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EXCHANGE RATE OVERSHOOTING IN BANGLADESH: AN AUTOREGRESSIVE DISTRIBUTIVE LAG (ARDL) MODEL BOUND TESTING APPROACH

MONIR UDDIN AHMED[1] and MD MONIRUZZAMAN MUZIB[*2]

Department of Economics, ShahJalal University of Science and Technology, Sylhet-3114, Bangladesh[1]; Department of Economics, Mawlana Bhashani Science and Technology University, Tangail-1902, Bangladesh[2]

Abstract

This paper examines Dornbusch's (1976) sticky-price monetary model to exchange rate determination by employing newly developed cointegration technique, Autoregressive Distributive Lag (ARDL) Mode bound test, developed by Pesaran *et al.* (2001) for the quarterly data of Bangladesh and USA over the period 1980:01-2009:04. With the advantage that ARDL bound test incorporates both I (1) and I (0) series, this paper concludes on the basis of empirical evidence that there is a long-run equilibrium relationship between exchange rates and macro fundamentals. Moreover, the short-run dynamic response, getting from the result of the ARDL short-run dynamic model where the verified lag-length is used, supports the overshooting of currency depreciation as described by Dornbusch (1976). Moreover, the models are specified through by model specification diagnosis tests.

Key words: Nominal exchange rate, Overshooting, ARDL, Bound test, Co-integration

JEL Code: F31, F37, F41

Introduction

Having accepted the outward-oriented industrialization strategy, Bangladesh has followed a relatively flexible exchange rate policy since the late 1980s. In 1989 a reform program was introduced to unify multiple exchange rates. Since the early 1980s the increased availability of foreign exchange from export earnings, worker's remittances and foreign aid has led the government to lower controls over capital outflows. Along with easing of capital controls since then, the government has particularly encouraged foreign private investment. As monetary policy is coupled with the fiscal policy, very often it fails to maintain its prime objective, price stability. In that case, the main goal of central bank is turned into exchange rate stability and output generation.

Given the long run equilibrium exchange rate, any macroeconomic policy which are not consistent with equilibrium real exchange rates will lead to a real exchange rate misalignment. Such a real exchange rate misalignment may create a boom in the tradable goods sector if the currency is undervalued and vice versa for the second country whose currency is overvalued. This is not fruitful, because, any sustained loss of output may ultimately create a protectionist trade regime.

In an effort to explain the abnormal fluctuation in an exchange rate, Dornbusch (1976) introduced his Sticky-Price monetary model which contained an 'overshooting' hypothesis. The main feature of his model is that since prices are sticky in the short-run,

[*] Author for correspondence: zamanmuzib@gmail.com

an increase in money supply which results in lower interest rates and thus capital outflow, will cause currency depreciation. The currency will actually depreciate over and beyond its long-run value, i.e., in the short-run it will overshoot itself. However, over time commodity prices will rise and result in a decrease in real money supply and thus, in a higher interest rate. This in turn will cause the currency to appreciate. What happens to the long-run value of a currency is an empirical question. The empirical research is mixed at best. While Frankel (1979), Driskill (1981), Papel (1988), and Park & Rhee (1998) provide supportive results but Hacche and Townend (1981), Backus (1984), and Flood & Taylor (1996) do not.

Dornbusch (1976) argued that volatility is in fact a far more fundamental property than the lack of information, which creates disequilibrium. His model assumes that, while the prices of goods are sticky (slow to adjust), the exchange rate adjusts instantaneously to any change in current financial market conditions. Yet the stickiness of goods prices causes evolution over time in the goods market, and due to market linkages this leads to evolution over time in the foreign exchange market equilibrium. This result in variability in the exchange rate even after a shock to that market has gone away and hence the exchange rate volatility.

