Seasonal Long-Term Dependence: Evidences From the Bangladeshi Financial Series

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Abstract
It is well-known that many time series exhibit strong-dependence – long memory property. In this paper, the seasonal structure of the Bangladeshi quarterly financial series is examined by means of recently proposed fractional integration test. Evidences suggest that most of the series are seasonal long-term dependent. Thus, the standard approach of taking seasonal differences to get the series stationary at different frequencies (which is required) may lead to spurious results, because outcomes suggest that the series having a component of long memory behavior. Findings of this study are useful to the following groups: (i) Policy makers who are interested to make wise financial policies, (ii) different practitioners whose success depends on the ability to predict financial series and (iii) applied researchers who want to improve the model specifications of the selected series.

Keywords: Long-memory; Quarterly unit roots; Seasonality; Financial Series
JEL Classifications: C12; C15; C22

1. Introduction

Financial time series are continually brought to our attention (e.g. the daily newspapers, TV, radio and others inform us the latest stock index values, exchange rates, inflation rates, interest rates and also other prices). The prime objective of this paper is to find the appropriate order of integration for the quarterly Bangladeshi financial series. Detecting the appropriate order of integration for a time series is important for any applied econometric works. The reason behind this most of the empirical econometric theories built on the assumption of stationarity. Therefore, the standard approach of taking differences to get the series stationary may lead to spurious results if stationary assumption unaccounted for. Thus, testing whether the series is stationary, long-range-dependence or non-stationary is routinely carried out prior to modeling and conducting reliable statistical inferences. We have chosen the financial series under the following reasons. First, it is important to understand how series behave in the long run. The second is to use our knowledge of series behavior to reduce risks or take better decisions. Since we are using the seasonal time series, to find the order of integration of the considered series, we should select the stochastic seasonality tests. Generally, two types of tests are used in econometric literature: (a) seasonal integration test and (b) seasonal fractional integration test. Our purpose is to apply both kinds of tests to find the appropriate order of integration for the quarterly Bangladeshi financial series. Several empirical applications with the evidences of seasonal behavior have been carried out in relation to seasonal models: For examples, see Porter and Hodak (1990), Ray (1993), Arteche and Robinson (2000), Gil-Alana and Robinson (2001), Banik (2005), Gil-Alana and Candelon (2004) and others. Although research (e.g Hasan *et al.* (2000), Rahman and Yamagata (2004), Ahmed *et al.* (2006), Muhammad and Rasheed (2001) and others) have been conducted to test the time series behavior for the Bangladeshi financial series, to the best of our knowledge, this is the first empirical study regarding the seasonal behavior of the quarterly Bangladeshi financial series. Thus, it is expected that the findings of this study will be great interest to academics, policy makers and investors who are interested in the development of financial issues for Bangladesh. This paper is planned as follows: The next section will give an idea about the type of stochastic seasonal models used for our study. Section 3 talks about the selected tests. Data series and findings are explained in the section 4. The final section concludes the paper with some proposed future works.

2. Models

Consider the model

$$(1-L^s)Y_t = u_t, \; t = 1, 2, 3, \ldots, n \tag{1}$$

where Y_t are the considered quarterly financial series, L^s is the seasonal lag operator, s is the number of time periods in a year and u_t are i.i.d$(0,\sigma^2)$. Note that the operator $1-L^s$ with s = 4 (e.g. quarterly data) can be factored as $(1-L)(1+L)(1+L^2)$. Thus, Y_t in (1) contains 4 unit roots: one at '0' frequency, one at two cycles per year (corresponding to 'π' frequency) and two complex pairs at one cycle per year (corresponding to frequencies 'π/2 and 3π/2') of a cycle of 2π (for details, see Hylleberg et *al.* (1990)). The model (1) is known as stochastic seasonal model, where seasonal differencing operators (1-L), (1+L) and $(1+L^2)$ remove '0' frequency, 'π' frequency and 'π/2 and 3π/2' frequencies (annual frequency) non-stationarity seasonal effects respectively from the time series. Over the years, a number of testing procedures have been suggested to test stochastic seasonality [e.g. the DHF test (proposed by Dickey *et al.* (1984) test), the HEGY test (suggested by Hylleberg *et al.* (1990), which is an extension of the DHF test at zero to the seasonal frequencies), the Beaulieu and Miron (1993) test (HEGY's extension for the monthly series), the CH test (introduced by Canova and Hansen (1995)) and others]. A good deal of empirical works with the evidences of seasonal unit roots can be found in Hylleberg *et al*. (1993), Otto and Wirjanto (1990), Linden (1994), Banik and Silvapulle (1999) and many others.

