SEASONAL INTEGRATION AND CO-INTEGRATION EXCHANGE RATE AND MONETARY POLICY DYNAMICS IN A CARIBBEAN ENVIRONMENT.

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SEASONAL INTEGRATION AND COINTEGRATION: MONEY AND EXCHANGE RATE DYNAMICS IN A CARIBBEAN ENVIRONMENT

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INTRODUCTION

Most Caribbean nations have been experiencing balance payments (BOPs) difficulties which appear to have grown worst i the 1990s. In particular, the BOPs of Jamaica worsened from a deficit of US$ 0.3m. in 1965 to US$ 86.5m. in 1980. By 1991, the BOPs deficit had reached US$ 115.1m.

During the same period, Trinidad-Tobago's BOPs deficit which was US$3.1m. in 1965 deteriorated to US$ 276.5m. in 1991, with some significant improvement from the mid 1970s to early 1980s largely stemming from oil price hikes by the members of the organization of petroleum exporting countries (OPEC).[1]

The BOPs situation of the members of the Organization of East Caribbean States (OECS) experienced minor changes during the mid 1970s and 1980s. In particular, Barbados which had a BOPs deficit of US$5.9m. in 1970 improved its BOPs position from US$ 8.7m. in 1975 to US$ 22.3m. in 1985. However, the BOPs surplus could not be sustained. By the close of 1991, the country's BOPs position registered a deficit of US$ 39.9m.

The poor BOPs performance in the Caribbean, especially, Jamaica and Trinidad-Tobago result from high inflation and abysmal real per capita economic growth. In Jamaica, for instance, the inflation rate which was 3.2 per cent in 1965 rose to 14.3 per cent in 1970. During this period Trinidad-Tobago had inflation rate of 3 per cent.

However, by 1975, inflation rate in Jamaica had risen to 17.8

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[1]Trinidad-Tobago is a member of the OPEC. The BOPs of Trinidad-Tobago experienced a surplus of US$ 458.1m. in 1970, which increased to US$ 648.3m. in 1980.

per cent whilst that of Trinidad-Tobago rose to 17 per cent. Note that this period immediately followed the first OPEC oil price hike. From 1980 to 1990, the inflation rate in Jamaica averaged about 25 per cent. However, in Trinidad-Tobago the inflation rate dropped to 7.6 per cent in 1985. In 1991 Jamaica's inflation rate reached 51.1 per cent while Trinidad-Tobago's inflation rate rose by 11 per cent in 1990.

The inflation rate in Barbados remained below 10 per cent throughout the period under study, with the exception of 1975 and 1980 when the country experienced 20.2 per cent and 14.4 per cent inflation rate respectively. Note that these periods overlapped the two destabilizing oil price hikes by the OPEC members in 1973 and 1978.

The foreign exchange rate of Jamaica slided downward from 16.7 per cent in 1965 to 44.5 per cent in 1990. Infact from 1980 to 1985 the Jamaican dollar fell by 212.1 per cent. Trinidad-Tobago's foreign exchange rate fell from 16.7 per cent in 1965-70 to 73.5 per cent in 1985-90, while Barbados continued to maintain the same foreign exchange rate from 1980 to 1990.

In this study, we shall examine the long-run economic implications of money, and exchange rates by developing an asset-market theoretic model. The dynamic aspects of the model will be studied from error correction representations (ECR) for the long-run, annual and bi-annual periods. See Engle and Granger (1987) and Engel, Granger, Hylleberg and Lee (EGHL) (1993).

Quarterly data covering 1960.1 to 1992.4 from various issues of the *International Financial Statistics* and Gordon (1989) are used in the study, with the U.S. dollar as the standard exchange rate.

In section 2, we shall review briefly the literature on money, and exchange rates; develop the monetary approach to exchange rate model, and discuss seasonal integration, cointegration, causality, and error correction techniques in section 3. Section 4 will contain the report of the empirical results. The conclusions will be summarized in section 5.

2. LITERATURE REVIEW

The recent victory of free market system which was highlighted by the failure of planned economies especially in Eastern Europe has underscored the pursuit of liberalized markets. Most countries have resorted to flexible exchange rate, albeit with some adjustable peg twist. It has become, therefore, important to develop a policy guide to govern exchange rate. See Artus (1978).

The monetary approach to determine the exchange rate evolved from the early works of Frenkel and Johnson (1978), and Mussa (1979). In particular, the requirements of purchasing power parity (PPP) by convention are: long time series data, higher inflation and/or drastic monetary shocks which clouds out real shocks, and efficient foreign exchange markets. Dornbusch (1980), Frenkel (1981) and Daniel (1986) failed to support the monetarists model because of violation in some of the conventional requirements.

Frenkel (1981) attributes the success of PPP to hyper inflationary environment. This was further supported by McNown and

Wallace (1989). However, Davutyan and Pippenger (1985) argued that the PPP works under both stable monetary climate and hyper inflation. This means that we can employ the monetarist model to study the exchange rate in even small, highly open, and moderate inflationary economies such as the Caribbean nations.

The violation of PPP has been explained away by the fact that relative prices are determined in commodity market which is less efficient, while exchange rates are determined in asset market which is highly efficient. See Dornbusch (1976) and Frenkel (1984). We shall circumvent this problem by using the monetarists model to determine the exchange rate. Here, the assumed steady state condition equates inflation rate to money growth rate. See section 3 following.

