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A nonlinear ARDL analysis on the relation between stock price and exchange rate in Malaysia.

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Abstract

This paper analyzes the relation between stock prices and exchange rates in Malaysia using monthly observations from 1993M01 to 2015M12. Although plenty of studies have discussed on this issue by employing various empirical techniques, these studies often assumed that the dynamics between stock prices and exchange rates are symmetric. This study wonders if introduction of nonlinearity in exchange rate movement can shed new light on this issue, with application of the recently developed nonlinear autoregressive distributed lags (NARDL) technique. The bounds test of the NARDL specification indicates the presence of cointegration among the variables, which include the stock returns, currency appreciations and depreciations, national production, money supply, and inflation. The estimated NARDL models suggest that exchange rate movements have significant short-run and long-run effects on stock prices in Malaysia, and that stock market responds asymmetrically against currency appreciation and depreciation. Namely, in the long run, changes of KLCI are only responding to RM depreciation but not RM appreciation. In addition, stock price–exchange rate relation is sensitive to observation periods and change in exchange rate regimes.

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1. Introduction

The relation between stock prices and exchange rate movements has attracted a special attention from both academics and practitioners. A strong relationship between them would have important implications for economic policies and investment decision making because shocks in foreign exchange market may be transmitted quickly to stock market and thus affecting stock returns.

Research on the relation between exchange rates and stock prices has evolved over time. While some investigate causality between stock prices and exchange rates, some try to distinguish the long-run relationship from short-run effects by establishing cointegration between the two variables[1]. For examples, the bivariate study of Bahmani-Oskooee and Sohrabian (1992) applied Engle and Granger (1987) two-step procedure (EG) on US monthly data from 1973-1988 and found no long-run correlation between share prices and exchange rates. However, they found a bi-directional causality between the two variables in the short run. Similar findings are found in other developed countries (Nieh and Lee, 2001), South-Asian countries (Smyth and Nandha, 2003), and Southeast Asian countries (Lean *et al*., 2005). All the findings above are generated using the Engel-Granger (1987) and Johansen-Juselius (1988) cointegration procedure (JJ). In a multivariate setting, Ibrahim and Aziz (2003) explored the cointegration between Kuala Lumpur composite index (KLCI) and several macroeconomic variables, namely consumer price index, exchange rates, industrial production index, and *M*2. In consistency with the previous findings in the bivariate study of Ibrahim (1999), their rolling regressions of the VAR model showed that stock prices respond negatively to Ringgit depreciation shocks. However, the variance decomposition suggested that most of the variations in KLCI can be attributed to its own variations. Tian and Ma (2010) studied the relationships among stock prices and macroeconomic variables like exchange rates, money supply, industrial production and consumer price index using monthly data from 1995 to 2009 for China. They employed the ARDL bound test approach. Their results showed that prior to financial liberalization of 2005, no cointegration exists between the major foreign exchange rates and the Shanghai stock price index. After the liberalization, cointegration exists.

Although plenty of studies have examined the relation between stock prices and exchange rates by employing various techniques, these studies often assumed that the adjustment between stock prices and exchange rates are symmetric. One exception is Ismail and Isa (2009), who used a two regime Markov-Switching VAR model to examine whether the cointegration between stock returns and exchange rates is state dependent. By using Malaysian monthly data from 1990 to 2005, their analysis showed that a non-linear model is more fitted to model all the series than the linear model. Another recent study is by Cuestas and Tang (2015) who investigated the exchange rate exposure of stock returns in the Chinese industries by using the nonlinear autoregressive distributed lag (NARDL) model for asymmetric analysis and VAR model for linear estimation. Since their nonlinear model of exchange rate exposure is more fitted than the linear model, they suggested that exchange rate exposures of Chinese industry returns are genuinely asymmetric.

[1] A thorough review can be found in Bahmani-Oskooee and Saha (2015).