In this paper we try to test the overshooting hypothesis by employing Bangladesh's data and most recent advances in applied research. After 1973, when the international monetary system changed from fixed to relatively flexible exchange rate system, then in 1980, about fifteen Taka was buying one U.S. dollar. Today, that rate stands at more than Taka seventy eight per dollar. We would like not only to test the monetary approach but also to determine whether Taka has overshot its short-run as well as its long-run relationship.

Theoretical Framework

The monetary approach of exchange rate theory combines the quantity theory of money under fully flexible prices determined by real money demand and nominal money supply with strict purchasing power parity (PPP) to arrive at a theory of the exchange rate. The approach can be simply formulated in terms of a combined theory of monetary equilibrium and exchange rate determination. Following Dornbusch (1976), let M, P, V and Y be the nominal quantity of money, the price level, velocity and real income of domestic country.

From the theory of the exchange rate it may be drawn on a strict version of PPP which states that domestic price level is equal to foreign prices, P*, converted at the exchange rate, E:

$$P = P^* E \tag{1}$$

where E is the domestic currency price of foreign exchange. This yields an expression for the equilibrium exchange rate:

$$E = (1/P^*)V\frac{M}{P} \tag{2}$$

The equilibrium exchange rate depends on nominal money, real output and velocity. The theory argues that domestic prices fully flexible, but are linked to world prices by PPP. Given the nominal quantity of money any variations in the demand for money must be offset by compensating changes in the level of prices and thus in the exchange rate. An increase in real money demand, say of an increase in real income, will be accommodated by a decline in the level of prices so as to raise the real value of the existing nominal money stock. With a decline in domestic prices, though, as domestic country is out of line with world prices and thus require an appreciation of the exchange rate.

$$E = \left(\frac{M}{M^*}\right)\left(\frac{V}{V^*}\right)\left(\frac{Y^*}{Y}\right) \tag{3}$$

By taking logarithm, we have the following equation

$$\ln E = (\ln M - \ln M^*) - (\ln Y - \ln Y^*) + (\ln V - \ln V^*) \tag{4}$$

or

$$e = m - y + v \tag{5}$$

where e = ln*E*, m=(InM- InM*) and v= (InV- InV*)

The last step in arriving at the monetary model is to identify the determinants of velocity in two countries. We shall assume that interest rate and inflation rate in two countries are the main determinant of velocities. Thus, denoting the interest rates by i_B and i_{US} and inflation rates by π_B and π_{US}, the monetary model that we plan to estimate takes the following form:

$$e_t = a + bm_t + cy_t + di_t + e\pi_t + \varepsilon_t \tag{6}$$

where $i = i_B - i_{US}$ and $\pi = \pi_B - \pi_{US}$

It is expected that estimate of b>0 indicating that a faster growth of money supply in Bangladesh over that of the U.S. will depreciate the Taka. Indeed, monetarists would predict estimate of b=1. Following the monetarist prediction, estimate of c is expected to be negative indicating an appreciation of the Taka due to an increase in Bangladesh income relative to that of the U.S. Estimates of d and e are expected to be positive indicating a depreciation of the Taka due to an increase in Bangladesh’s interest rate and inflation rate respectively.

Definition and Sources of variables

Before going to explore the long-run relationship, it is important to look at the sources and definition of the variables. This is shown in Table 1. Quarterly time series data are employed from 1980:1 to 2009:4 in this study. It is to be mentioned that the Quarterly GDP of Bangladesh has been used in too few cases in Bangladesh.

Following the literatures, broad money, M2 includes more than just physical money such as currency and coins (also termed narrow money). It generally includes demand deposits at commercial banks, and any monies held in easily accessible accounts. Components of broad money are still very liquid, and non-cash components can usually be converted into cash very easily. It includes currency and coins, and deposits in checking accounts, savings accounts and small time deposits, overnight repos at commercial banks, and non-institutional money market accounts. This is the main measure of the money supply, and is the economic indicator usually used to assess the amount of liquidity in the economy, as it is relatively easy to track.

Table 1: Variable definition and sources.