However, evidences (Gil-Alana and Robinson (2001), Baillie (1996) and others) suggest that seasonal unit roots can be viewed not only in an AR framework but also as a particular case of fractional process, known as stochastic fractional seasonal process. In empirical literature, this kind of process is found to be useful in modeling and forecasting the future values of a time series. To understand this process, consider the model

$$(1-L)^{d_1}(1+L)^{d_2}(1+L^2)^{d_3}Y_t = u_t, \quad t = 1, 2, ..., n \qquad (2)$$

where seasonal fractional differencing operators $(1-L)^{d_1}$, $(1+L)^{d_2}$ and $(1+L^2)^{d_3}$ remove '0' frequency, 'π' frequency and 'annual' frequency seasonal long-memory effects respectively from the considered time series and d_i (i = 1, 2, 3) are the fractional integration parameters. The operators $(1-L^4)^{d_i}$ can be expressed in terms of its Binomial expansion, such that ∀ real d_i: $(1-L^4)^{d_i} = \sum_{j=0}^{\infty}\binom{d_i}{j}(-1)^j L^{4j}$. When d_i>0, Y_t is known to posses a seasonal long memory property, which is a characteristic of time series that exhibits strong dependency between distance observations. Thus, the higher d_i is, the higher will be the degree of seasonal dependence between observations.

3. Tests

To detect the appropriate order of integration, first the HEGY test and the CH test are applied. Then, A particular version of the Robinson (1994) tests, introduced by Gil-Alana and Robinson (2001) is applied in order to confirm or/and to detect the appropriate order of seasonal integration. A brief description of the selected tests is as follows:

a) Testing I(1) Seasonal Models

HEGY test

In this test, the stochastic seasonality is tested against the stationary seasonality. The model used to test for seasonal unit roots is given as

$$\Delta_4 Y_t = x_t'\beta + D_t'\alpha + \pi_1 Y_{1,t-1} + \pi_2 Y_{2,t-1} + \pi_3 Y_{3,t-2} + \pi_4 Y_{3,t-1} + \sum_{i=1}^{p} \rho_i \Delta_4 Y_{t-i} + e_t \qquad (3)$$

where x_t includes an intercept and/or a linear time trend, D_t is the set of deterministic process[1], $\Delta_4 Y_t = Y_t - Y_{t-4}$, $Y_{1t} = (1 + B + B^2 + B^3)Y_t$ removes the seasonal unit roots but leaves a unit root at the '0' frequency, $Y_{2t} = -(1 - B + B^2 - B^3)Y_t$ leaves a unit root at the 'π' frequency, $Y_{3t} = -(1 - B^2)Y_t$ leaves unit roots at the 'annual' frequency and e_t is white noise process. To test for the '0' frequency or the 'π' frequency unit root, H_{k0}: $\pi_k = 0$ is tested against H_{k1}: $\pi_k < 0$, k = 1,2. The statistics are the t-type (non-standard) and accept H_{10} (H_{20}) at $\alpha = 0.05$ if $t_{\pi_1} \geq -3.52$ ($t_{\pi_2} \geq -2.93$). To test for the 'annual' frequency unit root, H_0: $\pi_3 = \pi_4 = 0$ is tested against H_1: at least one of the π's is ≠ 0. The statistic is the F-type (non-standard) and accept H_0 at $\alpha = 0.05$ if $F_{3,4} \leq 7.59$. To test for 'π' and 'annual' frequencies[2] unit root jointly, H_0: $\pi_2 = \pi_3 = \pi_4 = 0$ is tested against H_1: at least one of the π's is ≠ 0. The statistic is the F-type and accept H_0 at $\alpha = 0.05$ if $F_{2,3,4} \leq 5.99$.