The duration of our data coverage meets the long time series requirement of PPP. Note that whereas monthly or quarterly data increase the frequency of data, they are not synonymous to increasing the size of data span. Hence our use of quarterly data is not intended to improve the quality of dynamic relations. See Hendry (1986) and Shiller and Perron (1985).[2]

However, quarterly data are used so that we can employ EGHL test for unit roots at the seasons and the long run[3], and conduct short run dynamic analysis using bilateral exchange rate-money

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[2]It was for this reason that Frenkel (1986) and Kim (1990) used annual data.

[3]Note that most of the studies which reject PPP for low inflation countries using cointegration, do so for the long run. Here, we will extend our study to examine if moderate or low inflationary countries observe PPP at other frequencies.

relationship between the U.S. and the Caribbean nations: Barbados, Jamaica, and Trinidad-Tobago.

Finally, the efficiency of the foreign exchange markets in each country are evaluated through a causality test between the log of nominal foreign exchange rate and relative monies. See Caves and Feige (1980).

3. THE MODEL

The monetary approach to determine the exchange rate and the PPP relationships are derived below. See McCallum (1989) and Schwarz (1973). Given GNP (Y), consumption (C), government spending (G) and net exports (X), the goods market equilibrium real income equation is specified as follows:

$$y = c + i + g + x$$

The behavioural equations are

$$c = c(y,r)$$

$$i = i(y,r)$$

$$x = x(s,\ y/y^f)$$

So, $y = y(r,\ s,\ y^f,\ g);\ y_1 < 0;\ y_2,\ y_3,\ y_4 > 0$ (1)

where the superscript f denotes a foreign variable.

The asset market is simplified by considering interest bearing asset and money demand function. The latter is specified as follows:

$$m_t - p_t = m(y,R),\ m_1 > 0,\ m_2 < 0 \qquad (2)$$

All small case letters denote the logarithmic forms of real variables. Three definitions are added to complete the model. The real exchange rate (s) or PPP is

$$s_t = e_t + p^f_t - p_t$$

Fisher's effect is

$$r_t = R_t - E_t(p_{t+1} - p_t), \text{ and}$$

Covered interest parity is

$$R_t = R^f_t + E_t(e_{t+1} - e_t), \text{ where}$$

Expectations are

$$E_t p_{t+1} = E(p_{t+1}/\Omega_t) \text{ and } E_t e_{t+1} = E(e_{t+1}/\Omega_t)$$

From behavioural equations (1) and (2), the equilibrium conditions of the goods market and asset market respectively, can be re-written as follows:

$$y_t = \alpha_0 + \alpha_1 r_t + \alpha_2 s_t + \alpha_3 y^f_t + \alpha_4 g + u_t \qquad (3)$$

$$m_t - p_t = \beta_0 + \beta_1 R_t + \beta_2 y_t + v_t \qquad (4)$$

By substituting the definitions for s and r into equation (3), and R into equation (4), we obtain the following:

$$y_t = \kappa_0 + \kappa_1(R_t - E_t[p_{t+1} - p_t]) + \kappa_2(e_t + p^f_t - p_t) + \kappa_3 y^f_t + \kappa_4 g + u_t \qquad (5)$$

$$m_t - p_t = \tau_0 + \tau_1(R^f_t + E_t[e_{t+1} - e_t]) + \tau_2 y_t + v_t \qquad (6)$$

where,

- r = real interest rate
- R = nominal interest rate
- y = normal or market clearing real output
- Ω = all available information
- E_t = expectation conditioned on Ω at time t
- m = money supply or currency and demand deposits
- p = price level

The exogenous variables are g, e, p, p^f, R^f, and y^f. The endogenous variables are r, R, s, y and m. In the steady state, $\Delta g = 0$, $E_t(\Delta[p_{t+1} - p_t]) = 0$, $E_t(\Delta[e_{t+1} - e_t]) = 0$, $\Delta y^f_t = \Delta y_t = 0$, $\Delta R_t = 0$, and $\Delta R^f_t = 0$, $\Delta e_{t+1} = \Delta e_t = \Delta e$, $\Delta p_{t+1} = \Delta p_t = \Delta p$, $\Delta p^f_t = \Delta p^f$, $\Delta m^f_t = \Delta m^f$, and $\Delta m_t = \Delta m$, where Δ denotes the first difference. So, we have

$$0 = \kappa_2(\Delta e + \Delta p^f - \Delta p) \quad (7),$$ and

$$\Delta m - \Delta p = 0. \quad (8)$$

Note that we have dropped subscript t which denotes period from the steady state equations (7) and (8). The dynamic PPP relationship is derived from equation (7) as follows:

$$\Delta e = \delta_0 + \delta_1(\Delta p - \Delta p^f) + \epsilon_1, \; \delta_1 \geq 0, \quad (9)$$

and the monetary approach to exchange rate relationship is obtained by substituting $\Delta m = \Delta p$ and $\Delta m^f = \Delta p^f$ into equation (9) as follows:

$$\Delta e = \eta_0 + \eta_1 \Delta\mu + \epsilon_2, \; \eta_1 \geq 0, \quad (10)$$

where $\mu = m - m^f$. It should be noted that whereas the above equations indicate that inflation rate or money growth rate ($\Delta\mu$) causes exchange rate growth rate (Δe), Frenkel (1978, p.183) asserts a reverse causation to be the case. We shall therefore, establish the direction of causation as part of the dynamic analysis of the model. Note that the monetary approach means that $\Delta\mu$ causes Δe. However, a reverse causation can imply that the foreign exchange market is inefficient. See Caves and Feige (1980).

In an attempt to test for seasonal integration and cointegration, we shall test for unit roots in e_t and μ_t at frequencies corresponding to $\theta = 0, 0.25, 0.5, 0.75$ of a cycle (2π). We shall consider all roots of modulus one in our test. Note that any of these roots will cause the series to have long memory, infinite variance, and the estimated parameter will have non-normal asymptotic distribution. See HEGY (1990).

