Testing for Unit Roots in Nepalese Macroeconomic Data

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Unit root test is viewed as mandatory on time series data since these data may possess specific properties like memory, trend and structural break. The results obtained by employing conventional regression methods without testing for the unit root in time series data might be misleading. This paper presents an overview of various unit root test methods and conducts the unit root test on Nepalese key macroeconomic data allowing one endogenous structural break. The test results show that out of the 18 macroeconomic variables, 10 have unit roots and the remaining 8 are stationary. An analysis of the structural break dates of these variables suggests that the Nepalese economy has gone through a structural change after mid-1980s.

I. Background

Most of the applied economic research works use time series data. The reliability of findings of such works depends heavily upon the model specification and selection of statistical or econometric methods. As time series data may posses some specific properties such as memory, trend and structural break, the methods that are commonly used to analyse other data may not be appropriate for time series data.

The ordinary least square (OLS) method is widely used to analyse the pattern of effect of one variable on another variable. The test statistics may often show a significant relationship between variables in the regression model even though no such relationship exists between them. This type of regression is known as 'spurious regression'. The suitability and the reliability or the goodness of fit of a regression model is determined by checking the coefficient of determination (R^2) and the value of Durbin-Watson (DW). The value of R^2 close to 1 and the value of DW close to 2 shows that the goodness of fit of the model is high and the regression results are reliable. However, when R^2 is greater than the DW value, it is a good rule of thumb to suspect that the estimated regression is spurious (Granger and Newbold 1974).

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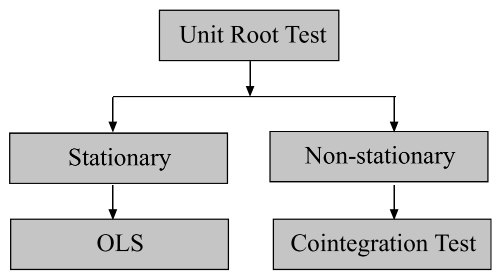
The case of spurious regression is frequently encountered while dealing with the time series data. Spurious regression occurs mainly because of the non-stationarity in the time series. To solve such a problem of spurious regression, the stationarity of the time series is examined by conducting unit root test.

A time series is considered to be stationary if its mean and variance are independent of time. If the time series is non-stationary, *i.e.*, having a mean and or variance changing over time, it is said to have a unit root. The regression analysis done in a traditional way will produce spurious results, if the time series is non-stationary. Therefore, in order to examine stationarity of the time-series, the unit root test is conducted first. The standard procedure for analysing the time series data can be explained by the following schematic diagram:

DIAGRAM 1: Procedure for Analysing Time Series Data



Most of the past empirical studies conducted on various aspects of Nepalese economy have used OLS method. The results obtained by employing time series data without considering unit roots in data may be misleading. Therefore, this paper conducts a comprehensive unit root test on key macroeconomic data of Nepal and presents the unit root results for these time series.

The subsequent section reviews various unit root test methods with and without structural change. In section 3, the nature and sources of data of this study are discussed. The unit root test results obtained by following a sequential test procedure are presented and discussed in section 4. Finally, the concluding remarks are presented in section 5.

II. UNIT ROOT TEST METHODS

There are several methods available for conducting unit root test. Dickey-Fuller (DF), Augmented Dickey-Fuller (ADF), and Phillip-Perron (PP) test methods are commonly used to examine the stationarity of a time series.

The Dickey-Fuller (DF) model is as follows:

$$y_t = \mu + \alpha y_{t-1} + e_t \tag{1}$$

Where μ is an intercept and e_t is a white noise. In this model, the null hypothesis is $\alpha = 1$ (nonstationary series) against the alternative hypothesis of $\alpha < 1$ (stationary series).

The error term in DF test might be serially correlated. The possibility of such serial correlation is eliminated in the following Augmented Dickey-Fuller model:

$$\Delta y_t = \mu + \delta y_{t-1} + \sum_{i=1}^{k} \beta_i \Delta y_{t-i} + e_t \tag{2}$$

where $\delta = \alpha - 1$

The null hypothesis of ADF is $\delta = 0$ against the alternative hypothesis of $\delta < 0$. Non-rejection of the null hypothesis implies that the time series is non-stationary, whereas rejection means the time series is stationary.

Phillips and Perron (1988) have suggested a non-parametric test as an alternative to the ADF test. Although the ADF test has been reported to be more reliable than the Philips-Perron test, the problem of size distortion and low power of test make both these tests less useful (Maddala and Kim 2003).

Perron (1989) argues that the structural break is common in the time series data and creates problem in determining the stationarity of that time series. He shows that in the presence of a structural break in the time series, many perceived non-stationary time series may be in fact stationary. The structural break may occur due to regime change, change in policy direction, external shocks, war, etc. Perron (1989) re-examined Nelson and Plosser (1982) data and found that 11 of the 14 US macroeconomic variables were stationary when known exogenous structural break was included. Perron (1989) allows one time structural change occurring at a time T_B ($1<T_B<T$).

Following are the models developed by Perron (1989) for three different cases:

Null Hypothesis:

Model (A) $$y_t = \mu + dD(TB)_t + y_{t-1} + e_t \tag{3}$$

Model (B) $$y_t = \mu_1 + y_{t-1} + (\mu_2 - \mu_1)DU_t + e_t \tag{4}$$

Model (C) $$y_t = \mu_1 + y_{t-1} + dD(TB)_t + (\mu_2 - \mu_1)DU_t + e_t \tag{5}$$

Where $D(TB)_t = 1$ if $t = T_B + 1$, 0 otherwise, and
$DU_t = 1$ if $t > T_B$, 0 otherwise.

Alternative Hypothesis:

Model (A) $$y_t = \mu_1 + \beta t + (\mu_2 - \mu_1)DU_t + e_t \tag{6}$$

Model (B) $$y_t = \mu + \beta_1 t + (\beta_2 - \beta_1)DT_t^* + e_t \tag{7}$$

Model (C) $$y_t = \mu_1 + \beta_1 t + (\mu_2 - \mu_1)DU_t + (\beta_2 - \beta_1)DT_t + e_t \tag{8}$$

where $DT_t^* = t - T_B$, and
$DT_t = t$ if $t > T_B$, 0 otherwise.

The first model (Model A) permits an exogenous change in the level of the series whereas the second model (Model B) permits an exogenous change in the rate of growth. The third model (Model C) allows change in both.

Perron (1989) models include one known structural break. These models cannot be applied where such breaks are unknown. Therefore, this procedure is criticised for assuming known break date which raises the problem of pre-testing and data-mining regarding the choice of the break date (Maddala and Kim 2003).

Zivot and Andrews (1992), Perron and Vogelsang (1992), and Perron (1997) have developed unit root test methods which include one unknown structural break.