CH test[3]

Now we will briefly outline the CH test for the null of stationary seasonality against the stochastic seasonality[4]. Consider the model

$$Y_t = x_t'\beta + f_t'\gamma_t + e_t \qquad (4)$$

[1] A linear time trend that might capture deterministic non-stationarity and quarterly dummies to capture deterministic seasonality.

[2] It is proposed by Ghysels, Lee and Noh (1994), which is like the HEGY F-type test.

[3] To distinguish between unit root at the seasonal frequency and at the '0' frequency, it is required that Y_t does not have a unit root at the '0' frequency. If Y_t has a '0' frequency unit root, then $\Delta Y_t = Y_t - Y_{t-1}$ is considered as the dependent variable.

[4] Hylleberg (1995) compares small sample properties of HEGY and CH tests, concluding that both tests are complement to each other. Thus, rejection of the null hypothesis would imply the strong result that the data are indeed non-stationary at seasonal frequencies, a conclusion that the HEGY test cannot yield.

where x_t is defined in (3), $f_t = (f_{1t}, f_{2t}, \ldots f_{qt})'$, $f'_{jt} = \left(\cos\left(\frac{j\pi t}{q}\right), \sin\left(\frac{j\pi t}{q}\right), (-1)^t\right)$ with $A'\gamma_t = A'\gamma_{t-1} + u_t$, $j = 1,2,\ldots,q$, $q=s/2$, $s=4$ and u_t are i.i.d. To test for joint unit roots at 'π' and 'annual' frequencies, H_0: stationary seasonality is tested against H_1: unit root at the seasonal frequencies with $A = I_{s-1}$. The test statistic is the LM-type, defined as $L_f = \frac{1}{n^2}\operatorname{tr}\left((\hat{\Omega}^f)^{-1}\sum_{t=1}^{n}\hat{F}_t\hat{F}_t'\right)$, where $\hat{F}_t = \sum_{i=1}^{t} f_i\hat{e}_i$, $\hat{\Omega}^f = \sum_{k=-m}^{m} w(k/m)\frac{1}{n}\sum_t f_{t+k}\hat{e}_{t+k}f_t'\hat{e}_t$, $w(.)$ is any kernel function producing positive semi-definite covariance matrix estimates, m is the lag truncation number and $\hat{e}_t$ is the estimated OLS residual in (4) under H_0. Reject H_0 at $\alpha = 0.05$ if $L_f \geq 1.01$.

To test for the 'π' or the 'annual' frequency unit root specifically, consider the model

$$Y_t = x_t'\beta + \sum_{j=1}^{q} f_{jt}'\gamma_j + e_t,\ q=s/2,\ s=4 \tag{5}$$

where γ_j corresponds to the seasonal cycle for the frequency ($j\pi/q$). Here H_{0j}: stationary seasonality is tested against H_{1j}: unit root at the 'π' frequency (or the 'annual' frequency) with an appropriate restriction imposed on A. To test for a unit root at the 'π' frequency, set $A = (\tilde{0}\ 1)'$ and to test for a unit root only at the 'annual' frequency, set $A = (\tilde{0}\ I_2\ \tilde{0})'$. The test statistics are the LM-type: $L_{(\pi j/q)} = \frac{1}{n^2}\sum_{t=1}^{n}\hat{F}_{jt}'(\hat{\Omega}_{jj}^f)^{-1}\hat{F}_{jt}$, where $\hat{F}_{jt} = \sum_{i=1}^{t} f_{ji}\hat{e}_i$ is the sub-vector of $\hat{F}_t$ partitioned conformably with γ and $\hat{\Omega}_{jj}^f$ denote the jth block diagonal of $\hat{\Omega}^f$. Reject $H_{01}(H_{02})$ at α=.05 if $L_{\pi/2} \geq 0.749$ ($L_\pi \geq 0.470$).

