Empirical Support for Augmented Taylor Rule with Asymmetry in Selected Emerging Markets

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Keywords
Inflation Targeting, Augmented Taylor Rule, Exchange Rates, NARDL.

Abstract
This paper’s aim is twofold: Firstly, it aims to extend the traditional Taylor rule with the real exchange rate. Secondly, by using the NARDL model, it aims to provide empirical results that the effects of real exchange rate changes on interest rate is asymmetric in selected emerging markets of Brazil, Chile, Mexico, South Africa, South Korea, and Turkey.

The NARDL estimation results and dynamic multipliers indicate the presence of long-run asymmetric cointegration relationship between interest rate and the variables of the inflation gap, output gap and the real exchange rate. Especially, the empirical findings indicate that the real exchange rate has asymmetrical effects on interest rate for all selected countries, except Brazil.

The estimation results suggest that the policy reaction functions in the selected emerging countries are not only responding to inflation gap and output gap, but also reacting asymmetrically to real exchange rate changes. Hence, these empirical results support that the augmented Taylor rule with exchange rate and asymmetric form is a better representation for monetary policy reaction of the selected emerging countries.

1. Introduction and the Literature Review

Economic performance and stability of both developed and developing countries can be improved by the efficiency of applied monetary policy. In the late 1990s, many countries, especially some emerging countries, adopted inflation targeting regime (IT) in order to control price level and attain their inflation objectives by using interest rate. In order to control inflation, Mishkin (2000) suggest that the inflation targeting regime of emerging countries must follow some preliminary steps as follows: 1) the announcement of the medium-term numerical target inflation rate to the public; 2) institutionally arranging the price stability as the primary goal of monetary policy; 3) using many variables for deciding the setting of policy instruments; 4) increasing transparency of the monetary policy strategy

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through communication; and 5) increasing the central bank’ accountability.

In order to show how the central banks coordinates their policies, Taylor (1993) explored simple policy rules as guides for monetary policy. The simple Taylor rule can be implemented with either for price stability or economic growth. In the USA, this rule uses federal funds rate (FFR) as a policy instrument in response to changes in the price level or changes in real income. The original Taylor rule is used in modelling the central bank monetary policy reaction function. This rule allows the central bank interest rate to adjust the inflation at the targeted level and output at the potential level by studying the deviation between targeted and actual levels of inflation and output, as to keep the economy in equilibrium. The Taylor rule equation can be written as:

\[ i_t = r^* + \delta(\pi_t - \pi_t^*) + \theta(y_t - y_t^*) \]

where \( i_t \) is the central bank rate at time \( t \), \( r^* \) is the real interest rate, \( \pi_t \) is the actual inflation rate, \( (\pi_t - \pi_t^*) \) is the deviation of the actual inflation rate from its target level, \( \pi_t^* \), and \( (y_t - y_t^*) \) is the deviation of actual output, \( y_t \), from its full-employment level, \( y_t^* \). The parameters \( \delta \) and \( \theta \) in equation indicate the sensitivity of the central bank interest rate changes to inflation gap \( (\pi_t - \pi_t^*) \) and output gap \( (y_t - y_t^*) \). The equation above suggest that the larger the coefficients, the more aggressive the monetary policy will be.

There are several studies showing the use and effectiveness of this simple Taylor rule for the purpose of price stability or economic growth. Taylor (1993, 1999) and Orphanides (2002) argue that the policy of the Fed is an interest rate rule based on the original Taylor rule and the adaptation of this a rule had significant impact on economic performance in the USA according to Bernanke (2004) and Taylor (2013). Similar results and conclusions are reached by Clarida et al. (1998) for G-7 countries, Gerlach and Schnabel (2000) for EMU area, Stuart (1996) for UK and Côté et al. (2004) for the Canadian economy.

Even though there are many studies showing the success and effectiveness of the application of the original Taylor rule, there are also many criticism against the use of the rule as this way. Ball (1999) and Svensson (1999) suggest that the exchange rate should be included into Taylor rule. Ball (1999) propose an extension of Svensson-Ball (1997) model for open economy that monetary policy affects the economy through both interest-rate and exchange-rate channels. Additionally, Svensson (2000) points out that Taylor rule is not suitable for a small open economy where the exchange rate and the shocks from the rest of the world are important for conducting monetary policy. Also, Ball (1999) and Aizenman et al. (2011) suggested that the optimal policy response in open emerging economies includes the exchange rate. In order to represent the developing countries’ monetary policy reactions, the original Taylor rule has been modified in various ways. Raghavan and Dungey (2015) by using the SVECM approach for ASEAN5, suggested that the policy reaction function of these countries is additionally responding to developments in stock markets. Shrestha and Semmler (2015), by using the ARDL model for Malaysia, Korea, Thailand, Indonesia and Philippines, concluded that the original Taylor rule is not adequate in describing the policy function of these economies. Caporale et al. (2016), for Indonesia, Thailand, Israel,
South Korea and Turkey, Manogaran and Sek (2016), for Asian5, claimed that the augmented nonlinear Taylor rule correctly presents the behavior of policy rule. Beside these empirical studies, the individual-country studies from Khalid et al. (2014), for Malaysia, Luengwilai (2012), for Thailand and Chow et al. (2014), for Singapore also suggested the augmented Taylor-rule with exchange rate.

