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Evidence on Unit Roots and Structural Breaks: A Chosen Macroeconomic Series from Pakistan

Sarfaraz Ahmed Bhutto
PhD Scholar, Institute of Commerce, Faculty of Management Sciences, Shah Abdul Latif University Khairpur, Pakistan. Email: Sarfaraz_ahmed0333@yahoo.com
Zulfiqar Ali Rajper
Assistant Professor, Department of Commerce, Shaikh Ayaz University Shikarpur , Pakistan.
Jai Kishan
Lecturer, Department of Commerce, Shaikh Ayaz University Shikarpur , Pakistan.
Ashique Hussain Lashari
Lecturer, Department of Economics, Shah Abdul Latif University, Khairpur

Abstract
Observing certain properties of Unit Root in the time series of macro-economic indicators have become a necessary pre-requisite for establishing order of integration. The study used conventional unit root tests that indicate level stationary or non-stationary using annual data for Pakistan. Perron (1989) and Zivot and Andrews (1991) tests failed to reject the hypothesis of unit root even after the inclusion of structural break. Results showed that all variables witnessed the existence of structural break during 1970s. Lumsdaine and Papell (1997) test results after incorporating multiple structural breaks indicate M3, exports and saving show trend stationarity. The study concludes that shocks in economy have effected in a long run behavior of these variables and implications for economic growth.

Keywords: Unit Roots, Stationarity, Structural Breaks, Time Series, Pakistan, OLS

1. Introduction

During last four decades, topic of stationarity of macroeconomic series has gained prominence. In this context, the subject of unit roots in macro-economic time series had received a great attention in terms of theoretical and applied research after the seminal contributions of Nelson and Plosser (1982). It is observed that macro-economic variables tend to increase or less frequently decrease over time. For example, output increases as available technology for production improves or innovations occur in the economy as population grows and so on. This means that commonly macro-economic variables are unit root variables (King *et al.*, 1991). The Ordinary Least Squares (OLS) method may give misleading inferences incorporating non-stationary variables in estimating regression equations. Therefore, pretesting for existence of unit roots is a pre-requisite for investigating long run relationships. Although empirical evidence was provided by many contributors (Nelson and Plosser, 1982; King *et al.*, 1991) for different countries. There are hardly a few studies that have explored the stationarity features of major

macroeconomic series (Waheed *et al.,* 2006). Present study has bridged this gap by considering not only stationarity testing but also by considering the effects of structural breaks on stationarity of major macroeconomic time series for Pakistan from 1964-2018.
However, Banerjee et al (1992), Christiano (1992) and Zivot and Andrews (1992) most notably challenged this approach, arguing that the a priori selection of the structural break based on an ex post analysis or awareness of the data may lead to an over-rejection of the unit root hypothesis. They found out that traditional critical values for parameter change testing are not true when the break point is estimated from predictive analytics. In addition, Piehl et al. (1999) pointed out that due to uncertainty about the exact timing of the split, the dummy variable does not actually join at the required time, and for this reason, the calculated model may not be accurate. In response, a series of research have established distinct methodologies for endogenizing the break dates in the study of unit root [e.g., Zivot and Andrews (1992), Lumsdaine and Papell (1997), Perron (1997), Lee and Strazicich (2003)]. This endogenization of break-points had an important effect of 3 on the results of the unit root. For example, for four of the Nelson and Plosser series—for which Perron rejected the hypothesis—Zivot and Andrews (1992) (hereinafter referred to as Zivot and Andrews) were unable to reject the unit root hypothesis. In addition, for a further three series of finite sample essential values, they failed to reject the unit root null hypothesis; jobs, nominal wages and stock prices.
The overall core objective of this research study is to examine the properties of stationary of chosen macroeconomic time series for Pakistan. The hypothesis of the study is whether these series are stationary or non-stationary without and with structural breaks. Moreover, following sections elaborated the extensive review of literature, methodology, analysis, results, conclusions and discussion.