The quarterly data is stationarized with the seasonal differencing operator $(1 - B^4)$. The operator is factorized as

$$(1 - B^4) = (1 - B^2)(1 + B^2) = (1 - B)(1 + B)(1 + B^2)$$

Now let $i = \sqrt{-1}$ so $i^2 = -1$. Therefore $-i^2 = 1$.

This yields,

$$\begin{aligned}(1 - B^4) &= (1 - B)(1 + B)(1 - i^2B^2) \\ &= (1 - B)(1 + B)(1 - iB)(1 + iB) \\ &= (1 - B)(1 + B + B^2 + B^3)\end{aligned}$$

Thus, the seasonal difference operator has four roots: +1, -1, +i, and -i. The complex conjugate, +i and -i, are similar for quarterly data, and are both referred to as the annual cycle. The roots of the operator are: +1 *(zero cycle)*, -1 *(biannual cycle) and* ±i (annual cycle).

HEGY's (1990) method is adopted to test for the class of seasonal process. The autoregressive process used to generate the quarterly data is

$$\phi(B)x_t = \Lambda_t + \epsilon_t$$

where,

x = the quarterly time series data

Λ = contains the deterministic seasonality

B = backshift operator

$\phi(B)$ = seasonal differencing operator

ϵ = zero mean white noise process

The root of $\phi(B)$ is obtained from the following auxiliary regression equation:

$$\phi^{*}(B)y_{4,t} = \pi_1 y_{1,t-1} + \pi_2 y_{2,t-1} + \pi_3 y_{3,t-2} + \pi_4 y_{3,t-1} + \Lambda_t + \varphi_i y_{4t-1} + \epsilon_t, \quad (11)$$

where,

$$y_{1t} = (1 + B + B^2 + B^3)x_t$$

$$y_{2t} = -(1 - B + B^2 - B^3)x_t$$

$$y_{3t} = -(1 - B^2)x_t = -\Delta_2 x_t$$

$$y_{4t} = (1 - B^4)x_t = \Delta_4 x_t$$

Equation (11) is estimated by ordinary least squares (OLS), with an additional lag of y_{4t} as a regressor to whiten the residuals. The distribution is the same. Additionally, seasonal dummies and trend (deterministic terms) can be added. However, these additions will change the distribution.

For a seasonal unit root test (zero frequency) $\phi^{*}(1) = 0$, the null hypothesis (H_0): $\pi_1 = 0$ is set against the stationary alternative hypothesis (H_1): $\pi_1 < 0$. Thus rejection of H_0 means the variable is stationary. In testing for seasonal negative unit root (biannual frequency) $\phi^{*}(-1) = 0$, H_0: $\pi_2 = 0$ is set against the stationary alternative H_1: $\pi_2 < 0$. Finally, for the complex roots (yearly frequency) $|\phi^{*}(i)| = 0$, H_0: $\pi_3 = \pi_4 = 0$ is set against H_1: $\pi_3 \cap \pi_4 \neq 0$.[4] Note that the distributions are different for different specifications of the model. Simultaneous rejection of seasonal negative unit roots and complex roots imply that the data have no

[4]See HEGY (1990) for a detail discussion of the sequential test, and the critical values of the first two t-tests, and the joint F-test.

seasonality problems.

The ECR system for e and μ are

$$\Delta_4\mu_t = \beta_1 EC_{1t} + \beta_2 EC_{2t} + \beta_3 EC_{3t} + \Sigma\lambda_i\Delta_4\mu_{t-i} + \Sigma\gamma_j\Delta_4 e_{t-j} + \nu_t, \quad (12)$$

and

$$\Delta_4 e_t = \beta_1' EC'_{1t} + \beta_2' EC'_{2t} + \beta_3' EC'_{3t} + \Sigma\lambda_i'\Delta_4 e_{t-i} + \Sigma\gamma'_j\Delta_4\mu_{t-j} + \nu_t'', \quad (13)$$

where

$$EC_{1t} = \mu_{1t-1} - \alpha_{1t-1}, \qquad EC'_{1t} = e_{1t-1} - \alpha'_1\mu_{1t-1}$$

$$EC_{2t} = \mu_{2t-1} - \alpha_2 e_{2t-1}, \qquad EC'_{2t} = e_{2t-1} - \alpha'_2\mu_{2t-1}$$

$$EC_{3t} = \mu_{3t-2} - \alpha_3 e_{3t-2} - \alpha_4\mu_{3t-3} - \alpha_5 e_{3t-3}$$

$$EC'_{3t} = e_{3t-2} - \alpha'_3\mu_{3t-2} - \alpha'_4 e_{3t-3} - \alpha'_5\mu_{3t-3}$$

The cointegration relations at the different frequencies are EC_{1t}, EC_{1t}', EC_{2t}, EC_{2t}', EC_{3t}, and EC_{3t}'. See Engle and Granger (1987).

4. DISCUSSION OF EMPIRICAL RESULTS

In Table 1a, we have tested for unit roots in e for all the countries. There are no seasonal unit root in any of the countries. However, there are unit roots at the zero frequency or the long-run in Jamaica and Trinidad-Tobago; albeit, no unit root was found in the long run in Barbados, except the case where there are no deterministic components.

