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Waheed, Muhammad and Alam, Tasneem and Ghauri,
Saghir Pervaiz

State Bank of Pakistan

15 December 2006

Online at <https://mpra.ub.uni-muenchen.de/1797/>

MPRA Paper No. 1797, posted 15 Feb 2007 UTC

Structural Breaks and Unit Root: Evidence from Pakistani Macroeconomic Time Series

By

Muhammad Waheed*

Tasneem Alam

Saghir Pervaiz Ghauri

Abstract

The purpose of this paper is to examine the unit root properties of eleven Pakistani macroeconomic series using annual data. Along with traditional unit root tests, we use the procedure developed by Zivot and Andrews to test the null of unit root against the break-stationary alternative. Conventional unit root tests indicate that all variable are non-stationary at the levels. Results from Zivot and Andrews test suggest that we can reject the null of unit root for CPI and WPI at 5 percent significance level while we fail to reject the unit root hypothesis for the remaining 9 series. At the same time, the Zivot and Andrews test identifies endogenously the point of the single most significant structural break in every time series examined. The results show that ten of the eleven series studied bear witness to the presence of a structural break during the period 1972 to 1976.

Email Addresses:

muhammad.waheed@sbp.org.pk

tasneem.alam@sbp.org.pk

saghir.pervaiz@sbp.org.pk

* Authors are PhD students at Pakistan Institute of Development Economics, Islamabad. Authors wish to thank Waseem Shahid Malik and Muhammad Shuaib Malik for their helpful comments.

I. Introduction:

It is now well established that different characterizations of the data generating process of a macroeconomic time series have drastically dissimilar implications for theories and empirics in macroeconomics. For instance, traditional theories of economic fluctuations have claimed that (i) fluctuations are mainly caused by aggregate demand shocks and (ii) demand shocks have only short-term effects, and the economy reverts to the natural rate of output in the long run. Consequently, evidence of unit roots in real output time series compelled many to question the validity of these theories¹. Similarly, economists have conjectured over the unit root properties of other economic variables, such as unemployment rate, price level, inflation rate, consumption expenditure, and stock prices. In each case, the unit root properties of the variable considered is shown to have significant implications for economic theories². From an empirical perspective, the order of integration of macroeconomic variables has crucial consequences for appropriate modeling of time series data. These observations have led many economists to vigorously explore whether macroeconomic time series could be characterized as containing a unit root.

In their seminal contribution on the dynamic properties of macroeconomic time series, Nelson and Plosser (1982) found evidence in favour of the unit root hypothesis for 13 out of 14 economic and financial aggregates for the United States. Realizing the immense economic implications of this result, many economists focused their attention on the

¹ Statistically, a stationary process fluctuates around a constant long-run mean and, also, the effects of shocks dissipate over time. Alternatively, if the series features a unit root then it has no tendency to return to a long-run deterministic path and more importantly, a current shock to the series produces permanent effect on the long-run level of the series.

² In this perspective, some interesting studies include Gilbeto (2005), Christiano and Eichenbaum (1990), Ball (1993), and Chaudhuri and Wu (2003).

possible source of this result. In particular, Perron (1989) (hereafter referred to as Perron) demonstrated that if the years of the Great Depression (1929) and the first oil crisis (1973) are treated as points of structural change in the economy and the observations corresponding to these years are removed from the noise function of the Nelson and Ploser data, then the result derived by Nelson and Ploser (1982) could be reversed for most of the variables. Based on his results, Perron asserted that Nelson and Plosser's strong evidence in support of the unit root hypothesis rested on failure to account for structural change in the data. Perron's approach consisted of incorporating an exogenous structural break in the model and then test for the presence of a unit root in the variable. Thus, dating of the potential break was assumed known *a priori* in Perron and test statistics were constructed by adding dummy variables representing different intercepts and slopes, thereby extending the standard Dickey-Fuller procedure.

This approach was however questioned most notably by Banerjee *et al* (1992), Christiano (1992) and Zivot and Andrews (1992), who argued that selecting the structural break *a priori* based on an *ex post* examination or knowledge of the data could lead to an over rejection of the unit root hypothesis. They pointed out that conventional critical values for test of parameter change are not valid when the break point is inferred from examination of data. Additionally, Piehl et al., (1999) highlighted that the dummy variable may not actually enter at the appropriate time due to uncertainty about the precise timing of the break, and for this reason estimated model may not be correct. In response, a number of studies have developed different methodologies for endogenizing the break dates in the analysis 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 major

impact on the unit root results. For instance, Zivot and Andrews (1992) (hereafter referred to as Zivot and Andrews) were unable to reject the unit root hypothesis for four of the Nelson and Plosser series— for which Perron rejected the hypothesis. Further, with finite-sample critical values, they failed to reject the unit root null hypothesis for a further three series; employment, nominal wages and stock prices.