Variables	Unit	Sources
Nominal Exchange rate, e	Taka price of Dollar, i.e, how much taka can be found against \$1. The variable is defined as the natural logarithm of original series.	Bangladesh Bank Statistics
M2 money supply, m	Difference between M2 money supply, Bangladesh and M2 money supply, USA. The variable is defined as the natural logarithm of original series of difference.	Bangladesh Bank, Bangladesh and Federal Reserve, USA
Real Income or GDP, y	Difference between GDP, Bangladesh and GDP, USA	Federal Reserve, USA and Hossain and Joarder (2010)
3-months Treasury bill rate, i	Difference between the interest rate on treasury bill, Bangladesh and the interest rate on treasury bill, USA.	Bangladesh Bank Statistics and Federal Reserve, USA
Inflation rate, π	Calculated as the difference between π_B and π_{US}, where, in both cases π is calculated as: $\pi_B = [(CPI_t - CPI_{t-1})/CPI_{t-1}]$ and same as for π_{US}	For π_B, Bangladesh Bank Statistics and for π_{US}, WDI.

The choice of interest rates depends on the measure of money being modeled. In this case we have used money market interest rate such as 3-months Treasury bill rate. It is to be expected that the Treasury bill rate is a risk-free rate of interest rate. Other variables such as income differentials (y) and inflation rate differentials (π) are taken as theory prescribed.

Methodology

Since the overshooting hypothesis is a short-run phenomenon, an appropriate method to test it would be to employ error-correction modeling and cointegration techniques. The first step in applying such techniques is to determine the order of integration of each variable. However, depending on the power of unit root tests, different tests yield different results (Bahmani-Oskooee and Brooks, 1999). Due to this uncertainty, especially when some variables in the model are at their level (e.g., e, m, y) and some are at the rate of change (e.g., π), Pesaran and Shin (1995a, 1995b) and Pesaran et al. (1996) introduce yet another method of testing for cointegration. The approach known as the Autoregressive Distributed Lag (ARDL) model approach has the advantage of avoiding the classification of variables into I(1) or I(0) and unlike standard cointegration tests, there is no need for unit root pre-testing. Following Bahmani-Oskooee & Brooks (1999), the error correction version of the ARDL model pertaining to the variables in Eq. (6) is as follows:

$$\Delta e_i = \alpha_0 + \sum_{i=1}^{p} \beta_i \Delta s_{t-i} + \sum_{j=1}^{m} \gamma_i \Delta m_{t-j} + \sum_{k=1}^{n} \theta_i \Delta y_{t-k} + \sum_{l=1}^{q} \mu_i \Delta i_{t-l} + \sum_{u=1}^{r} \varphi_i \Delta \pi_{t-u} + \delta_1 s_{t-1} + \delta_2 m_{t-1} + \delta_3 y_{t-1} + \delta_4 i_{t-1} + \delta_5 \pi_{t-1} + \vartheta_t \qquad (7)$$

Two steps are involved in the ARDL procedure. First, the null of no cointegration defined by H_0: $\delta_1 = \delta_2 = \delta_3 = \delta_4 = \delta_5 = 0$ is tested against the alternative H_1: $\delta_1 \neq \delta_2 \neq \delta_3 \neq \delta_4 \neq \delta_5 \neq 0$ by the means of familiar F-test. However, the asymptotic distribution of this F-statistic is non-standard irrespective of whether the variables are I (0) or I (1). Pesaran et al. (1996) have tabulated two sets of appropriate critical values. One set assumes all variables are I (1) and another assumes that they are all I (0). This provides a band covering all possible classifications of the variables into I (1) and I (0) or even fractionally integrated. If the calculated F-statistic lies above the upper level of the band, the null is rejected, indicating cointegration. If the calculated F statistic falls below the lower level of the band, the null cannot be rejected, supporting lack of cointegration. If, however, it falls within the band, the result is inconclusive.

