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A Vector Error Correction Model (VECM) Approach in Explaining the Relationship Between Interest Rate and Inflation Towards Exchange Rate Volatility in Malaysia

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Abstract: The exchange rate is one of the most important determinants of a country's relative level of economic health. Exchange rate plays a vital role in a country's level of trade, which is critical to most free market economies in the world. This paper is an attempt to analyze the relationship between interest rate, inflation rate and exchange rate volatility in Malaysia covering the period between 1999-2009. This paper used time-series Vector Error Correction Model (VECM) approach of stationarity test, cointegration test, stability test and Granger causality test. Impulse Response Function (IRF) has also been generated to explain the response to shock amongst the variables. The results show that the inflation rate impacts the interest rate as indicated by Granger-cause. Subsequently the interest rate influences the exchange rate as shown by the Granger cause test. Taking into account a long term relationship, interest rate moves positively while inflation rate goes negatively towards exchange rate volatility in Malaysia. The implication of this study is that increasing the interest rate can be efficient in restraining exchange rate volatility. Future researchers should attempt to use panel data and cover longer study duration of above10 years by using other variables.

Key words: Exchange rate · Interest rate · Inflation rate · Vector Error Correction Model (VECM) · Impulse Response Function

INTRODUCTION

Exchange rates play a vital role in a country's level of trade, which is critical to most every free market economies in the world. For this reason, exchange rates are among the most watched analyzed and governmentally manipulated economic measures[1] and most countries attempted to moderate their domestic currency fluctuations by imposing regulatory restrictions on exchange rate movements [1]. However, controlling the exchange rate could be very costly and even become pointless, when speculators attack a currency, even under government protection. High interest rate will prevent capital outflows, hinder economic growth and, consequently, hurt the economy [2].

In July 1997, financial crisis has gripped much of Asia. The crisis started in Thailand with the financial collapse of the Thai baht caused by the decision of the Thai government to float the baht, cutting its peg to the USD, after exhaustive efforts to support it in the face of a severe financial over extension that was in part real estate driven [3]. Malaysia was also under “attacked” by speculators within days of the Thai baht devaluation. Then the premier, Mahathir Mohammad imposed strict capital controls and introduced a MYR3.80 peg against the US dollar.

Therefore, it would be interesting to explore the factors of exchange rate volatility in Malaysia. The study intended to look at the factors of exchange rate movements in Malaysia. In linking exchange rate changes with changes in interest and inflation rates, the International Fisher Effect theory states that the future spot rate of exchange can be determined from nominal interest differential. According to [4], the differences in anticipated inflation that are embedded in the nominal interest rates are expected to affect the future spot rate of exchange.

[1] Bergen, J.V., 2003. Six factors that influence Exchange rates. Retrieved March 10, 2011 from http://www.investopedia.com/articles/basics/04/050704.asp

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An exchange rate has been defined by [5] as a relative price of two national monies. More specifically, it can be stated that the exchange rate is the ratio between a unit of one currency and the amount of another currency for which that unit can be exchanged at a particular time. The macroeconomic analysis of exchange rate volatility starts with [6] Optimal Currency Area hypothesis. He shows that countries with relatively large bilateral trade and countries with correlated economic shocks might benefits from a common currency. According to the fitted GARCH (Generalized Auto-Regressive Conditional Heteroscedasticity) models, the exchange rate variance is persistent and serially correlated [7, 8]. Thus current and past volatility of exchange rates can be used to predict future volatility. However, trajectories with nearly identical initial conditions can differ a lot from each other [9].

There is, indeed, a substantial amount of research about the effects of volatility of a country's own real exchange on certain macroeconomic variables. Higher volatility of the real exchange rate hurt exports in a large group of developing countries [10]. Recent and stronger evidence of a negative impact of exchange rate volatility on trade flows can be found in [11] and [12]. While [13] suggested that the financial variables such as external debt also affect optimal exchange rate volatility.

It is an explanatory variable that explained the sensitivity of the exchange rate due to the changes in interest rate. The more popular intervention tool in the exchange rate is changing interest rate [14]. Irving Fisher, an American economist, developed a theory relating exchange rates to interest rates. Interest rate differentials tend to reflect exchange rate expectations which also known as Fisher Effect. In a study by [15], The International Fisher Effect (IFE) theory explained the derivation of relationship of the actual return to investors in home country is the foreign interest rate and the change in the foreign currency value [16].

