ANALYSIS OF THE BEHAVIOR OF THE NEW ZEALAND DOLLAR EXCHANGE RATE:
Comparison of Four Major Models

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Abstract: *The purpose of this paper is to compare four major exchange rate models. Based on the value of adjusted R^2, the uncovered interest parity model performs best, followed by the purchasing power parity model using the relative PPI, the Mundell-Fleming model, and the monetary model. The unexpected negative sign of the relative money supply in the monetary model and the unexpected negative sign of real money supply and the domestic interest rate in the Mundell-Fleming model suggest that more study is needed to examine the behavior of exchange rate fluctuations for the New Zealand dollar.*

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INTRODUCTION

Since the early 1970s, the USD/NZD exchange rate has fluctuated from 1.1194 in 1971.M1 to a high of 1.4864 in 1973.M10 and a low of 0.4520 in 1986.M5. Since then, it has fluctuated between 0.4 and 0.8. During 2000.M11–2007.M7, it rose 97.04% from a low of 0.3990 to a high of 0.7862. The New Zealand dollar is more volatile than some of the other currencies in the industrialized countries. During July 24–August 16, 2007, partly due to the carry trade, the New Zealand dollar depreciated 16.22% against the U.S. dollar. One possible cause for the trend of a stronger New Zealand dollar may be due to relatively high interest rates that New Zealand has offered in recent years in order to attract international capital inflows. For example, in 2000.M11, interest rates in New Zealand and the U.S. were close. But in 2007.M7, the money market rate in New Zealand was 8.20% compared to 5.26% in the U.S, and the deposit rate in New Zealand was 7.99% compared with the CD rate of 5.32% in the U.S. Other possible reasons for a stronger New Zealand dollar include a lower relative price, a lower relative money supply, a higher relative output, a lower relative expected inflation rate, etc.

This paper attempts to examine the behavior of the New Zealand dollar exchange rate. Since the passage of the Policy Targets Agreement in 1989, New Zealand has set an inflation

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target of 1%-3% in the medium term, suggesting that the exchange rate would be monitored in order to avoid inflationary pressures due to a weak New Zealand dollar. The Reserve Bank of New Zealand has been pursuing a relatively high interest-rate monetary policy. It would be interesting to determine whether a relatively high interest rate would cause the New Zealand dollar to appreciate. It is important to compare the performance of different exchange rate models, understand their strengths and weaknesses, and select the one which would have the minimum forecast error or the highest explanatory power.

The paper has several focuses. First, four different models are considered in determining the behavior of the New Zealand dollar exchange rate. They consist of the purchasing power parity model, the uncovered interest parity model, the monetary model, and the Mundell-Fleming model. Second, in the monetary model, four different versions developed by Dornbusch (1976), Frenkel (1976), Bilson (1978), and Frankel (1979) are compared. Third, comparative-static analysis is applied to determine the impact of a change in an exogenous variable on the equilibrium exchange rate. Fourth, the Newey-West (1987) method is applied in order to address the issue of both autocorrelation and heteroskedasticity when their forms are unknown.

LITERATURE SURVEY

Several studies published by the Reserve Bank of New Zealand explained why the New Zealand dollar appreciated or depreciated and the transmission mechanism of monetary easing or tightening. Brash (1999) indicated that the New Zealand dollar appreciated in the mid-1990s mainly due to a tight monetary policy in response to inflationary pressures, which was caused by the expansionary or inflationary gap showing that aggregate demand was greater than potential output. He also revealed that a 1% appreciation (depreciation) in the trade-weighted exchange rate would reduce (increase) the CPI inflation rate by 0.3%. Brash (2000) attributed substantial depreciation of the New Zealand dollar during 1997 -2000 to large balance of payment deficits, an overvalued currency, lack of convincing reasons to buy the New Zealand dollar assets, and a strong U.S. economy and strong demand for U.S. dollar. Bollard (2003) suggested that a stronger economy, a smaller current account deficit, a higher domestic interest rate, change in investors' expectations, etc. were major reasons for a stronger New Zealand dollar during 2002 and 2003. Drew and Sethi (2007) indicated that a tight monetary policy or a higher official cash rate would raise the short-term wholesale interest rate, which in turn would cause the New Zealand dollar to appreciate. A stronger New Zealand dollar combined with a higher interest rate would cause imports to rise and exports, tradable inflation, general inflation, business investment activities, and output to decline.

