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# Is Monetary Variable a Determinant in the Ringgit-Dollar Exchange Rates Model?: A Cointegration Approach

(Adakah Pemboleh Ubah Monetari Penentu Kepada Model Kadar Pertukaran Ringgit-Dollar?: Satu Pendekatan Kointegrasi)

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ABSTRACT

*The main aim of this paper was to validate the relative price monetary model (RPMM) of exchange rate determination for the Malaysian exchange rate (RM/USD) using monthly data set from 1986-2010. The Johansen multivariate cointegration test and vector error correction model were employed. Because the time period under consideration includes the South East Asian financial crisis, the analysis is done using two time periods; the full time period as well as the period after the crisis. Two interesting results were observed from this empirical exercise. First, there is a long-run relationship between exchange rate and the selected macro variables only for the period after the crisis. Second, the forecasting performance of monetary approach based on the error correction model outperformed the Random Walk model.*

*Keywords: Cointegration; error-correction model; exchange rate; relative price monetary model*

ABSTRAK

*Tujuan utama kertas ini adalah untuk menentusahkan model monetari harga relatif bagi kadar pertukaran ringgit Malaysia (RM/USD) menggunakan data bulanan dari 1986-2010. Ujian multivariat Johansen dan model vector pembetulan ralat digunakan. Oleh sebab tempoh kajian merangkumi masa krisis, maka analisis telah dilakukan ke atas dua tempoh masa; tempoh keseluruhan dan selepas krisis. Dua keputusan telah diperoleh melalui kajian empirik tersebut. Pertama, wujud hubungan jangka panjang antara kadar pertukaran dengan pembolehubah makro hanya pada tempoh masa selepas krisis. Kedua, peramalan menggunakan pendekatan model monetari melalui kaedah vektor pembetulan ralat adalah lebih baik berbanding model pejalanan rawak.*

*Kata kunci: Kadar pertukaran; kointegrasi; model pembetulan ralat; model monetari harga relatif*

## INTRODUCTION

The purpose of this study was to empirically re-examine the relationship between the Ringgit-Dollar exchange rate and a vector of explanatory macro variables using the relative price monetary model fundamental in order to show whether the behavior of this exchange rate supports the monetary model. This paper differs from the previous studies in three aspects; (1) longer period of time is considered which includes the financial crisis in South East Asia (2) the Johansen-Juselius cointegration approach was used to validate the relative price monetary model (RPMM) of exchange rate determination for the Malaysian exchange rate and (3) evaluation and comparison on the forecasting performance of the VECM and the Random walk model is done.

The validity of the monetary model has been examined through a large number of literature over the past three decades. The studies done by Frenkel (1976) and Dornbusch (1979) support the monetary model. In contrast, Rasula and Wilford (1980), Meese and Rogoff (1983) and Backus (1984) used the time period after the 1970s and found no evidence to support the monetary model. Driskill and Sheffrin (1981) also report the poor performance of the monetary model due to the imposition of constraints on relative monies, interest rate and incomes as well as the assumption of Purchasing Power Parity, exogeneity of money supply and uncovered interest rate parity.

Studies by McDonald and Taylor (1992, 1994), Moosa (1994), Choudhry and Lowler (1997), Francis et al. (2001) and Goren (2002) using Johansen-Juselius method have shown support for the monetary model. Other studies such as McNown and Wallace (1994) have applied the cointegration techniques for developing countries (Chile and Argentina) and found support for monetary model.

Bilson (1976) combined the assumption of Purchasing Power Parity (PPP) with the money market and successfully estimated the UK-German exchange rate; he incorporated dynamics into the model via the Bayesian estimation procedure. Frenkel (1976) examined the Mark-Dollar exchange rate during the German hyperinflation based on the PPP. He found that the model satisfied the goodness of fit of variables. Humphrey and Lawler (1977) used the quarterly data and basic monetary model to investigate the behavior of the US-UK and US-Italy exchange rates.

Their results indicate that the model does not represent an accurate explanation of the existing exchange rate regimes.