Empirical Results and Discussions

Unit Root Test

Before we proceed the ARDL bound tests, we have to test the stationarity of the variables to determine their order of integration. We have to make sure that the variables or one of the variables are not I(2) because, in this case the ARDL bound test would fail to identify the cointegration and the regression would be spurious because bound test is based on the assumption that the variables are either I(0) or I(1) (Pesaran et al., 2001). Therefore, the implementation of unit root tests in the ARDL procedure might still be necessary in order to ensure that none of the variables is integrated of order 2 or beyond.

Table 2: Unit root test of the variables.

Variable	Augmented Dicky-Fuller Test				Phillips-Perron Test			
	Level	Decision	Difference	Decision	Level	Decision	Difference	Decision
E	-3.900***	I(0)	-8.396***	I(0)	-3.322**	I(0)	-8.664***	I(0)
M	0.398	I(1)	-13.263***	I(0)	0.429	I(1)	-13.001***	I(0)
Y	-2.025	I(1)	-10.560***	I(0)	-2.052	I(1)	-10.565***	I(0)
I	-2.035	I(1)	-10.077***	I(0)	-2.139	I(1)	-10.081***	I(0)
Π	-8.432***	I(0)	-15.652***	I(0)	-8.514***	I(0)	-20.370***	I(0)

Notes: ****denote significant at 1% level. The MacKinnon critical values for ADF test are -3.689, -2.975 and -2.619 at 1%, 5% and 10% level of significance respectively. The MacKinnon critical values for Phillips-Perron test are -3.689, -2.975 and -2.619 at 1%, 5% and 10% level of significance respectively.*

In this study, we used both the methods of testing the order of integration of the variables: Augmented Dicky-Fuller Test[1] and Phillips-Perron[2] Test. The test regression included both a constant and trend for the log-levels and a constant with no trend for the first differences of the variables. Table 1 shows that all of the variables except e and π, are integrated of order one, i.e, I(1) at levels but I(0) at their first difference. These results are robust to the Phillips-Perron test. From the Table 3, we see that the variables are the combination of I(0) and I(1) variables and none of them are I(2), i.e. integrated of order two. One of major conditions for proceeding ARDL method is to have the variables of integrated of order zero or one or both. Our investigations of the nature of the conintegration of the variables suggest moving into the next stage, ARDL bound test. Before going to next step, it is reasonable to select the optimal lag of the variables (Pesaran et al., 2001). Considering the small sample data set we cannot take lag more than 2 on basis of minimum value of Final Prediction Error (FPE) and Akaike

[1] see Dickey and Fuller. (1979).
[2] see Phillips and Perron. (1988).

Information Criterion (AIC). Literature reveals that the calculation of ARDL F-statistics is quite sensitive to the selection of lag order in the model (Bahmani-Oskooee and Brooks, 1999; Bahmani-Oskooee and Harvey, 2006). We use the Vector Auto regression (VAR) lag length selection method by considering both the FPE and AIC criteria. In this case, we would use the maximum lag of 1 for their first difference of the variables in which we both taking FPE and AIC criteria in both cases.

Bounds testing procedure

In the first step, we examine the long-run relationship of Eq. 6 by using the Eq. 7 by OLS and then examine the joint significance of the coefficients of the lagged levels of the variables, $H_0 : \delta_1 = \delta_2 = \delta_3 = \delta_4 = \delta_5 = 0$ against $H_1 : \delta_1 \neq \delta_2 \neq \delta_3 \neq \delta_4 \neq \delta_5 \neq 0$. We denote the test which normalize on *f(e |m ,y ,i ,π)*. A table for asymptotic critical F-values for bounds test is provided by Pesaran et al. (2001) to test cointegration when the independent variables are I(d) (where 0 ≤ I ≤ 1): a lower value assuming that the regressor are I(0) where the upper value assume that the regressor are I(1). If the F-statistics is above the critical value, then the null hypothesis of no long-run relationship can be rejected irrespective of the order of integration of the variables. If the F-statistics lies below the lower critical value we cannot reject the null hypothesis. If the F-statistics lies between the lower and upper critical values, then the decision is inconclusive. The following table shows the F-statistics and critical values.