Indeed, the literature has offered several explanations for the potential nonlinearity or asymmetry between the relation of stock price and exchange rate. The first reason is due to the asymmetric hedging. As argued by Miller and Reuer (1998), if firms use real options to hedge against exchange rate changes, exposure coefficients are expected to be different for periods of exchange rate appreciation as compared to periods of depreciation. Default risk is also said to be another factor causing nonlinearity or asymmetry if it is associated with foreign exchange rate risk. A depreciation of home currency can cause an increase in cost of transactions in foreign currency which in turn causes a domestic client to default. This does not happen when domestic currency appreciates.

Given the reasons above, it might be misleading if the estimation of the relation is assumed symmetric. Therefore, this study wonders if introduction of nonlinearity in exchange rate movement can shed new light on evidence of the issue. Specifically, the purpose of this study is to analyze the short-run and long-run relation between stock market returns and exchange rate movements in Malaysia using a multivariate setting, and to find out whether there are asymmetries in stock return adjustments due to currency appreciation and depreciation.

2. Methodology

2.1 The Data

This study employs five variables and Malaysian monthly data. Variable wise, the stock prices are proxied by the KLCI (*SP*), which is an adequate proxy of stock returns after natural log-transformed. The nominal effective exchange rate is denoted by *EX*. The monetary policy action is indicated by money supply (*M*3). The consumer price inflation is measured by the consumer price index (*CPI*, base year 2005), and national production is indicated by Industrial Production index (*IPI*, base year 2005), respectively. The choice of variables are mostly inspired from Bahmani-Oskooee and Saha (2015), in which multivariate model is adopted to avoid omitted variable bias.

Data wise, all variables are monthly observations because most macroeconomic data are only available at monthly frequency. All data are obtained from Monthly Statistical Bulletins of Bank Negara Malaysia, except that stock prices are obtained from Bursa Malaysia and exchange rates from IMF's International Financial Statistics. The observation period covered 1993M01 to 2015M12, which gives 276 observations in total. All series are expressed in natural logarithms, and *IPI* is seasonally adjusted.

2.2 NARDL Model

In the literature, researchers tend to adopt the standard cointegration framework of error-correction modelling to analyze the long-run relations between stock prices and exchange rates. Some of the commonly used methods include Engel-Granger (1987) two-step cointegration procedure, Johansen-Juselius (1988) multivariate cointegration approach, and the autoregressive-distributed (ARDL) model (Pesaran and Shin, 1999; Pesaran *et al*., 2001). The reasons of why this study prefers the ARDL model over other alternatives are twofold. First, the EG procedure is limited to the case of bivariate analysis, which is not appropriate in this study since there are six variables included in the model. Second, while the JJ approach is designed in multivariate structure, it requires all variables in the model to be integrated at same order, e.g. all variables must be integrated at first order for the cointegration analysis. This requirement is less stringent when using ARDL model because ARDL model can be estimated if each variable is integrated at order below two.

While the standard ARDL model enables evaluation of the long-run relations between time series variables, it only presumes linear or symmetric relations between them. Hence, the standard ARDL model and other techniques that presume symmetric dynamics are not able to capture the potential nonlinearity or asymmetry lie within the relationship between stock returns and exchange rate movements, as aforementioned. In light of this, this study adopts the NARDL approach, which is developed by Shin *et al*. (2014) as an asymmetric extension to the standard ARDL model. The NARDL model is designed to capture both short run and long run asymmetries in a variable of interest, while reserving all merits of the standard ARDL approach.