More recent studies using the cointegration technique found mixed results for the monetary model (Neely and Sarno 2002). Mcnown and Wallace (1989) applied the cointegration technique and found little or no evidence for the monetary approach to the exchange rate determination. Rapach and Wohar (2004) supported the monetary model using panel data procedures. Civcir (2003) applied the Johansen cointegration technique for the Turkish lira/U.S dollar exchange rate and validate the monetary model. To follow the above mentioned studies, this paper therefore proceeds to investigate the Ringgit-Dollar exchange rate determination with a monetary approach using the data from 1986-2010.

Since the monetary model is built on perfect capital mobility, so it is not reasonable that these models hold well in South East Asia countries. Dekle and Pardhan (1996) in their paper argued that in South East Asia there is no evidence of cointegration. A similar specification incorporating a relative price variable is used in Clements and Frenkel (1980), Wolff (1987) and Chinn and Meese (1995).

The main aim of this paper was to validate the relative price monetary model (RPMM) of exchange rate determination for the Malaysian exchange rate (RM/USD) using monthly data from 1986-2010. The organization of this paper is as follow; next section represents the methodology, section three is the data set, finding and results while fourth section concludes the paper.

## THE MONETARY MODEL OF EXCHANGE RATE DETERMINATION

Before we proceed to the monetary approach, the definition of exchange rate is necessary. Exchange rate is defined as the relative price of two monies in two countries, e.g. Ringgit Malaysia over USD. That relative price of monies will be modeled in terms of the relative supply and demand for those monies. In discrete time, monetary equilibrium in the domestic and foreign country is given by:

$$m_t = p_t + ky_t - \lambda i_t, \tag{1}$$

$$m^*_t = p^*_t + ky^*_t - \lambda i^*_t, \tag{2}$$

where $m_t$, $p_t$, $y_t$ and $i_t$ are the log levels of the money supply, price level, income, and the interest rate respectively, at time $t$; $k$ and $\lambda$ are positive constants; Asterisks denote foreign variables and parameters. In the monetary model under the assumption of perfect capital mobility, the real interest rate is exogenous in the long run and is determined in the world markets.

Another building block of monetary model is the absolute purchasing power parity (PPP), which states that the goods market arbitrage will tend to adjust the exchange rate to make the prices to be the same in two countries. The assumption of the monetary model is that the PPP holds continuously, so:

$$e_t = p_t - p^*_t, \tag{3}$$

where, $e_t$ is the log level of nominal exchange rate (The domestic price of the foreign currency). The domestic price level is determined by domestic money supply, and also the exchange rate is determined by relative money supplies. Subtracting equation (3) from equation (2), solving for $(p_t - p^*_t)$ and inserting the result into equation (4) gives the solution for the nominal exchange rate:

$$e_t = (m_t - m^*_t) - (ky_t - k^*y^*_t) + (\lambda i_t - \lambda^* i^*_t). \tag{4}$$

Equation (4) is the fundamental equation for flexible price monetary model. The model can be simplified by assuming that the elasticity of income and interest rate semi-elasticity of demand for money is the same for both countries ($k=k^*$ and $\lambda=\lambda^*$), so that equation (4) can be written as:

$$e_t = (m_t - m^*_t) - k(y_t - y^*_t) + \lambda(i_t - i^*_t). \tag{5}$$

The main assumption of flexible price monetary model is that the purchasing power parity (PPP) holds until an exogenous exchange rate's shock occurs. The sticky-price assumes that goods prices relative to asset prices are adjusted slowly, and thus this model allows deviations from PPP to be slowly damped. Monetary model of exchange rate determination is built on the perfect capital mobility assumption, but it is not reasonable that these models hold well in South East Asia countries. Based on the above mentioned reason for the lack of appropriateness of basic monetary model, the relative price monetary model (Balassa 1964; Chinn 1997; Samuelson 1964) is examined here.

