Purchasing Power Parity (PPP) Validity and Mean Reversion in Real Exchange Rate: Bangladesh Evidence.

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Abstract: *In this paper, our objective is to test the stationarity of real exchange rate of Bangladesh to see empirical validity of PPP in short run or at least in long run. We examine the presence of mean-reversion in the real exchange rate using the unit root test approach i.e. Augmented Dickey-Fuller test ,DF-GLS test and conintegration framework. Our results from unit root tests fail to support PPP which means there is nonstationarity in real exchange rate time series. In addition, conintegration cannot be applied as price levels, nominal exchange rate are not integrated in same order. We also cannot use ARDL model as price levels are I(2) series .*

Keywords: Purchasing Power Parity**,** Real exchange rate.

JEL Classification: F31.

Introduction

Validity of Purchasing Power Parity (PPP) is significant to policymakers for two reasons. First, PPP can be used to forecast exchange rate to conclude whether a currency is overvalued or undervalued. This is important for developing countries, along with countries experiencing large differences between domestic and foreign inflation rates. Second, PPP is used as the foundation for numerous theories of exchange rate determination. Therefore, the validity is important to those policymakers in developing countries who base their adjustment of exchange rate determination on the concept of PPP (Chang et al., 2010). Furthermore, estimates of PPP exchange rates are important for some practical purposes, including measuring nominal exchange rate misalignment, determining exchange rate parities, and comparing the national incomes of different countries. In the paper, we aim to examine the empirical validity of PPP theory; by looking into the existence of stationarity in real exchange rate of Bangladeshi currency i.e. taka. In order to investigate the validity of PPP, unit root testing has become a very popular approach. If the real exchange rate includes a unit root, the shocks should have permanent effects and the variable will never return to its long run equilibrium. On the other hand, if the real exchange rate is stationary, shocks tend to die out in the long run and the equilibrium is achieved some time after the shock has occurred (Cuestas & Regis, 2008).

Objective of the Study

The concept of purchasing power parity (PPP) remains a cornerstone of exchange rate theory and international macroeconomics. PPP is based on the law of one price and implies that exchange rates should equalize the national price levels of different countries in terms of a common currency.

According to The law of one price, identical goods sold in same price in different countries, expressed in same currency. If it holds true for individual commodity, ppp holds true automatically. However, problem is that reference basket is different across countries for ppp holding true, as a result ppp validity does not require law of one price holds exactly. The absolute version of PPP theory asserts that the same basket of goods and services should cost the same when expressed in terms of the same currency. Meanwhile, relative version of the theory asserts that the perchantage change in the exchange rate between two countries should be equal in perchantage change in national price level.

International finance theory reflects two puzzles about ppp validity(see Kenneth Rogoff) for details .There is no consensus in obtaining similar conclusions about ppp in the long run (the first puzzle) and the real exchange rate has a higher volatility in the short term compared with a slower mean reversion in the long run (the second puzzle) (Nicholae Ghiba,2011).

In this respect, the particular of objective of the study is:

- To solve PPP puzzle, that means mean reversion in real exchange rate at least in the long run.
- In addition, to see whether there is any volatility in real exchange rate in the short run.

Few Previous Literatures

Tons of previous literatures (See for example David H. Papell & Ruxandra Prodan ;Georgios Chortareas & George Kapetanios,2008; Matteo Pelagatti & Emilio Colombo) can be found on the empirical test of PPP hypotheses. We can find many literatures attempted to test the stationary or random walk[1] test to verify holding of PPP theory. The empirical validation of the purchasing power parity (PPP) theory is generally based on real exchange rates using consumer price indexes (CPI). The empirical evidence fails to provide clear support to the theory resulting in the purchasing power parity puzzle. Even if the law of one price holds for all the goods traded in two countries, real exchange rates based on CPI are not mean-reverting and therefore statistical tests based on them should reject the PPP hypothesis. Meanwhile, test for consistency of the PPP hypothesis in emerging economies is obstacle mainly due to the frequent variation in the exchange rate arrangement, which resulting in long periods of fixed exchange rates. Furthermore, the same specification of the PPP hypothesis is not applicable to countries adopting different exchange rate regime.