The purpose of the present paper is to examine the unit root properties of eleven Pakistani macroeconomic series with simultaneously determining the break-year in each variable. To this end, we use the procedure developed by Zivot and Andrews to test the null of unit root against the break-stationary alternative hypothesis. We also compare these results with the conventional unit root tests that do not account for any break in the data. The paper is set out as follows. The next section explains the econometric methodology. Section III explains the data and presents the results. Final section briefly concludes the paper.

II. Econometric Methodology

Unit Root Test without Structural Break

We begin through testing for the presence of a unit root in each of the macroeconomic series using the Augmented Dicky-Fuller (1979) test. The ADF test constructs a parametric correction for higher-order correlation by assuming that the series follows an AR(k) process and adding lagged difference terms of the dependent variable to the right-hand side of the test regression:

$$\Delta y_t = c + \alpha y_{t-1} + \sum_{j=1}^k d_j \Delta y_{t-j} + \varepsilon_t \quad (1)$$

$$\Delta y_t = c + \alpha y_{t-1} + \beta t + \sum_{j=1}^k d_j \Delta y_{t-j} + \varepsilon_t \quad (2)$$

Equation (1) tests for the null of a unit root against a mean-stationary alternative in y_t where y refers to the time series examined, and Equation (2) tests the null of a unit root against a trend-stationary alternative. The term Δy_{t-j} is lagged first differences to accommodate serial correlation in the errors. We select the lag length through the ‘t sig’ approach proposed by Hall (1994). As shown by Ng and Perron (1995) the ‘t sig’ approach produces test statistics which have better properties in terms of size and power than when lag length is selected with some information-based criteria.

As illustrated by the above equations, we may elect to include a constant, or a constant and a linear time trend in ADF test regression. For either case, Elliot, Rothenberg and Stock (1996) propose a simple modification of the ADF approach to construct DF-GLS test, in which the time series are detrended so that explanatory variables are "taken out" of the data prior to running the test regression. Phillips and Perron (1988) propose an alternative (nonparametric) method of controlling for serial correlation when testing for a unit root.

The PP method estimates the non-augmented DF test equation [Equation (1) and (2)

without $\sum_{j=1}^k d_j \Delta y_{t-j}$ term on rhs], and modifies the t-ratio of the α coefficient so that serial

correlation does not affect the asymptotic distribution of the test statistic³. For comparison purposes, we also perform the DF-GLS and PP tests and report their results in addition to the generally favored ADF test.

³ We skip detailed theoretical description of the various unit root tests in this paper. Those interested in the underlying theory of these test would find Maddala and Kim (1998) very helpful.

Zivot and Andrews Model:

A problem common with the conventional unit root tests —such as the ADF, DF-GLS and PP tests, is that they do not allow for the possibility of a structural break. Assuming the time of the break as an exogenous phenomenon, Perron showed that the power to reject a unit root decreases when the stationary alternative is true and a structural break is ignored. Zivot and Andrews propose a variation of Perron’s original test in which they assume that the exact time of the break-point is unknown. Instead a data dependent algorithm is used to proxy Perron’s subjective procedure to determine the break points. Following Perron’s characterization of the form of structural break, Zivot and Andrews proceed with three models to test for a unit root: (1) model A, which permits a one-time change in the level of the series; (2) model B, which allows for a one-time change in the slope of the trend function, and (3) model C, which combines one-time changes in the level and the slope of the trend function of the series. Hence, to test for a unit root against the alternative of a one-time structural break, Zivot and Andrews use the following regression equations corresponding to the above three models.

$$\Delta y_t = c + \alpha y_{t-1} + \beta t + \gamma DU_t + \sum_{j=1}^k d_j \Delta y_{t-j} + \varepsilon_t \quad (\text{Model A})$$

$$\Delta y_t = c + \alpha y_{t-1} + \beta t + \theta DT_t + \sum_{j=1}^k d_j \Delta y_{t-j} + \varepsilon_t \quad (\text{Model B})$$

$$\Delta y_t = c + \alpha y_{t-1} + \beta t + \theta DU_t + \gamma DT_t + \sum_{j=1}^k d_j \Delta y_{t-j} + \varepsilon_t \quad (\text{Model C})$$

where DU_t is an indicator dummy variable for a mean shift occurring at each possible break-date (TB) while DT_t is corresponding trend shift variable. Formally,

$$DU_t = \begin{cases} 1 & \text{if } t > TB \\ 0 & \text{otherwise} \end{cases} \quad \text{and}$$

$$DT_t = \begin{cases} t - TB & \text{if } t > TB \\ 0 & \text{otherwise} \end{cases}$$

