TESTING UNIT ROOTS IN THE PRESENCE OF STRUCTURAL BREAKS IN SOME NEPALESE MACROECONOMIC INDICATORS*

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Abstract

This paper attempts to examine the unit roots of important Nepalese macroeconomic indicators in light of known structural breaks present in the data. The data series in this study was affected by the civil war launched by Maoist guerrillas in 1996, and it is appropriate to test unit roots in the presence of structural breaks. After conducting augmented Dickey-Fuller (ADF) tests that do not consider structural breaks, we applied Perron's (1989) approach to test the unit roots in the presence of structural breaks. Our results show that out of seven series, the unit root hypothesis is rejected in the case of two series, namely imports and CPI, when structural breaks are considered. The rest of the series contains unit roots whether structural breaks are considered or not.

Key words: civil war, macroeconomic indicators, unit roots, structural breaks

1. Introduction

The Maoist insurgency in Nepal began in February 1996, when Maoist guerrillas launched a civil war in the remote mid-western region. The war then rapidly spread throughout the country, destroying much physical infrastructure and inciting violence. During the war, economic performance was affected in various ways. Conflict-related disruptions, such as strikes, security checks, blockades, and extortion increased the cost of economic activity and contributed to an economic slowdown. The economy suffered a decline in development expenditures, which fell by 4.2% between fiscal years 2002 and 2004, compared with a growth of 10.4% in the period 1990–2000; real per capita income was $232 U.S. in 1991, but had fallen to $162 U.S. by 2001.[1] Table 1 shows the ten-year average percentage changes in some important macroeconomic time series data. Ten-year average percentage changes in nominal gross domestic product (GDP) fell from 16.8% per annum (pa) in the pre-war period i.e., 1986/87–1995/96 to 9.3% pa during the war i.e., 1996/97–2005/06. Real GDP, which before the war had been growing at 5.6% pa fell to 3.9% pa

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[1] Sungsup and Singh (2005).

Table 1. Ten years Average Percentage Change (pre-war and during war)

Variables	Pre-war period (1986/87 to 1995/96)	During war period (1996/97 to 2005/06)
Nominal GDP	16.8	9.3
Real GDP	5.6	3.9
Money supply	18.6	12.3
Exchange rate	9.3	3.8
Exports	15.2	13.8
Imports	23.2	8.8
CPI	11.2	6.1

Source : Compiled from Economic surveys various issues, published by HMG Nepal.

during the war. Other variables show a similar pattern. The scenario presented in Table 1 indicates that the macroeconomic indicators were strongly influenced by the civil war launched by Maoists. Visual inspection of the ten-year average percentage changes in the data between the pre-war and war periods reveals the presence of a break in the data.

In this study, we attempt to examine the stationarity of Nepalese macroeconomic indicators as shown in Table 1, in the light of the known structural break present in the data. A non-stationary time series will have a time-varying mean or time-varying variance or both.[2] In the absence of a unit root, a stationary series fluctuates around a constant long-run mean. This implies that the series has finite variance, which does not depend on time, and thus the behavior of each set of data can be generalized to other time periods. As a result, stationary series are more important in many economic and social research studies. Economics is one field where the hypothesis of a unit root has important implications. This is because a unit root is often a theoretical implication of models that postulate the rational use of the information available to economic agents. Examples include financial market variables, such as future contracts and stock prices, and even aggregate variables like real consumption and exchange rates. The test of unit roots helps evaluate the nature of the non-stationarity contained in the macroeconomic data. In particular, it helps to determine, whether the trend is stochastic or deterministic.

Empirical work in applied economic research has been fundamentally changed by a revolution in time-series modeling. It is now widely accepted that there are substantial implications for empirical modeling when one or more of the time series being used is found to contain a unit root. In a novel opinion, Perron (1989) suggested that it may be necessary to isolate some unique economic events and to consider them as changing the pattern of the time series permanently. The approach of identifying isolated economic events *a priori* has given way to selecting break

[2] Gujarati (2003), p. 798.

dates of economic data series, and then examining unit roots in the presence of structural breaks. Perron's work was on the topics of the great crash, the oil price shock, and the unit root hypothesis; he isolated the event of the economic crash of 1929, which was the reason for the sudden change in the level of series, so that he selected 1929 as an exogenous break point. Nepalese macroeconomic data series were extremely influenced by the decade-long Maoist civil war. The civil war was isolated as a cause of the economic slowdown that made a sudden change in the level of data series. We attempt to test the unit roots of the major macroeconomic data series of Nepal, which shows the impact of civil war in time series analysis.