2. Literature Review

Numerous empirical and theoretical studies have investigated the single and multiple structural breaks procedure on macro-economic time series of developed and underdeveloped countries (Li and Daly, 2009; Khan, 2014; Daly and Khan, 2016 and Khan and Daly, 2018). These studies have found different aspects of structural breaks and shows fair mechanism between structural changes in macroeconomic series and their long-term effect on growth and countries economic performance. The test like ADF (1979) is most frequently used UR test to identify the existence stationarity in analysis of time series studies. It has become an initial process to test the null hypothesis of the UR in contradiction of the alternative hypothesis of stationary. Nelson and Plosser (1982) found the incidence of UR with standard ADF test for 13 series of United States, showing random walk behavior rather than like transitory movements from gradually upward trend.
However, Perron and Phillips (1988) disclosed that the catastrophe to document for a prevailing break indications to a bias that decreases the capacity to reject a false UR null hypothesis. To resolve such complexities in the process, it had recommended a test that permits structural break having single exogenous break with ADF test. Considering this improvement, some renowned researchers, like Zivot and Andrews (1992) proposed the test with single break and break point is determined 'Endogenously' from the data itself. This provides evidence that confirmed Nelson and Plosser's findings mostly of the non-stationarity.

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The study of Lumsdaine and Papell (1997) documented the model of Zivot and Andrews's (1992) for necessary improvement. It is being expanded in model to include double structural breaks. Conversely, such type of endogenous tests had been criticized in the treatment of null hypotheses under the process of certain structural breaks. Having certain breaks were completely missing in null hypothesis of unit root and there could be certain propensity for such tests to recommend the presence of stationarity along with particular structural breaks. Moreover, Lee and Strazicich (2003) formulated two structural breaks Minimum Lagrange Multiplier (LM) UR tests in which he introduced an alternative hypothesis that unambiguously implies that series is trend stationary.

According to Waheed *et al.,* (2006), they had tested to develop by Zivot and Andrew (1992) on eleven macro-economic variables of the Pakistan economy and found single break in monetary aggregates from 1975 to 1976. However, UR test without considering SB in time series data show mixed results for Turkish economy (Kum, 2009). Furuoka (2011) reported the process of stationarity in GDP real per capita among nine countries of ASEAN family. Some studies recommended that per capita GDP had been characterized by a non-stationary process and found stationarity process after using cross-sectional independence assumption by applying first generation tests.

Ali and Reetu (2012) explored the time series properties of Libyan economy from (1970-2007) by applying traditional ADF and LM UR tests, Lee and Strazicich (2003) with two unknown structural breaks and found break points are stable with the oil related shocks of the late (1970) early (1980) and after (2000). While, results from ADF test appear to indicate a random walk in the given period (Dickey and Fuller, 1981). Furthermore, endogenous break Augmented Dickey Fuller ADF test were used with and without structural breaks in ASEAN macro-economic time series and results suggest that shocks have permanent effect (Ling, *et al.,* 2013). Also, Nigerian money demand function is stable but experienced volatility between 1986 and 2008 (Nduka, 2014).

3. Methodology and Data Sources

3.1 Empirical Model

As study has used econometric methodology requiring univariate estimation of variables. Equations given below are ingredient of our central modeling that is used in the study with some changes according to necessity of our work.

$$\Delta y_t = c + \propto y_{t-1} + \sum_{j=0}^{k} dj\Delta y_{t-j} + \epsilon_t \qquad (1)$$

$$\Delta y_t = c + \propto y_{t-1} + \beta_t \sum_{j=0}^{k} dj\Delta y_{t-j} + \epsilon_t \qquad (2)$$

Where

Y our variable of concern

Δ means the first difference *t y* is the time series being tested *t* is the time trend variable *k* is the number of lags.

Acceptance of the null hypothesis means that the series is at first difference of stationary trend; while rejection of null shows that series is level stationary.

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3.2 Data Collection

To inspect the unit root attributes of nine macro-economic variables of Pakistan economy this study utilized World Development Indicators (WDI) based on annual time series. As univariate analysis it is not necessary that starting, and end date of each variable remain same because each macro-economic variable in the study treated separately for estimation of results. In tradition of Nelson and Plosser (1982) and Waheed *et al.,* (2006), present study selected all the variables on which data was available for Pakistan economy.

