\alpha_2 + \beta_2$ (stock index)+ e_2			
Residual term	-2.335	-1.913	2.915	2.500

[a] The statistic for $\lambda \geq 0$ under $\Delta y_t = \alpha + \lambda y_{t-1} + \varepsilon_t$, where y is the data series of error terms of regressions of stock index on exchange rate and exchange rate on stock index.

[b] The statistic for $\lambda \geq 0$ under $\Delta y_t = \alpha + \beta t + \lambda y_{t-1} + \varepsilon_t$.

[c] The statistic for $\alpha = 0, \beta = 0, \lambda = 0$ under $\Delta y_t = \alpha + \beta t + \lambda y_{t-1} + \varepsilon_t$.

[d] The statistic for $\beta = 0, \lambda = 0$ under $\Delta y_t = \alpha + \beta t + \lambda y_{t-1} + \varepsilon_t$

Engle and Granger (1987) argue that if two series are co-integrated, there should exist an error correction mechanism between the series. We also employ Engle and Granger's concept to examine if the stock price index and the dollar exchange rate are co-integrated. The results are reported below.

Δ(stock index)= 7.332	-277.596Δ(exchange rate)	-0.056(residual series 1)+ ε_t
(0.101)	(-1.483)	(-1.682)
Δ(exchange rate)= -0.130	-0.000Δ(stock index)	-0.037(residual series 2)+ ε_t
(-3.607)	(-1.960)	(-3.123)

where residual series 1 is the one period lag residual series of the regression of stock index on the dollar exchange rate; residual series 2 is one period lag the residual series of the regression of dollar exchange rate on the stock index, in the parentheses are the t-values.

Since the residual series 1 is not significant (t=-1.682), the error correction mechanism based on the exchange rate does not cause the stock price index to revise its current level. However, the change of the current level of dollar exchange rate is significantly dependent on the error correction mechanism based on the stock index. Therefore, it is difficult to conclude that the stock price index and the dollar exchange rate are co-integrated either by Engle and Yoo (1987) or by Engle and Granger (1987) measure.

Table 8 reports the results of Johansen co-integration test. In table 8, the λ_{trace} shows that one co-integration equation is significant at 5% level and that there exists at most one co-integration equation. Furthermore, the λ_{max} also indicates one significant (at 1% level) co-integration equation. Therefore, the Johansen co-integration test supports the co-integration relationship between the stock index series in Taiwan and the US dollar exchange rate series.

Table 8 Johansen co-integration test

Johansen co-integration tests of stock index and exchange rate by testing the stationarity of the residual terms of the regressions of stock index on exchange rate and of exchange rate on stock index. 96 monthly data series are collected from AREMOS database and IMF International Financial Statistics over the period of 1986 to 1993.

Series	Likelihood ratio	5% critical value	1% critical value	Hypothesized number of co-integration equation
Panel A: λ_{trace}				
Stock index	25.305	19.96	24.60	None**
Exchange rate	4.972	9.24	12.97	At most 1
Panel B: λ_{max}				
Stock index	20.334	15.67	20.20	0 against 1***
Exchange rate	4.972	9.24	12.97	1 against 2

Panel C: VAR model

$\Delta stock_t$=0.000($Stock_{t-1}$-42593$Dollar_{t-1}$+1214981)+0.304$\Delta stock_{t-1}$-368$\Delta Dollar_{t-1}$-16
$\Delta Dollar_t$=0.000($Stock_{t-1}$-42593$Dollar_{t-1}$+1214981)+0.000$\Delta stock_{t-1}$-0.179$\Delta Dollar_{t-1}$-0.10

Conclusion

Previous studies that work on the relationship between the stock prices and the foreign exchange rate focus on the leading effect of the currency market to the stock market. However, we conjecture that there should exist a bi-directional rather than uni-directional relationship between the currency market and the stock market. Therefore, we design a simultaneous equation system to investigate the short-run relationship. Our results show that when the NT dollar depreciates, the stock market declines. On the other hand, when the stock market booms, the NT dollar appreciates.

Besides the short-run relationship between the stock price index and the dollar exchange rate, we also examine their long-run relationship through co-integration tests. We find that the Taiwanese stock price index is co-integrated with the dollar exchange rate. Therefore, we can set up a long run connection between the Taiwanese stock market and the US dollar currency market.

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