1.1. The Reasons to Include Exchange rate in to the Taylor Rule

In today’s current real world, the economies are quite open and changes in nominal and real exchange rates can require the re-designation of the monetary policy frameworks. Given the fact that the existence of the high degree of pass-through of the exchange rate into domestic prices, this is true especially for the countries that implement inflation targeting regime in order to ensure competitiveness of the tradable sector and to maintain financial stability. Edwards (2006) suggest that central bank may respond directly to exchange rate movements rather than waiting for its impact on inflation and output to materialize. According to Svensson (2000), Ball (2000) and Benlialper and Cömert (2016), there are three main reasons why developing countries’ inflation targeting (IT) central banks are likely to include the exchange rate explicitly in their reaction functions. Since the exchange rate is an important determinant of inflation in developing countries, the first reason is for preserving the credibility of the IT regime. Secondly, since the exchange rate movements affect inflation through import prices and hence works faster than conventional monetary policy channels, the central banks can use this direct exchange rate channel in order to control inflation. Third of all, in case of the interest rate policy is ineffective in achieving the policy goals, the central banks in developing countries may use the exchange rate channel in order to be more effective than the conventional aggregate demand channel.

Theoretical studies from Clarida et al., (1998), Svensson, (1999), Taylor (1999), Ball (2000), Martin and Milas (2013) and Caglayan et al. (2016) extended the original linear Taylor rule and emphasized the possible nonlinearities in the reaction function of central banks. The nonlinearities in the reaction function can arise either from nonlinear macroeconomic relationships as Robert-Nobay and Peel, (2003) and Dolado et al. (2005) suggest or can arise from asymmetric objectives of the policymakers as suggested by Taylor and Davradakis (2006), Castro (2011) and Ahmad (2016).

Also, there exist several empirical studies showing evidence of nonlinearities in the reaction of monetary authorities to inflation and output gaps. Empirical study examples for developed countries include Favero et al. (2000), Taylor and Davradakis (2006), Surico (2007), Martin and Milas (2013). There are even a few papers which addressed the case of emerging economies including studies from Hasanov and Omay (2008), Akyürek et al. (2011) and Akdoğan (2015).

There are few studies detecting asymmetries in Taylor rule including exchange rate for the developing and emerging countries. Caporale et al. (2016) examined the rule for Indonesia, Israel, South Korea, Thailand, and Turkey by using GMM with a nonlinear threshold specification and found that an augmented nonlinear Taylor rule appears to capture more accurately the behavior of monetary
authorities. Manogaran and Sek (2016) investigated the augmented Taylor rule in ASEAN5 by using Nonlinear Autoregressive Distributed Lags (NARDL) model and found that all these countries are effectively responding to exchange rate movements with higher or lower policy rates. Benlialper et al. (2017) by using a panel threshold model for inflation targeting developing countries found that central banks in developing countries implementing inflation targeting tolerated appreciation by remaining inactive in the case of appreciation, but fought against depreciation pressures beyond some threshold.

Following the previous studies of Caporale et al. (2016), Manogaran and Sek (2016) and Benlialper et al. (2017), among others, this paper also extends the traditional Taylor rule with real exchange rate by using the NARDL model to show which rule better represents the monetary policy reaction among the selected emerging countries. The study provides empirical results that the effects of real exchange rate changes on interest rate is asymmetric in selected emerging markets. The NARDL model in the study is used to estimate the asymmetric effects of real effective exchange rate changes on policy reaction function from each selected Inflation Targeting countries; Brazil, Chile, Mexico, South Africa, South Korea and Turkey.

In this study, the NARDL method is applied on estimating the policy reaction function for selected emerging markets. It is assumed that the central bank moves policy rates in response to the inflation gap, output gap and changes in the real exchange rate. As Ball (1999) and Aizenman et al. (2011) suggest, the optimal policy response in open economies includes the exchange rate. The policy reaction function for each selected country is estimated by using time series data for each individual market economy. The NARDL estimation results provides evidence that monetary policy is reacting asymmetrically to exchange rate changes in these countries except Brazil. Also, monetary policy rate reacts significantly to inflation and output gaps. These results firstly imply the presence of central bank's intervention through exchange rate adjustments and also suggest that the augmented policy rule is used to represent the monetary policy in these selected countries.

