Asymmetric causality between exchange rate and interest rate differentials: a test of international capital mobility

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Abstract: The study employs asymmetric causality to reinvestigate international capital mobility. We simulate critical values based on the leverage bootstrapping and asymmetric causality test. The result reveals that positive shocks in exchange rate causes positive shocks in interest rate in Malaysia. This leads to increase capital inflow into Malaysia. The result further indicates that an increase in exchange rate in Malaysia, Nigeria and South Africa during bad time lowers their capital inflow due to low rate of return to the foreign investors. Furthermore, a decrease in the domestic interest rate in Nigeria influences an increase in the exchange rate during the bad time. This causes fall in the demand for domestic currency from foreigners. The policy implication is that Malaysian policymakers can control capital outflow and encourage inflow during both good and bad times. However, the monetary authorities in Nigeria and South Africa can only control the nations’ capital mobility during bad time.

Keywords: ARCH effect; asymmetric causality; bad times; exchange rate; good times; interest rate differential; international capital mobility; leverage bootstrap; structural break; Toda-Yamamoto.

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1 Introduction

The causal linkage between exchange rate and interest rate has been conflicting for the past three decades (Hnatkovska, Lahiri and Vegh, 2013). This affects policy formulation, especially on the nation’s capital mobility. The previous literatures on the exchange rate and interest rate causal relationship use a restrictive assumption of equal response to both positive and negative shocks when testing causality despite, the asymmetric information hypothesis where the response to negative and positive shocks are expected to vary across the two regimes. Moreover, the previous studies examine the properties of the time series variables without considering the effect of the structural breaks, especially in the emerging countries where the data generating process is characterised by structural changes.

This paper differs from the prior studies in the following ways: unlike the recent study by Hacker, Karlsson and Månsson (2014), who employ a wavelets analysis and vector autoregressive (VAR) impulse response causality test in the context of Sweden, Choi and Park (2008), who study the causality in four Asian countries using VAR, and Dąbrowski, Papież and Śmiech (2015), who use country-specific bootstrap critical values and Wald test on panel Granger causality based on seemingly unrelated regression (SUR) in Central and Eastern European countries, the present study applies the bootstrap asymmetric causality method to distinguish between the existence of causality in good (exchange rate appreciation) and bad (exchange rate depreciation) times. The employed procedures work better when normality assumption is violated and in the presence of ARCH effect. The methods also solve the problem of nuisance parameter estimates and size distortion under small sample size (Guru-Gharana, 2012; Hacker and Hatemi-J, 2006).

To the best of our knowledge, this study is among the first to be conducted on the emerging economies of Malaysia, Nigeria and South Africa using the leverage bootstrap asymmetric causality in addition to the potent Toda and Yamamoto (1995) causality approach. Moreover, the study estimates four variables’ vector to avoid estimation bias associated with previous studies that mostly employ bivariate models.

The rest of the paper is divided as follows: the next section offers the review of literature and theoretical framework; Section 3 describes data and methodology; Section 4 deals with the empirical findings and Section 5 presents the conclusion and policy implication of the study.
2 Literature review and economic theory

The previous literature on the nature of causality between interest and exchange rates reveals inconclusive findings. Furthermore, Hnatkovska, Lahiri and Vegh (2013) argue that the relationship between interest and exchange rates has not been clear for the past 30 years. The nature of this relationship is cherished, especially in the measurement of nation’s capital mobility. Some studies report bidirectional causality between interest and exchange rates. Such studies include Hacker, Karlsson and Månsson (2014), Paramati and Gupta (2011), Srinivasan, Kalaivani and Devakumar (2014) and Kayhan, Bayat and Uğur (2013).

Some other previous studies argue that there exists a unidirectional causality between interest rate and exchange rate. The vast majority of the literature report an initial causality running from interest rate to exchange rate. This is evident in the studies of Adrangi and Allender (1995), Choi and Park (2008), Hatemi-J and Irandoust (2000), Kisaka, Kithitu and Kamuti (2014), Olatunji, Sunday and Omolara (2012) and Pi-Anguita (1998). However, another strand in the literature shows the absence of causation between exchange rate and interest rate. This is reported in Alimi and Ofenyelu (2013), Ashfan and Batul (2014), Hamrita and Trifi (2011) and Mok (1993). The findings of the studies unanimously indicate that interest rate does not cause exchange rate and the other way round.