Table 3: Cointegration test.

Model	LHS variable	Forcing variable	F Statistics	95% Critical bounds (with no trends)		t statistics	95% Critical bounds		Cointegra-tion
				I(0)	I(1)		I(0)	I(1)	
1	e	m,y,i,π	6.67 (0.000)***	2.26	3.48	-0.0507	-3.41	-3.69	Present
2	m	e,y,i,π	0.90(0.483)	2.26	3.48	-0.0504	-3.41	-3.69	Absent
3	i	e,m,y,π	3.79(0.003)***	2.26	3.48	-0.2902	-3.41	-3.69	Present[a]
4	y	e,m,i,π	0.58(0.713)	2.26	3.48	-0.0548	-3.41	-3.69	Absent
5	π	e,m,y,i	4.71(0.000)***	2.26	3.48	-0.8223	-3.41	-3.69	Present[a]

N.B: (1) F statistics are bold when they are significant at the 5% level. The null hypothesis for the F test is $H_0 : \delta_1 = \delta_2 = \delta_3 = \delta_4 = \delta_5 = 0$. The null hypothesis for the t statistics is $\delta_1 = 0$, where δ_1 denotes the coefficient on the lagged *level of the dependent variable. Critical bounds for the t statistics are taken from Table CII (v) in* Pesaran et al. (2001), p. 304 which are also applicable for unrestricted trend and intercept as before. The LHS and Forcing variables are expressed in their first difference form. All of the tests are based on the equation (7) where appropriate lag length are used using unrestricted VAR. *, ** and *** indicates 10%, 5% and 1% level of significance respectively.
(2) [a]Although the models show the cointegration, but the models are misspecified because, theory does not suggest these specification.

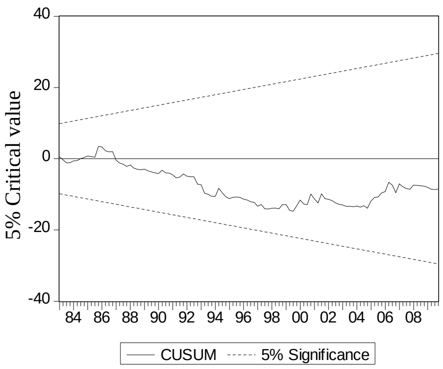
The results of the ARDL bound test are shown in Table 3. The model 1, which is supported by the theory, suggest the rejection of the null hypothesis of no long-run relationship at 5% level of significance at no intercept and no trend case as shown in Pesaran et al. (2001) when e is treated as dependent variables and (m,y,i,π) are treated as its long-run forcing variables. As can be seen from the Table 3, the estimated F-statistic is greater than the upper bound critical values suggested by at the 5% level in the case where e is the dependent variable and (m,y,i,π) are the independent variables. On the other hand, Model 2 and Model 4 fail to reject the null hypothesis of no long-run relationship. Again we could have Model 3 and Model 5, which show that they both reject the null hypothesis of no long-run relationship. But, it is to be noted that these models are misspecified, because, they are not supported by the exchange rate theories (Dornbusch, 1976; Frankel, 1987). Moreover, there are endogeneity problems and fail to support Dornbusch (1976). Our cointegration test suggests that there is a strong long-run relationship between the exchange rate, e, and the other repressors, m, y, i and π.

In the second step, we would find out the short run dynamics which is associated with the long-run relationship obtained from the Error Correction Model (ECM) equation. The estimation of this equation is given in Table 4.