The remainder of this paper is organized as follows: Section 2 discusses the data and methodology. Section 3 presents the empirical results. The last section outlines concluding remarks and policy implications.

2. The Data and Methodology

This study uses quarterly data covering from different time periods of the selected emerging markets of Brazil (1999), Chile (2000), Mexico (2001), South Africa (2000), South Korea (2001), and Turkey (2002) which adopted inflation targeting regime up to 2017:Q3. The variables used in the study for each country are the interbank interest rate (INTR), the consumer price index (CPI), the Real Gross Domestic Product (RGDP) and the real effective exchange rate (RER). All the variables are expressed in natural logarithm except interest rates. Based on the RGDP data, the output gap (RGDPGAP) is calculated by using Hodrick-Prescott filter (1997). Based on the each country’s CPI and official IT data, the Inflation gap (INFGAP) is calculated by subtracting IT from the actual inflation rate. The
The equation used is; \( \text{INFGAP} = (\text{Actual Inflation} - \text{Inflation Target}) \). The data is retrieved from the statistical database of the Organization for Economic Cooperation and Development (OECD).

This study employs the Nonlinear Autoregressive Distributed Lags Model (NARDL) developed by Shin et al. (2014) to examine the asymmetric effects of real exchange rate changes on policy reaction function in selected emerging markets. The NARDL model is an asymmetric extension of the linear ARDL model proposed by Pesaran and Shin (1999) and Pesaran et al. (2001). The unrestricted error-correction model in the linear ARDL model takes the following form:

\[
\Delta \text{intr}_t = \\
\alpha_0 + \sigma \Delta \text{intr}_{t-1} + \delta \text{INFGAP}_{t-1} + \varphi \text{outputgap}_{t-1} + \delta \Delta \text{infr}_{t-1} + \\
\sum_{i=1}^{q-1} \beta_i \Delta \text{infr}_{t-i} + \sum_{i=0}^{q-1} \lambda_i \Delta \text{outputgap}_{t-i} + \sum_{i=0}^{q-1} \eta_i \Delta \text{infr}_{t-i} + \epsilon_t 
\]  

(1)

where \( \text{intr}_t \) is the dependent variable, \( \text{INFGAP}_t \), \( \text{outputgap}_t \), and \( \text{infr}_t \) are \( k \times 1 \) vector of regressors. The parameters of \( \sigma, \varphi, \delta \) and \( \delta \) represent the long-run and the parameters of \( \mu_i, \beta_i, \lambda_i \) and \( \eta_i \) represent the short-run coefficients respectively. \( \epsilon_t \) is the error term.

Following Shin et al. (2014), the asymmetric long-run regression in the NARDL model is written as follows:

\[
\text{intr}_t = \pi^+ \text{infr}_t^+ + \pi^- \text{infr}_t^- + u_t 
\]  

(2)

\[
\Delta \text{infr}_t = v_t 
\]  

(3)

where \( \text{intr}_t \) and \( \text{infr}_t \) are scalar stationary \((1(1))\) variables, and \( \text{infr}_t \) is decomposed as \( \text{infr}_t = \text{infr}_0 + \text{infr}_t^+ + \text{infr}_t^- \) where \( \pi^+ \) and \( \pi^- \) represent the long-run coefficients associated with the positive and negative changes in \( \text{infr}_t \):

\[
\text{infr}_t^+ = \sum_{i=1}^{t} \Delta \text{infr}_i^+ = \sum_{i=1}^{t} \max(\Delta \text{infr}_i, 0) \\
\text{infr}_t^- = \sum_{i=1}^{t} \Delta \text{infr}_i^- = \sum_{i=1}^{t} \min(\Delta \text{infr}_i, 0) 
\]  

(4)

Then, the asymmetric error correction model can be written as by combining the equations 1 and 4 as follows:

\[
\Delta \text{intr}_t = \alpha_0 + \sigma \Delta \text{intr}_{t-1} + \delta \text{INFGAP}_{t-1} + \varphi \text{outputgap}_{t-1} + \delta^+ \Delta \text{infr}_{t-1}^+ + \delta^- \Delta \text{infr}_{t-1}^- + \\
\sum_{i=1}^{q-1} \beta_i \Delta \text{intr}_{t-i} + \sum_{i=0}^{q-1} \lambda_i \Delta \text{INFGAP}_{t-i} + \sum_{i=0}^{q-1} \lambda_i \Delta \text{outputgap}_{t-i} + \sum_{i=0}^{q-1} (\beta_i^+ \Delta \text{infr}_{t-i}^+ + \\
\beta^- \Delta \text{infr}_{t-i}^-) + \epsilon_t 
\]  

(5)

In equation 4, both dependent and explanatory variables are defined as \( \delta^+ = -\sigma \pi^+ \) and \( \delta^- = -\sigma \pi^- \) and \( \beta_i^+ \) and \( \beta_i^- \) are the short-run adjustments to positive and negative changes in the explanatory variables \( \text{infr}_t \).