Several studies empirically tested the impact of interest rates on exchange rates, the tradeoffs of volatility among exchange rates, inflation rates, interest rates, and output, and other related subjects. Wilkinson, Young, and Young (2001) found that monetary policy cause exchange rate changes for both New Zealand and Australia, that there is little evidence of overshooting, and that the New Zealand dollar exchange rate may depreciate after monetary tightening or move in the opposite direction as the theory would predict. West (2004) showed that there is a tradeoff between real exchange rate volatility and the volatility in other objective variables. His estimates suggest that a 25% decrease in real exchange rate volatility in New Zealand would increase inflation volatility by 0-15%, interest rate volatility by 15-40%, and output volatility

by 10-15%. Munro (2004) used an asset price view to explain exchange rates and showed that fixed asset prices, export commodity prices, interest rates, and a notion of equilibrium can explain a significant portion of exchange rate cycles, but they explain only a small portion of short-term exchange rate movements. He also pointed that the tradeoffs between exchange rate volatility and the volatility in inflation, output, and interest rates are substantial. Zettelmeyer (2004) revealed that a one percentage point increase in the money market rate would lead to an appreciation of the currencies for New Zealand, Australia, and Canada by 2%-3%. He attributed some observed currency depreciation after interest rate increases to reverse causality. Karim, Lee, and Gan (2007) found that monetary tightening by the Reserve Bank of New Zealand would cause the nominal and real effective exchanges rate to appreciate. Lubik and Schorfheide (2007) applied the Taylor-type rules to determine whether monetary policy would respond to inflation, output, and exchange rates and found that New Zealand and Australia do not include exchange rates in their monetary policy functions whereas Canada and the U.K. considered exchange rates in their monetary policy functions

THE MODEL

This section presents four exchange rate models, namely, the purchasing power parity model, the uncovered interest parity model, the monetary model, and the Mundell-Fleming model.

The Purchasing Power Parity Model

In the purchasing power parity model (Taylor, 1988; Fraser, Taylor, and Webster, 1991; Lothian and Taylor, 1996, 2006; Taylor, Peel, and Sarno, 2001; Taylor and Taylor, 2004; Sarno, Taylor, and Chowdhury, 2004; Coakley and Snaith, 2005; Sideris, 2006; Taylor 2006; Sarno and Valente, 2006; Yotopoulos and Sawada, 2006), the nominal exchange rate is a function of the relative price:

$$E = F(P / P^*) \tag{1}$$

where

E   = the NZD/USD exchange rate,

P   = the price level in New Zealand, and

P^* = the price level in the U.S.

The sign of the relative price in equation (1) is expected to be positive, suggesting that a higher relative price would cause the NZD/USD exchange rate to rise and the New Zealand dollar to depreciate against the U.S. dollar.

The Uncovered Interest Parity Model

In the uncovered interest parity model (Edison and Pauls, 1993; Baxter, 1994; Dekle, Hsiao, and Wang, 2001, 2002; Chinn and Meredith, 2004; Sollis and Wohar; 2006; Chen, 2006), under the assumption of perfect capital mobility, the interest rate differential can be offset by the exchange rate depreciation or appreciation. If the domestic interest rate is greater than the foreign interest rate, then the domestic currency is expected to depreciate by the same magnitude. If the domestic interest rate is less than the foreign interest rate, then the domestic currency is

expected to appreciate by the same magnitude. The uncovered interest parity model can be expressed as:

$$R = R^* + (E^e - E) / E \tag{2}$$

where

R = the interest rate in New Zealand,

R^* = the interest rate in the U.S.,

E^e = the expected exchange rate.

Expanding the second term on the right-hand side and moving E to the left-hand side and other terms to the right-hand side in equation (2), in general form, the nominal exchange rate is a function of the interest rate differential and the expected exchange rate:

$$E = H(R - R^*, E^e) \tag{3}$$

The sign of the relative interest rate is expected to be negative, and the sign of the expected exchange rate is expected to be positive, suggesting that when the relative interest rate rises, the New Zealand dollar would appreciate against the U.S. dollar.