Table 4: Short-run ARDL Regression [Dependent variable Δ e]

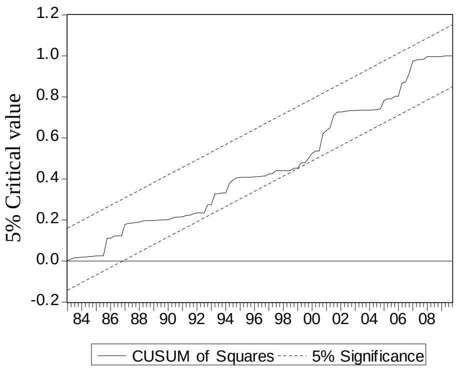
Variable	Lag order		
	0	1	
Δ e(-1)		0.586207(0.000)***	
Δm	-0.208673(0.000)***		
Δy	-0.003707(0.2094)		
Δi	-0.000848(0.5922)		
$\Delta\pi$	0.000222(0.6590)		
ecm(-1)	-0.611911(0.0001)***		
R^2	0.435225		
Adj R^2	0.403849		
Durbin-Watson stat	2.014956		
Akaike info criterion	-5.563497		
Schwarz criterion	-5.396414		
ARCH(1)	χ^2 = 1.003 (0.3167)	ARCH(3)	χ^2 = 9.091 (0.0281)
ARCH(2)	χ^2 =1.754 (0.4161)	ARCH(4)	χ^2 = 12.214 (0.0158)
Breusch-Pegan-Godfrey LM Test(1)	χ^2 = 0.613 (0.4337)	Breusch-Pegan-Godfrey LM Test(2)	χ^2 = 3.602 (0.1651)
Durbin Alternative test	χ^2 = 0.573 (0.4489)		
Jarque-Berra Normality	10.994(0.004)***		

N.B: This regression contains robust standard error. The values in the parenthesis indicate p-value. ***, ** and * are 1%, 5% and 10% level of significance respectively.



1(a) CUSUM

Fig. 1(a): CUSUM



1(b) CUSUMQ

Fig. 1(b): CUSUMQ

The short-run ARDL regression shows that the equilibrium correction coefficient (ecm), estimated -0.61191 (0.0001) is highly significant (at 1% level of significance), has the correct sign and imply a fairly high speed of adjustment to the equilibrium after a shock. Approximately 61% of disequilibria from the previous quarter's shock converge back to the long-run equilibrium in the current quarter.

The regression for the underlying short-run ARDL fits very well. The Durbin-Watson d statistics is 2.01 which indicate that the estimated model is free from autocorrelation. Again, R^2 and Adjusted R^2 show that the model is highly specified. In diagnostic checking, we have seen that the estimated regression passes the serial correlation test at lag 1 and 2 and autoregressive conditional heteroscedasticity test at lag 1 and 2 but fails at lag 3 and 4. The residuals have passed the test of normality provided by Jarque-Bera normality test.

Figure 1(a) and Figure 1(b) show that the short-run ARDL regression passes both the Cumulative Sum of residuals (CUSUM) and Cumulative Sum of Squared residuals (CUSUMQ) test of residuals. The left-hand side figure shows that the recursive residual line is downward but it is significant. The right-hand side figure, Figure 1(b) shows that CUSUMQ is also significant at 5% level of significance. These graphs suggest no systematic or haphazard changes in the regression coefficients which have remained within the 5% bounds of parameter stability. These diagnostic tests are important because the short-run dynamics remain essential in testing for stability of the long-run coefficients in the model (Pesaran and Pesaran, 1997).

Conclusion

This paper examines Dornbusch's (1976) sticky-price monetary model to exchange rate determination by employing the newly-developed ARDL bound test by Pesaran et al. (2001). Since various unit root tests show that variables considered in this study are inconclusive of being I (1) or I (0), with the advantage that ARDL bound test incorporates both I (1) and I (0) series, we conclude our empirical evidence that there is a long-run equilibrium relationship between exchange rates and macro fundamentals. Moreover, for the short-run dynamic response, the result from the ARDL (1, 1, 1, 1, 1) setting supports the overshooting of currency depreciation as described in the sticky-price monetary exchange rate model by Dornbusch (1976).