Many of previous literatures, using different time series and econometric techniques, found mixed results. Although numerous studies supported the existence of PPP, some of them found very little or no evidence for PPP. One explanation for this unexpected result is the use of short data with standard unit root tests. In prior literatures, long run PPP has been tested in most cases, and support found

[1] The random walk hypothesis is a financial theory stating that stock market prices evolve according to a random walk and thus cannot be predicted. For example, one might consider a drunken person's path of walking to be a random walk because the person is impaired and his walk would not follow any predictable path.

using unit root test such as ADF, DF-GLS and PP (NicolaeGhiba, 2011). Meanwhile, Yin Wong Cheung et al found that modified Dicky Fuller test exhibit better result for PPP support. .

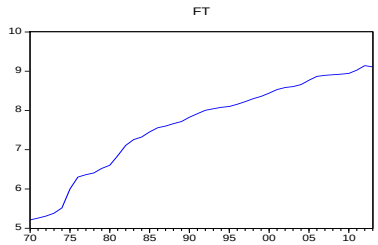
Conversely, conventional univariate unit root tests fail to support PPP (Joseph D. Alba and Dongh yun Park). They also found evidence of non-linear mean reversion in real exchange rates. This implies that PPP holds in one threshold regime but not in another. Matteo Pelagatti and Emilio Colombo proved that such real exchange rates are neither stationary nor integrated, and so both unit-root and stationarity tests should reject the null according to their power properties. Giorgio Valente and Lucio Sarno provided strong evidence that long-run PPP is valid.

There are many papers that look into stationarity of real exchange rate of Bangladesh. For example Zaman et al (1999), by using co-integration technique, assured a long term relationship among PPP and exchange rate. Ahmed (2005) found some empirical support only for the relative version of PPP as a theory of price determination in Pakistan. His paper also discusses potential reasons for empirical failure of PPP in developing countries. Anwar & Ahmed (2006) used Engle-Granger co-integrating relationship, on a data set of 1984 to 2002 of India, Pakistan, Bangladesh, Sri Lanka. They found PPP holds in weaker form with respect to Pakistan, India and Sri Lanka; meanwhile strong indication of lack of PPP for Bangladesh. However, Hoque & Banarjee(2012) used unit root tests with structural change for same four countries on 55 year data set , found that real exchange rate is not constant and no support for long run ppp holding. Chowdhury applied nonlinear econometric technique on data from 1994 to 2002 of Bangladesh context, found strong evidence for highly nonlinear mean reversion towards a stable long run equilibrium.

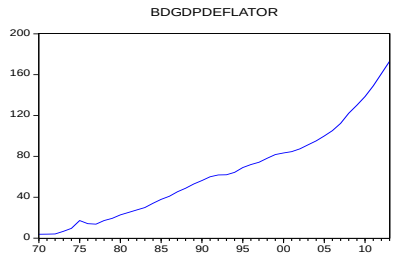
Data

We used data for Bangladesh and USA is foreign country**.** The data for this study is annual real exchange rate data which is constructed from nominal exchange rates and national price levels. GDP Deflator is used as national price level .The data ranges from 1970 to 2013. The data sample collected from World Bank database. The graphs of variables are as follows:

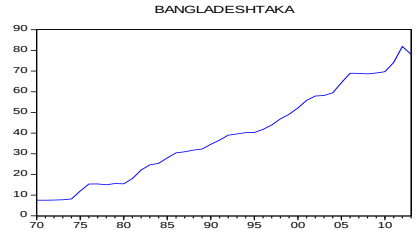
Figure 1: Graphs of variables



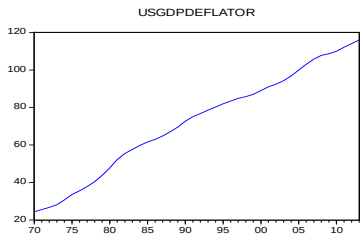
Log Nominal Exchange Rate+ Log US GDP deflator



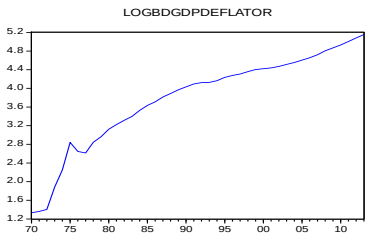
BD GDP deflator



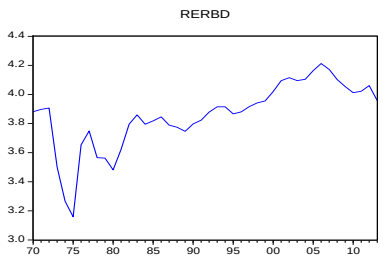
Nominal Exchange Rate of Bangladeshi Taka