Table 1: Variables

Variables
Broad money (M3)
Money and Quasi money (M2) Gross domestic product per capita.
Final consumption expenditures Gross fix Capital formation.
Gross National income per capita.
Exports of goods and services.
Imports of goods and services.
Gross savings.

3.3 Data Source: Word development indicators World Bank reports. All variables are converted into per capita form and then into log form before estimations.

3.4 ADF Test of Stationarity

A leading approach to check for existence of unit root(s) is ADF. The essential need of UR literature contemplates on whether time series are exaggerated by permanent shocks. ADF test has following hypothesis;

H_0: *Series is non-stationary or containing unit root*

H_1: *Series is stationary have no unit root*

3.5 PP Unit Root Test (1988)

Phillip and Perron (1988) have established a more inclusive test to check the non-stationarity process. This test differs from ADF test and ignores any serial correlation in the test regression and user does not have to stipulate a log length for test regression. The hypotheses are given as; ***$_0$:*** *Series is non-stationary or containing unit root*

H_1:*Series is stationary have no unit root*

3.6 DF-GLS UR Test

It is considered as modified type of ADF UR test. It follows same procedure excluding that the transformation of time series into generalized least square regression before performing the UR test. This test has considerably greater power than the previous version. It has following hypothesis;

H_0 : Series exhibits random walk

H_1: Series is stationary with linear time trend

3.7 Perron (1989) Exogenous Single Structural Break Test

Perron (1989) maintained that majority of macroeconomic variables as having no unit root. Large and infrequent shocks in the economy are main cause of this persistent. He used amended Dickey Fuller test which include dummy variable for justification of one-time break. Their hypotheses are;

H_0: *Unit root with 1-time structural break in data.*

H_1: *Stationarity with one-time break.*

$$x_t = \propto_0 + \propto_1 Du_t + d(DTB)_{(t)} + \beta_t \sum_{i=1} p_i \Delta x_{t-1} + \epsilon_t \quad (3)$$

$$x_t = \propto_0 + YDT_t + \beta_{(t)} + px_{t-1} + \sum_{i=1}^{p} \varphi_i \Delta x_{t-1} + \epsilon_t \quad (4)$$

$$x_t = \propto_0 + \propto_1 Du_t + d(DTB)_t + YDT_{(1)} + \beta_t + px_{t-1} + \sum_{i=1}^{p} \omega_i \Delta x_{t-1} + \epsilon_t \quad (5)$$

Above model (3) states the null hypothesis of unit root with one-time structural break in the deterministic trend of the series. Model (4) shows change in slope parameters and Model (5) shows both effects combined.

3.8 Zivot and Andrews Endogenous Structural Break Test (1992)

The endogenous structural break introduced by Zivot and Andrews (1992) test offers a consecutive test which employs the full sample and uses a diverse dummy variable for each possible break date. Important point to be noted is that both Zivot and Andrews (1992); and Perron (1989) calculated different critical values for their tests.

$\Delta y_t = c + \propto y_{t-1} + \beta_t + ydu_t + \sum dj \Delta y_{t-j} + \epsilon_t$ (6)

j=1964-2018 k

$\Delta y_t = c + \propto y_{t-1} + \beta_t 1964 + \varphi DT$-2018+ $\sum dj \Delta y_{t-j} + \epsilon_t$ (7)

1964-2018,=0

$$\Delta y_t = c + \propto y_{t-1} + \beta_t + \varphi DU_t + yDT_t \sum_{j=0}^{k} dj \Delta y_{t-j} + \epsilon_t \quad (8)$$

Model (6) shows the break in the level of series. Model (7) shows slope change and Model (8) shows one-time break in intercept and slope.

3.9 LM Multiple Structural Break Test (1997)

Lumsdaine and Papell (1997) popularized a method that recommended to test for two significant structural breaks were better than one break tests. Lumsdaine and Papell had been expanded the Zivot and Andrews (1992) model and additionally allow for breaks in level and trend.