To begin with, consider the following long run model of stock price as in Bahmani-Oskooee and Saha (2015):

$$SP_t = c_0 + c_1 EX_t + c_2 M3_t + c_3 CPI_t + c_4 IPI_t + e_t \quad (1)$$

where *SP* is the stock price, *EX* is the exchange rate, *M3* is the nominal money supply, *CPI* is the consumer price inflation, and *IPI* is the industrial production index. Equation (1) can be modified and extended to an asymmetric long run equation as:

$$SP_t = \alpha_0 + \alpha_1 POS_t + \alpha_2 NEG_t + \alpha_3 M3_t + \alpha_4 CPI_t + \alpha_5 IPI_t + \varepsilon_t \quad (2)$$

where α_0, α_1, …, α_6 are long run parameters to be estimated and ε_t is the white-noise error term. The constant term α_0 captures all the exogenous factors such as a constant term, linear trend, and dummy variables for structural breaks, if any. In Equation (2), *POS* and *NEG* represent the element of asymmetry in the ARDL model. The values of *POS* and *NEG* are generated by computing

$$POS_t = \sum_{j=1}^{t} \Delta EX_j^+ = \sum_{j=1}^{t} \max(\Delta EX_j, 0) \quad (3)$$

and

$$NEG_t = \sum_{j=1}^{t} \Delta EX_j^- = \sum_{j=1}^{t} \min(\Delta EX_j, 0) \quad (4)$$

where *POS* is partial sum of positive changes (currency appreciations) in *EX*, and *NEG* is partial sum of negative changes (currency depreciations) in *EX*. As discussed previously, the impact of an exchange rate appreciation on stock prices may be asymmetric to what exchange depreciation does. This hypothesis can be tested by evaluating α_1 and α_2 in Equation (2) as they capture the effect of exchange rate appreciation and depreciation on stock return, respectively. The scenario of $\alpha_1 = \alpha_2$ indicates no asymmetry is found between stock prices and exchange rate movements. If $\alpha_1 \neq \alpha_2$, then the presence of nonlinear relation is concluded.

The expected signs of α_1 and α_2 are empirically ambiguous as there are contradictory theoretical explanations provided in the existing literature body to explain the long-run effect of exchange rate movements on stock valuations. On one hand, a negative value of α_1 and a positive value of α_2 support the traditional view of flow-oriented model, which suggests that currency depreciation would improve the trade competitiveness of domestic exporters, and then leads to higher stock prices of exporters. On the other hand, a positive value of α_1 and a negative value of α_2 imply that the firms in Malaysia are mainly net importers, where their trade competitiveness would be adversely affected by currency depreciation. In short, the currency appreciation and depreciation might have both a negative and a positive effect on the domestic stock market for an export-dominated and an import-dominated country, respectively.

In terms of other macroeconomic factors, a positive value of α_3 reflects the positive relation between a monetary expansion to stock price, where increase in money supply leads to a decrease in interest rates, hence to an increase in investment and GDP and eventually to an increase in stock prices. However, Fama (1981) argued that increase in money supply could lead to inflation which in turn might decrease stock prices. As for the expected sign of α_4, inflation usually leads to an increase in input prices and production cost. Increased costs are expected to hurt profit margins and stock prices. Lastly, the sign of α_5 is expected to be positive due to the general consensus that economic activity and stock prices are positively related. An increase in economic activity is expected to lead to an increase in higher corporate earnings then followed by an increase in stock prices.

As shown in Shin *et al*. (2014), Equation (2) can be framed into a normal ARDL bound test setting as follow:

$$\Delta SP_t = \beta_0 + \beta_1 SP_{t-1} + \beta_2 POS_{t-1} + \beta_3 NEG_{t-1} + \beta_4 M3_{t-1} + \beta_5 CPI_{t-1} + \beta_6 IPI_{t-1} + \sum_{p=1}^{n1} \theta_1 \Delta SP_{t-p} + \sum_{p=0}^{n2} \theta_2 \Delta POS_{t-p} + \sum_{p=0}^{n3} \theta_3 \Delta NEG_{t-p} + \sum_{p=0}^{n4} \theta_4 \Delta M3_{t-p} + \sum_{p=0}^{n5} \theta_5 \Delta CPI_{t-p} + \sum_{p=0}^{n6} \theta_6 \Delta IPI_{t-p} + \mu_t \tag{5}$$