US GDP deflator



Log BD GDP deflator



Real Exchange Rate of Bangladesh Taka

Source: Author calculation

Theoretical Model

The relationship between nominal and real exchange rates and its relationship with the concept of purchasing power parity, can be understood from the following equation:

$q_t = e_t - P_{BD,t} + P_{FOR,t}$----------(1)

Where q_t is the log real exchange rate, e_t is the log nominal exchange rate i.e.is the domestic currency price of a unit of the foreign currency, and $P_{BD,t}$ and $P_{FOR,t}$ is the log Bangladesh and foreign price levels, respectively. If purchasing power parity held perfectly, t would equal a constant, call it q, and we can rewrite (1) as

$P_{FOR,t} + et = q_t + P_{BD,t}$ ----------(2)

Methodology

Unit root test

We assume that Yt is a time series with intercept and trend

$Yt = \rho Y_{t-1} + \alpha + \beta t\beta + \varepsilon t$---------- (3)

By subtracting Yt-1 from both sides, we get:

$\Delta Yt = (\rho - 1)Y_{t-1} + \alpha + \beta t\beta + \varepsilon t$ ----------(4)

In above equation of ρ=1, then we conclude that there is unit root in the times series and thus non stationary.

Testing real exchange rate stationarity through augmented Dickey Fuller unit root test entails three assumptions: the intercept presence, the presence of an intercept and a time trend, and finally, the absence any deterministic element. For each supposition, we have build three different relationships:

a) Model 1 : includes both a drift and a linear time trend

$\Delta rer = \alpha_0 + \gamma\, rer_{t-1} + \alpha_2\, t + \varepsilon t$----------(4)

b) Model 2: random walk with a drift

$\Delta rer = \alpha_0 + \gamma\, rer_{t-1} + \varepsilon t$----------(5)

c) Model 3: p**u**re random walk

$\Delta rer = \gamma\, rer_{t-1} + \varepsilon t$----------(6)

If γ equals zero, than the real exchange rate sequence contains a unit root (the series is nonstationary). We applied model 1 and model 2 for ADF unit root test as there is trend in all data series. We also applied DF-GLS unit root test.

Cointegration

Around end of 80's, Engle and Granger (1987), followed by Johansen (1988), Johansen and Juselius (1992) used cointegration to find relationship among variables. The Johansen test for cointegration require fulfillment of asymptotic properties i.e. large sample of data series. If the sample size is too small then the results from Johansen test is not be reliable. In such situation, ARDL (Auto Regressive Distributed Lags) model by Pesaran and Shin (1999) and Pesaran et al., (2001) can be applied.

Engle and Granger (1987) tested the cointegration between a set of integrated variables of first order: I (1). If e_t , p_t^* and P_t refers to natural logarithms of real exchange rate ,foreign price level and domestic price level respectively. Long run PPP requires that $e_t + p_t^* - P_t$ be stationary. According to Engle and Granger, if the pt and pt* are cointegrated, PPP holds in the long-run under following conditions (Enders, 2009).

- $e_t + p_t^* = \beta 0 + \beta 1\, p_t + \mu$ between of the form exists a linear combination.
- Residua ls (μ_t) are stationary.
- Variables have the same integration order.

Cointegration and unit root tests

The concept of Cointegration has been widely applied in time series analysis as time series often have either deterministic or stochastic trends. Although there is no relationship between the two series, the regression results may suggest that there is a strong relationship. The R-square provides misleading results for time series with trends, also known as unit root processes or I(1).Such regression result is called spurious regression. Granger and Newbold (1974) suggested the idea for co-integration

between two or more I(1) series. Two series with I(1) trends can be co-integrated only if there is a genuine relationship between the two.

We consider ti**me se**ries y1,t and y2,t are I(1)

$$Y1 = \begin{pmatrix} Y1,1 \\ Y1,2 \\ . \\ . \\ Y1,T \end{pmatrix} \quad \text{----------(7)}$$

$$y2 = \begin{pmatrix} Y2,1 \\ Y2,2 \\ . \\ . \\ Y2,T \end{pmatrix} \quad \text{----------(8)}$$

I(1) variables tend to diverge as $T \to \infty$ because their unconditional variances are proportional to T.Thus I(1) could never be expected to obey any sort of long run equilibrium relationship.