In Table 1b, μ has unit roots at the zero frequency but no seasonal unit roots in all the countries. The results of cointegration at zero frequency are in Table 2. Here, we find unit roots in all the countries. Thus, there are no cointegration in the long run. However, in Table 3, e_{2t} and μ_{2t} are cointegrated at the

Table 1a: Tests for unit roots in the log of nominal exchange rates (e) in Barbados (B), Jamaica (J) and Trinidad-Tobago(TT)[a]

Var.	Det. Comp.	Long-run $t:\pi_1$	Bi-annual $t:\pi_2$	Annual $t:\pi_3$	$t:\pi_4$	F: $\pi_3 \cap \pi_4$
B$	-	0.84	-4.78	-5.83	-3.61	24.70
	I	-4.26	-4.94	-6.02	-3.68	25.96
	I,S	-4.23	-4.90	-5.98	-3.65	25.37
	I,T	-4.06	-4.98	-6.05	-3.73	26.27
	I,S,T	-4.02	-4.94	-6.01	-3.70	25.69
J$	-	1.72	-5.61	-2.29	-7.98	54.99
	I	1.25	-5.62	-2.37	-7.98	34.07
	I,S	1.29	-5.59	-2.47	-8.15	35.76
	I,T	-1.13	-5.50	-2.45	-7.65	31.80
	I,S,T	-1.02	-5.47	-2.54	-7.81	33.34
TT$	-	1.83	-6.87	-4.56	-7.50	52.02
	I	0.10	-6.86	-4.57	-7.46	51.76
	I,S	0.09	-6.73	-4.52	-7.43	51.41
	I,T	-2.08	-6.91	-4.83	-7.24	52.21
	I,S,T	-2.06	-6.80	-4.79	-7.20	51.81

[a]Notes: critical values at a 0.01 significant level for sample sizes 48 and 100. See HEGY (1990).

Det. Comp.	Long-run $t : \pi_1$	Biannual $t : \pi_2$	Annual $t : \pi_3$	$t : \pi_3$	F : $\pi_3 \cap \pi_4$
I, 48	- 2.72	- 2.67	- 2.66	- 2.51	5.02
100	- 3.66	- 2.61	- 2.55	- 2.43	4.89
S,I, 48	- 3.77	- 3.75	- 4.31	- 2.86	9.22
100	- 3.55	- 3.60	- 4.06	- 2.78	8.74
T,I,48	- 4.23	- 2.65	- 2.68	- 2.41	4.64
100	- 4.07	- 2.58	- 2.56	- 2.38	4.70
I,S,T,48	- 4.46	- 3.80	- 4.46	- 2.75	9.27
100	- 4.09	- 3.60	- 4.12	- 2.76	8.79

Table 1b: Tests for seasonal unit roots in the log of domestic-U.S. money supply (μ) in Barbados (B), Jamaica (J), and Trinidad-Tobago (TT)[a]

Var.	Det. Comp.	Long-run $t:\pi_1$	Bi-annual $t:\pi_2$	Annual $t:\pi_3$	$t:\pi_4$	F: $\pi_3 \cap \pi_4$
B: μ	-	-1.45	-5.94	-6.60	-5.09	51.73
	I	-2.09	-5.78	-6.72	-4.74	49.88
	I,S	-2.19	-6.19	-8.02	-4.94	76.57
	I,T	-1.38	-5.74	-6.54	-4.70	47.06
	I,S,T	-1.18	-6.10	-7.84	-4.91	72.66
J: μ	-	1.69	-3.30	-2.42	-4.47	12.98
	I	2.07	-3.41	-2.61	-4.62	14.12
	I,S	0.04	-3.37	-2.59	-4.47	13.33
	I,T	2.43	-4.77	-4.35	-7.01	33.94
	I,S,T	0.77	-4.76	-4.34	-6.91	32.97
TT: μ	-	-0.20	-5.81	-8.96	-5.11	89.91
	I	-0.87	-5.76	-8.83	-4.95	84.31
	I,S	-0.95	-6.75	-8.79	-4.79	80.52
	I,T	-0.88	-5.76	-8.82	-4.91	83.87
	I,S,T	-0.87	-6.73	-8.77	-4.74	80.05

[a]See the notes in table 1a. I is intercept term, T is time trend (t), and S is seasonal dummies s1, s2 and s3.

Table 2: Cointegration estimates at zero frequency: Long run[a]

Dep. Var.	Coef. of Indep. Vars. (e_{1t})	Cointegration Regression Det. Comp.	Auxiliary Regression Det. Comp.	# of Lags	R^2	D.W.	t: π_1
Barbados:							
μ_{1t}	-1.016	-	-	1	0.52	2.04	-2.28
	[24.62						
μ_{1t}	9.45	I	-	1	0.30	1.94	-1.95
	[2.99]						
μ_{1t}	3.60	T,I	-	1	0.48	1.85	-1.25
	[1.79]						
Jamaica:							
μ_{1t}	0.75	-	-	1	0.62	1.34	-2.40
	[24.93						
μ_{1t}	0.86	I	-	1	0.65	1.33	-3.04
	[31.63						
μ_{1t}	0.25	T,I	-	1	0.59	1.58	-2.29
	[7.91]						
Trinidad-Tobago:							
μ_{1t}	0.64	-	-	1	0.65	2.19	-1.37
	[10.01						
μ_{1t}	1.84	I	-	1	0.65	1.92	-1.56
	[11.18						
μ_{1t}	-1.56	T,I	-	1	0.64	1.96	1.79
	[5.83						

[a]The auxiliary regression is $\Delta u_t = \pi_1 u_{t-1} + \Delta u_{t-1} + \epsilon_t$, where u_t is the residual from the cointegrating regression. R^2 is the adjusted coefficient of determination, and DW is the Durbin-Watson statistic. See also notes in Table 1a.