In order to test the short and long-run asymmetric effect of real exchange rate changes on policy reaction function, the equation 5 in NARDL model entails the following steps. First, standard OLS should be estimated. Second, the bounds test approach can be applied to test the presence of an asymmetrical long-run cointegration relationship among the levels of the series \( \text{intr}_t, \text{infr}_t^+, \) and \( \text{infr}_t^- \). Thus, the pragmatic bounds-testing procedure is used in the NARDL model since the \( F_{pss} \) statistics developed by Pesaran et al. (2001) have non-standard distributions that depend on the order of integration of the underlying variables.
The F-statistics ($F_{PSS}$) refer to the joint null hypothesis of no cointegration against the alternative of cointegration. It can be written as:

$$H_0: \sigma = \delta^+ = \delta^- = 0$$  \hfill (6)

$$H_1: \sigma \neq \delta^+ \neq \delta^- \neq 0$$  \hfill (7)

The third step is to test for long-run and short-run symmetry by using standard Wald test. The Wald test involves the null hypothesis is $\sigma = \delta^+ = \delta^-$ for the long-run symmetry and $\sum_{i=0}^{q-1} \beta^+ = \sum_{i=0}^{q-1} \beta^-$ for the short-run symmetry.

The fourth step is utilized to derive asymmetric cumulative dynamic multipliers effect on $\Delta \Delta r_t$, of the change in $r_{t+1}$ and $r_{t-1}$ in the equation 5. This can be expressed as follows:

$$m^+_h = \sum_{j=0}^{h} \frac{\partial \Delta \Delta r_t}{\partial \Delta r_{t+j}}, \text{ and } m^-_h = \sum_{j=0}^{h} \frac{\partial \Delta \Delta r_t}{\partial \Delta r_{t-j}}$$  \hfill (8)

where $(h = 0,1,2, \ldots)$. For the equation 8, if $h \to \infty$, then $m^+_h \to \pi^+$ and $m^-_h \to \pi^-$. The long-run coefficients of $\pi^+$ and $\pi^-$ are calculated as $\pi^+ = -\frac{\delta^+}{\sigma}$ and $\pi^- = -\frac{\delta^-}{\sigma}$.

The NARDL model consists of the short and long-run of the positive and negative partial sums. Thus, the NARDL model takes following form:

$$\Delta \Delta r_t = \alpha_0 + \sigma \Delta \Delta r_{t-1} + \delta \Delta \Delta \text{fgap}_{t-1} + \omega \Delta \Delta \text{outputgap}_{t-1} + \delta^+ \Delta \Delta r^+_{t-1} + \delta^- \Delta \Delta r^-_{t-1} + \sum_{i=1}^{q-1} \delta \Delta \Delta \text{outputgap}_{t-i} + \sum_{i=0}^{q} \beta_1 \Delta \Delta \text{fgap}_{t-i} + \sum_{i=0}^{q} \beta_2 \Delta \Delta \text{outputgap}_{t-i} + \sum_{i=0}^{q} \beta_3 \Delta \Delta \text{LRER}_{t-i} + \varepsilon_t$$  \hfill (9)

3. The Empirical Results

3.1. The Results of the Unit Root Tests

The Zivot and Andrews (1992) Unit Root test is used to examine stationarity of the variables in the presence of potential structural breaks for the selected emerging countries. In the presence of structural break, the Augmented Dickey-Fuller (ADF) test is criticized on the basis of a failure to allow for an existing break leading to a bias that reduces the ability to reject a false unit root null hypothesis (Glynn et al., 2007). In order to reduce bias in the conventional unit root tests, Zivot and Andrews (1992) unit root test is applied for endogenously determining structural break date.