Y1,T and Y2,T will be cointegrated if there exist a vector $\tau = (1.\tau 2)'$ such that Y1,T and Y2,T are in equilibrium, τ is called cointegrating vector.

Financial time series are found to be integrated to order one, which is I (1). A certain linear combination of such variables is integrated to order zero, which I (0) or in such case those variables can be called stationary.

Purchasing power parity (PPP) implies cointegration between the nominal exchange rate and foreign and domestic prices. For example, the Fisher equation implies cointegration between nominal interest rates and inflation.

Early empirical PPP approaches in 70s had analyzed following relationship:

Nominal Exchange Rate $_t$ =α + β0 P_t +$\beta_1 P_t$ *+u_t---------- (9)

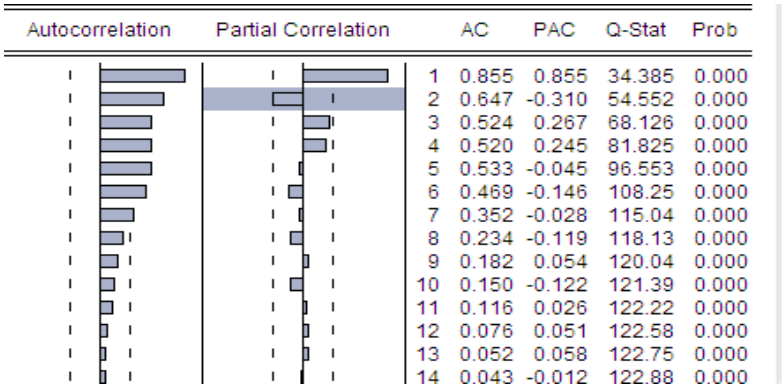
Authors who studied the relationship had applied coefficient restrictions tests: β=1, β*=-1.

Price levels to be cointegrated, it is required that each price series is integrated of the same order. To demonstrate this, we conducted augmented Dickey-Fuller and DF-GLS test..

Empirical Results

The autocorrelation function (ACF) and partial auto correlation function (PACF) for real exchange rate of Bangladesh does not decay to zero quickly (**see figure 2**) and hence there is an indication of nonstationary.

Figuire2: Correlogram of Real Exchange rate of Bangladesh

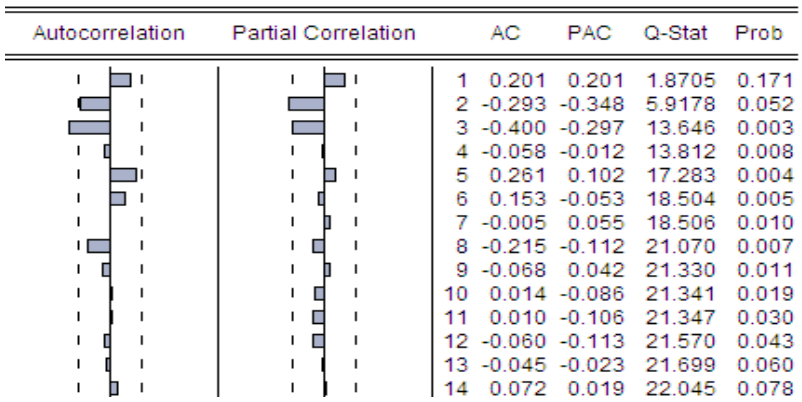


Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob
		1	0.855	0.855	34.385	0.000
		2	0.647	-0.310	54.552	0.000
		3	0.524	0.267	68.126	0.000
		4	0.520	0.245	81.825	0.000
		5	0.533	-0.045	96.553	0.000
		6	0.469	-0.146	108.25	0.000
		7	0.352	-0.028	115.04	0.000
		8	0.234	-0.119	118.13	0.000
		9	0.182	0.054	120.04	0.000
		10	0.150	-0.122	121.39	0.000
		11	0.116	0.026	122.22	0.000
		12	0.076	0.051	122.58	0.000
		13	0.052	0.058	122.75	0.000
		14	0.043	-0.012	122.88	0.000

Source: Authors calculation.