Zivot and Andrews (1992) models are as follows:

Model with Intercept

$$y_t = \mu + \theta DU_t(\lambda) + \beta t + \alpha y_{t-1} + \sum_{j=1}^{k} c_j \Delta y_{t-j} + e_t \tag{9}$$

Model with Trend

$$y_t = \mu + \beta t + \gamma DT_t^*(\lambda) + \alpha y_{t-1} + \sum_{j=1}^{k} c_j \Delta y_{t-j} + e_t \tag{10}$$

Model with Both Intercept and Trend

$$y_t = \mu + \theta DU_t(\lambda) + \beta t + \gamma DT_t^*(\lambda) + \alpha y_{t-1} + \sum_{j=1}^{k} c_j \Delta y_{t-j} + e_t \tag{11}$$

where $DU_t(\lambda) = 1$ if $t > T\lambda$, 0 otherwise;
$DT_t^*(\lambda) = t - T\lambda$ if $t > T\lambda$, 0 otherwise.

The above models are based on the Perron (1989) models. However, these modified models do not include DT_b. On the other hand, Perron and Vogelsang (1992) include DT_b but exclude t in their models. Perron and Vogelsang (1992) models are given below:

Innovational Outlier Model (IOM)

$$y_t = \mu + \delta DU_t + \theta D(T_b)_t + \alpha y_{t-1} + \sum_{i=1}^{k} c_i \Delta y_{t-i} + e_t \tag{12}$$

Additive Outlier Model (AOM)– Two Steps

$$y_t = \mu + \delta DU_t + \tilde{y}_t \tag{13}$$

and

$$\tilde{y}_t = \sum_{i=0}^{k} w_i D(T_b)_{t-i} + \alpha \tilde{y}_{t-1} + \sum_{i=1}^{k} c_i \Delta \tilde{y}_{t-i} + e_t \tag{14}$$

Perron (1997) includes both t (time trend) and DT_b (time at which structural change occurs) in his Innovational Outlier (IO1 and IO2) and Additive Outlier (AO) models.

Innovational Outlier Model allowing one time change in intercept only (IO1):

$$y_t = \mu + \theta DU_t + \beta t + \delta D(T_b)_t + \alpha y_{t-1} + \sum_{i=1}^{k} c_i \Delta y_{t-i} + e_t \tag{15}$$

Innovational Oulier Model allowing one time change in both intercept and slope (IO2):

$$y_t = \mu + \theta DU_t + \beta t + \gamma DT_t + \delta D(T_b)_t + \alpha y_{t-1} + \sum_{i=1}^{k} c_i \Delta y_{t-i} + e_t \tag{16}$$

Additive Outlier Model allowing one time change in slope (AO):

$$y_t = \mu + \beta t + \delta DT_t^* + \tilde{y}_t \tag{17}$$

where $DT_t^* = 1(t > T_b)(t - T_b)$

$$\tilde{y}_t = \alpha \tilde{y}_{t-1} \sum_{i=1}^{k} c_i \Delta \tilde{y}_{t-i} + e_t \tag{18}$$

The Innovational Outlier models represent the change occurring gradually whereas Additive Outlier model represents the change occurring rapidly.

More recently, some new methods have been proposed for unit root test allowing multiple structural breaks (Lumsdaine and Papell 1997; Bai and Perron 2003).

From the above discussion it is clear that there are several methods for unit root test. Different models are suggested for the time series with intercept only, with trend only, and with both. Similarly, different models are prescribed for the time series with structural break and with time trend. In such a case, certain judgement has to be applied based on economic theory in order to make assumptions about the nature of the time series under consideration. But such assumptions may not be always true and may lead to misspecification and totally wrong inferences. To solve this problem, Shrestha and Chowdhury (2005) have proposed a sequential test procedure to select an optimal method of the unit root test allowing one endogenous structural break in data. They argue that different type of test methods or models may be appropriate for different time series. In such a case, sticking to only one method for all the time series could be inappropriate when one is dealing with a large number of time series in a single research. The Shrestha-Chowdhury sequential procedure is as follows:

Stage 1. Run Perron (1997): Innovational Outlier Model (*IO2*)

As mentioned earlier, this model includes t (time trend) and DT_b (time of structural break), and both intercept (DU) and slope (DT).

- Check t and DT_b statistics
- If both t and DT_b are significant, check *DU* and *DT* statistics
- If both *DU* and *DT* are significant, select this model
- If only *DU* is significant, go to Perron (1997): *IO1* model.
  This model includes t (time trend) and DT_b (time of structural break), and DU (intercept) only.
- If only *DT* is significant, go to Perron (1997): Additive Outlier model (*AO*)

This model includes t (time trend) and DT_b (time of structural break), and slope (DT) only.

In some cases, t and DT_b may be insignificant in IO2 but significant in IO1 or AO. Therefore, IO1 and AO tests should be conducted after IO2 in order to check the existence of such condition.

Stage 2. If only t is significant in stage 1, go to Zivot and Andrews (1992) models:

Zivot and Andrews (1992) models include t but exclude DT_b.

- Run Zivot and Andrews test with intercept, trend, and both separately and compare the results. Select the model that gives the results consistent with the economic fundamentals and the available information.

Stage 3. If only DT_b is significant in stage 1, go to Perron and Vogelsang (1992) models:

Perron and Vogelsang (1992) models include DT_b but exclude t.

- Run *IOM* and *AOM*. Compare the statistics and select the appropriate model.

Stage 4. If both t and DT_b are not significant in stage 1, this implies that there is no statistically significant time trend and or structural break in the time series. In such a case, certain judgement has to be used to select the test method.

The rationale behind employing the above sequential procedure is that the inclusion of irrelevant information and the exclusion of relevant information may lead to misspecification of the model. Following the above procedure, a set of mixed methods or models is selected for the unit root test in this study. The results given by such a set of the mixed methods would be more realistic and consistent with the economic fundamentals and known facts.

III. THE DATA

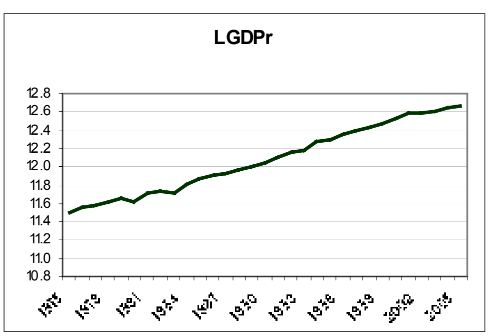
The data analysed in this paper consists of 18 macroeconomic time series of Nepal. These include 5 real sector time series, 4 money and credit time series, 3 government finance time series, 3 external sector time series, and 3 rate related time series. The sources of the data include various issues of Economic Survey published by His Majesty's Government of Nepal, Ministry of Finance, and Quarterly Economic Bulletin published by Nepal Rastra Bank. The money and credit data are available from 1960 but most of the real sector data, the government finance data and the external sector data are available from 1975 only. Out of the 3 rate related time series, the data for 2 series are available from 1965 and the data for one time series is available from 1973. For the consistency purpose, the data range covered in this study is 1975 to 2005.