Most studies have been tested and analyzed the influence of interest rate differentials on change in exchange rates based on the IFE theory and previous studies [4] therefore [1] states that high real interest rate is successful in curbing exchange rate volatility. According to the journal written by [17], The common external factors influencing the stock return would be stock prices in global economy, the exchange rate and the interest rate, for instance, capital inflows are not determined by domestic interest rate only but also by changes in the interest rate by major economies in the world. Thus, the single economy evidence revives the more reasonable hypothesis that exchange rate volatility is fundamentally negatively correlated with interest rate.

An empirical study [18] by using existence of threshold effects in the relationship between inflation rate and growth rate of GDP in the context of Malaysia shows that below the threshold level, there is a statistically significant positive relationship between inflation rate and growth. New evidence from a Dynamic Panel Threshold Analysis by [19], applying the dynamic panel threshold model to the analysis of thresholds in the inflation-growth nexus.They provided new evidence on the non-linear relationship between inflation and long-term economic growth. However, the correlation remains insignificant.

Generally, the inflation rate is used to measure the price stability in the economy. Conceptually, [20] through his survey shows the inflation can be divided into two sides, namely: demand side inflation (demand pull inflation) and supply side inflation (cost push inflation). In a study by [21], it is shown that money growth rate and inflation rate have a positive relationship. The changes in exchange rates do not affect the inflation rate in ASEAN, except Thailand [22]. On the other hand, [23] empirically found the relationships between inflation and the real exchange rates in most countries of Asia and Latin America. In the case of Malaysia, [24] found the exchange rate is an important determinant of inflation in the country. However, [25], who examine inflation in six Asian countries found that the growth of money stock is not the primary source of inflation in these countries. The impact of exchange rate also related to the imports and exports for the country. Referred to the journal written by [26] the study examines the significant impact of exchange rate shock on prices of Malaysian imports and exports. It is found that inflation in a number of industrial and developing countries has remained surprisingly stable in the face of wide swings in exchange rate. A research by [27] found that the relationship between inflation rates differentials and exchange rates is not perfect even in the long run, but it supports the use of inflation differentials to forecast long-run movements in exchange rates.

MATERIALS AND METHODS

Theoretical Model: The identified model is three variable models which hypothesize that exchange rate as a function of interest rate and inflation rate.

$$EXC_t = F\ (IR_t, INF_t) \quad (1)$$

Where, EXC represents monthly exchange rate in Malaysia (RM/USD), IR represents monthly interest rate, INF represents inflation rate where t-sign represents time trend. The sample consists of 132 monthly data from 1999 to 2009 and was obtained from Bank Negara Malaysia (BNM) Statistical Report website. The data on exchange rate is valued in rate while data on interest rate and inflation rate are valued in percent. All data then being converted into log-log equation for time series processing. Thus, the coeeficient can be interpreted as an elasticity.

Stationarity Test: Stationarity of a series is an important phenomenon because it can influence its behaviour. If *x* and *y* series are non-stationary random processes (integrated), then modelling the *x* and *y* relationship as a simple OLS relationship as in equation 2 will only generate a spurious regression.

$$Y_t = \alpha + \beta X_t + \varepsilon_t \quad (2)$$

Time series stationarity is the statistical characteristics of a series such as its mean and variance over time. If both are constant over time, then the series is said to be a stationary process (i.e. is not a random walk/has no unit root), otherwise, the series is described as being a non-stationary process (i.e. a random walk/has unit root). Differencing a series using differencing operations produces other sets of observations such as the first-differenced values, the second-differenced values and so on.

x level	x_t
x 1st-diiferenced value	$x_t - x_{t-1}$
x 2nd-diiferenced value	$x_t - x_{t-2}$ (3)

If a series is stationary without any differencing it is designated as I (0), or integrated of order 0. On the other hand, a series that has stationary first differences is designated I (1), or integrated of order one (1). Augmented Dickey-Fuller test suggested by [28] and the Phillips-Perron test recommended by [29] have been used to test the stationarity of the variables.

Johansen and Juselius Cointegration Test: [30] procedures uses two tests to determine the number of cointegration vectors: the Maximum Eigenvalue test and the Trace test. The Maximum Eigenvalue statistic tests the null hypothesis of r cointegrating relations against the alternative of r+1 cointegrating relations for r = 0, 1, 2…n-1. This test statistics are computed as:

$$LR_{\max}(r/n+1) = -T * \log(1-\hat{\lambda}) \quad (4)$$

Where λ is the Maximum Eigenvalue and T is the sample size. Trace statistics investigate the null hypothesis of r cointegrating relations against the alternative of n cointegrating relations, where n is the number of variables in the system for r = 0, 1, 2…n-1. Its equation is computed according to the following formula:

$$LR_{tr}(r/n) = -T * \sum_{i=r+1}^{n} \log(1-\hat{\lambda}_i) \quad (5)$$

In some cases Trace and Maximum Eigenvalue statistics may yield different results and [31] indicates that in this case the results of trace test should be preferred.