## RELATIVE PRICE MONETARY MODEL

Following Chinn (1997a), the log aggregate price index is given as a weighted average of log price indices of tradable and non-tradable goods:

$$P_t = (1-\alpha)P_t^T + \alpha P_t^N, \tag{6}$$

where $\alpha$ is the share of non-tradable goods in the price index. If the foreign country's price index is constructed by same way, then the relative price monetary model can be represent as follow:

$$\begin{aligned} e_t &= \alpha_1\left(m_t - m_t^*\right) + \alpha_2\left(y_t - y_t^*\right) + \alpha_3\left(i_t - i_t^*\right) + \\ &\alpha_4\left(\pi_t - \pi_t^*\right) + \alpha_5\left[\left(P_t^T - P_t^N\right) - \left(P_t^{T*} - P_t^{N*}\right)\right], \end{aligned} \tag{7}$$

where $\pi$ is the inflation rate. The relative price variable can be determined by any number of factors. In Balassa (1964) and Samuelson (1964), this variable is driven by relative differential in productivity in the tradable and non-tradable sector. The price of tradable goods and non-tradable goods are proxied by *PPI* and *CPI* respectively, so it can be written as follows and abbreviated by (*rp*) hereinafter;

$$\left[\left(P_t^T - P_t^N\right) - \left(P_t^{T*} - P_t^{N*}\right)\right] = Log\left(PPI / CPI\right) - Log\left(PPI * / CPI *\right). \tag{8}$$

## Empirical Methodology

The relative price monetary model of Ringgit-Dollar exchange rates is assessed empirically by cointegration methodology. The Johansen-Juselius (1990) and vector error correction (VEC) modeling techniques are well known and used in applied econometrics. Cointegration technique examines whether a set of variables has a common trend in such a way that the stochastic trend in one variable is related to the stochastic trend in some other variable(s). The Johansen-Juselius approach is used to test for cointegration among the variables

Johansen cointegration analysis involves the estimation of following reduced form of vector error correction model:

$$\Delta z_t = \sum_{t=1}^{k} \Gamma_t \Delta z_{t-i} + \Phi z_{t-1} + \Psi d + \varepsilon_t, \tag{9}$$

where $z_t$ is a vector of non stationary variables. The matrix $\Phi$ has reduced rank equal to $r$ and can be decomposed to $\Phi=\alpha'\beta$, where $\alpha$ and $\beta$ are $p \times r$ full rank matrices and represent adjustment coefficients and cointegrating vectors respectively. d is the vector of deterministic variables which may include constant term, linear trend, seasonal dummies and impulse dummies. The error term is assumed to follow the normal distribution.

In order to find out the number of cointegration relationship among the variables, Johansen-Juselius (1990) provide two different tests, namely trace and maximum eigenvalue tests. In trace test, the null hypothesis assumes that there are at most $r$ cointegrating vectors and it is tested against general alternative. In the maximum eigenvalue test, the null hypothesis of $r$ cointegrating vectors is examined against $r$+1 cointegrating vectors (Civcir 2003).

## Data and Empirical findings

All of the data are collected from International Financial Statistics (Data Stream) based on monthly series from January 1986 to September 2010. Unit root tests were performed on the logarithm form of data set of Ringgit-Dollar exchange rate and the differences of national money supplies, real income, inflation and tradable and non-tradable goods, respectively using the Augmented Dickey Fuller test and Phillips-Perron test procedure. The results of stationary test indicate that all the variables are stationary at first difference, hence cointegration test is performed. Finally, the cointegration test supports the relative price monetary model. The trace and maximum eigenvalue tests are conducted and each test finds at least one cointegrating vector at 5% level, indicating a long-run relationship between RM/USD exchange rate and selected macro variables.

Many financial and economic time series exhibits trending behaviour or non stationarity in their mean such as exchange rates, prices and stock market. An important econometric task is determining the most appropriate form of the trend in the data. If the data are trending, then some form of trend removal is required. In first step ADF and PP unit root tests are applied to check the Stationarity of the data set, as reported in Table 1, all the data are stationary at first difference.

It has to be mentioned that the real exchange rate is used in this study. Since the monthly data is not available for real income, it is proxied by Industrial Production Index (IPI),

TABLE 1. ADF and PP test-statistics for unit root

| Variables | Test | Level | | First difference |
|---|---|---|---|---|
| | | Intercept | Trend, Intercept | intercept |
| Exchange rate | *ADF statistics* | -1.36 | -0.71 | -15.28* |
| | *PP statistics* | -1.50 | -1.10 | -15.47* |
| Money supply | *ADF statistics* | -0.99 | -0.75 | -13.86* |
| | *PP statistics* | -0.91 | -0.86 | -14.08* |
| Real income | *ADF statistics* | -2.27 | -3.47 | -4.68* |
| | *PP statistics* | -2.35 | -5.04 | -33.84* |
| Interest rate | *ADF statistics* | -0.91 | -1.67 | -14.68* |
| | *PP statistics* | -0.96 | -1.66 | -14.69* |
| Inflation | *ADF statistics* | -2.52 | -2.61 | -13.81* |
| | *PP statistics* | -2.26 | -2.33 | -13.58* |
| Relative price | *ADF statistics* | -1.37 | -3.08 | -15.39* |
| | *PP statistics* | -1.43 | -3.20 | -15.43* |