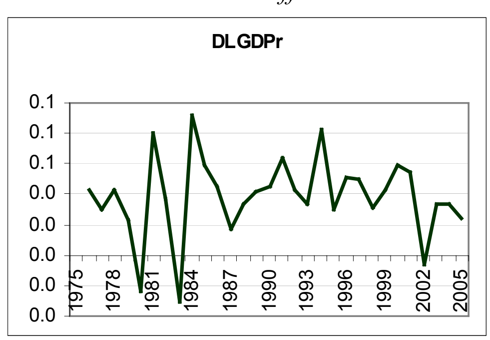
The annual data of the 16 time series for the above period have been transformed into natural log form. However, the annual data of inflation and real interest rate have not been transformed into natural log form, as some of the data of these time series are negative. The data are plotted in the graph at level as well as at first difference. The description of the data and their graphs are given below.

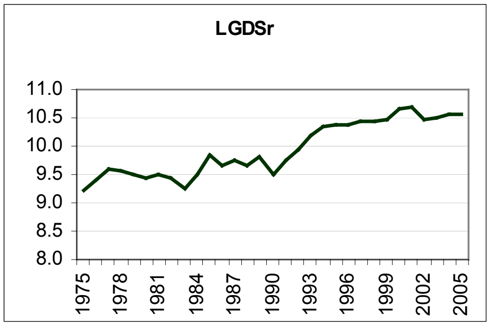
A. Real Sector Data

1. Natural Log of the Real Gross Domestic Product (*LGDPr*)
2. Natural Log of the Real Gross Domestic Saving (*LGDSr*)
3. Natural Log of the Real Investment (*LINVESTr*)
4. Natural Log of the Real Total Consumption (*LCONSUMr*)
5. Natural Log of the Real Gross Fixed Capital Formation (*LCAPFORMr*)

Level | *First Difference*



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10.0
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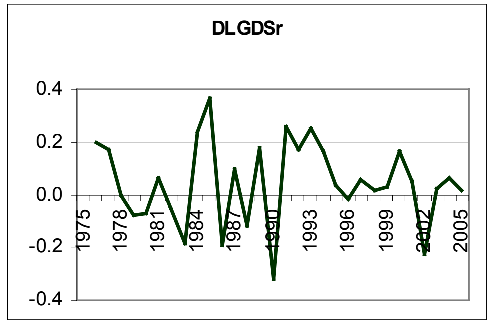
1975 1978 1981 1984 1987 1990 1993 1996 1999 2002 2005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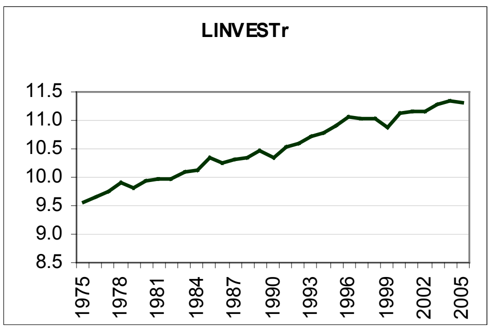
0.0
-0.2
-0.4
1975 1978 1981 1984 1987 1990 1993 1996 1999 2002 2005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9.5
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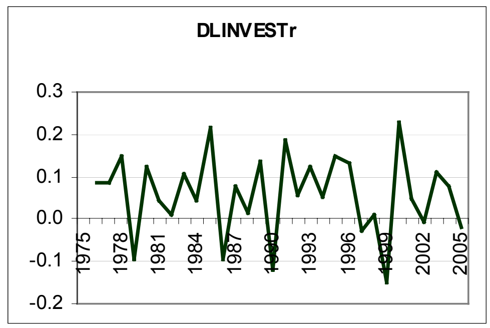
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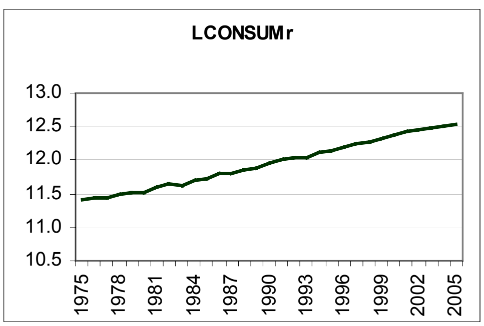
1975 1978 1981 1984 1987 1990 1993 1996 1999 2002 2005


LCONSUMr
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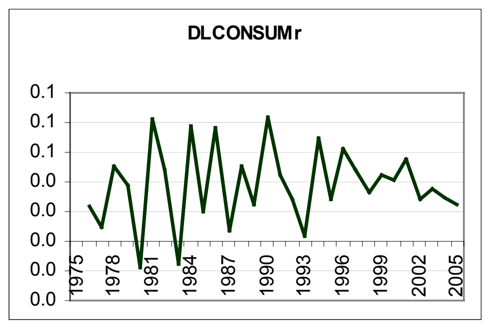
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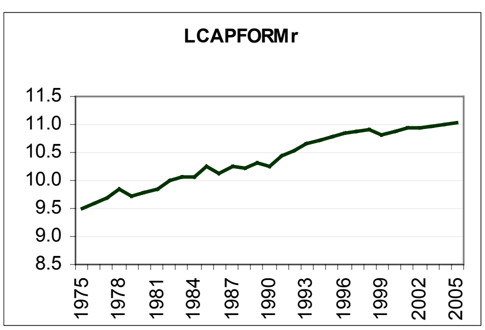
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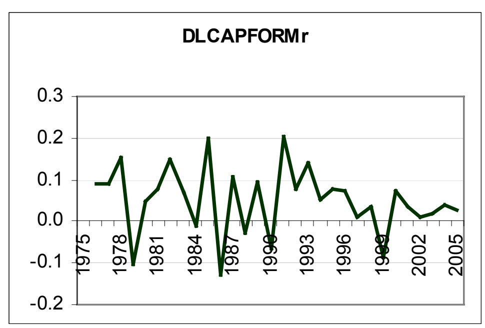
DLCAPFORMr
0.3
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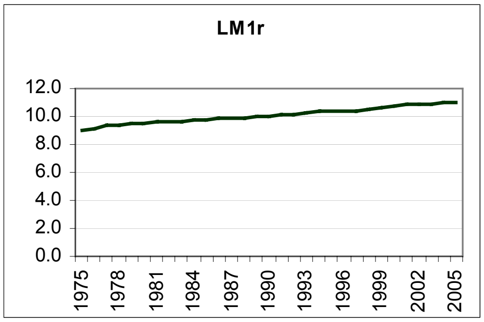
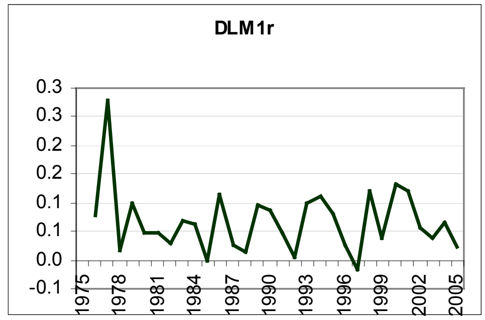
-0.1
-0.2
1975 1978 1981 1984 1987 1990 1993 1996 1999 2002 2005