The study employs the monetary theory of exchange rate determination to explain the phenomenon. The theory explains the significance of money and other variables (assets) as determinants of exchange rate under flexible regime and balance of payment under pegged regime (Frenkel, 1976; Frenkel and Johnson, 2013). Frenkel (1976) argues that high domestic interest rate attracts new capital inform of savings and investment from abroad which leads to an increase in the demand for domestic currency. This causes appreciation of exchange rate relative to its steady-state level. Furthermore, Eun and Resnick (2007) argue that exchange rate is caused by relative interest rate between two countries. They state that under the interest rate parity framework, a higher domestic interest rate will cause exchange rate appreciation in the domestic economy. This is similarly reported in the Mundell-Fleming model of exchange rate. Nonetheless, Dornbusch (1976) argues that an increase in interest rate leads to a decrease in the demand for real balances which causes a rise (depreciation) in exchange rate.

3 Data and methodology

3.1 Data

This study uses annual time series data from 1970 to 2013 for Malaysia, Nigeria and South Africa. The data on exchange rate, interest rate, inflation rate and income (real gross domestic products) are collected from the World Development Indicators (WDIs). The US counterpart of the series are considered as the foreign variables in the model.
3.2 Unit root

The methodology of Toda and Yamamoto (1995) and asymmetric causality are applicable regardless of the integration properties of the variables (Hacker and Hatemi-J, 2006; Toda and Yamamoto, 1995). However, (Lee and Strazicich, 2013) minimum Lagrange multiplier (LM) with one structural break is employed to determine the maximum order of the integration. This test differs from the traditional test in that the test is break point nuisance invariant under the alternative hypothesis, unaffected by neither size nor location distortion. Besides, the test is free from spurious rejection and unaffected by the size and incorrect estimation whether the break exists or not.

3.3 Toda-Yamamoto causality

The study employs Toda and Yamamoto (1995) methodology based on the augmented VAR \((p+d_{\text{max}})\) model to determine the causality between exchange rate and interest rate. The model performs better; if there is no omitted variable bias and appropriate lag lengths are employed (Zapata and Rambaldi, 1997). Thus, following Toda and Yamamoto (1995) and Shan and Sun (1998) methodology, the following vector autoregressive (VAR) system is estimated:

\[
\begin{bmatrix}
\text{EXC}_t \\
\text{r}_t - \gamma_1 \\
\pi_t - \gamma_2 \\
y_t - \gamma_3 \\
\end{bmatrix} = \begin{bmatrix}
\text{EXC}_0 \\
\text{r}_0 - \gamma_1 \\
\pi_0 - \gamma_2 \\
y_0 - \gamma_3 \\
\end{bmatrix} + \begin{bmatrix}
a_{11} & a_{12} & a_{13} & a_{14} \\
a_{21} & a_{22} & a_{23} & a_{24} \\
a_{31} & a_{32} & a_{33} & a_{34} \\
a_{41} & a_{42} & a_{43} & a_{44} \\
\end{bmatrix} \begin{bmatrix}
\text{EXC}_{t-1} \\
\text{r}_{t-1} - \gamma_1 \\
\pi_{t-1} - \gamma_2 \\
y_{t-1} - \gamma_3 \\
\end{bmatrix} + \begin{bmatrix}
a_{11} \text{EXC}_{t-1} \\
a_{12} \text{r}_{t-1} \\
a_{13} \pi_{t-1} \\
a_{14} y_{t-1} \\
\end{bmatrix} + \begin{bmatrix}
\epsilon_t \\
\epsilon_{t-1} \\
\epsilon_{t-2} \\
\epsilon_{t-3} \\
\end{bmatrix} \tag{1}
\]

where **EXC** denotes the exchange rate, \(r\) represents the domestic interest rate, \(\pi\) denotes the inflation rate and \(y\) represents the income, whereas the variables with asterisk represent the foreign counterpart. To test the null hypothesis of whether interest rate causes exchange rate or not, the following restriction is specified \(H_0: a_{12} = 0\), where \(a_{12}\) is the coefficient of the restricted lag value of interest rate differential in the model. Similarly, the second hypothesis that exchange rate does not causes interest rate is tested by imposing the following restrictions: \(H_0: a_{11} = 0\), where \(a_{11}\) is the coefficient of the lag value of the exchange rate. The significance of the MWALD statistics of the lagged values of the explanatory variables in the two hypotheses, respectively, indicate the rejection of the null hypotheses of no Granger causality from interest rate differential to exchange rate and vice versa.