Table 3: Cointegration estimates at 1/2 frequency: Biannual[a]

	Cointegration Regression		Auxiliary Regression			
Dep. Var.	Coef. of Indep. Vars. (e_{2t})	Det. Comp.	Det. Comp.	R^2	D.W.	t: π_2
Barbados:						
μ_{2t}	0.232	-	1	0.59	2.102	-3.37
	[0.384]					
μ_{2t}	0.169	I	1	0.59	2.095	-3.39
	[0.280]					
μ_{2t}	0.156	I,S	1	0.59	2.097	-3.36
	[0.253]					
Jamaica:						
μ_{2t}	0.299	-	1	0.58	1.700	-3.16
	[4.099]					
μ_{2t}	0.168	I	1	0.62	1.700	-3.21
	[2.273]					
μ_{2t}	0.195	I,S	1	0.64	1.800	-4.30
	[3.092]					
Trinidad-Tobago:						
μ_{2t}	-0.156	-	1	0.63	2.31	-2.55
	[0.690]					
μ_{2t}	-0.261	I	1	0.63	2.27	-2.61
	[1.136]					
μ_{2t}	-0.190	I,S	1	0.66	2.33	-3.34
	[0.909]					

[a]The auxiliary regression is $(v_t + v_{t-1}) = \pi_2(-v_{t-1}) + \lambda_1(v_{t-1} + v_{t-2}) + \epsilon'_t$, where v_t is the residual from the cointegration regression.

Table 4: Cointegration estimates at 1/4 (and 3/4) frequency: Annual[a]

Dep. Var.	Coef. of Indep. Var. (e_{3t})	(e_{3t-1})	Det. Comp	Aug. Lag#	R^2	D.W.	$t{:}\pi_3$	$t{:}\pi_4$	F: $\pi_3 \cap \pi_4$
	Cointegration Regression			Auxiliary Regression			Unit Roots Test in Residuals		
Barbados:									
μ_{3t}	0.19	0.47	-	1	0.57	1.87	3.17	2.06	7.1
	0.32	0.84							
μ_{3t}	0.22	0.42	I	1	0.58	1.86	3.16	2.07	7.1
	0.36	0.74							
μ_{3t}	0.31	0.08	I,S	1	0.64	1.89	4.04	3.42	13.4
	0.57	0.16							
Jamaica:									
μ_{3t}	0.17	0.12	-	1	0.61	1.78	2.20	4.20	11.2
	1.62	1.13							
μ_{3t}	0.11	0.05	I	1	0.66	1.78	2.38	4.33	12.2
	1.09	0.50							
μ_{3t}	0.06	0.13	I,S	1	0.71	1.93	3.94	6.59	29.8
	0.70	1.57							
Trinidad-Tobago:									
μ_{3t}	0.03	0.00	-	1	0.72	1.87	5.94	1.70	19.0
	0.17	0.00							
μ_{3t}	0.02	0.06	I	1	0.71	1.86	5.91	1.73	18.9
	0.09	0.29							
μ_{3t}	0.06	0.04	I,S	1	0.72	1.92	4.58	2.58	15.2
	0.30	0.19							

[a]The auxiliary regression is $(w_t + w_{t-2}) = \pi_3(-w_{t-2}) + \pi_4(-w_{t-1}) + \delta_1(w_{t-1} + w_{t-3}) + \epsilon_t''$, where w_t is the residual from the cointegration regression. See also notes in Table 1a.

biannual period for Barbados and Jamaica. In Trinidad-Tobago, the cointegration is strong only for the case where the deterministic component consists of an intercept term.[5]

In Table 4, e_{3t} and μ_{3t} are higly cointegrated in all the countries. Thus, cointegration exists for six months and a year. The ECR results are presented in Table 5a. Cointegration exists for all the countries at the bi-annual and annual periods. However, in Trinidad-Tobago, the cointegration is weak at the bi-annual period. In Table 5b, cointegration exists at the bi-annual period in all the countries. However, Trinidad-Tobago reveals non-cointegration at the annual period. The non-cointegration at the long-run in all the countries means that the level form of the variables are non-stationary.

Having established an absence of seasonality problems in the data, we proceed to test for the order of integration using Mackinnon's (1990) critical values for the Dickey-Fuller (DF) and the augmented DF (ADF) tests . The results in Table 6 indicate that with the exception of e in Barbados, all the level form of the variables in all the countries are insignificant. However, Δe and $\Delta\mu$ are significant at the 0.01 level in all the countries. Thus, the entire series are integrated of order unity, I(1,0).

In Table 7, we present causality[6] and cointegration results of

[5]See HEGY (1990, p.226) for critical values at a 0.05 significant level.

[6]See Ghartey (1993) for details about the test of the causal relationships. We have been very brief here to conserve space.

Table 5a: Estimated results of ECR at zero and seasonal frequencies[a]: Money growth rate as a dependent variable

Barbados:

$$\Delta_4\mu_t = -\underset{[2.487]}{0.019}\bullet EC_{1t} - \underset{[3.681]}{0.445}\bullet EC_{2t} - \underset{[3.828]}{0.339}\bullet EC_{3t} + \underset{[4.121]}{0.384}\bullet\lambda_1 - \underset{[0.575]}{0.270}\gamma_1,\ R^2 = 0.66,\ D.W. = 1.85$$

$$\Delta_4\mu_t = -\underset{[1.995]}{0.017}EC_{1t} - \underset{[3.990]}{0.630}\bullet EC_{2t} - \underset{[3.409]}{0.333}\bullet EC_{3t} + \underset{[1.710]}{0.250}\lambda_1 + \underset{[1.377]}{0.213}\lambda_2 - \underset{[2.563]}{0.380}\lambda_3 + \underset{[1.926]}{0.217}\lambda_4 - \underset{[1.233]}{0.675}\gamma_1 + \underset{[1.446]}{0.806}\gamma_2 + \underset{[1.781]}{1.001}\gamma_3 + \underset{[0.009]}{0.004}\gamma_4,\ R^2 = 0.70,\ D.W. = 2.02$$