The Table 1, below, presents the Zivot-Andrews Unit Root test results. For Brazil and Mexico, the test results indicate that INFGAP and RGDGPAG are level stationary, but INFGAP and RGDGPAG are stationary at their first differences. For Chile, the test results indicate that the variables of INFGAP is level stationary and all other variables (INTR, RGDGPAG and LRER) are stationary at their first differences. For South Africa, the test results indicate that no variable is level stationary, but all variables (INTR, INFGAP, RGDGPAG and LRER) are stationary at their first differences. For South Korea, the test results indicate that the RGDGPAG and LRER are level stationary, but INTR and INFGAP are stationary at the first differences. For Turkey, the test results indicate that no variable is level stationary, but all variables (INTR, INFGAP, RGDGPAG and LRER) are stationary at their first differences.
Table 1: Zivot-Andrews Unit Root Test Results

<table>
<thead>
<tr>
<th>Variable/ Countries</th>
<th>INTR</th>
<th>INFGAP</th>
<th>RGDPGAP</th>
<th>LRER</th>
<th>Chosen Break Point</th>
</tr>
</thead>
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<tr>
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<td></td>
<td></td>
<td></td>
<td>INTR</td>
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<tr>
<td></td>
<td>(-5.08)</td>
<td>(-5.08)</td>
<td>(-5.08)</td>
<td>(-4.93)</td>
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First Difference (Trend and Intercept)

<table>
<thead>
<tr>
<th>Variable/ Countries</th>
<th>INTR</th>
<th>INFGAP</th>
<th>RGDPGAP</th>
<th>LRER</th>
<th>Chosen Break Point</th>
</tr>
</thead>
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<td>(-5.08)</td>
<td>(-5.08)</td>
<td></td>
</tr>
<tr>
<td>SOUTH KOREA</td>
<td>-6.122</td>
<td>-5.516</td>
<td>-5.516</td>
<td>-6.603</td>
<td>2008:Q4</td>
</tr>
<tr>
<td></td>
<td>(-5.08)</td>
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</table>

Note: The numbers in parentheses indicate the critical values at 5% significance level.

3.2. The NARDL Estimation Results

The Zivot-Andrews Unit Root test results show for all countries that the dependent variable (INTR) is stationary at first difference I(1) and all independent variables are level or difference stationary. These results from unit root tests confirm a strong justification for the use of the NARDL model because all the variables are not found to be I(2) and dependent variable for all countries is I(1). The NARDL estimation results are reported for selected emerging countries in Tables 2 and 3.

Table 2 presents the NARDL estimation results for Brazil, Chile and Mexico.

Brazil: In the long-run, a 1% increase and decrease in real exchange rate (LRER) cause around ~ 0.12% and ~0.11% decreases in Brazilian INTR respectively. These results about the effect of exchange rate changes show that the policy reaction function of Brazilian central bank responding negatively to the effects of both increase in RER (a real appreciation) and decrease in RER (a real depreciation). On the other hand, for Brazil, a 1% change (increase) in INFGAP leads to an increase in INTR by 3.80%. This result indicates central bank of Brazil can increase its interest rate when actual output is higher than the potential output. For Brazil, the effect of RGDPGAP changes on INTR is found to be insignificant.

Chile: In the long-run, changes in real exchange rate (LRER) on INTR for Chile is found to be insignificant. For the effect of the changes in INFGAP on INTR, the test results show that a 1% change (increase) in INFGAP leads to an increase in INTR by 2.19%. On the other hand, a 1% change (increase) in RGDPGAP leads to an
increase in INTR by 0.62%. This results indicate central bank of Chile can increase its interest rate when INFGAP and RGDPGAP increase.

_Mexico:_ Test results for Mexico show the existence of asymmetrical effects of RER on INTR in the long-run. While a 1% increase (appreciation) of RER causes -0.19% decrease in INTR, a decrease (depreciation) in real exchange rate (LRER) causes around – 0.11% decrease in Mexico’s INTR. These results about the effect of exchange rate changes show that the policy reaction function of Mexican central bank responding negatively to the effects of both increase and decrease in RER. For the effect of the changes in INFGAP on INTR, the test results show that a 1% change (increase) in INFGAP leads to a decrease in INTR by -0.57%. On the other hand, a 1% change (increase) in RGDPGAP leads to an increase in INTR by 0.36%. This results indicate central bank of Mexico should decrease its interest rate when INFGAP goes up and increase its interest rate when RGDPGAP increase.

Table 2: The NARDL Estimation Results for BRAZIL, CHILE, MEXICO

<table>
<thead>
<tr>
<th>Dependent variable = INTR</th>
<th>Long-Run Asymmetric Effects on INTR</th>
<th>Brah</th>
<th>Chile</th>
<th>Mexico</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Variable</strong></td>
<td><strong>BRAZIL</strong></td>
<td><strong>CHILE</strong></td>
<td><strong>MEXICO</strong></td>
<td></td>
</tr>
<tr>
<td>INFGAP</td>
<td>3.805681*</td>
<td>2.196001*</td>
<td>-0.574221*</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.0012)</td>
<td>(0.0112)</td>
<td>(0.0594)</td>
<td></td>
</tr>
<tr>
<td>RGDPGAP</td>
<td>0.219801</td>
<td>0.626557*</td>
<td>0.363150*</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.4986)</td>
<td>(0.0002)</td>
<td>(0.0023)</td>
<td></td>
</tr>
<tr>
<td>LRER_P</td>
<td>-0.123051*</td>
<td>0.054710</td>
<td>-0.199068*</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.0000)</td>
<td>(0.1941)</td>
<td>(0.0000)</td>
<td></td>
</tr>
<tr>
<td>LRER_N</td>
<td>-0.112867*</td>
<td>0.078473</td>
<td>-0.118182*</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.0009)</td>
<td>(0.1046)</td>
<td>(0.0003)</td>
<td></td>
</tr>
</tbody>
</table>