The Monetary Model

There are several versions of the monetary model (Meese and Rogoff, 1983; Reinton and Ongena, 1999; Sarno, Valente, and Wohar, 2004; Cheung, Chinn, and Pascual, 2005). A general case of the monetary model (Frankel, 1979) indicates that the nominal exchange rate is determined by the relative money supply, the relative output, the relative interest rate, and the relative expected inflation rate:

$$E = V(M - M^*, Y - Y^*, R - R^*, \pi^e - p^{e^*}) \tag{4}$$

where

M = money supply in New Zealand,

Y = real GDP in New Zealand,

π^e = the expected inflation rate in New Zealand,

M^* = money supply in the U.S.,

Y^* = real GDP in the U.S.,

π^{e^*} = the expected inflation rate in the U.S.

In the Frankel model in equation (4), the nominal exchange rate is expected to have a positive relationship with the relative money supply and the relative expected inflation rate and a negative relationship with the relative output and the relative interest rate. The Dornbusch model and the Bilson model do not include the term of the relative expected inflation rate whereas the Frenkel model does not include the term of the relative interest rate. The sign of the relative interest rate is negative in the Dornbusch model and positive in the Bilson model.[1] The sign of the expected inflation rate is positive in the Frenkel model.

The Mundell-Fleming Model

Extending Romer (2000a), we can express the equilibrium in the goods market and the money market as:

$$Y = Z(Y, R - \pi^e, G, T, \varepsilon) \tag{5}$$

$$M / P = L(Y, R) \tag{6}$$

where

ε = the real exchange rate,

G = real government spending,

T = real government taxes, and

L = the demand for money.

Note that net exports in the aggregate spending function are influenced by the real exchange rate. Solving for Y and ε, we have the equilibrium real exchange rate as:[2]

$$\overline{\varepsilon} = f(M / P, G, T, R, \pi^e) \tag{7}$$

The impact of a change in real money supply, the domestic interest rate, or real government deficit spending on the equilibrium real exchange rate can be written by:

$$\partial\overline{\varepsilon} / \partial(M / P) = -(1 - Z_Y) / |J| > 0, \tag{8}$$

$$\partial\overline{\varepsilon} / \partial R = [L_R(1 - Z_Y) + L_Y Z_R] / |J| > 0, \tag{9}$$

$$\partial\overline{\varepsilon} / \partial(G - T) = (Z_G + Z_T)L_Y / |J| < 0 \tag{10}$$

where $|J|$ is the endogenous-variable Jacobian with a negative value. Thus, the equilibrium real exchange rate is expected to have a positive relationship with real money supply and the nominal interest rate and a negative relationship with real government deficit spending.

EMPIRICAL RESULTS

The data were collected from the *International Financial Statistics* published by the International Monetary fund. The nominal exchange rate is measured as New Zealand dollar per U.S. dollar. In estimating the purchasing power parity model, the relative consumer price index (CPI) and the relative produce price index (PPI) are both considered. In estimating the uncovered interest parity model, the 3-month Treasury bill rate in New Zealand and the 3-month Treasury bill rate in the U.S. are used to measure the interest rate differential. The lagged exchange rate is chosen to represent the expected exchange rate.[3] In estimating the monetary model, M2 money, real GDP, the 3-month Treasury bill rate, and the lagged inflation rate for both New Zealand and the U.S. are used. To avoid a potential high degree of multicollinearity, real government deficit spending is employed in empirical work. In estimating the Mundell-Fleming model, the real exchange rate, real M2, real government deficit spending, the 3-month Treasury bill rate, and the lagged inflation rate are used. The consumer price index is used to derive real M2, real

government spending, and real government tax revenues. Nominal M2, real M2, real GDP, government spending, and government taxes are measured in millions for New Zealand and billions for the U.S. The log scale is used except for variables with negative values. Monthly data are not used because the data for real GDP are available on a quarterly or yearly basis. The sample runs from 1987.Q2 to 2006.Q3.