Jamaica:

$$\Delta_4\mu_t = -\underset{[1.400]}{0.007}EC_{1t} - \underset{[2.958]}{0.244}\bullet EC_{2t} + \underset{[3.954]}{0.305}\bullet EC_{3t} + \underset{[9.098]}{0.624}\bullet\lambda_1 + \underset{[3.312]}{0.119}\bullet\gamma_1,\ R^2 = 0.71,\ D.W. = 1.61$$

$$\Delta_4\mu_t = -\underset{[1.365]}{0.008}EC_{1t} - \underset{[2.477]}{0.226}EC_{2t} - \underset{[3.243]}{0.283}\bullet EC_{3t} + \underset{[7.142]}{0.808}\bullet\lambda_1 - \underset{[0.998]}{0.142}\lambda_2 - \underset{[1.341]}{0.186}\lambda_3 + \underset{[1.515]}{0.146}\lambda_4 + \underset{[1.322]}{0.107}\gamma_1 + \underset{[0.709]}{0.090}\gamma_2 - \underset{[1.213]}{0.156}\gamma_3 + \underset{[1.019]}{0.086}\gamma_4,\ R^2 = 0.73,\ D.W. = 2.03$$

Trinidad-Tobago:

$$\Delta_4\mu_t = -\underset{[1.408]}{0.004}EC_{1t} - \underset{[2.729]}{0.207}\bullet EC_{2t} - \underset{[4.715]}{0.442}\bullet EC_{3t} + \underset{[4.375]}{0.397}\bullet\lambda_1 - \underset{[0.725]}{0.067}\gamma_1,\ R^2 = 0.70,\ D.W. = 1.72$$

$$\Delta_4\mu_t = -\underset{[1.097]}{0.004}EC_{1t} - \underset{[2.350]}{0.231}EC_{2t} - \underset{[2.593]}{0.343}\bullet EC_{3t} + \underset{[3.642]}{0.432}\bullet\lambda_1 + \underset{[1.213]}{0.169}\lambda_2 - \underset{[0.564]}{0.073}\lambda_3 - \underset{[0.871]}{0.096}\lambda_4 - \underset{[0.145]}{0.024}\gamma_1 + \underset{[0.414]}{0.096}\gamma_2 - \underset{[1.422]}{0.330}\gamma_3 + \underset{[1.460]}{0.240}\gamma_4,\ R^2 = 0.70,\ D.W. = 1.76$$

Notes: *The absolute values of the calculated t-statistics are reported within the square brackets. DW-statistics show no autocorrelation problems. * significant at a 0.01 level.*

Table 5b: Estimated results of ECR at zero and seasonal frequencies[a]: Exchange rate as a dependent variable

Barbados:

$$\Delta_4 e_t = -\underset{[2.127]}{0.003} EC'_{1t} - \underset{[4.821]}{0.413}{}^{\bullet} EC'_{2t} - \underset{[6.814]}{0.454}{}^{\bullet} EC'_{3t} - \underset{[1.549]}{0.015}\lambda_1 - \underset{[1.490]}{0.123}\gamma_1, \quad R^2 = 0.54, \; D.W. = 1.38$$

$$\Delta_4 e_t = -\underset{[0.602]}{0.001} EC'_{1t} - \underset{[3.771]}{0.433}{}^{\bullet} EC'_{2t} - \underset{[7.838]}{0.681}{}^{\bullet} EC'_{3t} - \underset{[0.770]}{0.010}\lambda_1 - \underset{[1.290]}{0.026}\lambda_2 + \underset{[1.290]}{0.021}\lambda_3 - \underset{[1.074]}{0.014}\lambda_4 - \underset{[0.848]}{0.083}\gamma_1 + \underset{[0.673]}{0.068}\gamma_2 + \underset{[0.596]}{0.062}\gamma_3 + \underset{[2.375]}{0.172}\gamma_4, \quad R^2 = 0.66, \; D.W. = 1.74$$

Jamaica:

$$\Delta_4 e_t = -\underset{[1.181]}{0.006} EC'_{1t} - \underset{[4.448]}{0.502}{}^{\bullet} EC'_{2t} - \underset{[6.323]}{0.601}{}^{\bullet} EC'_{3t} + \underset{[4.677]}{0.304}{}^{\bullet}\lambda_1 + \underset{[7.161]}{0.502}{}^{\bullet}\gamma_1, \quad R^2 = 0.86, \; D.W. = 1.42$$

$$\Delta_4 e_t = -\underset{[0.868]}{0.005} EC'_{1t} - \underset{[1.974]}{0.260} EC'_{2t} - \underset{[5.412]}{0.617}{}^{\bullet} EC'_{3t} + \underset{[1.769]}{0.195}\lambda_1 + \underset{[0.600]}{0.088}\lambda_2 - \underset{[0.567]}{0.082}\lambda_3 + \underset{[0.927]}{0.098}\lambda_4 + \underset{[7.092]}{0.983}{}^{\bullet}\gamma_1 - \underset{[3.092]}{0.536}{}^{\bullet}\gamma_2 + \underset{[0.752]}{0.125}\gamma_3 + \underset{[0.272]}{0.027}\gamma_4, \quad R^2 = 0.88, \; D.W. = 1.75$$