Vector Error Correction Model (VECM): If cointegration has been detected between series we know that there exists a long-term equilibrium relationship between them so we apply VECM in order to evaluate the short run properties of the cointegrated series. In case of no cointegration VECM is no longer required and we directly precede to Granger causality tests to establish causal links between variables. The regression equation form for VECM is as follows:

$$\Delta Y_t = \alpha_1 + p_1 e_1 + \sum_{i=0}^{n} \beta_i \Delta Y_{t-i} + \sum_{i=0}^{n} \delta_i \Delta X_{t-i} + \sum_{i=0}^{n} \gamma_i Z_{t-i}$$
$$\Delta X_t = \alpha_2 + p_2 e_{i-1} + \sum_{i=0}^{n} \beta_i Y_{t-i} + \sum_{i=0}^{n} \delta_i \Delta X_{t-i} + \sum_{i=0}^{n} \gamma_i Z_{t-i} \quad (6)$$

In VECM the cointegration rank shows the number of cointegrating vectors. For instance a rank of two indicates that two linearly independent combinations of the non-stationary variables will be stationary. A negative and significant coefficient of the ECM (i.e. *et-1* in the above equations) indicates that any short-term fluctuations between the independent variables and the dependant variable will give rise to a stable long run relationship between the variables.

Granger-Causality: A general specification of the Granger causality test in a bivariate (X, Y) context can be expressed as:

$$Yt = \alpha 0 + \alpha 1Yt\text{-}1 + \ldots\ldots + \alpha iYt\text{-}i + \beta 1Xt\text{-}1 + \ldots\ldots\ldots \beta iXt\text{-}i + \mu \quad (7)$$

$$Xt = \alpha 0 + \alpha 1Xt\text{-}1 + \ldots\ldots + \alpha iXt\text{-}i + \beta 1Yt\text{-}1 + \ldots\ldots\ldots \beta iYt\text{-}i + \mu \quad (8)$$

In the model, the subscripts denote time periods and μ is a white noise error. The constant parameter "0 represents the constant growth rate of Y in the equation 7 and X in the equation 8 and thus the trend in these variables can be interpreted as general movements of cointegration between X and Y that follows the unit root process. We can obtain two tests from this analysis: the first examines the null hypothesis that the X does not Granger-cause Y and the second test examines the null hypothesis that the Y does not Granger-cause X. If we fail to reject the former null hypothesis and reject the latter, then we conclude that X changes are Granger-caused by a change in Y [32]. Unidirectional causality will occur between two variables if either null hypothesis of equation (7) or (8) is rejected. Bidirectional causality exists if both null hypotheses are rejected and no causality exists if neither null hypothesis of equation (7) nor (8) is rejected [33].

RESULTS AND DISCUSSION

Stationarity Test: It is clear from Table 1 that the null hypothesis of no unit roots for all the time series are rejected at their first differences since the ADF and PP test statistic values are less than the critical values at 1% levels of significances. Thus, the variables are stationary and integrated of same order, i.e., I (1). However, the application of the ADF and PP tests for IR revealed that this variable is stationary in both its levels and its first differences. In this case, IR does not need no differencing, just the log transformation. In short, all the variables became stationary and do not contain unit root in first difference.

Determination of Lags: As proposed by [34], he used lowest SBIC value as primary concern. Table 2 reports lag-order selection statistics. The result shows lags order at two. So, we precede further tests with lags (2).

Cointegration Test: Cointegration rank (rank of matrix Đ) is estimated using Johansen methodology. Johansen's approach derives two likelihood estimators for the CI rank: a trace test and a maximum Eigen value test.

Table 1: ADF and PP unit root tests

	ADF		PP	
Series	Level	First Difference	Level	First Difference
EXC	-0.840	-9.710^{***}	-1.078	-9.723^{***}
IR	-3.805^{***}	-7.043^{***}	-3.785^{***}	-7.016^{***}
INF	-2.823	-6.012^{***}	-3.106	-5.516^{***}

*Notes: ***denote significant at 1% using t-stat approach*

Table 2: Lag-order selection criterion

Selection-order criteria
Sample: 1999m5 - 2008m11 Number of obs = 115

lag	LL	LR	df	p	FPE	AIC	HQIC	SBIC
0	295.213				1.2e-06	-5.08196	-5.0529	-5.01086
1	675.3	760.17	9	0.000	2.0e-09	-11.5357	-11.4194	-11.2492
2	720.313	90.025	9	0.000	1.0e-09	-12.162	-11.9585*	-11.6607*
3	734.013	27.399*	9	0.001	9.7e-10*	-12.2437*	-11.953	-11.5276
4	742.168	16.311	9	0.061	9.8e-10	-12.229	-11.8512	-11.2981