(b) Testing I(d) Seasonal Models

Gil-Alana and Robinson test

This test is applied in order to confirm or/and to detect the appropriate order of seasonal integration. In this test, the stochastic seasonality is tested against the fractional seasonality. To understand the test procedures, consider the models

$$Y_t = x_t'\beta + D_t'\alpha + z_t, \quad (6)$$
$$\rho(L,\theta)z_t = u_t, \quad (7)$$

where Y_t, x_t and D_t are explained as above, $\rho(L,\theta)$ is a pre-described function of L (described below) and $u_t \sim$ i.i.d.

Case-1: $\rho(L,\theta) = (1-L)^{d+\theta}$ with d =1 implies a unit root at the '0' frequency.
Case-2: $\rho(L,\theta) = (1+L)^{d+\theta}$ with d =1 implies a unit root at the 'π' frequency.
Case-3: $\rho(L,\theta) = (1+L^2)^{d+\theta}$ with d=1 displays unit root at the 'annual' frequency.
Case-4: $\rho(L,\theta) = (1+L+L^2+L^3)^{d+\theta}$ with d=1 displays unit root at 'π' and 'annual' frequencies jointly.

To test H_0:θ=0 vs. H_0:θ ≠ 0, the test statistics are the LM-type, defined as $\hat{R} = \frac{n}{\hat{\sigma}^4}\hat{a}'\hat{A}^{-1}\hat{a}$,

where $\hat{a} = -\frac{2\pi}{n}\sum_j \psi(\lambda_j)\, g(\lambda_j;\hat{\tau})^{-1} I(\lambda_j)$, $\hat{\sigma}^2 = \frac{2\pi}{n}\sum_{j=1}^{n-1} g(\lambda_j;\hat{\tau})^{-1} I(\lambda_j)$

$$\hat{A} = \frac{2}{n}\left(\sum_j \psi(\lambda_j)\psi(\lambda_j)' - \sum_j \psi(\lambda_j)\hat{\varepsilon}(\lambda_j)'\left(\sum_j \hat{\varepsilon}(\lambda_j)\hat{\varepsilon}(\lambda_j)'\right)^{-1}\sum_j \hat{\varepsilon}(\lambda_j)\psi(\lambda_j)'\right)$$

$\psi(\lambda_j)$ = [log|2sin(λ/2)|, log|2cos(λ/2)|, log|2cosλ|], $\hat{\varepsilon}(\lambda_j) = \frac{\partial}{\partial\tau}\log g(\lambda_j;\hat{\tau})$, $g(\lambda_j;\tau) = \left|1-\tau e^{i\lambda_j}\right|^{-2}$, $I(\lambda_j)$ is the periodogram of $\hat{u}_t$, $\lambda_j = 2\pi j/n$, $-\pi < \lambda_j < \pi$, $\hat{\tau} = \arg\min_{\tau\in H}\sigma^2(\tau)$, with $H \in R^q$ Euclidean space and n is the sample size. The distribution of the test statistic follows χ^2_p and accept H_0 if $\hat{R} < \chi^2_p$ (for details, see Gil-Alana and Robinson (2001)).