This paper is organized as follows. Section 2 reviews the literature about testing unit roots in the presence of structural breaks. Section 3 presents our models and methodology. Section 4 presents the empirical analysis of data by using different models, and the last section presents our conclusion.

2. Reviews of Literature

Until the work of Nelson and Plosser (1982), the general view was that macroeconomic data series were stationary around a deterministic trend.[3] However, by using the unit root tests of Dickey and Fuller (1979, 1981), Nelson and Plosser (1982) found that all historical time series have a unit root except for the unemployment rate. An important implication of their findings is that, under the unit root hypothesis, random shocks have permanent effects on the long-run effects of macroeconomics. In other words, fluctuations are not transitory. However, this finding was challenged by Perron (1989), who argued that in the presence of a structural break, the standard ADF (augmented Dicky Fuller) tests are biased towards non-rejection of the null hypothesis.[4] Perron's unit root test allows for a break under the null and alternative hypotheses, and he showed that if an exogenous break is present, then most of the macroeconomic time series used by Nelson and Plosser (1982) are not characterized by the presence of a unit root. In addition, he also showed that persistence arises only from large and infrequent shocks, and that after frequent shocks, the economy returns to a deterministic trend.

Several methods using different methodologies for endogenously determining the break point have been developed since the work of Perron (1989). These include Banerjee *et al.* (1992), Zivot and Andrews (1992), Perron and Vogelsang (1992), and Perron (1997). All these studies have shown that bias in the usual unit root tests can be reduced by introducing endogenously determined break points.[5] There exist several studies on multiple structural breaks. For example, Lumsdaine and Papell (1997), Bai and Perron (1998), Papell and Prodan (2007), and Lee and

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[3] Razvan (2007), p. 2.

[4] Glynn et al. (2007), p. 67.

[5] Glynn et al. (2007), p. 68.

Strazicich (2003) all found more than one endogenously determined break point.

Looking at the Nepalese macroeconomic data series, Thapa (2002) showed by using ADF that the exchange rate and GDP had unit roots. Surya and Neupane (2006) tested unit roots for the real GDP, nominal GDP, and market capitalization of Nepalese indicators by using the DF and ADF tests. They showed that these variables are non-stationary. Shrestha and Chowdhury (2005) and Shrestha (2006) proposed a sequential test procedure for selecting an optimal method of unit root tests by allowing one endogenous break in the data. Both these studies showed that most of the series under study were non-stationary when taking the one endogenous break point in the data. Shrestha and Chowdhury (2005) applied the additive outlier model proposed by Perron (1997) to GDP, the Perron and Vogelsang (1992) model to imports and the Zivot and Andrews (1992) model to exports and money supply. They found that these series have unit roots. Thapa (2002) and Surya and Neupane (2006) of the above studies relating to Nepalese macroeconomic data did not consider structural breaks ; Shrestha and Chowdhury (2005) and Shrestha (2006) considered an endogenous structural break in the data.

Perron and Vogelsang (1992) concluded that the test is more powerful when the break point is assumed to be known and less powerful when the break point is unknown.[6] From this knowledge, it can be said that the unit root tests with a known exogenous break point are more powerful than others. Since our data have an exogenous break and there are powerful tests for this type of break, we decided to use Perron's (1989) approach in our study.