where all variables are defined as above. The optimal lag lengths $n = (n1, n2, \ldots, n6)$ are first determined using the Akaike (1974) information criterion (AIC), and then further trimmed by using the general-to-specific method as in Katrakilidis and Trachanas (2012). The model specification of Equation (5) is finalized when it is exempted from any misspecification biases, especially the problem of serial correlation and parameter instability. This can be reached once Equation (5) passed various diagnostic tests. As demonstrated in Shin *et al*. (2014), the bound test approach (Pesaran *et al*., 2001) can be applied to Equation (5) to detect the presence of short-run and long-run relation between stock price and its determinants. A Wald F-statistics will be calculated assuming a null hypothesis of joint significance where H_0: $\beta_1 = \beta_2 = \ldots = \beta_6 = 0$. If the F-statistics is greater than the upper bound critical values (Pesaran *et al*., 2001), we can conclude that a long-run relation exists between stock price and the macroeconomic variables.

3. Results and discussions

Given the requirement of the bounds testing procedure that no I(2) variables are involved, we first subject each time series to the augmented Dickey-Fuller (1981) and Phillips-Perron (1988) unit root tests. The results of these tests are given in Table I.

Table I: Results of Unit Root Tests

Series	Exogenous	Augmented Dickey-Fuller	Phillips-Perron
Level			
SP	*c*, *t*	–2.9628	–2.4317
EX	*c*, *t*	–2.3814	–1.9905
M3	*c*, *t*	–2.1711	–2.9486
IPI	*c*, *t*	–3.0129	–2.7249
CPI	*c*, *t*	–3.5833**	–3.0108
First-Difference			
ΔSP	*c*	–5.5733***	–14.663***
ΔEX	*c*	–8.0268***	–13.929***
$\Delta M3$	*c*	–3.6515***	–14.116***
ΔIPI	*c*	–9.5093***	–24.238***
ΔCPI	*c*	–9.0080***	–12.724***

Notes: *c* indicates a constant and *t* a trend. Lag length selections for ADF test are based on AIC and the maximum lag length allowed is 12. The bandwidth selections and the spectral estimations in PP test are based on Newey-West and Bartlett kernel approach.
, * represents null rejection at 5% and 1% level of significance, respectively.

Clearly, both ADF and PP unit root tests concluded that there is no I(2) variable, this fulfills the requirement to proceed to the bounds testing procedure.

We then estimate Equation (5) in four different fashions for the bound test procedure. Model (I) reports the linear ARDL version of Equation (5), which assumes symmetric effect of exchange rate on stock price, whereas Model (II) presents the asymmetric counterpart. A comparison between Model (I) and (II) provides additional robustness evidence to asymmetric response of stock returns to exchange rate changes, if any. Both Model (I) and (II) include full observation period from 1993M01 to 2015M12. Given the long observation periods covered in the first two models, several episodes of structural breaks are expected to affect the estimates of the full-sample models. In addition, since the exchange rate regime in Malaysia has been altered few times by the central bank during 1993−2015 (see Figure 1), splitting the observation period can be effective to capture any regime effects on the stock return model. Therefore, two NARDL models (III) and (IV) are estimated to represent the period of free-floating (1993M01 to 1998M08) and managed-floating (2005M07 to 2015M12), respectively. The period of currency peg (1998M09 to 2005M06) is dropped out from estimation as the Ringgit Malaysia is fixed at RM3.8000/USD during the said period. In line with the literature, the maximum lag order considered is 7 for each variable in all models. Table II reports the bound test results.

From Table II, the Wald F-statistics values in all models exceed the 95% upper critical bounds. The result supports that there is a cointegrating relationship between stock prices and its macroeconomic determinants in Malaysia. The results also provide the reason for estimating the long-run elasticities of each variable on changes of stock price. The estimates of Equation (2) and (5) are tabulated in Table III.