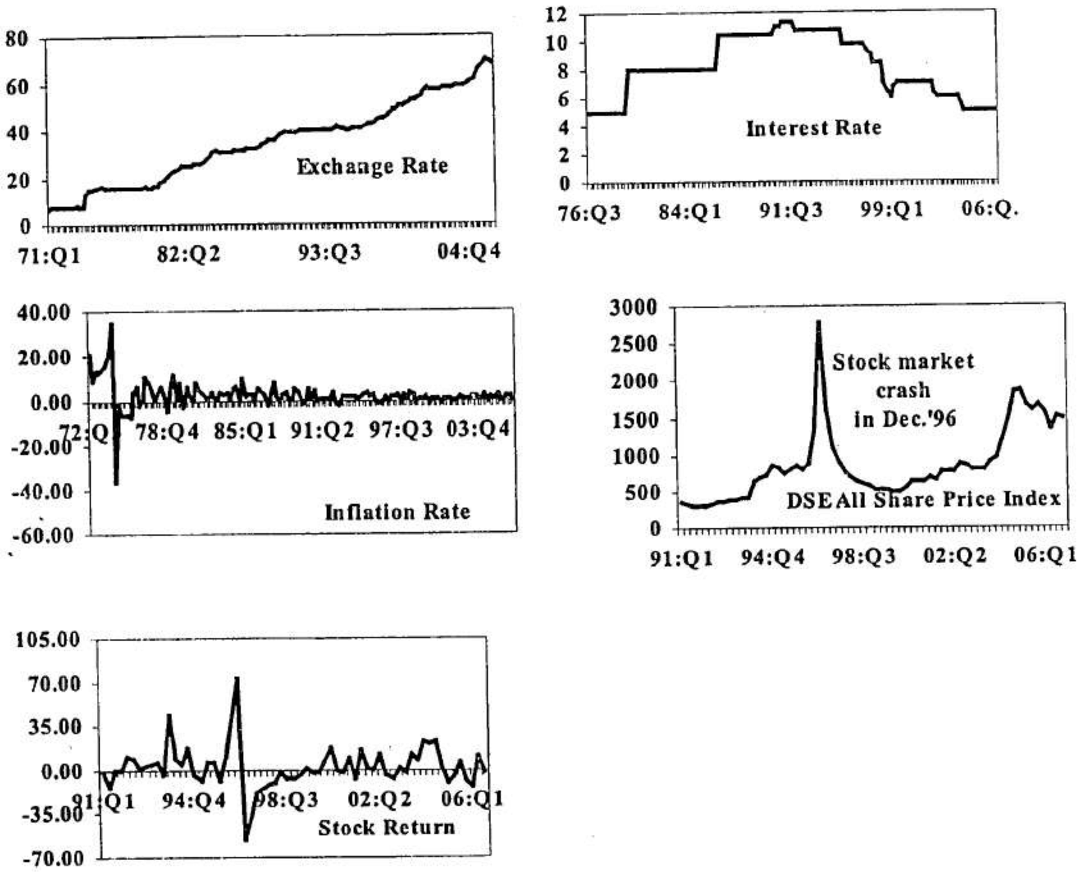
4. Data Series and Findings

The data series used in this study are the quarterly seasonally unadjusted financial series for Bangladesh, namely exchange rates (QEXR), interest rates (QIR), inflation rates (QINF) and stock returns (QSR), extracted from various sources (see Table 1). To know the data characteristics appropriately, we plotted the financial series w.r.t time in the Fig-1 and the numerical summary statistics in the Table 2. The prominent features of the graphs (see Fig-1) are the changing seasonal fluctuations except the QEXR series, which shows a strong upward trending behavior. The possible explanation for this: Bangladesh is one of the least developing countries, suffers from a number of structural changes: large domestic savings, heavy dependence of foreign assistance, labor remittances from abroad, national and international political events and many others. Thus, it may be

Table 1: Bangladeshi Quarterly Financial Series

Series	Time Periods[5]	Total Observations	Sources
QEXR[6]	1971:Q1-2007: Q1	145	International Financial Statistics
QIR[7]	1976:Q3-2007: Q1	123	International Financial Statistics
QINF[8] (Base period – 2000)	1972:Q3-2007: Q1	139	International Financial Statistics and http://laborsta.ilo.org
QSR[9] (Base period – 2000)	1991:Q1-2007: Q1	65	Dhaka Stock Exchange - http://www.dsebd.org

Fig. 1: Time Plots of the Bangladeshi Financial Series



believable that the above incidents had major impacts on the Bangladeshi economy and caused a relatively unstable environment. Statistics in Table 2 include minimum values,

[5] The starting periods differ because of unavailability.
[6] An exchange rate of Taka 69 to the US$ means that Taka 69 is worth the same as $1.
[7] A rate that is charged or paid for the use of money. For example, if a lender (a bank) charges a customer Taka 90 in a year on a loan of Taka 1000, then the interest rate would be 9%[(90/1000)*100%].
[8] Used CPI (because of availability) to measure quarterly inflation, is calculated as: $Y_t = 400((p_t-p_{t-1})/p_{t-1})$, p_t=log(CPI), e.g. a 6% (-3%) inflation rate means that the price level for that given year has risen 6% (fallen 3%) from a certain measuring period.
[9] It is calculated as Y_t = (log SPI_t-logSPI_{t-1})*100, where SPI stands the quarterly closing DSE stock price index. Note that the DSE index is a market capitalization weighted all share price index in the Dhaka Stock Exchange, the largest stock exchange in Bangladesh.