$H_0 = x_t = C + x_{t-1} + \epsilon_{1t}$ (9)

$H_A = x_t = C + \beta_t + d_1 D_{1t} + d_2 D_{2t} + \epsilon_{2t}$ (10)

Where

D_{1t}=1 for t>TB_1+1 and 0 otherwise

D_{2t}=1 for t> TB_2 +1 and 0 otherwise

TB_1 and TB_2 are the dates corresponding to the break's points.

The testing strategy used in the LP test is like ZA test.

4. Results and Discussion

4.1 UR Test

As most of the macroeconomic time series data is nonstationary at levels so if study applies OLS regression on data the results would not be reliable.

Table-2

Variables	C	C+t	K
GDPPC	-0.8041	-2.0258	7
GNPPC	-0.5656	-2.0950	9
GFCF	-2.3409	-2.3288	7
Exports	-0.9084	-3.2271	5
Imports	-2.9165	-2.4390	3
Savings	-1.5488	-2.6499	2
Consumption	-2.0492	-2.3745	3
M2	0.7712	-3.1219	1
M3	0.9745	-2.5417	1

Note: C means constant, C+T means constant +trend, K shows the
lag length selected and *, **, *** shows significance at 1%, 5 % and 10% respectively.

Table 3: ADF UR Test Results

Variables		**Levels**		**First Difference**		
	C	**C+T**	**K**	**C**	**C+T**	**K**
GDPPC	-0.8403	-2.2134	1	-8.5421	-8.5131	1
GNPPC	-0.5263	-2.1601	3	-7.4431	-7.3628	3
GFCF	-2.3146	-2.3181	1	-8.1318	-7.9904	1
Exports	-1.5198	-3.0308	5	-6.3464	-6.2534	5
Imports	-3.5547	-2.6642	3	-5.5183	-5.6533	1
M2	0.3508	-2.3406	9	-2.9854		
M3	0.7924	-1.2541	5	-3.5417		
Savings	-0.7680	-2.8097	1	-7.0666	-7.1054	1
Consumption	-2.0492	-2.4109	1	-5.9498	-6.1563	1
M2	-2.7244	-3.0044	1	-6.3464	-6.1626	1
M3	0.7571	-3.8171	1	-6.6761	-6.5341	1

Note: C means constant, C+T means constant +trend, K shows the log length

Results reported in table 2 clearly indicate that DF-GLS UR test also unsuccessful in rejecting the null hypothesis of UR in each macro-economic time series at level of .05 level of significance, so all the macroeconomic variables in the study are non-stationary at levels without considering the break point but series became stationary when study takes first difference.

4.2 Perron (1989) Exogenous Single Structural Break Test

Results reported in table 4 are derived by using following equation developed by modifying ADF unit root test that incorporates both effects shift in trend and slope.

$$\ln y_t = \propto_1 + \theta dut + \beta_1 t + \delta dtb + \alpha(\ln y - 1) + \sum^{k}_{i=0} \lambda(\Delta \ln y_{t-1}) + \in_t \qquad (11)$$

Table 4: Perron (1989) Exogenous Structural Break Test Results

Parameters	Variables Ln CONPC	Ln GDPPC	Ln GFCF	Ln M2	Ln M3	Ln GNPPC	Ln exports	Ln imports	Ln savings
Break date	1970	1972	1973	1974	1974	1972	1971	1973	1975
μ	-15.81	-4.667	-5.221	-6.331	-5.221	-3.2147	-4.124	-9.137	-7.124
β	0.012	0.0025	-2.154	-4.23	-4.20	-3.77	-2.18	-1.832	0.256
δ	0.16	-.045	-.332	-.032	-.031	-.0912	-1.97	0.053	-.513
θ	-0.01	-.013	0.042	0.007	0.007	0.0206	0.008	0.102	0.035
γ			2.531	4.022	4.231	3.7994	2.119	1.855	-0.255
α	**0.15**	**0.8578**	**0.717**	**0.771**	**0.717**	**0.7931**	**0.226**	**0.716**	**0.892**
Lag length	2	2	2	3	2	2	2	3	2

Note: *, **, *** shows significance at 1%, 5% and 10% respectively.