_F-statistics (F_{PE})_ | 8.052007** | 7.371856** | 9.036685** |

**The Wald Test for Long-run asymmetry**

| LRER | 0.785354 | 5.993609 | 53.74709 |
|      | (0.3793) | (0.0175) | (0.0000) |

_Statistics and diagnostics_

| Adj. $R^2$ | 0.609868*** | 0.620809*** | 0.446909*** |
|           | (0.6758)    | (0.3818)    | (0.2969)    |
| $\chi^2_\text{LM}$ | 9.314783*** | 12.82575*** | 14.05958*** |
|             | (0.3818)    | (0.3818)    | (0.2969)    |
| $\chi^2_\text{D}$ | 66.322388*** | 66.970022*** | 58.24194*** |
|              | (0.4311)    | (0.3755)    | (0.0737)    |

CUSUM AND CUSUMQ | STABLE | UNSTABLE | UNSTABLE |

_Note:_ **"** indicates the level of significance at 5%.

**The bounds critical values are taken from Pesaran et al. (2001) with unrestricted intercept and no trend (Case III). Upper (lower) bound with k=3 is 4.35 (3.23) at 5% significance level.

****Adj. $R^2$ represents the estimated value of the adjusted $R^2$ coefficient in the model.

**** $\chi^2_\text{LM}$ and $\chi^2_\text{D}$ denote the Breusch-Godfrey serial correlation LM tests and heteroscedasticity tests (White) respectively.

The Table 3 illustrates the NARDL estimation results for South Korea, South Africa and Turkey.

_South Africa:_ NARDL test results for S. Africa show the existence of asymmetrical effects of RER on INTR in the long-run. In the long-run, while a 1% increase (appreciation) of RER causes -0.16% decrease in INTR, a decrease (depreciation) in real exchange rate (LRER) causes around – 0.10% decrease in South Africa’s INTR. These results about the effect of exchange rate changes show that the policy reaction function of S. African central bank responding negatively to the effects of both increase and decrease in RER. For the effect of the changes in INFGAP on
INTR, the test results show that a 1% change (increase) in INFGAP leads to an increase in INTR by 5.66%. On the other hand, the effect of RGDPGAP changes on INTR is found to be insignificant for S. Africa. This results indicate central bank of S. Africa can increase its interest rate when actual inflation is higher than its target inflation rate.

**South Korea:** Test results for Korea show the existence of asymmetrical effects of RER on INTR in the long-run. In the long-run, while an increase in RER does not create any significant change in INTR, a 1% decrease in real exchange rate (a real depreciation) causes an increase in INTR by 0.07%. On the other hand, for Korea, a 1% change (increase) in RGDPGAP leads to an increase in INTR by 1.98%. This result indicates central bank of S. Korea can increase its interest rate when actual output is higher than the potential output. For Korea, the effect of INFGAP changes on INTR is found to be insignificant.

**Turkey:** Test results for Turkey show the existence of asymmetrical effects of RER on INTR in the long-run. While a 1% increase (appreciation) of RER causes -0.51% decrease in INTR, a decrease (depreciation) in real exchange rate (LRER) causes around – 0.34% decrease in Turkey’s INTR. These asymmetrical results about the effect of exchange rate changes show that the negative policy reaction function of Turkish central bank is higher in case of real appreciation of the Lira than the real depreciation of the Lira against other currencies. For the effect of the changes in INFGAP on INTR, the test results show that a 1% change (increase) in INFGAP leads to an increase in INTR by 1.07%. On the other hand, a 1% change (increase) in RGDPGAP leads to an increase in INTR by 1.008%. This results indicate central bank of Turkey should decrease its interest rate when INFGAP and RGDPGAP go up.
Table 3: The NARDL Estimation Results for SOUTH AFRICA, SOUTH KOREA and TURKEY