In our Dornbusch's (1976) overshooting examination, we investigate whether the shock of monetary supply causes an overshoot of exchange rate depreciation over its long-run mean. The monetary model adopts the money supply differential between two countries (Bangladesh and the US in our example) as a key factor for determining the exchange rate movement. The lag term of money supply differential in the ARDL overshooting model describe the lag-lead implication of the effect of monetary shock on the exchange rate level. With the acknowledge that monetary interventions from both countries' monetary authorities (Bangladesh Bank and the FED of the US) significantly affect the exchange rate level, in order to add extra academic value, further research for exchange rate determination should be done by incorporating central bank's intervention as an impact innovation (e.g., add dummy variables to proxy for the interventions).

Reference

Backus, D. (1984). Empirical models of the exchange rate: Separating the wheat from the chaff. The Canadian Journal of Economics/Revue canadienne d'Economique, **17**(4) (Nov., 1984), pp. 824-846

Bahmani-Oskooee, M. and Brooks, T. J. (1999). Bilateral J-curve between US and her trading partners. Review of World Economics, **135**(1), 156-165.

Bahmani-Oskooee, M. and Harvey, H. (2006). How sensitive are Malaysia's bilateral trade flows to depreciation?. Applied Economics, **38**(11), 1279-1286.

Dornbusch, R. (1976). Expectations and exchange rate dynamics. The Journal of Political Economy, 1161-1176.

Dickey, D. A., and Fuller, W. A. (1979). Distribution of the estimators for autoregressive time series with a unit root. Journal of the American Statistical Association, 74(366a), 427-431.

Driskill, R. (1981). Exchange rate overshooting, the trade balance, and rational expectations. Journal of International Economics, **11**(3), 361-377.

Flood, R. P., and Taylor, M. P. (1996). Exchange rate economics: what's wrong with the conventional macro approach?. In The microstructure of foreign exchange markets (pp. 261-302). University of Chicago Press.

Frankel, J. A. (1979). On the mark: A theory of floating exchange rates based on real interest differentials. The American Economic Review, **69**(4), 610-622.

Hacche, G., and Townend, J. (1981). Exchange rates and monetary policy: modeling sterling's effective exchange rate, 1972-80. Oxford Economic Papers, **33**, 201-247.

Hossain, A.K.M. Nurul and Joarder, Abdul Munim. (2010). Does the central bank contribute to political business cycles in Bangladesh? National Conference on Contemporary Issues in Bangladesh, Shahjalal University of Science and Technology, Sylhet, Bangladesh, 23-24 February, 2010

Papell, D. H. (1988). Expectations and exchange rate dynamics after a decade of floating. Journal of International Economics, **25**(3), 303-317.

Park, D., and Rhee, C. (1998). Currency crisis in Korea: how was it aggravated? Asian Development Review, **16**(1), 149-181.

Pesaran, M. H. and Shin, Y.(1995a). Long Run Structural Modeling. DAE Working Paper, Department of Applied Economics, University of Cambridge.

Pesaran, M. H. and Shin, Y. (1995b). An Autoregressive Distributed Lag Modeling Approach to Cointegration Analysis. DAE Working Paper, No. 9514, Department of Applied Economics, University of Cambridge.

Pesaran, M. H., Shin, Y., and Smith, R. J. (1996). Testing for the Existence of a Long-Run Relationship. DAE Working Paper, No. 9622, Department of Applied Economics, University of Cambridge.

Pesaran, M. H., Shin, Y., and Smith, R. J. (2001). Bounds testing approaches to the analysis of level relationships. Journal of applied econometrics, **16**(3), 289-326.

Phillips, P. C., and Perron, P. (1988). Testing for a unit root in time series regression. Biometrika, **75**(2), 335-346.