Trinidad-Tobago:

$$\Delta_4 e_t = \underset{[0.465]}{0.001} EC'_{1t} - \underset{[5.355]}{0.715}{}^{\bullet} EC'_{2t} - \underset{[0.491]}{0.024} EC'_{3t} + \underset{[5.041]}{0.429}{}^{\bullet}\lambda_1 - \underset{[0.448]}{0.020}\gamma_1, \quad R^2 = 0.66, \; D.W. = 1.86$$

$$\Delta_4 e_t = \underset{[1.029]}{0.0019} EC'_{1t} - \underset{[4.840]}{0.849}{}^{\bullet} EC'_{2t} + \underset{[0.287]}{0.020} EC'_{3t} - \underset{[0.240]}{0.012}\lambda_1 + \underset{[0.648]}{0.0447}\lambda_2 + \underset{[0.108]}{0.007}\lambda_3 - \underset{[0.838]}{0.047}\lambda_4 + \underset{[2.141]}{0.342}\gamma_1 + \underset{[1.579]}{0.249}\gamma_2 - \underset{[2.748]}{0.408}\gamma_3 + \underset{[1.016]}{0.1014}\gamma_4, \quad R^2 = 0.68, \; D.W. = 2.06$$

See notes ina Table 5a

Table 6: Tests of order of integration I(1,0).[a]

Variable	DF (K = 1)	ADF (K = 4)
Barbados:		
e	- 9.50*	-4.26*
μ	- 2.35	-2.41
Δe	-10.36*	-3.94**
$\Delta\mu$	- 8.49*	-3.27
Jamaica:		
e	1.37	1.25
μ	2.20	2.07
Δe	- 6.02*	-4.45*
$\Delta\mu$	- 8.40*	-4.11*
Trinidad-Toabgo:		
e	- 2.31	-2.01
μ	- 0.67	-1.02
Δe	- 7.97*	-5.42*
$\Delta\mu$	- 7.33*	-3.20

[a]MacKinnon's critical values for both DF and ADF tests for both level and difference logarithmic forms of the variables are given as follows: -4.06, -3.46 and -3.16 at 0.01, 0.05 and 0.10 significant levels respectively. *, ** and *** denote significance at a 0.01, 0.05 and 0.10 levels respectively. The figures in parantheses are the number of lagged residuals.

Table 7: Causality and cointegration results and tests of the growth rate of exchange rate (Δe) and the growth rate of domestic-U.S. monies ($\Delta \mu$).[a]

Dep. Var.	Coint. Vectors		Coef. of residuals			Causal Direct.
Δe	$\Delta \mu$	Δe	u_{t-1}	DF(k=1)	F-test	
Barbados[†]	-0.003	1.000	-1.395	-10.41	0.107	$\Delta e \Rightarrow \Delta \mu$
Jamaica	-0.066	1.000	-0.605	- 5.98	0.611	$\Delta e \Rightarrow \Delta \mu$
Trinidad-Tobago	0.054	1.000	-0.907	- 6.26	0.019	$\Delta e \Rightarrow \Delta \mu$
$\Delta \mu$						
Barbados	1.000	-0.070	-1.339	- 8.54	1.889	$\Delta \mu \Rightarrow \Delta e$
Jamaica	1.000	-0.057	-1.168	- 8.66	6.587*	$\Delta \mu \Rightarrow \Delta e$
Trinidad-Tobago	1.000	0.232	-0.724	- 4.28	0.669	$\Delta \mu \Rightarrow \Delta e$

[a]MacKinnon's critical values are -4.02, -3.40 and -3.09 for 0.01, 0.05 and 0.10 significant levels respectively. [†]At the level form the F-statistic for $e \Rightarrow \mu$ is 3.67, and it is significant at the 0.05 level. $\Rightarrow$ denotes direction of causation.

Table 8: Estimates of the ECR system (Long-run case)[a].

Barbados:

$$\Delta e_t = \underset{[1.442]}{0.002} - \underset{[1.247]}{0.029}\Delta\mu_{-1} - \underset{[0.660]}{0.073}\Delta e_{-1} - \underset{[1.913]^{**}}{0.013}(e_{-1} + 0.85\mu_{-1})$$

$R^2 = 0.03$, $D.W. = 1.89$, $ARCH(1) = 23.72^{*}$, $Q(1) = 0.05$

$$\Delta\mu_t = -\underset{[1.843]}{0.080} - \underset{[0.305]}{0.034}\Delta\mu_{-1} - \underset{[0.053]}{0.029}\Delta e_{-1} - \underset{[2.018]}{0.060}(\mu_{-1} + 1.03e_{-1}$$

$R^2 = 0.02$, $D.W. = 2.02$, $ARCH(1) = 1.55$, $Q(1) = 0.04$

Jamaica:

$$\Delta e_t = \underset{[2.403]}{0.024} + \underset{[2.288]^{**}}{0.200}\Delta\mu_{-1} + \underset{[5.169]}{0.417}\Delta e_{-1} - \underset{[2.099]}{0.045}(e_{-1} - 1.12\mu_{-1})$$

$R^2 = 0.22$, $D.W. = 2.02$, $ARCH(4) = 0.34$, $Q(4) = 0.27$

$$\Delta\mu_t = \underset{[1.537]}{-0.038} - \underset{[0.565]}{0.052}\Delta\mu_{-1} - \underset{[0.101]}{0.009}\Delta e_{-1} - \underset{[1.985]}{0.061}(\mu_{-1} - 0.75e_{-1}) - \underset{[2.890]^{*}}{0.001}t$$