Figure 1: Malaysian Stock Price and Nominal Exchange Rate, 1993-2015

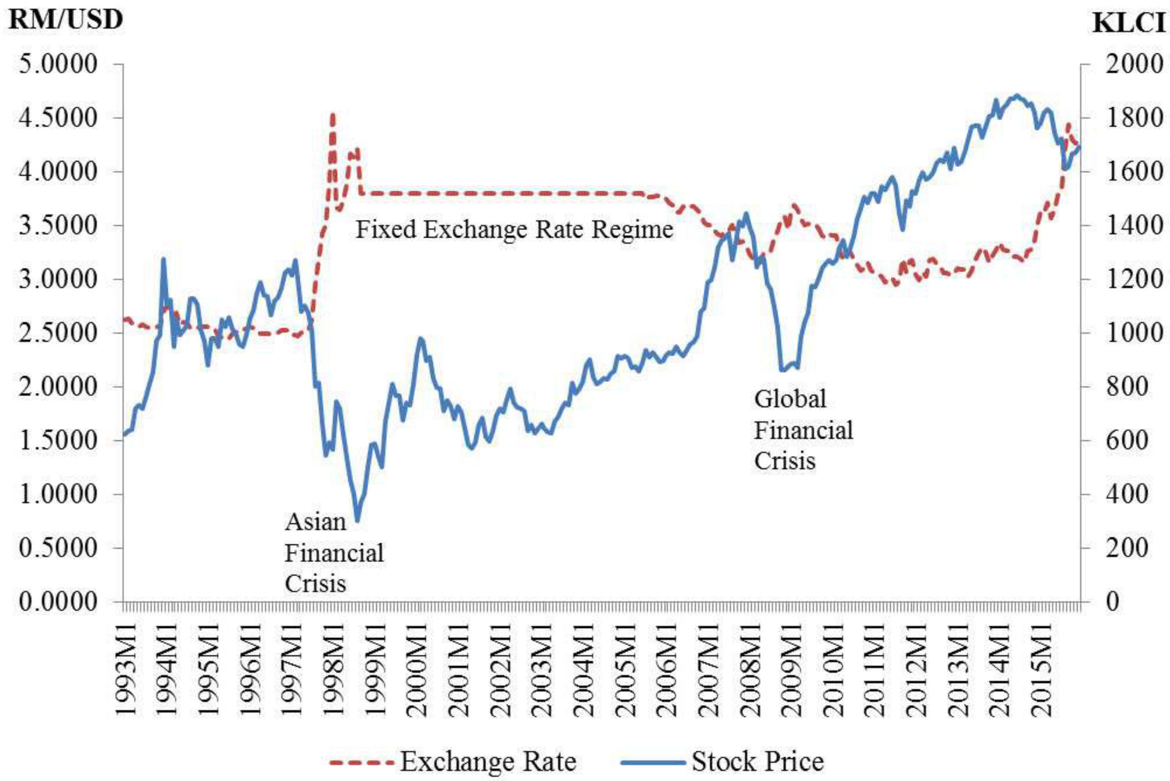

Table II: Bound Test for Cointegration

Model	F-Statistics	95% lower bound	95% upper bound	Conclusion
(I)	6.7883	2.86	4.01	Cointegrated
(II)	5.4613	2.62	3.79	Cointegrated
(III)	5.1384	2.82#	4.10#	Cointegrated
(IV)	4.4996	2.62	3.79	Cointegrated

Notes: Critical values are obtained from Pesaran *et al*. (2001) assuming unrestricted intercept and no trend (Case III). #Critical values for Model (3) are obtained from Narayan (2005) assuming unrestricted intercept and no trend (Case III), given the small sample size.

Prior to further inferences, we first evaluate the adequacy of the dynamic specification of all models based on various diagnostic tests. These include the Jarque-Bera test for error normality, the LM test for serial correlation, the ARCH test for autoregressive conditional heteroskedasticity, CUSUM and CUSUMSQ plots (95% bounds) for testing parameter and variance stability, and coefficient value of the normalized cointegrating equation to see whether the long run relation is significant as error correction mechanism for short-run disequilibrium. The results of diagnostic tests are presented at Panel C of Table III.