Endogenous: lnexc lnir lninf
Exogenous: _cons

Table 3: Results of co-integration tests

Johansen tests for cointegration
Trend: constant Number of obs = 117
Sample: 1999m3 - 2008m11 Lags = 2

maximum rank	parms	LL	eigenvalue	trace statistic	5% critical value
0	12	646.96776	.	73.1428	29.68
1	17	676.71101	0.39856	13.6563*	15.41
2	20	683.00504	0.10200	1.0682	3.76
3	21	683.53914	0.00909		

The CI rank (R) can be formally tested with the trace and the maximum Eigen value statistics. The results are presented in Table 3. The trace statistic either rejects the null hypothesis of no co-integration among the variables or does not reject the null hypothesis that there is one co-integration relation between the variables. Start by testing H_0: r = 0. If it rejects, repeat for H_0: r = 1. When a test is not rejected, stop testing there and that value of r is the commonly-used estimate of the number of cointegrating relations. In this test, H_0: r = 1 is not rejected at the 5% level (13.66 < 15.41). In other words, this trace test result does not reject the null hypothesis that these three variables are not cointegrated. The final number of cointegrated vectors with two lags is equal to one, i.e. rank (π) =1. Since, the rank is equal to 1 which is more than zero and less than the number of variables; the series are cointegrating among the variables. Nevertheless, we will proceed to estimate the VECM model.

Table 4: Vector Error Correction Model

Cointegrating equations

Equation	Parms	chi2	P>chi2
_ce1	2	83.25984	0.0000

Identification: beta is exactly identified
Johansen normalization restriction imposed

beta	Coef.	Std. Err.	z	P>|z|	[95% Conf.	Interval]
_ce1						
lnexc	1	.	.	.	.	.
lnir	.7982871	.0887773	8.99	0.000	.6242867	.9722875
lninf	-.1075532	.0349283	-3.08	0.002	-.1760114	-.039095
_cons	-2.138215	.	.	.	.	.

Vector Error Correction Model: The presence of cointegration between variables suggests a long term relationship among the variables under consideration. Then, the VEC model can be applied. The long run relationship between exchange rate, interest rate and inflation for one cointegrating vector for the Malaysia in the period 1999-2009 is displayed below (standard errors are displayed in parenthesis).

$$EXC = 0.7983\ IR - 0.1075\ INF - 2.1382 \quad (0.0888) \quad (0.0349) \tag{9}$$

In Table 4, all the coefficients were significant at 1% level of significance. According to[2] when the variables are in logarithms and one cointegrating vector is estimated, the coefficients can be interpreted as long run elasticities. The appreciations of the exchange rate are related to increasing interest rate, thus, the estimated model was able to produce a consistent result. Thus, 1% appreciation of the interest rate is likely to increase exchange rate by 0.7983% and this estimate was significant. Commonly believed; in the long run, inflation found to be detrimental to exchange rate changes. For 1% increase in inflation, exchange rate is reduced by .1075%, this coefficient was significant at 1% level of significance. Generally, the result of the EXC equation as shown above is found to be satisfactory in terms of correct signs. It is seen that interest rate has correct positive sign with the exchange rate relationship.

Based on [6], the higher interest differential would attract capital inflows and result in exchange rate appreciation. Higher interest rates offer lenders in an economy a higher return relative to other countries. Therefore, higher interest rates attract foreign capital and cause the exchange rate to rise. The impact of higher interest rates is mitigated, however, if inflation in the country is much higher than in others, or if additional factors serve to drive the currency down. Inflation also gives correct sign between the relationships with exchange rate, which is negative relationship. As a general rule, a country with a consistently lower inflation rate exhibits a rising currency value, as its purchasing power increases relative to other currencies. During the last half of the twentieth century, the countries with low inflation included Japan, Germany and Switzerland, while the U.S. and Canada achieved low inflation only later. Countries with higher inflation typically see depreciation in their currency in relation to the currencies of their trading partners [36].

Granger Causality Tests: Recall that although co-integration between two variables does not specify the direction of a causal relation, if any, between the variables. Economic theory guarantees that there is always Granger Causality in at least one direction [37]. Researchers verify the direction of Granger Causality between EXC, IR and INF. Estimation results for granger causality between the very variables are presented in Table 5. The study by [32] used chi-square statistics and probability to measure causality between the variables. Chi-Square statistics and probability values constructed under the null hypothesis of non causality show that there is a causal relationship between those variables.