Difference series of real exchange rate of Bangladesh is stationary since ACF and PACF of difference series quickly falls zero (see figure 3).

Figure 3: Correlogram of difference series of real exchange rate of Bangladesh



Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob
		1	0.201	0.201	1.8705	0.171
		2	-0.293	-0.348	5.9178	0.052
		3	-0.400	-0.297	13.646	0.003
		4	-0.058	-0.012	13.812	0.008
		5	0.261	0.102	17.283	0.004
		6	0.153	-0.053	18.504	0.005
		7	-0.005	0.055	18.506	0.010
		8	-0.215	-0.112	21.070	0.007
		9	-0.068	0.042	21.330	0.011
		10	0.014	-0.086	21.341	0.019
		11	0.010	-0.106	21.347	0.030
		12	-0.060	-0.113	21.570	0.043
		13	-0.045	-0.023	21.699	0.060
		14	0.072	0.019	22.045	0.078

Source: Author calculation.

Unit root test (Augmented Dicky Fuller test- ADF) test and DF –GLS test (see table 2) show that there is unit root in domestic price level , US price level ,nominal exchange rate of Bangladeshi taka ,real exchange rate of Bangladeshi taka . ADF and DF-GLS test show that domestic price levels is I(2) series , US price level I(1) series ,nominal exchange rate I(2) series , real exchange rate I(1) series .

We cannot run Johansen cointegration test as domestic price level is I(2), nominal exchange rate I(2), while US price level is I(1). In such situation where variables are differently integrated, we can run ARDL(auto regressive distributed lag model) bounds testing approach to cointegration. However We cannot apply ARDL as all domestic price levels are I(2) , and ARDL does not work for I(2) series. Et+pt* is I(1) and pt is I(0) , we cannot apply engle granger conintegration methodology as variables are not integrated in same order.

Conclusion

Our purpose was to test PPP validity in Bangladesh. We used data from 1970 to 2013 and applied unit root test such as ADF and DF-GLS to see stationarity in the real exchange rate of Bangladesh. Unit root test revealed that real exchange rate of Bangladesh is not stationary which suggest that PPP does not hold for Bangladesh in short run. Meanwhile, we cannot apply Engle-Granger cointegration, Johansen cointegration test and ARDL method to see long run equilibrium relationship among domestic, foreign price level and nominal exchange rate .So it can be said that PPP does not hold in the long run even.

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Appendices

Table 2: Unit root results for Data series

Bangladesh Domestic price level (GDP deflator) (Pt)	**Model 1**	**ADF t- statistic (P value)**	**DF-GLS t- statistic**
	Level Data	Lag Length Based on AIC= 2.52 (P=1.00) Lag Length Based on SIC=2.52 (P=1.00)	Lag Length Based on AIC= -.92
I(2) Series	First Difference	Lag Length Based on AIC= -1.06(P=.92) Lag Length Based on SIC= -3.20(.09)	Lag Length Based on AIC= -3.33**
	Second Difference	Lag Length Based on AIC= -7.33 (P=.000) Lag Length Based on SIC=-7.33 (P=.000)	Lag Length Based on AIC= -7.49*
	Model 2		
	Level Data	Lag Length Based on AIC= 2.97 (P=1.00) Lag Length Based on SIC=2.97 (P=1.00)	Lag Length Based on AIC= 1.49
	First Difference	Lag Length Based on AIC= .055 (P=.95) Lag Length Based on SIC= -2.02(.27)	Lag Length Based on AIC= .39
	Second Difference	Lag Length Based on AIC=-7.18 (P=.000) Lag Length Based on SIC==-7.18 (P=.000)	Lag Length Based on AIC=-7.26*
USA Price Level (US GDP deflator) Pt*	**Model 1**	**ADF t- statistic (P value)**	**DF-GLS t- statistic**
	Level Data	Lag Length Based on AIC= -1.82 (P=.6767)	Lag Length Based on AIC= -1.80