maximum values, means, SDs, skewness values and kurtosis values. The means values show that rates are almost similar for all quarters, except for QINF and QSR series. For the QINF series, mean rate is smaller for December than the other quarters. The mean return for QSR series is higher for June and September. Further, based on skewness and

Table 2: Important Descriptive Statistics

Series	Min	Max	Mean	SD	Skewness	Kurtosis
QEXR						
March	7.21	67.89	33.84	16.84	0.11	-0.93
June	7.61	69.92	34.36	16.93	0.13	-0.86
September	7.72	68.85	34.76	17.13	0.13	-0.88
December	7.66	68.37	35.03	17.18	0.12	-0.89
QIR						
March	5	11.25	8.14	2.13	-0.10	-1.33
June	5	11.25	8.18	2.18	-0.16	-1.41
September	5	11.25	8.20	2.11	-0.13	-1.27
December	5	11.25	8.16	2.12	-0.09	-1.30
QINF						
March	-7.48	15.32	1.37	4.07	1.48	4.11
June	-6.26	19.73	3.29	4.69	1.59	4.22
September	-6.02	34.71	4.38	6.36	3.41	15.90
December	-36.61	14.96	0.30	7.25	-3.97	21.70
QSR						
March	-38.28	22.48	-0.47	14.56	-1.09	2.19
June	-18.28	42.43	6.62	14.01	0.89	2.30
September	-15.40	72.02	8.06	20.42	2.35	7.09
December	-55.00	43.11	-3.40	19.21	-0.41	5.72

kurtosis values, it is possible to conclude that the considered series do not follow normal distribution for any quarters. Overall, the graphical and numerical summaries make it clear the quarterly financial series for Bangladesh appear to have a change in trend with seasonal and cyclical behavior. To detect these behaviors quantitatively, the selected tests in section 3 are applied and empirical results are reported in Tables 3-5.

Table 3 provides the test results of the seasonal unit root tests such as HEGY test and CH test. Results of HEGY test show that all series are I(1) at all frequencies except the QINF series, which is found I(0) at the 'annual' frequency. CH test results indicate that all series are I(1) at the 'π' frequency except the QSR series. It is also reveal that the QEXR

Table 3: Seasonal Unit Root Test Results[10]

HEGY and GLN test results (Model 3)					
Series	P[11]	'0 frequency'	'π' frequency	'Annual' frequency	Annual and 'π' frequencies
QEXR	6	-2.74	-2.54	6.66	5.98
QIR	8	-1.28	-1.81	5.69	6.07
QINF	4	-2.63	-2.29	8.59*	9.63*
QSR	7	-3.24	-2.38	4.60	5.62
CH test results (Models 4 and 5) [12]					
QEXR			0.56*	0.46	1.83*
QIR			0.49*	0.85*	1.50*
QINF			0.76*	0.35	1.82*
QSR			0.08	0.94*	1.11*

and QINF series are I(0) at the 'annual' frequency. Overall, it may be concluded that stochastic seasonality is present in all considered financial series at the '0' and the 'π' frequencies except the QSR series. At the 'annual' frequency, tests show contradictory results indicates a further study is needed to draw a conclusion about the degree of integration of the considered financial series.

Next, we try to solve the empirical puzzle encountered so far by considering recently proposed Gil-Alana and Robinson test. This test is applied to validate the classical seasonal unit root tests results and also to detect the appropriate order of seasonal integration. As mentioned above, this test examines the null of unit root in (6) and (7) with $\rho(L,\theta)$ like the cases assuming a wide range of null hypothesized d's from 0.50 through 2. Clearly non-rejections of the null of unit root imply unit roots at different frequencies. The results are reported in the Table 4 and the evidence of seasonal long memory behavior in the Table 5. Evidences show that the value of d is not equal to 1 suggesting that the first differencing may not be sufficient to get I(0) series at the '0' and the seasonal frequencies. According to our study, e.g., the recommended model for the Bangladeshi quarterly exchange rate series (read for other series also form the Table 5) is:

[10] * Indicates significance at the 5% nominal level.