*significant at 1% and 5%, critical values for intercept is -2.87 and for trend & intercept is -3.42 at 5% level federal fund rate is used for interest rate, M2 for money supply, CPI for inflation while the relative price variable is defined earlier. Johansen-Juselius maximum likelihood procedure is used to detect the long-run relationship among the variables and the Schwarz Information Criteria (SIC) suggests a lag length of 1 for the estimated time periods. Relative price monetary model appears to be a valid long-run model of exchange rate determination after the break. The results of trace and maximum eigenvalue tests are reported in Table 2 for the whole data set.

The results indicate that there is one cointegrating vector between exchange rate and macro variables based on maximum eigenvalue and trace tests. However, when we try to find out the long run relationship between the exchange rate and macro variables by vector error correction model, no long-run relationship can be identified since the coefficient of error correction term is not significant. This might be due to the financial crisis in South East Asia during 1997-1998. The results in Table 3 show that, there is no long run relationship between the variables, because the coefficient of error correction term is not significant.

Due to the possibility of break in exchange rate as a result of crisis, Zivot-Andrews (1992) test is applied to detect any break in the exchange rate series during the selected time span. The result indicates a break point at July 1997, so the model is adjusted based on the break date. The second time period is formed from August 1997 to September 2010. Applying the same procedure for detecting the existence of cointegration reveals that there is one cointegrating vector at 5% level. This result supports the relative price monetary model because there is a long-run relationship between the variables based on the significance of the error correction term. Table 4 presents the trace and maximum eigenvalue tests and Table 5 presents the long term as well as short term causal relationship between the exchange rate and selected macro variables.

## LONG TERM AND SHORT TERM CAUSALITY

A unique cointegrating vector between exchange rate and macro variables suggests a single stochastic shared trend. The existence of the long-run relationship lends support

TABLE 2. Cointegration tests for full time period

| $H_0$ | $H_1$ | Test Statistics | | 5% critical Level | |
|---|---|---|---|---|---|
| | | Max. Eigenvalue | Trace | Max. Eigenvalue | Trace |
| r = 0 | r > 0 | 40.53* | 98.55* | 39.37 | 94.15 |
| r = 1 | r > 1 | 29.20 | 58.02 | 33.46 | 68.52 |
| r = 2 | r > 2 | 13.32 | 28.81 | 27.07 | 47.21 |
| r = 3 | r > 3 | 7.93 | 15.49 | 20.92 | 29.68 |
| r = 4 | r > 4 | 5.97 | 7.55 | 14.07 | 15.41 |
| r = 5 | r > 5 | 1.58 | 1.58 | 3.76 | 3.76 |

* Maximum Eigenvalue and Trace statistics indicates one cointegrating vector at 5%

TABLE 3. Coefficient and t-statistic for error correction term for full time period

| Error Correction | *(exr)* | *(ms)* | *(y)* | *(i)* | *(π)* | *(rp)* |
|---|---|---|---|---|---|---|
| $ECT_{t-1}$ | -0.004 | -0.015 | 0.013 | -0.052 | -0.000 | -0.001 |
| *t-statistics* | -0.91 | -5.94 | 1.19 | -1.52 | -0.51 | -0.82 |

TABLE 4. Cointegration Tests after the Crisis (August 1997 to September 2010)

| $H_0$ | $H_1$ | Test Statistics | | 5% critical Level | |
|---|---|---|---|---|---|
| | | Max. Eigenvalue | Trace | Max. Eigenvalue | Trace |
| r = 0 | r > 0 | 87.80* | 155.52* | 39.37 | 94.15 |
| r = 1 | r > 1 | 31.84 | 67.72 | 33.46 | 68.52 |
| r = 2 | r > 2 | 18.48 | 35.87 | 27.07 | 47.21 |
| r = 3 | r > 3 | 14.65 | 17.38 | 20.97 | 29.68 |
| r = 4 | r > 4 | 2.67 | 2.72 | 14.07 | 15.41 |
| r = 5 | r > 5 | 0.05 | 0.05 | 3.76 | 3.76 |