The appropriate lag length is chosen through testing the significance of the lags in Eq. (1) for \(p > k\) condition (Toda and Yamamoto, 1995) and minimising the Hatemi-J (2003) information criterion. However, when normality assumption is not fulfilled, and the effect of autoregressive conditional heteroscedasticity exists, the usual asymptotic distribution theory does not work well (Hatemi-J and Irandoust, 2006; Hatemi-J, 2012). Thus, the more reliable leverage distribution theory and asymmetric causality are employed in this kind of finite sample to avoid size distortion and spurious inferences.
3.4 Test for asymmetric causality

The study checks asymmetric causality following Hatemi-J (2012). The above process is replicated, assuming \( y^+ = (y^+_{1t}, y^+_{2t}) \) and \( y^- = (y^-_{1t}, y^-_{2t}) \). The following VAR(\( p \)) order is applied as shown in Eqs. (2) and (3).

\[
y^+_t = \theta + A_y y^+_{t-1} + \ldots + A_p y^+_{t-p} + \epsilon^+_t, \tag{2}
\]

\[
y^-_t = \theta + A_y y^-_{t-1} + \ldots + A_p y^-_{t-p} + \epsilon^-_t, \tag{3}
\]

where \( y^+_t \) and \( y^-_t \) represent the vector of positive and negative variables, respectively. These include exchange rate, interest rate differential, inflation differential and income differential for both positive and negative aspects. \( \theta \) is a vector of constant parameters. The symbol \( A \) is a vector of parameters to be estimated and \( \epsilon^+_t \) and \( \epsilon^-_t \) denote the vector of both positive and negative error components for the cumulative sum of positive and negative shocks, respectively. The information criteria in testing the appropriate lag length is also adjusted to include the square of the number of observation in the VAR model (Hatemi-J, 2012). The remaining process is as presented in the previous and subsequent sections while taking into account asymmetric condition of positive and negative shocks in the model.

3.5 Bootstrap procedure

The asymmetric causality and leverage bootstrap critical values are generated using GAUSS based on the program procedure developed in Hatemi-J (2012) and Hacker and Hatemi-J (2006), respectively. The critical values are generated using the underlying empirical data through bootstrap simulation. The iteration is conducted 10,000 times and \( MWALD_t \)-statistics are estimated after every iteration to determine the upper quantile of the bootstrapped distribution of the \( MWALD_t \)-statistics in order to generate 1, 5 and 10% bootstrapped critical values. Finally, the raw data rather than the bootstrapped one is utilised to calculate the \( MWALD_t \) statistics. The hypothesis of no Granger causality is rejected if the \( MWALD_t \) statistics calculated using the original data is greater than the bootstrapped critical values.

4 Empirical results

The methodology of Toda-Yamamoto causality is robust regardless of the stationarity properties of the series, yet the maximum order of integration is required in modelling the augmented VAR framework. Therefore, the maximum order of integration of the variables is investigated using LS test (Lee and Strazicich, 2013). The result indicates that although some variables are found stationary at level in all the countries under both the intercept and trend models, the test establishes that the maximum order of integration of the variables for all countries is found to be \( I(1) \) order. It implies that the lag augmentation in estimating the VAR model for all the countries is determined as one. The result is available based on the request due to space limit.

From Table 1, the normality and autoregressive conditional heteroscedasticity (ARCH) tests in the VAR model show that the null hypotheses of both the normality and
ARCH effect are rejected for all countries under study. Therefore, the inability of the models to fulfil the normality assumption and the existence of ARCH effect renders the usual asymptotic distribution theory to be less effective and relevant (Hatemi-J and Irandoust, 2006; Hatemi-J, 2012). Furthermore, using the asymptotic distribution theory in this scenario would result to size distortion in addition to nuisance parameter estimates in establishing causality (Hacker and Hatemi-J, 2006). Thus, this study employs the more reliable leverage distribution theory and asymmetric causality test which perform better in the presence of non-normality and ARCH effect.