3. Models and Methodology

Perron (1989) developed a procedure for testing the unit root in the presence of a structural break. The null hypothesis is that a given series $\{y_t\}$ has a unit root with drift and that the exogenous break occurs at time $1 < T_B < T$, and the alternative hypotheses are that the series is stationary about a deterministic time trend function at time T_B, where T_B is the point of break and T is the total number of observations. Perron developed three different models with three different null and alternative hypotheses. Model A permits an exogenous change in the levels of the series under null and a one-time change in the intercept of the trend function under the alternative hypothesis. Model B permits an exogenous change in the rate of growth under null, and in the alternative hypothesis a change in the slope of the trend function without any sudden change in the level at the time of break is allowed. Model C allows both changes or effects to take place simultaneously. The test for a unit root via three different hypotheses involves the following regressions :

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6 Perron and Vogelsang (1992), p. 317.

$$\text{Model A}: y_t = \hat{\mu} + \hat{\theta}\, DU_t + \hat{\beta}\, t + \hat{d} D(TB)_t + \hat{\alpha}\, y_{t-1} + \sum_{i=1}^{k} \hat{c}_i \Delta y_{t-i} + \hat{e}_t \qquad (1)$$

$$\text{Model B}: y_t = \hat{\mu} + \hat{\beta}\, t + \hat{\gamma}\, DT_t^* + \hat{\alpha}\, y_{t-1} + \sum_{i=1}^{k} \hat{c}_i \Delta y_{t-i} + \hat{e}_t \qquad (2)$$

$$\text{Model C}: y_t = \hat{\mu} + \hat{\theta}\, DU_t + \hat{\beta}\, t + \hat{\gamma}\, DT_t + \hat{d}\, D(TB)_t + \hat{\alpha}\, y_{t-1} + \sum_{i=1}^{k} \hat{c}_i \Delta y_{t-i} + \hat{e}_t \qquad (3)$$

where, $DU_t = 1$, if $t > T_B$, 0 otherwise ; $D(TB)_t = 1$, if $t = T_B + 1$, 0 otherwise ;
$DT_t^* = t - T_B$, if $t > T_B$, 0 otherwise ; $DT_t = t$, if $t > T_B$, and 0 otherwise.

The t-statistic of coefficient $\hat{\alpha}$ for a unit root hypothesis is estimated by using $(\hat{\alpha} - 1)/S_{\hat{\alpha}}$, where $S_{\hat{\alpha}}$ is the standard error of $\hat{\alpha}$. The critical values for $t_{\hat{\alpha}}$ were calculated by Perron (1989) and can be checked for the three models mentioned.

4. Empirical Analysis

4.1 Data

The data analyzed in this paper consists of seven Nepalese macroeconomic variables. They are nominal GDP (1958-2006), real GDP (1965-2006), money supply (1960-2006), exchange rate (1952-2006), exports, imports (1964-2006), and consumer price index (1973-2006). The series money supply, exports, and imports are nominal. Exchange rates are Nepalese rupees per U.S. dollar, and the base year of the national urban consumer price index (CPI) is 1996. The sources of data include *Economic Surveys* by His Majesty's Government (HMG) of Nepal and the *Quarterly Economic Bulletin* by Nepal Rastra Bank (2006). We transformed all data to natural logarithms, because the original series seems to show exponential trends, and these series are shown in Figure 1. The figure shows that all of these series are characterized by a linear trend function with a constant slope.

4.2 ADF Test

The ADF test applied here is based on the following model :

$$\Delta y_t = \beta_1 + \beta_2 t + \alpha y_{t-1} + \sum_{i=1}^{k} c_i \Delta y_{t-i} + e_t \qquad (4)$$

where $\Delta y_t = y_t - y_{t-1}$ and e_t is the error term.

The data showed that the series have linear trends with constants, as shown in the model ; therefore, we conducted the ADF test for each series having a constant term with a trend. Table 2 shows the results of the unit root test using the ADF method. The critical value at the 5% level of significance is −3.50. Checking the unit roots for all series up to the number of lags (k) from 1 to 8, the calculated values $t_{\hat{\alpha}}$ were compared with critical values, and it was then found that the unit root hypothesis cannot be rejected for all the data series. When structural breaks are not considered, all the series under study have unit roots.