* Maximum Eigenvalue and Trace statistics indicates at least one cointegrating vector

TABLE 5. VECM result-After Crisis (August 1997 to September 2010)

| Dependent Variable: | *D(exr)* | *D(ms)* | *D(y)* | *D(i)* | *D(π)* | *D(rp)* |
|---|---|---|---|---|---|---|
| $ECT_{t-1}$ | -0.207 | -0.032 | -0.056 | 0.475 | -0.002 | -0.050 |
| | (-8.33)* | (-2.60)* | (-1.45) | (3.27*) | (-0.56) | (-4.50*) |
| *Constant* | 0.000 | 0.003 | 0.006 | 0.010 | 0.000 | 0.000 |
| | (0.28) | (2.90) | (1.938) | (0.83) | (0.07) | (0.69) |
| *D(exr(-1))* | 0.068 | -0.030 | -0.242 | 0.646 | 0.025 | 0.028 |
| | (0.98) | (-0.87) | (-2.22)* | (1.60) | (1.85) | (0.91) |
| *D(ms(-1))* | 0.144 | 0.211 | -0.438 | -0.881 | -0.013 | 0.095 |
| | (0.90) | (2.64)* | (-1.76) | (-0.95) | (-0.42) | (1.34) |
| *D(y(-1))* | 0.071 | -0.000 | -0.534 | -0.317 | -0.004 | 0.003 |
| | (1.69) | (-0.01) | (-8.17)* | (-1.30) | (-0.51) | (0.16) |
| *D(i(-1))* | 0.020 | -0.004 | -0.040 | 0.335 | 0.002 | 0.003 |
| | (1.65) | (-0.64) | (-2.08)* | (4.60)* | (0.86) | (0.64) |
| *D(π(-1))* | -0.560 | 0.414 | -1.340 | 1.662 | 0.231 | -0.322 |
| | (-1.21) | (1.78) | (-1.85) | (0.61) | (2.58)* | (-1.57) |
| *D(rp(-1))* | -0.593 | -0.024 | -0.434 | -0.027 | 0.001 | 0.031 |
| | (-3.08)* | (-0.24) | (-1.44) | (-0.02) | (0.03) | (0.37) |
| $R^2$ | 0.35 | 0.11 | 0.37 | 0.22 | 0.09 | 0.16 |
| *SE* | 0.02 | 0.01 | 0.03 | 0.14 | 0.00 | 2.02 |
| *DW* | 2.02 | 1.99 | 2.46 | 1.62 | 1.99 | 0.01 |

* Significance at 5% level, t-statistics are in brackets.

Note: D=first difference, (-1) = one period lag.

to the relative price monetary model as an explanation of exchange rate behavior over the time span. The significance of the lag error correction term suggests a long-term causality from all variables in the RPMM towards the exchange rate. The value of the coefficient of the error correction term (-0.20) shows that 20% of the adjustment towards the long-run equilibrium takes place per month.

The results from the VEC model in Table 5 also present the short term dynamics among the variables. It is of interest to note that there is empirical evidence showing that relative price Granger cause exchange rate in the short run and the direction of causality is unidirectional. Furthermore, both exchange rate and interest rate Granger cause real income in the short run. The diagnostic tests have been applied to the VECM and the model satisfied the tests. The results on these diagnostic tests are available upon request.