Results in above table clearly indicate that even the inclusion of single exogenous structural break in the model that allows slope -8.5050and level change to all macro-economic variables that are included in the study still cannot able to reject the unit root null hypothesis i.e. the series has a unit root with a structural break in both intercept and trend. Results also show possible break points and most of these series have structural breaks during the decade of 1970 due to separation of country and oil price shock (1973). So, this study moves forward to ZA endogenous single structural break unit root test for further investigation.

Table 5: Lumsdaine and Papell (1997) Multiple Structural Break Test Results

Parameters	Ln con/pc	Ln GDP/PC	Ln GFCF	Ln M2	Variables Ln M3	Ln GNI/PC	Ln exports	Ln imports	Ln savings
Break date Years	1974 1989	1974 1981	1989 2001	1975 1998	1976 2002	1974 2004	1973 2006	1974 1996	1976 2010
Lag length	5	2	7	3	6	0	4	3	1
μ	-5.123	-3.13	-4.12	-2.14	-3.10	-6.12	-1.234	-7.123	-2.31
β	-0.501	-4.01	-2.52	-5.32	-5.66	-3.23	-2.964	-2.143	-5.143
δ	0.049	0.007	0.123	-0.04	-0.03	-0.091	0.017	0.017	-0.321
θ	-0.001	0.043	0.014	-0.02	0.05	0.081	-0.037	-0.021	-0.123

γ	-0.505	4.017	2.527	5.123	3.41	5.241	4.123	9.124	4.213
μ1	-0.827	-0.712	-.618	-0.37	-0.513	-0.712	-0.591	-0.541	-0.612
β1	-15.8	-4.678	-5.21	-6.31	-5.221	-3.214	-4.124	-9.137	-7.14
δ1	0.01	0.025	-2.14	-4.22	-4.200	-3.754	-2.187	-1.832	0.253
θ1	0.168	-0.045	-.32	-0.02	-0.031	-0.012	-1.975	0.053	-0.510
γ1	-0.011	-0.032	0.022	0.07	0.007	0.020	0.008	0.102	0.035
α	**-2.68**	**-0.83**	**-0.65**	**-0.48**	**1.02* ***	**-0.34**	**0.71****	**-0.34**	**0.60****
α1	**-2.14**	**-1.24**	**-8.21**	**-5.20**	**-15.12**	**-6.33**	**-21.19**	**-4.09**	**-7.17**

*Note: *, **, *** shows significance at 1, 5 and 10 percent respectively. Critical values are from Lumsdaine and Papell with 54 observations. Critical values are -7.34, -6.32 and -6.45 at 1%, 5% and 10% Levels respectively.*

The results obtained from LP (1997) multiple structural break test have been reported in above table. Results indicate that after incorporation of multiple structural breaks broad money M3 and saving become stationary at one percent while exports become stationary at 10 percent. Results remain almost same for remaining six macro-economic time series as they were in the case of single structural break test methodology.

5. Conclusion and Policy Suggestion

The purpose of this study was to examine the unit root properties of nine macro-economic time series of Pakistan economy from 1964 to 2018 in order to detect unit root process and single and multiple structural breaks. This process is done by applying different types of quantitative methods for measuring unit root and structural break process. Unit root Tests including Perron (1989) and Zivot and Andrews (1991) failed to reject unit root hypothesis even after the inclusion of structural break. Results indicated that all variables observed the presence of structural break during 1970s. Lumsdaine and Papell (1997) test results after incorporating multiple structural breaks indicate M3, exports and saving show trend stationarity. The study concludes that shocks in economy have permanent effect on the long run behavior of these variables and implications for economic growth. These results are quite consistent with random walk hypothesis theory, so this study suggests that first step is to eliminate these events from the economy that causes such breaks in the data and try to stabilize these macroeconomic variables in the economy. This process may lead to a sustained growth process and then going forward to join regional and international trading blocks that favor our Pakistan's economy. Future studies may focus on using new methodologies developed and/or considering role of structural breaks for analyzing time series variables.

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