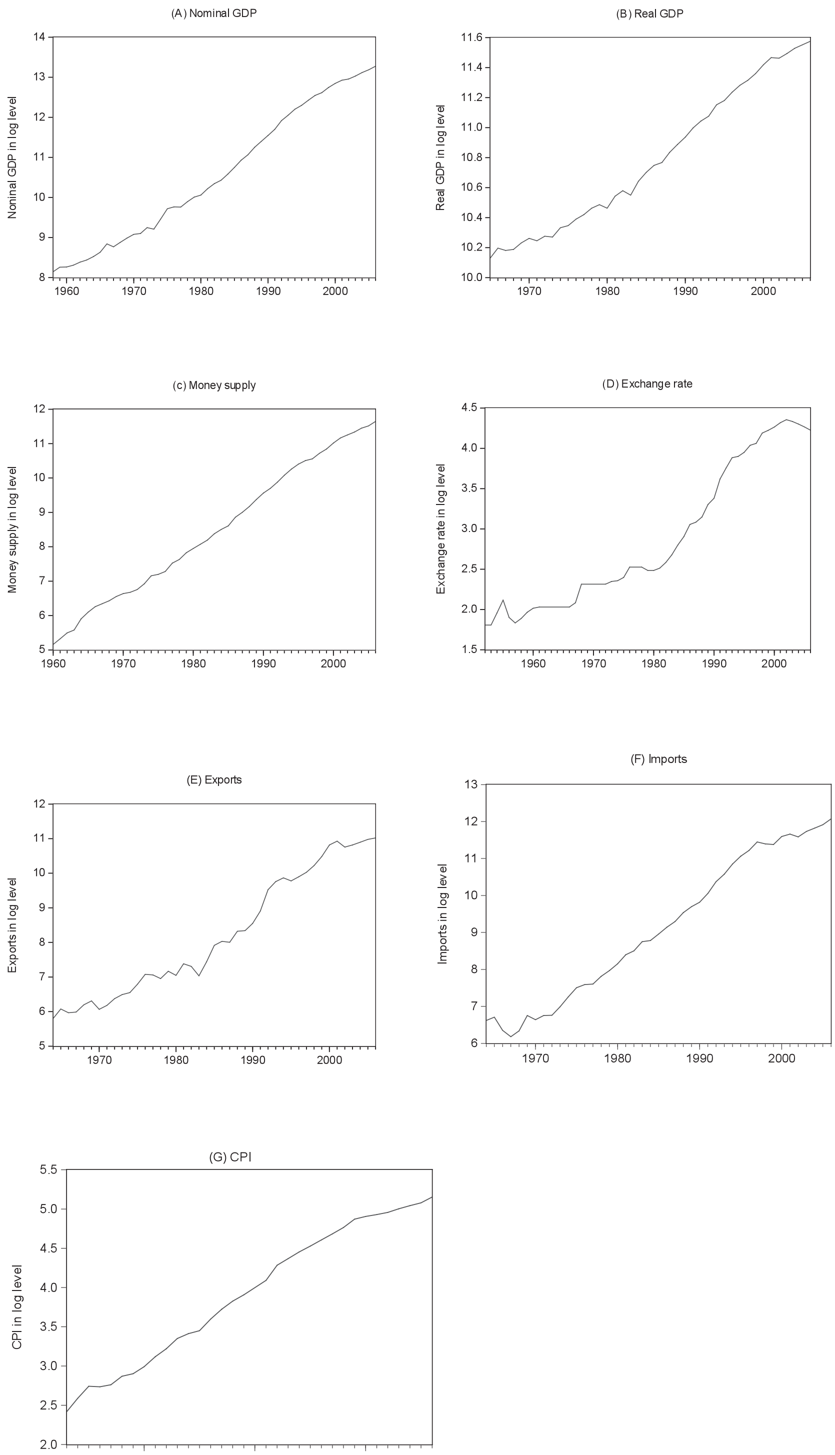

Figure 1 : Fluctuations of Nepalese Macroeconomic Variables

Source : *Economic Survey* and *Quarterly Economic Bulletin*

Table 2. ADF Test (Unit Root)-Results

Variables	$k=1$	$k=2$	$k=3$	$k=4$	$k=5$	$k=6$	$k=7$	$k=8$
Nominal GDP	−0.1349	−0.1241	−0.1228	−0.1311	−0.1250	−0.1465	−0.1649	−0.2393
	(−2.4481)	(−2.0495)	(−1.8944)	(−1.9514)	(−1.7120)	(−1.9922)	(−2.0552)	(−3.1638)
Real GDP	−0.0486	−0.05032	−0.05519	−0.06728	−0.08789	−0.10067	−0.13934	−0.13608
	(−1.6949)	(−1.6511)	(−1.7044)	(−1.9872)	(−2.3005)	(−2.1862)	(−2.5878)	(−2.1015)
Money supply	−0.1340	−0.1425	−0.1682	−0.1900	−0.2313	−0.2809	−0.2786	−0.2796
	(−1.6627)	(−1.6539)	(−1.8723)	(−2.2980)	(−2.5951)	(−2.8587)	(−2.3990)	(−2.0622)
Exchang rate	−0.0718	−0.0885	−0.1165	−0.0639	−0.0698	−0.0861	−0.1110	−0.1300
	(−1.7411)	(−2.1502)	(−2.7890)	(−1.5873)	(−1.6768)	(−2.0283)	(−2.5512)	(−2.7952)
Exports	−0.2205	−0.1788	−0.2009	−0.2374	−0.2400	−0.2082	−0.2387	−0.2795
	(−2.6327)	(−1.9509)	(−2.0343)	(−2.2304)	(−2.0750)	(−1.6491)	(−1.7667)	(−1.9355)
Imports	−0.3221	−0.1958	−0.1183	−0.1379	−0.2957	−0.2491	−0.3005	−0.2476
	(−3.8885)	(−1.9839)	(−1.0899)	(−1.1669)	(−2.7251)	(−1.9534)	(−1.9974)	(−1.4333)
CPI	−0.0747	−0.0221	−0.0742	−0.0464	−0.1211	−0.1687	−0.1545	−0.3361
	(−0.7661)	(−0.1958)	(−0.6305)	(−0.3367)	(−0.7240)	(−0.9632)	(−0.7854)	(−1.4634)

Note: First values denote $\hat{\alpha}$ and second for $t_{\hat{\alpha}}$ of all variables. k denotes the number of lag.

4.3 Selection of k