Table 1  
Test for normality and ARCH effect in the VAR model

<table>
<thead>
<tr>
<th>Country</th>
<th>Normality</th>
<th>ARCH effect</th>
<th>Optimal lag length</th>
</tr>
</thead>
<tbody>
<tr>
<td>Malaysia</td>
<td>0.000***</td>
<td>0.038**</td>
<td>1</td>
</tr>
<tr>
<td>Nigeria</td>
<td>0.000***</td>
<td>0.013**</td>
<td>1</td>
</tr>
<tr>
<td>South Africa</td>
<td>0.000***</td>
<td>0.013**</td>
<td>1</td>
</tr>
</tbody>
</table>

Note: *** and ** represent significant level at 1 and 5%, respectively. The lag length is chosen based on the Hatemi-J information criterion.

Source: Authors’ computations.

Table 2 shows the results of Granger and Toda-Yamamoto asymmetric causality for Malaysia, Nigeria and South Africa. The estimated order of the VAR \((p+d_{\text{max}})\) model is determined to be two for all the countries. The Granger non-causality results indicate that none of the tests in all the countries show any evidence of causation from either of the variables. However, the traditional test was conducted based on the VAR asymptotic critical values which leads to a spurious inference. Moreover, Sims, Stock and Watson (1990) and Toda and Phillips (1993) argue that the null hypothesis of the integrated Granger causality suffer from independence of nuisance parameter estimates, whereas the null hypothesis of level variables suffer from the non-standard asymptotic distribution. Nevertheless, Toda-Yamamoto MWALD statistics indicate the existence of unidirectional causality from exchange rate to interest rate differentials in Malaysia, bidirectional causality in Nigeria and a unidirectional causality from interest rate differentials to exchange rate in South Africa. However, Hatemi-J (2012) argues that the response to positive and negative asymmetric shocks may leads to varying causal relationship which has not been explore in the previous studies. In other words, the asymmetric causality test differentiate between the nature of causality during good and bad times.

Table 2  
Asymmetric dynamic Toda-Yamamoto causality and bootstrap simulation

<table>
<thead>
<tr>
<th>Null hypothesis</th>
<th>Non-Granger causality</th>
<th>MWALD statistic</th>
<th>Leverage bootstrap</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>t-statistics</td>
<td>1% CV</td>
</tr>
<tr>
<td>Malaysia (r - r'_r \neq EXC)</td>
<td>0.846 (0.358)</td>
<td>1.215</td>
<td>8.038</td>
</tr>
<tr>
<td>Malaysia (r - r'_{r'} \neq EXC)</td>
<td>2.095</td>
<td>10.242</td>
<td>4.520</td>
</tr>
<tr>
<td>Malaysia (r - r''_r \neq EXC)</td>
<td>0.339</td>
<td>9.407</td>
<td>4.487</td>
</tr>
</tbody>
</table>
Table 2  Asymmetric dynamic Toda-Yamamoto causality and bootstrap simulation (continued)

<table>
<thead>
<tr>
<th>Null hypothesis</th>
<th>Non-Granger causality</th>
<th>MWALD t-statistics</th>
<th>Leverage bootstrap</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>1% CV</td>
</tr>
<tr>
<td>EXC $\not\Rightarrow r_i$ $^*$</td>
<td>0.811 (0.368)</td>
<td>23.234***</td>
<td>9.968</td>
</tr>
<tr>
<td>EXC$^+$ $\not\Rightarrow r_i$ $^{**}$</td>
<td>48.448***</td>
<td>13.659</td>
<td>4.659</td>
</tr>
<tr>
<td>EXC$^-$ $\not\Rightarrow r_i$ $^{*}$</td>
<td>3.336*</td>
<td>7.937</td>
<td>4.226</td>
</tr>
</tbody>
</table>