Unit root tests show that all of these variables have unit roots in the level form and are stationary in the first difference form. The Johansen test reveals that the variables in each of the four models are cointegrated because the value of the trace statistic is greater than the critical value.[4]

Estimated regressions and related statistics are presented in Tables 1. The Newey-West method is applied in empirical work to correct for both autocorrelation and heteroskedasticity when their forms are unknown. Several comments can be made. In the PPP model, the relative PPI can explain 55.6% of the variation in exchange rate movements whereas the relative CPI can explain 5.2% of the variation in exchange rate fluctuations, and the sign of the relative CPI is negative and incorrect.[5]

In the uncovered interest parity model, 94.0% of the behavior of exchange rates can be explained by the two right-hand side variables. Both of the coefficients are highly significant. The negative significant sign of the interest rate differential suggests that when New Zealand raises its domestic interest rate relative to the foreign interest rate, it would attract foreign investors, increase international capital inflows, raise the demand for the New Zealand dollar, and cause the New Zealand dollar to become stronger.

In the monetary model, the nominal exchange rate has a negative relationship with the relative real output and is not affected by the other explanatory variables. The value of adjusted R^2 is 31.5%. The negative sign of the relative money supply is opposite to the expected positive sign. Empirical results suggest that the behavior of the exchange rate cannot be properly characterized by any of the monetary models.[6]

In the Mundell-Fleming model, the real exchange rate has a negative relationship with real M2, and government deficit spending, and the domestic interest rate and a positive relationship with the expected inflation rate. The value of adjusted R^2 is 41.2%. The unexpected negative sign of real M2 money and the domestic interest rate may be partially due to a high degree of multicollinearity.

Several other versions were considered. In the uncovered interest parity model, if the average exchange rate of past four quarters is selected as the expected exchange rate, the value of adjusted R^2 is 84.7%, which is smaller than that when the lagged exchange rate is used. Both the coefficients of the relative interest rate and expected exchange rate are positive and significant at the 1% level. In the monetary model, if the interest rates are measured in the level form, the coefficients of the relative money supply, the relative real output, and the relative interest rate are negative and significant at the 1% or 5% level, and the coefficient of the relative expected inflation rate is positive and insignificant. However, the mean absolute percent error (MAPE) and the root mean squared error (RMSE) are extremely large. Hence, the selection of log or level form for the relative interest rate would affect empirical outcomes.[7] In the Mundell-Fleming

model, if the ratio of government deficit spending to the nominal GDP is selected to replace real government deficit spending, its coefficient is negative and significant at the 1% level, suggesting that more deficit spending as a percent of GDP would cause the real exchange rate to appreciate. Other results are similar.[8]

SUMMARY AND CONCLUSIONS

This paper has examined the behavior of the New Zealand dollar exchange rate against the U.S. dollar. Four different models are considered in empirical work. Based on the value of adjusted R^2, the uncovered interest parity model performs best, followed by purchasing power parity model based on the relative PPI, the Mundell-Fleming model, and the monetary model. The uncovered interest parity model, the purchasing power parity model using the relative PPI, the monetary model, and the Mundell-Fleming model have the estimated mean absolute percent error (MAPE) of 6.89, 7.84, 9.27, and 10.00, respectively.[9] It seems that more sophisticated exchange rate models may not yield a higher value of adjusted R^2 in the explanatory power or a smaller value of the forecasting error.[10]

There are several policy implications. The relatively high interest rate policy that the Reserve Bank of New Zealand has pursued in recent years may have caused a strong New Zealand dollar against the U.S. dollar. On the other hand, the relatively high lending rate in New Zealand may have hurt investment and consumption expenditures. The unexpected negative sign of real M2 and the domestic interest rate in the Mundell-Fleming model and the relative money supply

Table 1
Estimated Regressions for the NZD/USD Exchange Rate

The Purchasing Power Parity Model:

$\text{Log}(E) = 0.615 + 2.799 \, \text{log}(PPI/PPI^*)$ Adj. $R^2 = 0.556$
     (26.724) (6.259)   AIC = -1.822
      SC = -1.762

$\text{Log}(E) = 0.586 - 1.028 \, \text{log}(CPI/CPI^*)$ Adj. $R^2 = 0.052$
     (10.100) (-1.226)   AIC = -1.063
      SC = -1.003