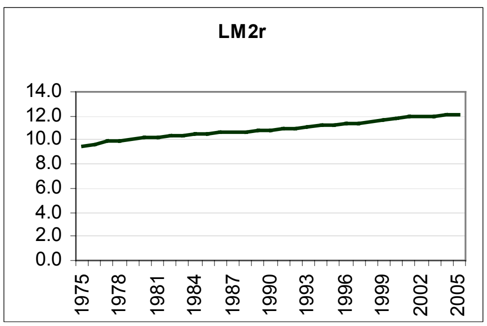
B. Money and Credit Data

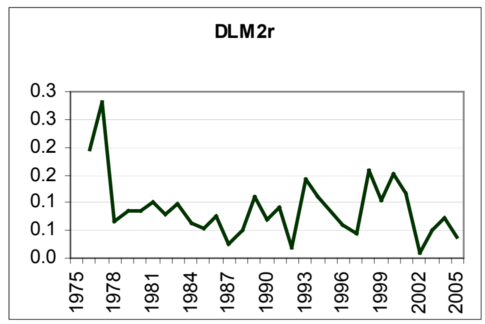
6. Natural Log of the Real Money Supply (*LM1r*)
7. Natural Log of the Real Broad Money (*LM2r*)
8. Natural Log of the Real Time Deposits (*LTDEPOSITr*)
9. Natural Log of the Real Domestic Credit (*LCREDITr*)

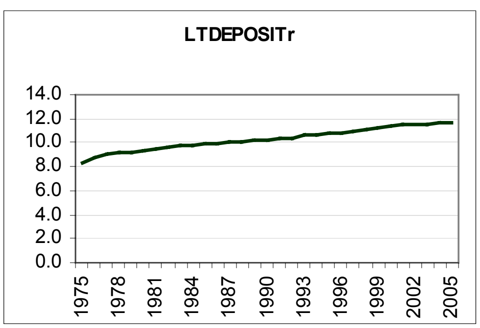
Level | *First Difference*

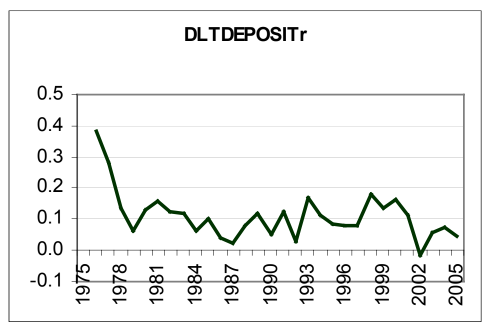


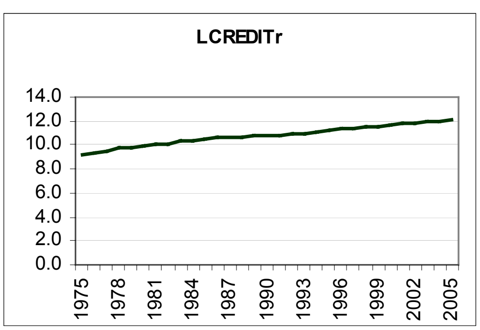


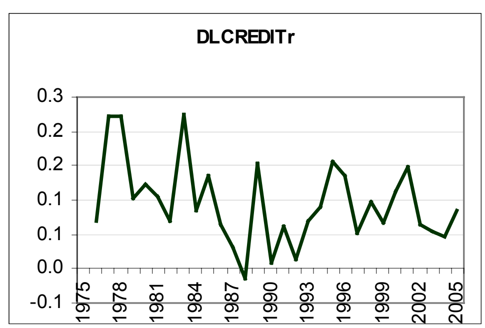








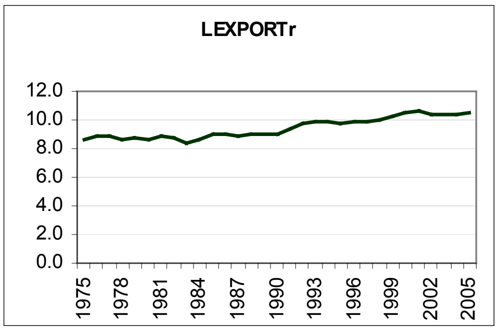


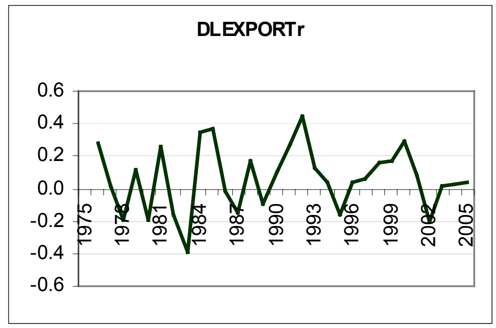


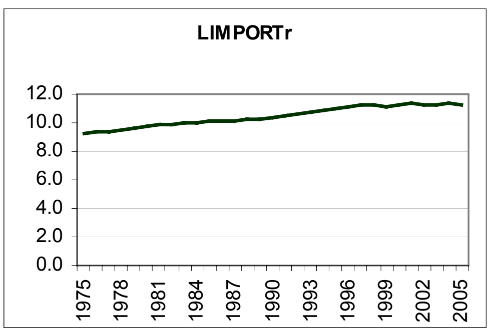
C. External Sector Data

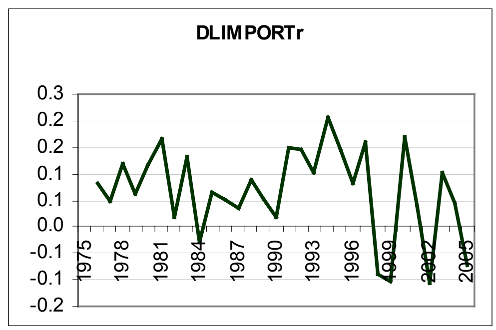
10. Natural Log of the Real Total Exports (*LEXPORTr*)
11. Natural Log of the Real Total Imports (*LIMPORTr*)
12. Natural Log of the Real Gross Forex Reserves (*LRESERVEr*)