Nigeria

| $r_i - r_i'$ $\not\Rightarrow EXC$ | 1.552 (0.213) | 3.653* | 7.304  | 4.126  | 2.878  |
| $r_i - r_i'^+$ $\not\Rightarrow EXC^+$ | 2.113 | 8.709  | 4.355  | 2.873  |
| $r_i - r_i'^-$ $\not\Rightarrow EXC^-$ | 2.879* | 8.736  | 4.292  | 2.814  |
| EXC $\not\Rightarrow r_i$ $^*$ | 0.593 (0.441) | 12.341*** | 7.651  | 4.279  | 2.949  |
| EXC$^+$ $\not\Rightarrow r_i'^+$ | 1.865 | 10.077 | 4.584  | 3.059  |
| EXC$^-$ $\not\Rightarrow r_i'^-$ | 4.852** | 10.252 | 4.477  | 2.862  |

South Africa

| $r_i - r_i'$ $\not\Rightarrow EXC$ | 0.067 (0.793) | 4.010* | 7.412  | 4.228  | 2.941  |
| $r_i - r_i'^+$ $\not\Rightarrow EXC^+$ | 0.166 | 11.869 | 7.216  | 5.499  |
| $r_i - r_i'^-$ $\not\Rightarrow EXC^-$ | 0.837 | 9.101  | 4.468  | 2.947  |
| EXC $\not\Rightarrow r_i$ $^*$ | 0.003 (0.956) | 0.579  | 7.685  | 4.281  | 3.036  |
| EXC$^+$ $\not\Rightarrow r_i'^+$ | 2.311 | 12.636 | 7.393  | 5.568  |
| EXC$^-$ $\not\Rightarrow r_i'^-$ | 4.852** | 9.521  | 4.416  | 2.848  |

***, ** and * represent rejection of the null hypothesis at 1, 5 and 10% significant level, respectively, with reference to bootstrap simulated critical values. The symbol $\not\Rightarrow$ represents Granger non-causality. The figures enclose in parenthesis under column two represent the $p$ values of Granger non-causality.

Source: Authors' computations

Thus, the result of the asymmetric causality test reveals that positive shocks (decrease) in the exchange rate causes positive shocks (increase) in the interest rate in the Malaysian economy. The associated increase in the interest rate differentials leads to increase capital inflow into Malaysia. The result further indicates that an increase in the exchange rate causes a decrease in the domestic interest rate in Malaysia, Nigeria and South Africa. The result implies that an increase in the countries’ exchange rate in relation to US dollar during bad period will lower the capital inflow into the economies due to low rate of return to the foreign investors. Furthermore, a decrease in the domestic interest rate in Nigeria influences an increase in the exchange rate during the bad times. This causes fall in the demand for the domestic currency from foreigners due to low interest rate. The
result is in line with the concept of interest rate parity, the Frenkel (1976) argument and Mundell-Fleming model of exchange rate.

5 Conclusion

The major contribution of this study is that we distinguish causality between the positive and negative shocks’ scenarios using data from emerging economies. The findings based on the asymmetric causality confirm the existence of the Frenkel (1976) flexible version of the monetary theory of exchange rate determination, the Mundel-Fleming model of exchange rate and the interest rate parity in the context of Malaysia, Nigeria and South Africa, respectively.

The asymmetric causality results reveal that both positive and negative cumulative shocks in exchange rate causes the respective cumulative positive and negative shocks in interest rate in Malaysia. The latter also holds for Nigeria and South Africa with a feedback running from the cumulative negative shock in interest rate differential to exchange rate in Nigeria. The policy implication is that Malaysian policymakers can control capital outflow and encourage inflow during both good and bad times through manipulating domestic interest rate and exchange rate. Any policy towards exchange rate appreciation can equally causes an increase in the domestic interest rate, thereby encouraging capital inflow and controlling capital outflow in Malaysia. However, in the Nigerian context, the monetary authority can only have control on the nation’s capital mobility during bad times. In South Africa, the monetary policy can only influence capital mobility in the bad time. The possible limitation of this study is that of generalisation of the results to other countries due to heterogeneity in the capital mobility and exchange rate policies which differ between countries. Thus, similar studies should be considered in other economies.

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References