Table III: Estimation Results of Linear and Nonlinear ARDL Models

Independent Variable	(I) ARDL	(II) Nonlinear ARDL	(III) Nonlinear ARDL	(IV) Nonlinear ARDL
	Dependent Variable: *SP*			
	Full Sample: 1993:01 – 2015:12	Full Sample: 1993:01 – 2015:12	Sub-Sample: 1993:01 – 1998:08	Sub-Sample: 2005:07 – 2015:12
Panel A: Short Run Dynamics				
ΔSP	0.1705**	–0.0077**	–1.5818***	-
ΔEX	0.7098***	-	-	-
ΔPOS	-	1.6890***	2.0224***	0.0528
ΔNEG	-	0.1580	0.5269	0.4465**
$\Delta M3$	1.0853***	0.9876**	0.8489***	0.2857***
ΔCPI	1.0283	1.1873	6.4174**	–1.3603***
ΔIPI	0.4458**	0.4967**	–2.2209**	0.1838
Panel B: Long Run Relations				
EX	0.9308	-	-	-
POS	-	0.0058	–6.2478	0.5960
NEG	-	1.1514*	3.1742***	–2.1969*
*M*3	2.2815***	1.8802***	3.4783**	3.2234**
CPI	–6.6696**	–2.7472	8.1265	–15.348**
IPI	–0.4759	–0.1666	–4.4608*	–1.2043
Constant	5.1050	–3.7075	–51.493	37.592*
Panel C: Diagnostics				
ECT	–0.1221***	–0.1372***	–0.2440*	–0.0886***
JB	93.247***	55.313***	7.8327**	22.506***
LM (1)	4.2619**	3.8567**	1.6620	0.0340
LM (2)	4.5552	5.0207*	2.2198	0.7093
ARCH (1)	3.5366*	4.3625**	0.2629	0.1604
ARCH (2)	8.7199**	6.8616**	2.1528	0.4167
CUSUM	S	S	S	S
CUSUMSQ	U	U	S	S

Notes: Numbers inside parentheses are lag lengths. Three structural dummy variables are included in models above (if applicable) for 1997 Asian Financial crisis, currency peg, and 2008 Global Financial crisis, respectively, but not reported above to conserve space. The letter 'S' and 'U' denote stable and unstable estimates from CUSUM and CUSUMSQ tests.
*, **, *** represents null rejection at 10%, 5% and 1% level of significance, respectively.

The diagnostic tests results show that all estimated models violated the assumption of error normality, and therefore it is necessary to further detect any other inadequacy in each specification. It seems that Model (I) and (II) do not pass most diagnostic tests, namely serial correlation, conditional heteroskedasticity and error variance stability. However, these diagnostic problems are not found in Model (III) and (IV), suggesting that data split is an appropriate specification. In addition, the values of the error-correction term suggest that the long-run relation is a valid error-correction mechanism in each specification, in which any short-run deviation occurred in stock price will be corrected back to the equilibrium. Since only Model (III) and (IV) have passed most adequacy tests, especially the critical assumptions of no serial correlation and no parameter instability (Pesaran *et al*., 2001; Shin *et al*., 2014), we conclude that the two models are adequately specified for NARDL estimation. Anyhow, a quick glance on the coefficients of exchange rate in Model (I) and (II) do provide hints on asymmetric response of stock price.

Consider first the linear Model (I), stock price is positively responding to currency appreciation in the short run but no significant long-run effect from exchange rate is found. However, estimates in nonlinear Model (II) suggest otherwise. The short-run coefficient of *POS* is significant at 1% while the short-run coefficient of *NEG* is not significant, which suggests that there is short-run asymmetry between the stock prices and exchange rate movements, where stock prices are significantly related to currency appreciation but not to currency depreciation in the short run. As for the long-run relation, asymmetry is found as well, but the direction of significant response of stock price is changed to currency depreciation. The findings above suggest that stock prices are asymmetrically responding to exchange rate movements, in both short-run and long-run.