In order to conduct Perron's test for the three models, the lag order of the model, k, should be selected. For selecting the values of k, we used two approaches. The first is that, as Perron (1989) suggested, the values of k are determined by the significance of the estimated coefficients $\hat{c}_i$ in the model used. By this approach, a value of k, say k^*, was selected such that the t-statistic on $\hat{c}_i$ was greater than 1.60 and the t-statistic on $\hat{c}_l$ for $l > k^*$ was less than 1.60.[7] By this approach, the value of k for all variables except real GDP was selected as zero because, in the three different models in which we checked the significance of $\hat{c}_i$, the values of all series from $i=1$ to $i=8$, all the $\hat{c}_i$ values were insignificant.

Another approach for selecting k is using Akaike's information criteria (AIC) and Bayesian information criteria (BIC). Using AIC and BIC values for each k from 1 to 8 of all variables for model A, model B and model C were separately compared; for all of the variables, model B shows the minimum value and the models have significance coefficients of break dummies and $\hat{c}_i$ values in some lags. Thus, we selected model B for all of the variables. The results of AIC and BIC values for k from 1 to 8 of model B are shown in Table 3. The results show that by AIC and BIC approach, for nominal GDP and money supply k is selected as zero; for real GDP and CPI, k is selected as two; and for exchange rate, exports, and imports, k is selected as 4, 1, and 3, respectively.

[7] Perron (1989), p. 1382.