<table>
<thead>
<tr>
<th>Long-Run Asymmetric Effects on INTR</th>
<th>Dependent variable = INTR</th>
</tr>
</thead>
<tbody>
<tr>
<td>Variable</td>
<td>SOUTH AFRICA</td>
</tr>
<tr>
<td>INFGAP</td>
<td>5.663638*</td>
</tr>
<tr>
<td></td>
<td>(0.0012)</td>
</tr>
<tr>
<td>RGDPGAP</td>
<td>0.549249</td>
</tr>
<tr>
<td></td>
<td>(0.1023)</td>
</tr>
<tr>
<td>LRER_P</td>
<td>-0.162298*</td>
</tr>
<tr>
<td></td>
<td>(0.0002)</td>
</tr>
<tr>
<td>LRER_N</td>
<td>-0.104050*</td>
</tr>
<tr>
<td></td>
<td>(0.0055)</td>
</tr>
</tbody>
</table>

Bounds Test for Cointegration

<table>
<thead>
<tr>
<th>F-statistics ($F_{pss}$)</th>
<th>13.47026**</th>
<th>10.45292**</th>
<th>22.36603**</th>
</tr>
</thead>
</table>

The Wald Test for Long-run asymmetry

<table>
<thead>
<tr>
<th>LRER</th>
<th>48.68719</th>
<th>5.924504</th>
<th>18.69336</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(0.0000)</td>
<td>(0.0183)</td>
<td>(0.0001)</td>
</tr>
</tbody>
</table>

Statistics and diagnostics

<table>
<thead>
<tr>
<th>Adj. $R^2$</th>
<th>0.690518***</th>
<th>0.753367***</th>
<th>0.678754***</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\chi^2_{LM}$</td>
<td>12.77049****</td>
<td>9.805588****</td>
<td>14.22239****</td>
</tr>
<tr>
<td></td>
<td>(0.3859)</td>
<td>(0.6330)</td>
<td>(0.2867)</td>
</tr>
<tr>
<td>$\chi^2_B$</td>
<td>60.38226****</td>
<td>55.10608****</td>
<td>41.01821****</td>
</tr>
<tr>
<td></td>
<td>(0.2562)</td>
<td>(0.4326)</td>
<td>(0.2235)</td>
</tr>
<tr>
<td>CUSUM AND CUSUMQ</td>
<td>STABLE</td>
<td>STABLE</td>
<td>STABLE</td>
</tr>
</tbody>
</table>

Note: ** indicates the level of significance at 5%.
***The bounds critical values are taken from Pesaran et al. (2001) with unrestricted intercept and no trend (Case III). Upper (lower) bound with k=3 is 4.35 (3.23) at 5% significance level.
****Adj. $R^2$ represents the estimated value of the adjusted $R^2$ coefficient in the model.
*****$\chi^2_{LM}$ and $\chi^2_B$ denote the Breusch-Godfrey serial correlation LM tests and heteroscedasticity tests (White) respectively.

The bottom parts of the Table 2 and Table 3 summarize the bounds test for cointegration, the Wald test for long-run asymmetry and the diagnostic tests of the NARDL model. In Tables 2 and 3, since the $F_{pss}$ statistics exceeds the bounds critical value at 5% significance level for all countries, the null hypothesis of no cointegration is rejected. Thus, these results indicate the presence of long-run asymmetric cointegration relationship between interest rate and the variables of the INFGAP, RGDPGAP, and the RER.

After determining the evidence of asymmetric cointegration for all countries, the Tables 2 and 3 also show the Wald test results to confirm the null hypothesis of long-run symmetry against the alternative of asymmetry between the interest rate and selected macroeconomic variables in the NARDL model. Based on the results presented on the tables, the null hypothesis of long-run symmetry can be rejected at the 5%, except for Brazil. So, the results indicate that the RER has asymmetrical effects on INTR for all selected countries, except Brazil.

The Table 2 and Table 3 report the presence of The Breusch-Godfrey serial correlation LM tests and heteroscedasticity tests in the errors of model. So, the model estimated in the study is well specified. Also, the stability of parameters is checked by using cumulative (CUSUM) and cumulative sum of squares (CUSUMSQ). The CUSUM tests and CUSUM of squares statistics confirm that the coefficients are stable except Chile and Mexico. This result indicate that coefficients seem to follow a stable pattern during the estimation period (results are not reported for brevity). Hence, these coefficients can be used for policy decision.
The results from all above the Tables, the policy reaction functions in emerging countries are not only responding to inflation gap (INFGAP) and output gap (RGDPGAP), but also reacting asymmetrically to exchange rate changes. Thus, the empirical results support that the augmented Taylor rule with exchange rate and asymmetric form is a better representation for monetary policy reaction of selected emerging countries.

### 3.3. The Dynamic Multipliers: Response of the Interest Rate to RER

Regarding the dynamic impacts of the real effective exchange rate (RER) changes on interest rate (INTR) for the selected emerging markets of Brazil, Chile, Mexico, South Africa, South Korea and Turkey, the study of the dynamic multipliers are presented in Figures 1.a to 1.f respectively in the Appendix.