Nonetheless, the above findings have to be interpreted with care since Model (I) and (II) did not pass certain diagnostic tests. Accordingly, we have re-estimated the NARDL model using sub-samples to obtain more valid arguments, in which the resulting Model (III) and (IV) are presented in Table III.

Moving to Model (III), the estimates show that currency appreciation has significant and positive short-run impact on stock price at 1% level, while currency depreciation has no significant short-run effect. In the long run, currency depreciation in turn has significant and positive effect on stock price at 1% level. Specifically, all else being equal, an additional 1% currency depreciation will lead to a higher stock price by 3.17% in the long run. However, when turning to Model (IV), the picture changes significantly. It implies that currency depreciation has significant effects on stock prices in both short run and long run, whereas currency appreciation has no significant effects at all. In the short run, currency depreciation has significant positive effect on stock price. In the long run, all else being equal, an additional 1% currency depreciation will lead to a lower stock price by 2.19%.

In summary, the results above indicate that exchange rate movements asymmetrically affect stock prices in short run and long run, whereas stock prices are generally responding only to currency depreciation in the long run. This result holds under different observation periods, and it agrees with the findings of Cuestas and Tang (2015). Additionally, asymmetric exchange rate effects occur between short-run and long-run dynamics within a same NARDL specification, in which stock prices are positively related to currency appreciation in the short run but positively related to currency depreciation in the long run. This finding supports the positive link of flow-oriented model, where currency depreciation would improve the trade competitiveness of exporting firms and therefore lead to higher stock prices in the long run. In a broader sense, this indicates that majority of firms in Malaysia are net exporters. Moreover, an interesting result is found after discriminating the observation periods to pre-peg and post-peg regime, where stock prices are responding differently to currency depreciation in the long run. One possible reason of the negative effect of currency depreciation is that Malaysia has experienced a sharp and prolonged decline in currency value (from RM3.3460/$ on 2014 January to RM4.2920/$ on 2015 December). This could adversely affect investors' confidence in holding RM denominated assets which in turn lead to a lower demand in Malaysian stocks and subsequently stock prices. Our results also conclude that the stock price effects from other macroeconomic factors are consistent with the economic priori.

4. Conclusion

This paper attempts to analyze the relation between stock market returns and exchange rate movements in Malaysia, using monthly observations from 1993M01 to 2015M12 with 4 different model specifications. This research has some important findings. First, we found that exchange rate movements have significant short-run and long-run effects on stock prices in Malaysia. Second, we found that relations between stock market and foreign exchange market are asymmetric rather than symmetric, where changes of KLCI are only responding to RM depreciation but not RM appreciation in the long run. Although this study does not directly address the causes of the exchange rate asymmetry, asymmetric hedging (Miller and Reuer, 1998) behavior of securities holders and asymmetric default risk might be the explanations. Third, the exercise to divide the NARDL estimation to pre and post currency peg periods showed that stock price – foreign exchange rate relation is sensitive to observation periods, and that structural changes in exchange rate regimes do have substantial influences to stock price model estimates.

Our empirical results carry several implications to different audiences. From the prospect of securities investor, it is advisable to stay responsive to the fluctuations of exchange rate, especially when currency is depreciating. As our results estimated that stock prices will drop in the long run when Ringgit Malaysia depreciates in value, as shown in the post peg model, share investors are expected to make their decisions accordingly to their short-long position. Our results also provide some suggestions on the direction of monetary policymaking. Monetary policy makers are recommended to be more attentive as they plan to announce any new policy change that might trigger persistent shocks to stock market. These policies include any that would affect currency rate, inflation rate, and money supply. The conclusion of non-linearity also provides suggestions to future researches on related topics. It is advisable to include the detection of non-linearity within dynamic adjustments whenever a study is designed to examine the equity-exchange rate nexus. The employment of non-linear technique would enhance future studies in terms of better model specification. Our findings also provide another explanation for mixed results found in the relationship between stock price and exchange rate. The asymmetric relations between the two variables could be one of the reasons.

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