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Structural Breaks and Unit Roots in Selected Macroeconomic Series: Evidence from Pakistan

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Examining unit root properties of macro-economic time series has become a necessary pre-requisite for establishing order of integration. The study used conventional unit root tests that indicate level stationarity or non-stationarity using annual data for Pakistan. Perron (1989) and Zivot and Andrews (1991) tests failed to reject unit root hypothesis even after the inclusion of structural break. Results showed that all variables witnessed 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 behaviour of these variables and implications for economic growth.

Keywords: Unit Roots, Stationarity, Structural Breaks, Time Series, Pakistan, OLS
JEL Classification: C01, C2, C13, C22, O53

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 amount of 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 non-stationary or unit root variables. The Ordinary Least Squares (OLS) method may give misleading inferences incorporating non-stationary variables in estimating regression equations. Therefore, pre-testing 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.

The overall objective of the study is to investigate the stationarity property of selected macroeconomic time series for Pakistan. The hypothesis of the study is whether these series are stationary or non-stationary without and with structural breaks. This study consists of five sections as introduction, literature review, theoretical framework and methodology, study results and conclusion and policy recommendations respectively.

Review of Literature

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 Augmented Dickey-Fuller (1979) test is most commonly used unit root test to identify stationarity of the time series studies in applied economic literature. It becomes a primary procedure to test the null hypothesis of the unit root against the alternative hypothesis of stationary. Nelson and Plosser (1982) found the incidence of unit root with standard ADF test for 13 series of United States, showing random walk behaviour rather than like transitory movements from gradually upward trend.

However, Perron and Phillips (1988) disclosed that the failure to permit for an existing break leads to a bias that reduces the ability to reject a false unit root null hypothesis. To overcome this process, it proposed a test that allows for a known or exogenous single structural break in the Augmented Dickey-Fuller (ADF) test. Following this development, some authors including, 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.

Lumsdaine and Papell (1997) improved the Zivot and Andrews's (1992) model to double structural breaks. However, these endogenous type tests were criticized for their treatment of structural breaks under the null hypothesis. Given that the breaks were absent under the null hypothesis of unit root and there may be tendency for these tests to suggest evidence of stationarity with structural breaks. Lee and Strazicich (2003) constructed a two structural break Minimum Lagrange Multiplier (LM) unit root test in which he purposed

an alternative hypothesis that unambiguously implies that series is trend stationary.

Waheed *et al.,* (2006) utilized the test developed 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, unit root test without considering structural break in time series data show mixed results for Turkish economy (Kum, 2009). Furuoka (2011) investigated stationarity process in real per capita gross domestic product GDP in nine ASEAN countries. Empirical results suggested 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 unit root 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).

Methodology and Data Sources

Empirical Model

As we use econometric methodology requiring univariate estimation of variables. Equations given below are ingredient of our central modelling 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 stationary after first differencing; while rejection of null shows that series is level stationary.

Data Collection

To inspect the unit root attributes of nine macro-economic variables of Pakistan economy this study utilized annual time series data collected from World Development Indicators (WDI). 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.	

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

ADF Test of stationarity

A leading approach to check for existence of unit root(s) is ADF. The main thrust of the unit root literature contemplates on whether time series are affected by transitory or 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

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;

H_0: Series is non-stationary or containing unit root

H_1 : Series is stationary have no unit root

DF-GLS Unit Root Test

This is modified form of ADF unit root test. It follows same procedure except that the time series is transformed into generalized least square regression before performing the unit root 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

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.

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

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

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

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.

Zivot and Andrews Endogenous Structural Break Test (1992)

Zivot and Andrews (1992) endogenous structural break test is a sequential test which utilizes the full sample and uses a different 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.

$$\Delta y_t = c + \propto y_{t-1} + \beta_t + ydu_t + \sum_{j=0}^{k} dj\Delta y_{t-j} + \epsilon_t \qquad (6)$$

1964-2018

$$\Delta y_t = c + \propto y_{t-1} + \beta_t + dt_t + \sum_{j=0}^{k} dj\Delta y_{t-j} + \epsilon_t \qquad (7)$$

1964-2018

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

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.

LM Multiple Structural Break Test (1997)

Lumsdaine and Papell (1997) popularized a method capable of dealing with two structural breaks and claimed that tests that consider for two significant structural breaks were better than one break tests. Lumsdaine and Papell extend the Zivot and Andrews (1992) model and additionally allow for breaks in level and trend.

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

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

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.

Results and Discussion

Unit Root Testing

As most of the macroeconomic time series data is non-stationary at levels so if we apply OLS regression on data the results would not be reliable. To test for stationary and to determine the order of integration of each series, both Augmented Dickey Fuller and Phillips-Perron unit root test are employed.

Table 2: ADF Unit Root Test Results

Variables	Levels			Intercept		
	C	C+T	K	C	C+T	K
GDPPC	-0.8041	-2.0258	7	-8.5447	-8.5050	7
GNPPC	-0.5656	-2.0950	9	-7.4247	-7.3505	9
GFCF	-2.3409	-2.3288	7	-8.1102	-7.9877	7
Exports	-0.9084	-3.2271	5	-5.6697	-5.6017	5
Imports	-2.9165	-2.4390	3	-5.5631	-5.6641	3
Savings	-1.5488	-2.6499	2	-6.7077	-6.8928	2
Consumption	-2.0492	-2.3745	3	-5.9574	-6.1567	3
M2	0.7712	-3.1219	1	-6.6172	-6.1451	1
M3	0.9745	-2.5417	1	-6.1451	-6.5412	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: PP Unit Root 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
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 selected and *, **, *** shows significance at 1%, 5%, and 10% respectively.