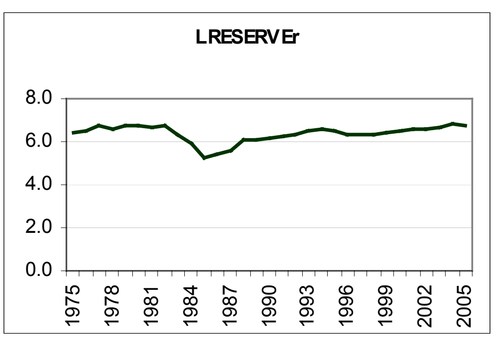
Level | *First Difference*

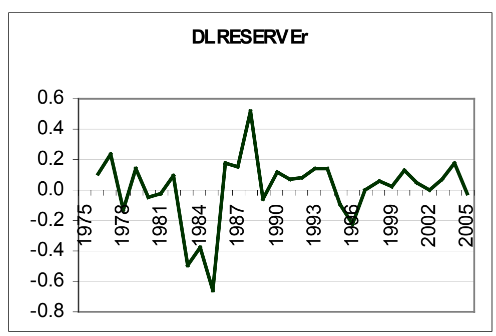








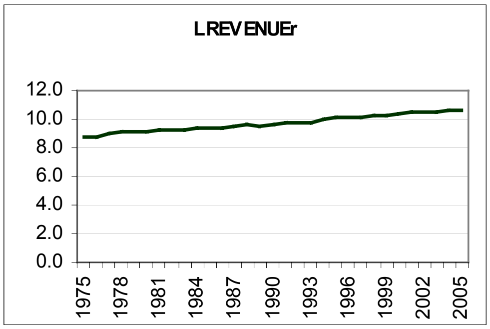


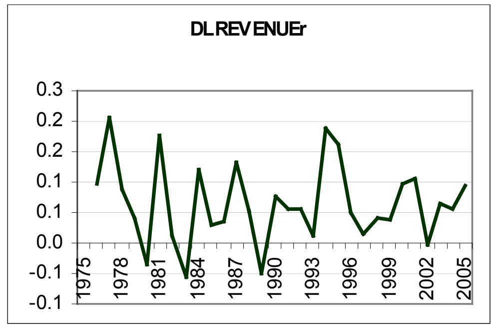


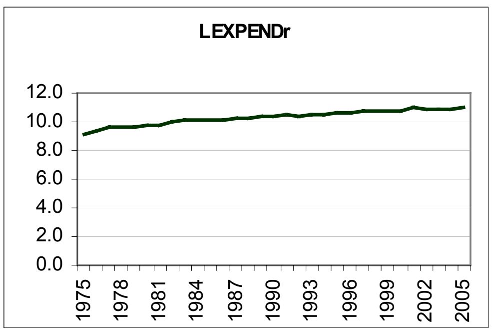
D. Government Finance Data

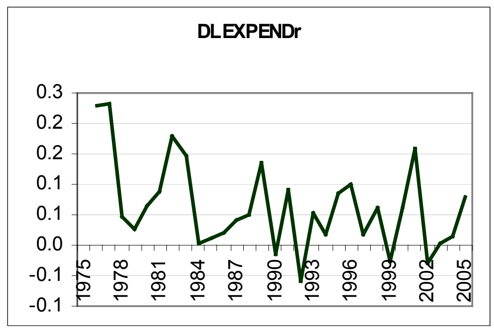
13. Natural Log of the Real Government Revenue (*LREVENUEr*)
14. Natural Log of the Real Government Expenditure (*LEXPENDr*)
15. Natural Log of the Real Government Budgetary Deficits (*LDEFICITr*)

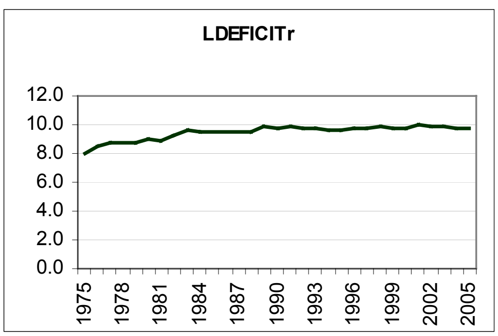
Level | *First Difference*

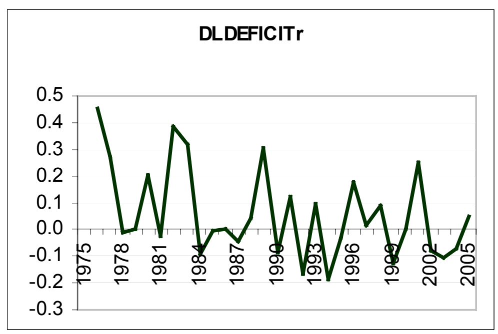






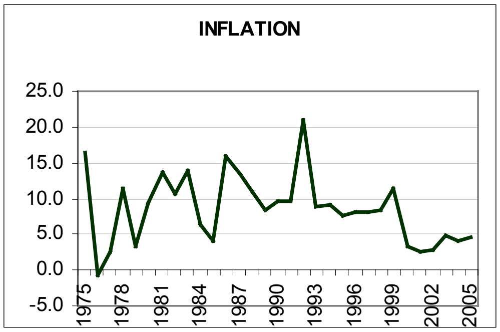


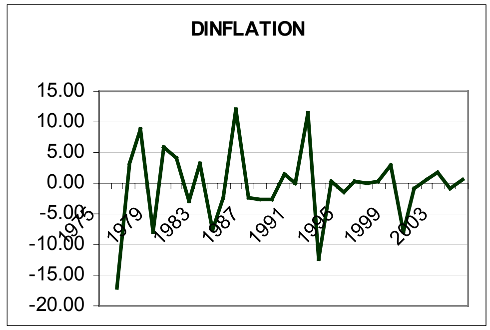


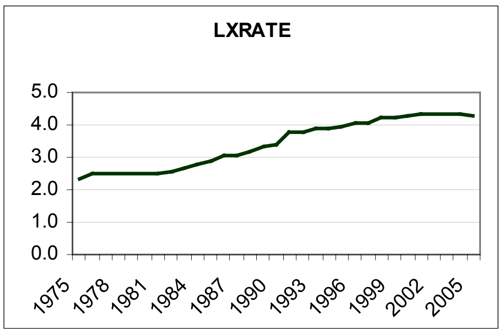


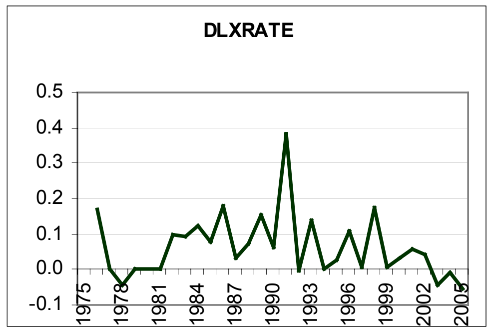
E. Rate Related Data

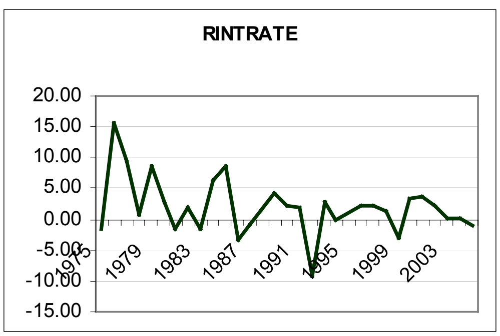
16. Inflation Rate (*INFLATION*)
17. Natural Log of the Exchange Rate (*LXRATE*)
18. Real Interest Rate (*RINTRATE*)