$R^2 = 0.04$, $D.W. = 2.01$, $ARCH(1) = 0.98$, $Q(1) = 0.0$

Trinidad-Tobago:

$$\Delta e_t = \underset{[1.780]}{0.010} + \underset{[0.072]}{0.003}\Delta\mu_{-1} - \underset{[1.966]^{**}}{0.172}\Delta e_{-1} - \underset{[0.960]}{0.008}(e_{-1} - 0.73\mu_{-1})$$

$R^2 = 0.01$, $D.W. = 1.97$, $ARCH(1) = 0.67$, $Q(1) = 0.03$

$$\Delta\mu_t = \underset{[2.985]}{0.042} - \underset{[1.828]^{**}}{0.163}\Delta\mu_{-1} + \underset{[0.236]}{0.044}\Delta e_{-1} - \underset{[0.728]}{0.008}(\mu_{-1} - 0.64e_{-1}) - \underset{[2.044]^{**}}{0.043}s_1 - \underset{[0.816]}{0.016}s_2 - \underset{[3.265]^{*}}{0.066}s_3$$

$R^2 = 0.11$, $D.W. = 1.92$, $ARCH(1) = 2.20$, $Q(1) = 0.07^{*}$

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[a]Notes: Ljung-Box Q statistics show the series to be white noise. The ARCH tests are insignificant in all cases, except for Δe in Barbados. The t-values are in square brackets. The number in parantheses for Q are the number of correlations computed. The number of lagged residuals of the autoregressive conditional heteroscedasticity (ARCH) tests are in the parantheses. *, ** and *** indicate significance at a 0.01, 0.05 and 0.10 levels respectively. The DW statistics show no autocorrelation.

e and μ. Cointegration is found in all cases. However, the F-tests indicate that with the exception of Jamaica where $\Delta\mu$ causes Δe, no such causation exists in the other countries.

In Barbados, since e was stationary at the level form, we tested for causality at that level. Here, we find that e uni-directionally causes μ which indicates an inefficient foreign exchange market in the country. Thus, monetary approach to determine exchange rate holds only in Jamaica.

In Table 8, the ECR estimates show that deviations from PPP cannot be corrected in a quarter in Trinidad-Tobago. However, in Barbados and Jamaica, a deviation from PPP will result in about 1.3 and 4.5 per cent devaluation in the respective countries within a quarter. Additionally, a similar deviation from PPP will result in about a 6 per cent drop in $\Delta\mu$ in Barbados and Jamaica.

In all these cases, the level of significance are weak. However, the Ljung-Box Q statistics in Table 8 indicate no serial correlation problem. The ARCH tests also indicate no heteroscedasticity, except in equation Δe for Barbados. In cases where there were indications of autocorrelation problems, we included a trend term and seasonal dummies to remove them.[7] The R^2 is low in all cases. However, in comparison with the DW statistic, it only indicates that the regression is spurious at the level form. See Granger (1990), and Granger and Newbold (1974).

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[7]A random walk with drift which resulted in a negative R^2 in equation $\Delta\mu$ for Jamaica was corrected by adding a trend term. In Trinidad-Tobago, an autoregressive conditional heteroscedasticity was corrected by adding seasonal dummies to equation $\Delta\mu$.

5. CONCLUSION

In this study, we have examined seasonal integration and stationarity of the level forms of the log of nominal exchange rate and relative monies in Barbados, Jamaica and Trinidad-Tobago. There are no seasonality problems in the series for the countries. However, there are unit roots in the long run in the data for the countries, except Barbados, where the level form of its exchange rate is highly stationary.

Additionally, the DF and ADF tests show that Δe and $\Delta \mu$ are stationary in the countries. Exchange rate and relative monies are cointegrated in six months and a year. The first difference forms of these variables are cointegrated in all three countries for the long run. Thus, PPP is valid in all the countries.

The ECR estimates indicate that a deviation from PPP cannot be corrected in a quarter in Trinidad-Tobago. However, in Barbados and Jamaica, there are indications that a deviation in PPP will result in about 1.3 and 4.5 per cent devaluation respectively in a quarter before returning to equilibrium, *ceteris paribus*. Furthermore, in Barbados and Jamaica, there are indications that a deviation from PPP will cause about 6 per cent drop in the growth rate of money supply, *ceteris paribus*, before returning to equilibrium.

The causality test reports indicate that $\Delta \mu$ uni-directionally causes Δe in Jamaica. There are no such causal relationship in Barbados and Trinidad-Tobago. However, e uni-drectionally causes μ in Barbados. Note that e is highly stationary in Barbados.

The basic conclusion is that PPP holds even for a small, moderately and low inflationary but highly open economies in the Caribbean. These results lend credence to Davutyan and Pippenger's (1985) thesis. Additionally, equilibrium relationship exists between these two variables for six months and a year in the countries. These findings suggest that the previous studies which invalidated PPP, such as Frenkel (1978), McNown and Wallace (1989), and Sarantis and Stewart (1993) should be further examined by using EGHL (1993) test for biannual and annual periods.

Finally, we find that the monetary approach to determine exchange rate holds only in Jamaica. Monetary policy can therefore be employed appropriately to control exchange rate there. Similar conclusion cannot be made for Barbados and Trinidad-Tobago because of insignificant results. In Trinidad-Tobago, this may be caused by the external influence of oil revenues on its money supply and exchange rate.

However, in Barbados, the causal direction of the level form variables suggests that its foreign exchange market is inefficient. Admittedly, this latter result is not robust, never the less, the importance of the Barbadian government acting to improve the efficiency of its foreign exchange market cannot be gainsaid.

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