I(1) series			Lag Length Based on SIC=-1.82 (P=.6767)	
		First Difference	Lag Length Based on AIC= -3.10(P=.12) Lag Length Based on SIC= -4.32(.007)	Lag Length Based on AIC= -3.75**
		Second Difference	Lag Length Based on AIC= -3.68 (P=.03) Lag Length Based on SIC=-5.60 (P=.002)	Lag Length Based on AIC= -3.78*
		Model 2		
		Level Data	Lag Length Based on AIC= -2.11(P=.23) Lag Length Based on SIC=-1.85 (P=.35)	Lag Length Based on AIC= -.13
		First Difference	Lag Length Based on AIC= -3.94(P=.004) Lag Length Based on SIC= -3.94(P=.004)	Lag Length Based on AIC= -3.24*
Nominal Exchange Rate (Bangladesh) Et		**Model 1**	**ADF** **t- statistic (P value)**	**DF-GLS** **t- statistic**
I(2) based on AIC **I(1) based in SIC**		Level Data	Lag Length Based on AIC= -2.40(P=.37) Lag Length Based on SIC=-2.97 (P=.15)	Lag Length Based on AIC= -1.37
		First Difference	Lag Length Based on AIC= -2.32(P=.40) Lag Length Based on SIC= -6.63(.00)	Lag Length Based on AIC= -1.69
		Second Difference	Lag Length Based on AIC= -7.59(P=.00)	Lag Length Based on AIC= -.39
		Model 2		
		Level Data	Lag Length	Lag Length

		Based on AIC= .64(P=.98) Lag Length Based on SIC=.77(P=.99)	Based on AIC= -.90
	First Difference	Lag Length Based on AIC= -2.29(P=.18) Lag Length Based on SIC= -6.62(.00)	Lag Length Based on AIC= -.76
	Second Difference	Lag Length Based on AIC= -7.58(P=.00)	Lag Length Based on AIC= -1.33
Real Exchange Rate (Bangladesh) **I(1) Series**	**Model 1**	**ADF** **t- statistic (P value)**	**DF-GLS** **t- statistic**
	Level Data	Lag Length Based on AIC= -1.75(P=.70) Lag Length Based on SIC=-5.12(P=.0008)	Lag Length Based on AIC= -2.21
	First Difference	Lag Length Based on AIC= -6.47(P=.00)	Lag Length Based on AIC= -1.61
	Model 2		
	Level Data	Lag Length Based on AIC= -1.99(P=.28) Lag Length Based on SIC=-1.75(P=.29)	Lag Length Based on AIC= -1.94***
	First Difference	Lag Length Based on AIC= -1.69(P=.42)	Lag Length Based on AIC= -1.61
		Lag Length Based on SIC -5.59(P=.00)	
Log Nominal Exchange Rate+ Log of Foreign Price Level. **Based on SIC I(1)**	**Mode 1**	**ADF test** **t-Statistics (p value)**	**DF-GLS** **t-Statistics**
	Level data	Lag Length Based on AIC= -2.18(P=.48)	Lag Length Based on AIC= -1.52

Based on AIC I(2)		Lag Length Based on SIC=-2.18(P=.48)	
	First Difference	Lag Length Based on AIC= -1.5(P=.60) Lag Length Based on SIC=-6.03(P=.0001)	Lag Length Based on AIC= -2.29
	Second Difference	Lag Length Based on AIC= -3.67(P=.03)	Lag Length Based on AIC= -1.87
	Model 2	Lag Length Based on AIC= -2.30(P=.17) Lag Length Based on SIC=-2.30(P=.17) Lag Length Based on AIC= -1.52(P=.51) Lag Length Based on SIC=-1.52(P=.51) Lag Length Based on AIC= -9.30(P=.00) Lag Length Based on SIC=-6.66(P=.00)	Lag Length Based on AIC= -.12 Lag Length Based on AIC= -2.25**
Log BD GDP deflator **Based on SIC I(0)**	**Mode 1**	**ADF test t-Statistics (p value)**	**DF-GLS t-Statistics**
	Level data	Lag Length Based on AIC= 2.32(P=.41) Lag Length Based on SIC=-3.57(P=.04)	Lag Length Based on AIC= -3.06***
	First Difference	Lag Length Based on AIC= -.39(P=.98)	

	Second Difference	Lag Length Based on AIC= -2.78(P=.21)	
	Model 2	Lag Length Based on AIC= .73(P=.99) Lag Length Based on SIC=-4.40(P=.00)	Lag Length Based on AIC= 1.65
		Lag Length Based on AIC= -1.97(P=.29)	Lag Length Based on AIC= -1.70**
		Lag Length Based on AIC= -1.55(P=.49)	

* 1% level significance** 5% level significance*** 10% level significance level