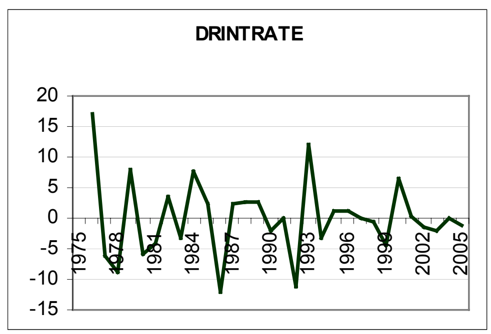












IV. UNIT ROOT TEST RESULTS

The summary test statistics given by various unit root test models using RATS programme are presented in Tables 1 to 7 below[1]. The results are compared in Table 8 and a list of selected models for each time series and their results are presented in Table 9.

[1] The coefficients and respective T-statistics of *t*, *DTb*, *DU*, and *DT* have not been reported.

TABLE 1. Perron 1997 – IO2 Model Statistics

Variables	*Tb*	*k*	*t*	DT_b	*DU*	*DT*	$T_\alpha = 1$		*Result*
LGDPr	1992	0	*				-3.1163		Non-stationary
LGDSr	2002	11					-9.9510	*	Stationary
LINVESTr	1999	9					-4.8947		Non-stationary
LCONSUMr	1975	12					-7.1383	*	Stationary
LCAPFORMr	2001	11					-13.7312	*	Stationary
LM1r	1999	0	*				-4.3601		Non-stationary
LM2r	2004	12					-7.3510	*	Stationary
LTDEPOSITr	1997	0	*			*	-7.5297	*	Stationary
LCREDITr	1996	11					-11.2852	*	Stationary
LIMPORTr	1997	11				*	-15.2759	*	Stationary
LEXPORTr	2004	12					-66.9656	*	Stationary
LRESERVEr	1990	11					-19.2465	*	Stationary
LREVENUEr	1990	11					-12.7410	*	Stationary
LEXPENDr	1981	2					-5.9988	*	Stationary
LDEFICITr	1999	10					-9.5095	*	Stationary
INFLATION	1990	11					-17.7838	*	Stationary
LXRATE	1999	2	*				-3.8787		Non-stationary
RINTRATE	1990	11					-17.9944	*	Stationary

Critical value for $T_\alpha = 1$ at 5% is –5.59

* Significant at 5% level (in the case of *t*, DT_b, *DU*, and *DT* coefficient close to zero and T-statistics significant at 5% level)

The above unit root test statistics given by Perron 1997- IO2 model shows that the set of all the first four features (values for *t*, DT_b, *DU*, and *DT*) is significant for none of the series. From this, it can be inferred that this model does not best fit for any of the time series.

TABLE 2. Perron 1997 – IO1 Model Statistics

Variables	*Tb*	*k*	*t*	DT_b	*DU*	$T_\alpha = 1$		*Result*
LGDPr	1986	7	*			-4.1452		Non-stationary
LGDSr	1991	0	*			-4.6917		Non-stationary
LINVESTr	1995	12		□	□	–14.1302	*	Stationary
LCONSUMr	1997	12				-147.2858	*	Stationary
LCAPFORMr	2002	5	*			-3.7412		Non-stationary
LM1r	1992	12				-15.8375	*	Stationary
LM2r	2004	12	*			-7.3510	*	Stationary
LTDEPOSITr	1996	0	*		*	-6.5028	*	Stationary
LCREDITr	1995	9		*		-6.0823	*	Stationary
LIMPORTr	2002	12				-33.0881	*	Stationary
LEXPORTr	2004	12				-66.9656	*	Stationary
LRESERVEr	1998	12				-44.9903	*	Stationary
LREVENUEr	1990	11				-14.6378	*	Stationary
LEXPENDr	1980	0	*			-6.1981	*	Stationary
LDEFICITr	1994	12		*		-27.6697	*	Stationary
INFLATION	1998	0				-6.0074	*	Stationary
LXRATE	2002	2	*			-3.0857		Non-stationary
RINTRATE	2001	12				-9.9212	*	Stationary

Critical value for $T_\alpha = 1$ at 5% is –5.23

* Significant at 5% level (in the case of *t*, DT_b, and *DU* coefficient close to zero and T-statistics significant at 5% level)

The above table shows that all the three features (t, DT_b, and DU) are significant for none of the time series. This implies that Perron 1997 – IO1 model also is not suitable for any of the variables under consideration.

TABLE 3. Perron 1997 – AO Model Statistics

Variables	*Tb*	*k*	*t*	*DT*	$T_\alpha = 1$	*Result*
LGDPr	1980	10	*	*	-4.0852	Non-stationary
LGDSr	1983	0		*	-3.1833	Non-stationary
LINVESTr	1997	0		□	–4.7738	Non-stationary
LCONSUMr	1981	0	*	*	-6.0760 *	Stationary
LCAPFORMr	2001	5			-4.6699	Non-stationary
LM1r	1996	0			-4.2608	Non-stationary
LM2r	1993	1			-3.7446	Non-stationary
LTDEPOSITr	2004	8			-3.6478	Non-stationary
LCREDITr	1989	6		*	-4.5807	Non-stationary
LIMPORTr	2001	3			-4.2794	Non-stationary
LEXPORTr	1982	1			-3.9595	Non-stationary
LRESERVEr	2000	12			-7.6631 *	Stationary
LREVENUEr	1990	1		*	-4.6790	Non-stationary
LEXPENDr	1983	2			-6.4830 *	Stationary
LDEFICITr	1986	1			-4.4572	Non-stationary
INFLATION	1996	0			-6.1113 *	Stationary
LXRATE	1991	11			-3.4958	Non-stationary
RINTRATE	1995	0			-6.5870 *	Stationary

Critical value for $T_\alpha = 1$ at 5% is –4.83

* Significant at 5% level (in the case of *t* and *DT* coefficient close to zero and T-statistics significant at 5% level)

The AO model statistics reported in the above table reveals that this model is relevant for LGDPr and LCONSUMr only as *t* and DT_b are significant for these variables.