The analysis of the dynamic effects of the real exchange rate on the interest rate can be complemented with the dynamic multipliers. Figure 1 in appendix plot the dynamic multipliers for the selected emerging markets. These multipliers show the pattern of adjustment of interest rate to their new long-run equilibrium following a negative or positive one unit shock in real exchange rate. The dynamic multipliers are estimated based on the best-suited NARDL models. As Shahzad (2017) shows, the positive (continuous black line) and negative (dashed black line) change curves in figures capture the adjustment of the interest rate to positive and negative shocks at a given forecast horizon for each country. The asymmetry curve (broken red line) reflects the difference between the dynamic multipliers associated with positive and negative shocks of real exchange rate. “This curve is displayed together with its lower and upper bands (dotted red lines) at the 95% confidence interval in order to provide a measure of the statistical significance of asymmetry at any horizon x. If the zero line is located between the lower and upper bands, then the asymmetric effects of the explanatory variable in question are not significant at the 5% level” (Shahzad, 2017, p.226).

Figure 1.a. depicts the adjustment pattern of the interest rate to a negative or positive unitary shock in the RER in Brazil. The graph in figure 1.a. confirm the existence of a significant asymmetry and an inverse relationship between the RER and INTR in the short-run, taking around 12 quarters to reach to long-run equilibrium. It is also shown that the effect of a positive shock in RER dominates that of a negative shock, especially in the short-run. Moreover, a significant asymmetric response to shocks in industry stock prices is observed mainly in the short-run for Brazil.

Figure 1.b. depicts the adjustment pattern of the interest rate to a negative or positive unitary shock in the RER for Chile. The graph in figure 1.b. confirm the existence of a significant asymmetry and a positive relationship between the RER and INTR in the short-run, taking around 8 quarters to reach to long-run equilibrium. It is also shown that the effect of a negative shock in RER dominates that of a positive shock, especially in the short-run. Moreover, a significant asymmetric response to shocks in industry stock prices is observed mainly in the very short-run for Chile.

Figure 1.c. depicts the adjustment pattern of the interest rate to a negative or positive unitary shock in the RER in Mexico. The graph in figure 1.c. confirm the
existence of a significant asymmetry and an inverse relationship between the RER and INTR in the very short-run, taking around 4 quarters to reach to long-run equilibrium. It is also shown that the effect of a positive shock in RER dominates that of a negative shock, especially in the short-run. Moreover, a significant asymmetric response to shocks in industry stock prices is observed mainly in the very short-run for Mexico.

Figure 1.d. depicts the adjustment pattern of the interest rate to a negative or positive unitary shock in the RER in South Africa. The graph in figure 1.d. confirm the existence of a significant asymmetry and an inverse relationship between the RER and INTR in the very short-run, taking around 4 quarters to reach to long-run equilibrium. It is also shown that the effect of a positive shock in RER dominates that of a negative shock, especially in the short-run. Moreover, a significant asymmetric response to shocks in industry stock prices is observed mainly in the very short-run for South Africa.

Figure 1.e. depicts the adjustment pattern of the interest rate to a negative or positive unitary shock in the RER for South Korea. The graph in figure 1.e. confirm the existence of a significant asymmetry and a positive relationship between the RER and INTR in the very short-run, taking around 2 quarters to reach to long-run equilibrium, but it reaches to disequilibrium in the long run again. It is also shown that the effect of a negative shock in RER dominates that of a positive shock, especially in the short-run. Moreover, a significant asymmetric response to shocks in industry stock prices is observed mainly in the very short-run for South Korea.

Figure 1.f. depicts the adjustment pattern of the interest rate to a negative or positive unitary shock in the RER in Turkey. The graph in figure 1.f. confirm the existence of a significant asymmetry and an inverse relationship between the RER and INTR in the short-run and long-run, taking around 3 quarters to reach to long-run equilibrium. It is also shown that the effect of a positive shock in RER dominates that of a negative shock, both in the short-run and long-run. Moreover, a significant asymmetric response to shocks in industry stock prices is observed in the short-run and long-run for Turkey.

4. Concluding Remarks and Policy Implications

This paper provides empirical results that the effects of real exchange rate changes on interest rate is asymmetric in selected emerging markets of Brazil, Chile, Mexico, South Korea, South Africa and Turkey. Also, the test results indicate the presence of long-run asymmetric cointegration relationship between the policy reaction function represented by the interest rate and the variables of the inflation gap, output gap and the real exchange rate. Especially, the test results indicate that the real exchange rate has asymmetrical effects on interest rate for all selected countries, except Brazil. Additionally, these empirical results illustrates that the augmented Taylor rule with exchange rate and asymmetric form is a better representation for monetary policy reaction.
References


Appendix