## FORECASTING

Finally, we examine the adequacy and validity of the estimated VECM (exchange rate as dependent variable) by assessing the out of sample forecasting performance. The vector error correction model is estimated by using 90 percent (train sample) of the data set namely from August 1997 through the May 2009 and then forecast the remaining 10 percent (test sample) namely from June 2009 to September 2010. The dynamic forecast is applied in which the value of the predicted of exchange rate is incorporated back into the model. For comparison, the random walk model is also used to forecast the exchange rate over the same sample size for estimation and forecasting. Some researchers argued that random walk is the best model for exchange rate prediction (Frankel & Rose 1994; Meese & Rogoff 1983, Meese & Rose 1991). In the other hand, evidence that monetary models can consistently and significantly outperform the random walk model is still elusive (Mark & Sul 2001; Rapach & Wohar 2002). Due to the lack of consensus in the literature, once again the superiority of random walk over monetary models or vice versa is examined here. Random walk model can be written as follows:

$$y_t = y_{t-1} + \varepsilon. \tag{10}$$

Based on the random walk equation, the future value of a variable is depending on the previous value of that variable. In above random walk equation we assumed that there is no drift term in the model. The estimation result of random walk model is presented in Table 6.

As it can be seen from Table 6, the random walk model is also adequate to forecast the exchange rate. In order to compare and evaluate the forecasting performance of relative price monetary model and random walk, four common criteria is applied here and represented in Table 7.

In the formula presented in Table 7 above, $F$ denotes the forecasted value and $X$ is the actual value, RMSE and MAE criteria depend on the scale of the dependent variable. These should be used as relative measures to compare the forecast value for the same series across different

TABLE 6. Random walk estimation results

| Variable | *coefficient* | *Std. error* | *t-statistic* | *Prob.* |
|---|---|---|---|---|
| *Exr(-1)* | 0.8957 | 0.0258 | 34.60 | 0.0000 |
| *R-squared* | 0.8952 | | | |
| *F-statistic* | 1197.60 | | | |
| *Prob(F-stat.)* | 0.0000 | | | |

TABLE 7. Performance comparison criterion

| Criteria | Formula |
|---|---|
| *Root Mean Square Error* | $RMSE = \sqrt{\sum_{i=1}^{n} (F_t - X_t)^2 / n}$ |
| *Mean Absolute Error* | $MAE = [\sum_{t=1}^{n} \lvert F_t - X_t \rvert] / n$ |
| *Mean Absolute Percentage Error* | $MAPE = [\sum_{t=1}^{n} \left\lvert \frac{F_t - X_t}{X_t} \right\rvert] / n \times 100$ |
| *Theil's U statistics* | $U = \sqrt{\frac{\sum_{t=1}^{n} (F_t - X_t)^2}{n}} / [\sqrt{\frac{\sum_{t-1}^{n} (X_t)^2}{n}} + \sqrt{\frac{\sum_{t=1}^{n} (F_t)^2}{n}}]$ |

models; the smaller value means the better the forecasting performance of that model. MAPE and Theil's U are scale invariant. The Theil's U lies between zero and one where zero indicates a perfect fit. Applying the RPMM and random walk model for exchange rate prediction provides the values for the performance comparison criterion as presented in Table 8. The results indicate the superiority of RPMM over random walk model based on the selected forecasting performance criteria.

TABLE 8. Performance comparison for two models

| Model | RMSE | MAE | MAPE | Theil's U |
|---|---|---|---|---|
| VECM | 0.04861 | 0.03756 | 3.04675 | 0.01990 |
| RW | 0.13060 | 0.11283 | 9.5595 | 0.051722 |

## CONCLUSION

In this paper, we examined the validity of the relative price monetary model (RPMM) of exchange rate determination by using cointegration test and VECM techniques to find out the relationship between RM/USD exchange rate from 1986 to 2010. This paper differs from the previous studies in at least three ways (1) longer period of time is considered which includes the financial crisis in South East Asia, (2) the Johansen-Juselius cointegration approach is used to validate the relative price monetary model (RPMM) of exchange rate determination for the Malaysian exchange rate, and (3) evaluation and comparison on the forecasting performance of the VECM and the Random walk model is done.

The application of Johansen-Juselius procedure using the time period after the crisis (August 1997 to September 2010) indicated a unique cointegrating vector. This implies that there was a long-run relationship between RM/USD exchange rate and real income, money supply, interest rate, inflation and relative price variables. The error correction term showed that 20% of the adjustment towards long-run equilibrium was borne by exchange rate. In addition, there was a unidirectional short term causality from relative price variable to exchange rate. Finally, the prediction performance of the monetary model based on VECM showed the better performance of this model compared with Random Walk. Overall, our results once again confirmed the validity of the long run relationship in RM/USD exchange rate using the relative price monetary model.

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