TABLE 4. Zivot and Andrews 1992 Model Statistics (With both intercept and trend)

Variables	*Tb*	*k*	*t*	$T_\alpha = 1$	*Result*
LGDPr	1980	0	*	-3.6382	Non-stationary
LGDSr	1993	0	*	-4.3934	Non-stationary
LINVESTr	1995	0	*	–5.4928 *	Stationary
LCONSUMr	1980	0	*	-6.0472 *	Stationary
LCAPFORMr	1993	0		-4.8340	Non-stationary
LM1r	2001	0	*	-4.3732	Non-stationary
LM2r	2000	0		-5.1305 *	Stationary
LTDEPOSITr	1998	0	*	-7.4465 *	Stationary
LCREDITr	1987	0	*	-3.0651	Non-stationary
LIMPORTr	1994	0		-3.8302	Non-stationary
LEXPORTr	1991	0	*	-3.3140	Non-stationary
LRESERVEr	1983	2		-6.7149 *	Stationary
LREVENUEr	1994	0	*	-5.1127 *	Stationary
LEXPENDr	1982	0		-5.5227 *	Stationary
LDEFICITr	1982	0		-5.5402 *	Stationary
INFLATION	1994	0		-6.9840 *	Stationary
LXRATE	1991	0		-2.7365	Non-stationary
RINTRATE	1984	0		-7.6789 *	Stationary

Critical value for $T_\alpha = 1$ at 5% is -5.08

* Significant at 5% level (in the case of *t*, coefficient close to zero and T-statistic significant at 5% level)

TABLE 5. Zivot and Andrews 1992 Model Statistics (With intercept only)

Variables	*Tb*	*k*	*t*	$T_{\alpha} = 1$	*Result*
LGDPr	1993	0	*	-4.6514	Non-stationary
LGDSr	1993	0	*	-5.0477 *	Stationary
LINVESTr	1993	0	*	–5.0477 *	Stationary
LCONSUMr	1980	0	*	-5.9782 *	Stationary
LCAPFORMr	1999	0		-3.7762	Non-stationary
LM1r	2000	0	*	-4.7259	Non-stationary
LM2r	1998	0		-5.3235 *	Stationary
LTDEPOSITr	1998	0	*	-6.6856 *	Stationary
LCREDITr	1990	0	*	-3.1506	Non-stationary
LIMPORTr	2001	0		-1.9247	Non-stationary
LEXPORTr	1992	0	*	-3.5272	Non-stationary
LRESERVEr	1983	2		-6.7990 *	Stationary
LREVENUEr	1994	0	*	-4.9619 *	Stationary
LEXPENDr	1982	0		-6.1248 *	Stationary
LDEFICITr	1982	0		-6.1338 *	Stationary
INFLATION	1981	0		-6.2987 *	Stationary
LXRATE	1989	0		-2.2136	Non-stationary
RINTRATE	1980	0		-7.1215 *	Stationary

Critical value for $T_{\alpha} = 1$ at 5% is –4.80

* Significant at 5% level (in the case of *t*, coefficient close to zero and T-statistic significant at 5% level)

TABLE 6. Zivot and Andrews 1992 Model Statistics (With trend only)

Variables	*Tb*	*k*	*t*	$T_{\alpha} = 1$	*Result*
LGDPr	1983	0	*	-3.5685	Non-stationary
LGDSr	1983	0	*	-3.2532	Non-stationary
LINVESTr	1981	0	*	–5.8605 *	Stationary
LCONSUMr	1997	0	*	-4.5542 *	Stationary
LCAPFORMr	1998	0		-3.9576	Non-stationary
LM1r	1993	0	*	-4.2780	Non-stationary
LM2r	1993	0		-4.5651 *	Stationary
LTDEPOSITr	2001	0	*	-5.6907 *	Stationary
LCREDITr	1979	0	*	-3.5910	Non-stationary
LIMPORTr	1998	0		-2.4638	Non-stationary
LEXPORTr	1984	0	*	-3.6375	Non-stationary
LRESERVEr	1986	2		-4.7334 *	Stationary
LREVENUEr	1991	0	*	-4.0304	Non-stationary
LEXPENDr	1984	0		-5.0671 *	Stationary
LDEFICITr	1984	0		-4.4678 *	Stationary
INFLATION	1993	0		-6.9417 *	Stationary
LXRATE	1999	0		-2.2189	Non-stationary
RINTRATE	1982	0		-7.7936 *	Stationary

Critical value for $T_{\alpha} = 1$ at 5% is –4.42

* Significant at 5% level (in the case of *t*, coefficient close to zero and T-statistic significant at 5% level)

The test statistics given by the Zivot and Andrews 1992 models are presented in Table 4, 5, and 6 above. Three different models (*viz*. with both intercept and trend, with intercept only, and with trend only) return identical *t* values[2] and number of *k*. But the structural break (*Tb*) date and values for $T_\alpha = 1$ are different for these three models. Regarding the stationarily of the time series, these models agree in the case of 16 time series except for LGDSr and LREVENUEr.

TABLE 7. Perron and Vogelsang 1992 Model Statistics (Innovational Outlier Model)

Variables	*Tb*	*k*	DT_b	*DU*	$T_\alpha = 1$		*Result*
LGDPr	1982	2		*	-1.7582		Non-stationary
LGDSr	1991	0			-4.0878		Non-stationary
LINVESTr	1990	1			–2.1199		Non-stationary
LCONSUMr	1984	2			-1.0416		Non-stationary
LCAPFORMr	1989	1			-3.4777		Non-stationary
LM1r	1992	0			-2.2811		Non-stationary
LM2r	1992	0			-3.9607		Non-stationary
LTDEPOSITr	1993	0			–4.4047	*	Stationary
LCREDITr	1993	0			-3.7263		Non-stationary
LIMPORTr	1989	3			-3.3513		Non-stationary
LEXPORTr	1989	0			-3.0950		Non-stationary
LRESERVEr	1988	2			-3.5535		Non-stationary
LREVENUEr	1992	2			-2.5022		Non-stationary
LEXPENDr	1994	4			–4.4205	*	Stationary
LDEFICITr	1980	0			-5.5703	*	Stationary
INFLATION	1991	0			-5.8141	*	Stationary
LXRATE	1987	4			-2.9876		Non-stationary
RINTRATE	1984	0			-6.3814	*	Stationary

Critical value for T_α at 5% is -4.19

* Significant at 5% level (in the case of DT_b, coefficient close to zero and T-statistic significant at 5% level)

As mentioned earlier, the Perron and Vogelsang model includes DT_b. In the above table, DT_b is found to be statistically significant for none of the time series, while *DU* is significant for LGDPr only.