Table 3. AIC and BIC values of model B

Variables/k	0	1	2	3	4	5	6	7	8	Opt. lag
Nominal GDP	−2.6751	−2.6701	−2.6706	−2.6099	−2.5382	−2.5445	−2.6205	−2.6012	−2.5906	0
	−2.5126	−2.4763	−2.4297	−2.3260	−2.2104	−2.1721	−2.3786	−2.4078	−2.3124	0
Real GDP	−4.3058	−4.5339	−4.6917	−4.6289	−4.5712	−4.5409	−4.4624	−4.4074	−4.4336	2
	−4.1368	−4.3205	−4.4330	−4.3241	−4.2193	−4.1409	−4.0134	−3.9085	−3.8839	2
Money supply	−2.9622	−2.7148	−2.6514	−2.6097	−2.9017	−2.8954	−2.7724	−2.8301	−2.8410	0
	−2.6117	−2.5120	−2.4056	−2.3200	−2.5673	−2.5153	−2.5356	−2.4214	−2.4648	0
Exchang rate	−2.3709	−2.3311	−2.4231	−2.5233	−2.7109	−2.6430	−2.6651	−2.5887	−2.4955	4
	−2.2221	−2.1434	−2.1958	−2.2555	−2.4020	−2.2921	−2.2714	−2.3158	−2.3525	4
Exports	−0.4311	−0.4433	−0.4398	−0.3648	−0.3107	−0.3442	−0.2753	−0.2813	−0.2203	1
	−0.2321	−0.2639	−0.1838	−0.0631	−0.0375	−0.0516	−0.1690	−0.0634	−0.1715	1
Imports	−1.4226	−1.6254	−1.6511	−1.8211	−1.6932	−1.8160	−1.7535	−1.6100	−1.7870	3
	−1.2554	−1.4142	−1.3952	−1.4518	−1.3448	−1.4252	−1.3716	−1.4421	−1.4166	3
CPI	−3.4942	−3.6930	−4.1502	−3.9969	−3.9743	−4.1049	−4.0308	−4.0600	−3.9752	2
	−3.3109	−3.4616	−3.8246	−3.6668	−3.5936	−3.7182	−3.5469	−3.6757	−3.5285	2

Note: For each variable, first values are AIC and second values are BIC.

4.4 Results for Perron's test

In order to test the unit root in the presence of a structural break, we assume that only the civil war that began in 1996 caused the major change in the trend function, and that each series in the dataset contains only one break point. The break fraction λ, (the ratio of pre-break sample size to total sample size) approximated for CPI was 0.7 and for the rest of the series it was 0.8. The values of k for the variables nominal GDP, real GDP, and money supply by the two approaches are the same; we show these variables for unique k values. As for the rest of the four variables, k has different values for the two approaches, and we analyze the results for two different values of k. We checked the significance of the coefficients of break dummies and $\hat{c}_i$ values for k from 1 to 8 for all variables separately for model A and model C, and the coefficients of one-time break dummy ($\hat{d}$) and $\hat{c}_i$ are insignificant in all cases. Due to the insignificance of the $\hat{d}$ and $\hat{c}_i$ values in all cases, and greater AIC and BIC values than model B, we could not suggest model A and model C for any of the variables, although there were significant $\hat{\theta}$ and $\hat{\gamma}$ values in a few cases of different k values.

The results from Model B are given in Table 4. The results show that the coefficient of the post break slope dummy ($\hat{\gamma}$) is significant in all cases except exports. $\hat{\mu}$ is significant in all cases except real GDP and exchange rate, and $\hat{\beta}$ is significant in all cases except money supply and exchange rate. The values of $\hat{c}_i$ are significant in the case of real GDP for the selected lags, and we therefore suggest Model B for all of the variables except exports. Testing the hypothesis $\hat{\alpha} = 1$,

Table 4. Estimation Results for model B

variables	k	$\hat{\mu}$	$t_{\hat{\mu}}$	$\hat{\beta}$	$t_{\hat{\beta}}$	$\hat{\gamma}$	$t_{\hat{\gamma}}$	$\hat{\alpha}$	$t_{\hat{\alpha}}$	Results
Nominal GDP	0	0.7723	(2.0347)*	0.0132	(2.2605)*	−0.0127	(−2.4542)*	0.9059	(−1.8748)	N.S.
Real GDP	2	0.7162	(1.0588)	0.0054	(2.1332)*	−0.0086	(−3.3175)*	0.9298	(−1.0295)	N.S.
Money supply	0	0.6881	(1.8317)*	0.0168	(1.5035)	−0.0081	(−1.6546)*	0.8871	(−1.4659)	N.S.
Exchange rate	0	0.0222	(0.3349)	0.0031	(1.3842)	−0.0157	(−2.4735)*	0.9829	(−0.3931)	N.S.
	4	−0.0187	(−0.2776)	0.0027	(1.1747)	−0.0188	(−2.5501)*	1.0048	(−0.1027)	N.S.
Exports	0	0.7888	(1.7139)*	0.0239	(2.0020)*	−0.0132	(−0.7474)	0.8546	(−1.6428)	N.S.
	1	1.0161	(2.1145)*	0.0319	(2.5333)*	−0.0105	(−0.5711)	0.8013	(−2.1184)	N.S.
Imports	0	1.5832	(4.1260)*	0.0506	(4.4838)*	−0.0345	(−3.4270)*	0.7179	(−4.0526)*	S.
	3	1.7177	(3.2526)*	0.0584	(3.2790)*	−0.0555	(−4.4372)*	0.6952	(−2.9778)	N.S.
CPI	0	0.7425	(2.6808)*	0.0287	(2.3529)*	−0.0177	(−3.1628)*	0.7046	(−2.3512)	N.S.
	2	1.0213	(4.3742)*	0.0452	(4.1865)*	−0.0273	(−6.0666)*	0.5591	(−3.9849)*	S.