The Uncovered Interest Parity Model:

$\text{Log}(E) = 0.051 - 0.047 \, (\text{log } R - \text{log } R^*) + 0.959 \, (E^e)$ Adj. $R^2 = 0.940$
     (3.110)(-4.637)   (35.853)   AIC = -3.803
      SC = -3.712

The Monetary Model:

$\text{Log}(E) = 5.114 - 0.081 \, (\text{log M-log } M^*) - 4.201(\text{log Y-log } Y^*) + 0.088 \, (\text{log R-log } R^*) + 0.021 \, (\pi^e - \pi^{e*})$
     (4.329) (-1.030)   (-4.109)   (1.383)   (0.902) Adj. $R^2 = 0.315$
      AIC = -1.325
      SC = -1.173

The Mundell-Fleming Model:

$\text{Log}(\varepsilon) = 2.740 - 0.130 \, \text{log}(M/P) - 0.0006 \, (G\text{-}T) - 0.388 \, \text{log}(R) + 0.068 \, \pi^e$ Adj. $R^2 = 0.412$
     (3.473) (-2.101)   (-3.266)   (-5.924)   (2.389)   AIC = -1.309
      SC = -1.157

in the monetary model may suggest that more work needs to be done in the study of exchange rate movements for New Zealand.[11] Both the relative PPI and the relative CPI need to be considered in testing purchasing power parity as the PPI may contain more tradable goods than the CPI.

There may be areas for future research. Monthly data may be considered for the purchasing power parity model in order to obtain more sample observations and determine whether the value of adjusted R^2 may increase and the estimated coefficient may vary significantly. The expected exchange rate plays a significant role in the determination of the exchange rate and may need to be constructed with more advanced methodologies. Different measures of fiscal policy may be considered to determine whether their impacts on the exchange rate may vary. The money demand function in the Mundell-Fleming model may be replaced by the monetary policy reaction function so that the central bank would determine the short-term interest rate based on the inflation gap, the output gap, and other related variables (Romer, 2000b).

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Notes

1. In the Dornbusch model, the expected negative sign of the relative interest rate is due to the focus on the uncovered interest parity model. In the Bilson model, the expected positive sign of the relative interest rate is due to the negative sign of the interest rate in the money demand function.

2. We assume that Y is one of the endogenous variables and does not appear in the equilibrium real exchange rate in equation (7).

3. It is a normal practice to use the lagged exchange rate as a proxy for the expected exchange rate (Hsing, 2007).

4. As Greene (2000, p. 790) indicated, if each of the individual series is I(1) and if a combination of the individual series is I(0), the level form can be used to represent the long-run relationship. The error-correction model has been estimated based on a lag interval of 2. The coefficient of the error-correction term is positive and significant in the PPP model using the relative PPI and the UIP model, negative and significant in the PPP model using the relative CPI, and positive and insignificant in the monetary model and the Mundell-Fleming model. Detailed results will be available upon request.

5. The negative insignificant sign may suggest that the relative CPI is not a good explanatory variable. In the literature, the relative PPI is recommended to be considered partly because the PPI reflects more tradable goods than the CPI does.

6. In monitoring exchange rate movements, policy makers are expected to pay attention to all these four models. Any emphasis on a popular model may not generate desirable outcomes as expected.

7. To be consistent, except for the negative values, all the variables are supposed to be measured in the log scale. On the other hand, if the nominal interest rate in the money demand function is measured in the level form, the relative interest rate will be measured in the level form.

8. This result is consistent with a priori expectations. The real exchange rate has a negative relationship with real money supply and the nominal interest rate and a positive relationship with the expected inflation rate.

9. The non-nested test procedure was considered for the first three models. The results show that the coefficient of the relative CPI is negative and insignificant at the 10% level, that the relative PPI is positive and

insignificant at the 10% level, and that the expected exchange rate is positive and significant at the 1% level.

10. To the author's best knowledge, none of previous studies has compared these four models for other countries.

11. Efforts were made to use M3 monetary aggregate to tackle this problem. The sign is still negative and insignificant.

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