[11] In HEGY and GLN tests, (3) includes 12 lagged differences to whiten the noise term (lag selection based on the AIC criterion).

[12] The CH test are applied in the long-run I(1) series in first differences. In constructing the estimate of the long-run covariance matrix, m = 3, 4 or 5 are considered for n= 50, 100 and 150 respectively.

Table 4: Seasonal Fractional Unit Root Test Results

Series	'0' frequency	'π' frequency	Annual frequency	Annual and 'π' frequencies
Fractional Parameter d = 0.5				
QEXR	4.20*	15.13*	1.69	44.22*
QIR	13.62*	21.44*	45.43*	62.57*
QINF	1.04	0.50	24.40*	1.23
QSR	0.48	3.24	7.62*	3.03
Fractional Parameter d = 0.75				
QEXR	12.67*	1.42	3.10	1.61
QIR	3.20	21.90*	3.39	64.00*
QINF	1.10	0.61	2.16	1.80
QSR	0.55	2.79	11.22*	1.08
Fractional Parameter d = 1.00				
QEXR	2.22	1.88	1.12	2.66
QIR	3.24	2.92	3.61	1.10
QINF	1.19	0.42	33.62*	2.13
QSR	0.64	7.78*	2.92	10.24*
Fractional Parameter d = 1.50				
QEXR	3.25*	20.98*	2.07	63.68*
QIR	25.70*	22.47*	48.30*	1.17
QINF	1.46	7.34*	37.70*	12.89*
QSR	7.29*	3.96*	17.06*	11.36*
Fractional Parameter d = 1.75				
QEXR	33.52*	21.53*	2.43	65.29*
QIR	28.73*	22.56*	48.58*	65.45*
QINF	1.02	3.69*	39.06*	13.18*
QSR	0.88	12.67*	18.23*	11.63*
Fractional Parameter d = 2.00				
QEXR	36.00*	22.00*	44.36*	66.42*
QIR	31.02*	22.66*	48.72*	65.61*
QINF	4.12*	10.11*	40.20*	13.32*
QSR	4.41*	8.47*	19.10*	11.76*

Table 5: I(d):Order of Integration d with the Different Frequencies

Series	'0' frequency	'π' frequency	'Annual' frequency	Annual and 'π' frequencies
QEXR	1.0	0.75 to 1.0	0.5 to 1.75	0.75 to 1.0
QIR	0.75 to 1.0	1.0	0.75 to 1.0	1.0 to1.50
QINF	0.5 to 1.75	0.5 to 1.0	0.75	0.5 to 1.0
QSR	0.5 to 1.0	0.5 to 0.75	1.0	0.5 to 0.75

$(1-L)^{1.0}(1+L)^{0.75}(1+L)^{0.5}QEXR_t = u_t$. Findings of this study are useful to the following groups: policy makers who are interested to make wise financial policies, different practitioners whose success depends on the ability to predict financial series, applied workers who want to improve the model specifications of the selected series.

5. Conclusion

Seasonally unadjusted quarterly financial series for Bangladesh such as exchange rates, interest rates, inflation rates and stock returns series are modelled using the recently proposed stochastic (integrated or fractionally.integrated) seasonality tests. The classical seasonal unit root tests show contradictory results. Thus, to validate the classical test results or/and to detect appropriate order of seasonal integration, Gil-Alana and Robinson (2001) test applied. Our empirical evidence suggests that the series are seasonal long-term dependent. Thus, the standard practise of taking first differences to achieve I(0) stationarity at different frequencies may be erroneous and all the analysis of the considered Bangladeshi series should be interpreted with care. The approach used in this paper to determine the degree of dependence of the considered series, is known as univariate approach. However, econometric models under the multivariate framework for the fractional structure of the Bangladesh series are not yet available. This is left for future research.

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