[2] Not reported here.

TABLE 8. Unit Root Test Result Comparison

	Perron 1997			Zivot & Andrews 1992			Perron & Vogelsang 1992	
Series	IO2	IO1	AO	Both	Intercept	Trend	IOM	Result
LGDPr	N	N	N*	N*	N*	N*	N	N*
LGDSr	S	N	N	N*	S*	N*	N	N*
LINVESTr	N	S	N	S*	S*	S*	N	S*
LCONSUMr	S	S	S*	S*	S*	S*	N	S*
LCAPFORMr	S	N	N	N	N	N	N	?
LM1r	N	S	N	N*	N*	N*	N	N*
LM2r	S	S	N	S	S	S	N	?
LTDEPOSITr	S	S	N	S*	S*	S*	S	S*
LCREDITr	S	S	N	N*	N*	N*	N	N*
LIMPORTr	S	S	N	N	N	N	N	?
LEXPORTr	S	S	N	N*	N*	N*	N	N*
LRESERVEr	S	S	S	S	S	S	N	?
LREVENUEr	S	S	N	S*	S*	N*	N	S*
LEXPENDr	S	S	S	S	S	S	S	?
LDEFICITr	S	S	N	S	S	S	S	?
INFLATION	S	S	S	S	S	S	S	?
LXRATE	N	N	N	N	N	N	N	?
RINTRATE	S	S	S	S	S	S	S	?

N = Non-stationary, S = Stationary

* Significant (All the given features, i.e., *t*, DT_b, *DU*, and *DT*, whichever relevant, have coefficient close to zero and T-statistics significant at 5% level)

The results given by various models are summarised in Table 8 above. It can be seen from the table that Perron 1997:AO model is optimal for 2 time series: LGDPr and LCONSUMr. The Zivot & Andrews 1992 models are the best models for 9 time series, *viz.* LGDPr, LGDSr, LINVESTr, LCONSUMr, LM1r, LTDEPOSITr, LCREDITr, LEXPORTr and LREVENUEr. However, there is no such a match for half of the time series under consideration, which include LCAPFORMr, LM2r, LIMPORTr, LRESERVEr, LEXPENDr, LDEFICITr, INFLATION, LXRATE and RINTRATE. Some judgement based on the economic fundamentals has to be used to select the optimal model for these 9 time series.

Regarding the power of test, the Perron and Vogelsang 1992 model is robust. The testing power of Perron 1997 models and Zivot and Andrews models are almost the same (Wilson 2004). On the other hand, Perron 1997 model is more comprehensive than Zivot & Andrews 1992 model as the former includes both *t* and DT_b while the later includes *t* only. Therefore, Perron 1997:AO model is selected for LGDPr and LCONSUMr and Zivot and Andrews 1992 model is selected for 7 time series. As there is no matching model for 9 time series, the Perron and Vogelsang 1992 model is selected for these series based on its robustness.

The selected models for all the 18 time series and their test results are presented in Table 9 below.

TABLE 9. Selected Models and Results

Series	Selected Model	Tb	$T_{\alpha} = 1$		Result
LGDPr	Perron 1997: AO	1980	-4.0852		N
LGDSr	Zivot & Andrews 1992: Both	1993	-4.3934		N
LINVESTr	Zivot & Andrews 1992: Both	1995	-5.4928	*	S
LCONSUMr	Perron 1997: AO	1981	-6.0760	*	S
LCAPFORMr	Perron & Vogelsang 1992	1989	-3.4777		N
LM1r	Zivot & Andrews 1992: Both	2001	-4.3732		N
LM2r	Perron & Vogelsang 1992	1992	-3.9607		N
LTDEPOSITr	Zivot & Andrews 1992: Both	1998	-7.4465	*	S
LCREDITr	Zivot & Andrews 1992: Both	1987	-3.0651		N
LIMPORTr	Perron & Vogelsang 1992	1989	-3.3513		N
LEXPORTr	Zivot & Andrews 1992: Both	1991	-3.3140		N
LRESERVEr	Perron & Vogelsang 1992	1988	-3.5535		N
LREVENUEr	Zivot & Andrews 1992: Both	1994	-5.1127	*	S
LEXPENDr	Perron & Vogelsang 1992	1994	-4.4205	*	S
LDEFICITr	Perron & Vogelsang 1992	1980	-5.5703	*	S
INFLATION	Perron & Vogelsang 1992	1991	-5.8141	*	S
LXRATE	Perron & Vogelsang 1992	1987	-2.9876		N
RINTRATE	Perron & Vogelsang 1992	1984	-6.3814	*	S

Critical values for $T_{\alpha} = 1$ at 5% level: Perron 1997:AO = -4.83, Perron & Vogelsang 1992 = -4.19, and Zivot & Andrews 1992:Both = -5.08.
N = Non-stationary, S = Stationary

The results given by the selected models (Table 9) show that 10 of the 18 macroeconomic variables of Nepal are non-stationary and the remaining 8 are stationary. The structural break dates show that, 15 macroeconomic time series have undergone through a structural break in or after 1984, while 3 time series, *viz*. LGDPr, LCONSUMr, and LDEFICITr had gone through a structural break before 1984. As Nepal started implementing various economic and financial liberalisation measures since 1984, it can be argued that Nepalese economy has gone through a structural change as a result of the implementation of liberalisation policy.

V. CONCLUDING REMARKS

Due to the specific properties possessed by the time series data, the traditional methods of regression may not be appropriate for analysing these data. The stationarity of the time series should be determined first by conducting unit root test before running any regression. There are several methods and models available for unit root test, which differ in their emphasis on one or more of the time series properties. The researcher has to apply certain judgement based on economic theory in order to make assumptions about the nature of the time series under consideration. But such assumptions may not be always true and may lead to misspecification of models and totally wrong inferences. For this reason, researchers face some practical problem in selecting appropriate methods and models of unit root test for the time series data. Against this backdrop, a sequential procedure proposed by Shrestha and Chowdhury (2005) have been followed in this study to select an optimal method of unit root test.

The results of the unit root test conducted employing the Shrestha-Chowdhury sequential procedure allowing one unknown structural break in the time series suggest that out of the 18 Nepalese macroeconomic variables considered in this study, 10 are non-stationary, while the remaining 8 are stationary. The results would be misleading if the ordinary least square (OLS) or similar traditional regression method were applied to analyse these non-stationary data. The results also show that 15 time series have undergone a structural change in or after 1984, while only three variables have gone through such a break before 1984. The structural break date of a time series also should be taken into account to correctly specify the model.

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