Unit root results reported in table 2 and 3 respectively. Both ADF and PP test failed to reject the null hypothesis of unit root in each macro-economic time series at 5 percent significant level, but series became stationary when we take first difference.

Table No 4: Unit Root Test Results

Variables	Levels			Intercept		
	C	C+T	K	C	C+T	K
GDPPC	0.2713	-2.2716	5	-8.5422	-8.6547	5
GNPPC	0.9714	-2.1159	3	-5.8078	-6.2541	3
GFCF	0.6324	-2.3318	9	-5.3128	-6.6143	9
Exports	0.7652	-2.9157	5	-3.3804	-4.6840	5
Imports	0.0499	-1.4527	3	-4.9815	-5.7365	3
Savings	-0.3431	-2.3406	5	-3.1424	-6.2153	5
Consumption	0.7763	-1.4805	5	-5.7417	-6.1435	5
M2	0.3508	-2.3406	9	-2.9854		
M3	0.7924	-1.2541	5	-3.5417		

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

Results reported in table 4 clearly indicate that DF-GLS unit root test also failed to reject the null hypothesis of unit root in each macro-economic time series at 5 percent significant so all the macroeconomic variables in the study are non-stationary at levels without considering the break point but series became stationary when we take first difference.

Perron (1989) Exogenous Single Structural Break Test

Results reported in table 5 are derived by using following equation developed by modifying ADF unit root test that incorporates both effects shift in trend and slope.

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

Table 5: 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	-4.6678	-5.221	-6.331	-5.221	-3.2147	-4.124	-9.137	-7.124
β	0.012	0.0025	-2.154	-4.232	-4.200	-3.7754	-2.187	-1.832	0.256
δ	0.16	-0.0045	-0.332	-0.032	-0.031	-0.0912	-1.975	0.053	-0.513
θ	-0.01	-0.0132	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**	**0.7175**	**0.7712**	**0.7173**	**0.7931**	**0.2267**	**0.7164**	**0.8929**
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 and level change to all macro-economic variables that are included in the study we 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, we move forward to ZA endogenous single structural break unit root test for further investigation.

Zivot and Andrew (1992) Endogenous Single Structural Break Test

The results obtained from ZA endogenous structural break test have been reported in above table. This test incorporates the single exogenous structural break to nine macroeconomic variables of the Pakistan economy.

Table 6: Results of Zivot and Andrew 1992 Endogenous Structural Break Test

Parameters	Variables								
	Ln con/pc	Ln GDP/PC	Ln GFCF	Ln M2	Ln M3	Ln GNI/PC	Ln exports	Ln imports	Ln savings
Break date	1974	1974	1989	1975	1976	1974	1973	1974	1976
μ	-5.1237	-3.2139	-4.1213	-2.154	-3.140	-6.412	-1.234	-7.123	-2.361
β	-0.5014	-4.0915	-2.5213	-5.312	-5.676	-3.123	-2.964	-2.143	-5.1437
δ	0.0494	0.0007	0.1273	-0.004	-0.023	-0.091	0.0179	0.0197	-0.3241
θ	-0.0019	0.0043	0.0124	-0.012	0.065	0.0081	-0.037	-0.0213	-0.123
γ	-0.3031	4.117	2.5217	5.1243	3.471	5.241	4.123	9.124	4.213
α	**0.8275**	**0.7712**	**0.6618**	**0.7397**	**0.5213**	**0.7912**	**0.5912**	**0.5641**	**0.6912**
Lag length	[illegible]	3	4	2	3	5	4	3	4

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

Results in table 6 shows that break date for GDP, GNI and consumption series is recorded in 1974 while for M2 and M3 is recorded in 1975 and 1976 respectively may be due to deliberate policy shift by central bank towards interest rate management. Similarly imports and exports series experienced break in 1974 and 1973 respectively that might be the effect of Nationalization program. GFCF series have break in 1989 which may be the side effect of Structural Adjustment Program (SAP) at that period. Results clearly indicate that we still not able to reject the null hypothesis. So, we move forward.

Lumsdaine and Papell (1997) Multiple Structural Break Test

We move forward to multiple structural breaks testing procedure developed by Lumsdaine and Papell in (1997) and results of this test are given in the table below.

Table 4.6: Lumsdaine and Papell (1997) Multiple Structural Break Test Results

Parameters	Variables								
	Ln con/pc	Ln GDP/PC	Ln GFCF	Ln M2	Ln M3	Ln GNI/PC	Ln exports	Ln imports	Ln savings
Break date	1974	1974	1989	1975	1976	1974	1973	1974	1976
Years	1989	1981	2001	1998	2002	2004	2006	1996	2010
Lag length	5	2	7	3	6	0	4	3	1
μ	-5.123	-3.139	-4.123	-2.14	-3.10	-6.12	-1.234	-7.123	-2.31
β	-0.501	-4.01	-2.523	-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	-0.618	-0.37	-0.513	-0.712	-0.591	-0.541	-0.612
β1	-15.8	-4.678	-5.217	-6.31	-5.221	-3.214	-4.124	-9.137	-7.14
δ1	0.01	0.025	-2.148	-4.22	-4.200	-3.754	-2.187	-1.832	0.253
θ1	0.168	-0.045	-0.321	-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.

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 behaviour of these variables and implications for economic growth.

These results are quite consistent with random walk hypothesis theory, so we suggest 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 favours 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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