Table 5 provides the results of pair wise analyses. Significant probability values denote rejection of the null hypothesis. This study reject the null hypothesis if the probability value is more than 1% otherwise do not reject the null hypothesis if the probability value is less than 1%. It is found that INF "Granger cause" EXC unidirectional at the 1% significance level. It means that EXC follow its mature counterparts in the short-run that there exists a lead-lag relationship between them. The causality test also tested between two independent variables. There is unidirectional causality running from IR to INF, implying that past values of interest rate have a predictive ability in determining the present values of inflation. This results also supported by many investors and economists in Turkey. They believe that any changes in nominal interest rate will cause a change in inflation. Research by [32] also shows interest rate Granger cause inflation. On the other hand, there is no causality in either direction between these series and between IR and EXC. This finding can be explained by the changes in the short term interest rate and it cannot reflect on the changes of exchange rate movement and vice versa.

[2]The Forces Behind Currency Exchange Rates, retrieved January 7, 2011 from http://www.currencynews.ws/? p=75 2009

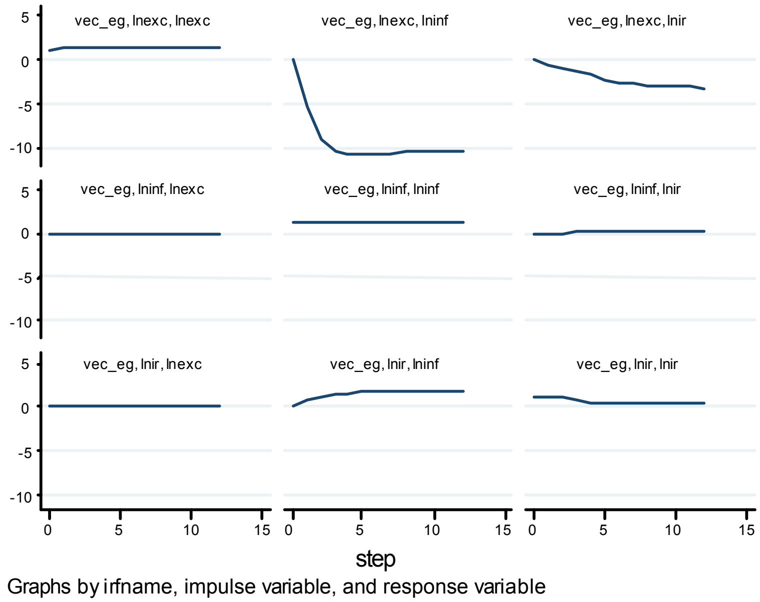

Fig. 1: Impulse-Response Functions

Table 5: Granger Causality Test

Null Hypothesis	χ^2	Probability	Decision
EXC does not Granger-cause IR	0.09	0.7646	Do not reject
IR does not Granger-cause EXC	1.24	0.2647	Do not reject
EXC does not Granger-cause INF	0.00	0.9856	Do not reject
INF does not Granger-cause EXC	6.71	0.0096***	Reject
IR does not Granger-cause INF	8.19	0.0042***	Reject
INF does not Granger-cause IR	1.19	0.2748	Do not reject

Notes: ***denote significant at 1%

Impulse Response Function (IRF): The study uses impulse response function as an additional check of the Cointegration test's findings. Followed by [37], Cholesktype of contemporaneous identifying restrictions are employed to draw a meaningful interpretation. The recursive structure assumes that variables appearing first contemporaneously influence the latter variables but not vice versa. It is important to list the most exogenous looking variables earlier than the most endogenous looking variables. Impulse response functions are shown in Figure 1.

In the initial response of exchange rate to a unit shock in inflation is negative and dies out. In the response of inflation to a shock in exchange rate is neutral, i.e., irresponsive. It is proven that inflation Granger-cause exchange rate. The initial response of inflation to a unit shock in interest rate is negative for the short period and can be consider as significant after that. A panel shows that the response of interest rate to an exchange rate shock is negative and dies out. Finally, the initial response of interest rate to a shock in inflation is positive and also can be considered as significant. Overall, from Figure 1 we see that the short-run equilibrium adjustment process is quite fast.

CONCLUSION

It can be concluded that increasing the interest rate can be efficient in restraining exchange rate volatility. Besides, information contained in the INF also concerning the future path of the EXC. This implies that there is information contained in the IR concerning the future path of the INF. For future studies, researchers should attempt to use panel data and cover longer study duration of above10 years by using other variables.

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