Note: Critical values at 5% level of significance for $\hat{\alpha}$ are −3.85 (for $\lambda=0.7$) and −3.82 (for $\lambda=0.8$). $t_{\hat{\alpha}}$ is t-value for $\hat{\alpha}=1$, other t-values are for parameters is equal to zero. N. S. denotes for non stationary and S. for stationary.

For first three variables value of k is unique from AIC and Perron (1989) approach and for rest of variables first values of k are from Perron (1989) approach and second values are from AIC approach, * denotes the values are significant at 5% level of significance.

by comparing the calculated values of $t_{\hat{\alpha}}$ with critical values at a 5% significance level, the null hypothesis cannot be rejected in all cases except CPI, where k is selected by the approach of AIC, and imports, where k is selected by the Perron (1989) approach. This means that when a structural break is considered, out of seven series, five are nonstationary. The series imports and CPI are stationary when the unit root is tested in the presence of structural breaks. The stationarity of these two series also depends on the approach to the selection of lags.

The results of previous studies of unit root tests related to Nepalese macroeconomic data series performed by Thapa (2002), Surya and Neupane (2006), Shrestha and Chowdhury (2005), and Shrestha (2006) showed that most of the series have unit roots. Comparison of our results with those of previous studies showed that most of the series under study have unit roots, whether there is an endogenous break, an exogenous break, or no break. Even so, different studies have used different models, and the point of break is not the same for all series; however, in most cases, they contain unit roots similar to our study. Though the results depend on the lag order k, it is important to consider structural change for the unit root.

5. Conclusion

The civil war (1996–2005) launched by Maoist guerrillas had a long-term effect in Nepal. The war ended with a comprehensive peace agreement signed by the United People's Front and the Maoists in 2006. Our study focused only on the impact of the conflict on macroeconomic time series data. The much lower average percentage growth of most macroeconomic data during the war period indicates the effect of the war on these variables. Our study shows that when structural change is not considered, all the series contain unit roots, which means they are nonstationary series.

Growth rates of macroeconomic time series indicators were decreasing order, which means there are the possibilities of multiple endogenous breaks or an exogenous break in any year during the during the period of civil war. Kwiatkowski *et al.* (1992) proposed another type of unit root test, which is known as the KPSS (Kwiatkowski, Phillips, Schmidt and Shin) test, by exchanging null and alternative hypotheses of the ADF test. This test is more powerful than the ADF test. Future work will extend for both of these cases. In this study, however, we isolated the event of the civil war that started in 1996 because of the extensive slowdown in economic growth trends; also, we found that an exogenous break unit root test is more powerful than any other type of test. We checked the stationarity of major macroeconomic data series focusing on exogenous breaks and found that all of the series under study have unit roots except imports and CPI. In the presence of a structural break, the imports series are stationary in some cases for k. We could not use our preferred models A and C for any of the variables because of the insignificance of most break dummies.

The nonstationarity presented in important macroeconomic variables indicates that the instability in such variables showed the low growth of the economy. Providing a stable macroeconomic environment (stability in prices, interest rates, and exchange rates) and a reliable legal framework for promoting domestic competition are essential.[8] Macroeconomic stability and strong competition between firms will lead to higher growth in the economy.

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