The null hypothesis in all the three models is $\alpha=0$, which implies that the series $\{y_t\}$ contains a unit root with a drift that excludes any structural break, while the alternative hypothesis $\alpha<0$ implies that the series is a trend-stationary process with a one-time break occurring at an unknown point in time. The Zivot and Andrews method regards every point as a potential break-date (TB) and runs a regression for every possible break-date sequentially. From amongst all possible break-points (TB), the procedure selects as its choice of break-date (\overline{TB}) the date which minimizes the one-sided t-statistic for testing $\hat{\alpha} (= \alpha - 1) = 1$. According to Zivot and Andrews, the presence of the end points cause the asymptotic distribution of the statistics to diverges towards infinity. Therefore, some region must be chosen such that the end points of the sample are not included. Zivot and Andrews suggest the ‘trimming region’ be specified as $(0.15T, 0.85T)$, which we follow.

Perron suggested that most economic time series can be adequately modeled using either model A or model C. As a result, the subsequent literature has primarily applied model A and/or model C. In a recent study, Sen (2003) shows that if one uses model A when in fact the break occurs according to model C then there will be a substantial loss in power. However, if break is characterized according to model A, but model C is used then the loss in power is minor, suggesting that model C is superior to model A. Based on these observations, we choose model C for our analysis of unit roots.

III. Data and Empirical results

We examine the unit root properties for eleven Pakistani macroeconomic time series using annual data. All variables are extracted from IMF's International Financial Statistics and converted into natural logs. The sample period for each variable starts from 1957 and finishes in 2004 or 2005 depending on data availability. The complete description of the data is given in Table 1.

Table 1: Variables and sample period

Variables	IFS series code	Sample period
1 Nominal GDP	56499B..ZF...	1957-2005
2 Broad Money (M2)	56435L..ZF...	1957-2005
3 Reserve money	56414...ZF...	1957-2005
4 Consumer Price Index (CPI)	56464...ZF...	1957-2005
5 Wholesale Price Index (WPI)	56463...ZF...	1957-2005
6 Exports	56470..DZF...	1957-2004
7 Imports	56471..DZF...	1957-2004
8 Manufacturing production	56466EY.ZF...	1957-2004
9 Call Money Rate	564..AE.ZF...	1957-2005
10 Total Revenue	56481...ZF...	1957-2005
11 Total Expenditure	56482...ZF...	1957-2005

Source: All data are extracted from IMF's IFS database(May 2006). All variables are taken in log.

Test Results without structural break

Results from ADF, DF-GLS and PP test are reported in Table 2. As is evident, all tests fail to reject the null hypothesis of a unit root in each time series at 5 percent significance level, implying that all 11 macroeconomic variables considered in this study are non-stationary at levels.

Table 2: Results of unit root tests without accounting for a structural break

Variables	ADF [k]	DF-GLS [k]	PP
1 Nominal GDP	-2.6598 [1]	-1.681272 [1]	-2.67009
2 Broad Money (M2)	-3.4609 [1]	-1.767202 [0]	-3.45216
3 Reserve money	-3.2893 [0]	-1.475798 [0]	-3.39904
4 Consumer Price Index (CPI)	-3.4039 [1]	-2.412650 [1]	-2.76032
5 Wholesale Price Index (WPI)	-3.0445 [1]	-2.137579 [1]	-2.93137
6 Exports	-2.7963 [1]	-2.679253 [1]	-2.55487
7 Imports	-1.8742 [0]	-2.174957 [1]	-2.23450
8 Manufacturing production	-2.9522 [1]	2.053410 [1]	-2.41262
9 Call Money Rate	-2.2562 [0]	-2.167052 [0]	-2.36948
10 Total Revenue	-1.8309 [0]	-1.894749 [0]	-1.95503
11 Total Expenditure	-1.6845 [0]	-1.669809 [0]	-1.80609

Linear trend included. For ADF, DF-GLS and PP tests, critical value at 5 percent significance level are -3.5005, -3.1868 and -3.4987 respectively.

Zivot and Andrews Test Results

An important aspect of unit root estimation in the presence of structural break is the trend property of the variables. Ben-David and papell (1997) show that if there is no upward trend in data, the test power to reject the no-break null hypothesis is reduced as the critical values increase with the inclusion of a trend variable. In contrast, if series exhibits a trend, then estimating the model without trend may fail to capture some important characteristics of the data. Since all series in this study depict upward or downward trend, we estimate model C with the inclusion of βt term.

The results for Zivot and Andrew unit root test are presented in Table 3. These results suggest that we can reject the null of unit root for CPI and WPI at 5 percent significance

Table 3: Result of Zivot and Andrews one-break test

Variables	[k]	t-statistics	Break year
1 Nominal GDP	[1]	-5.01363 **	1974
2 Broad Money (M2)	[1]	-4.83714 **	1975
3 Reserve money (RM)	[0]	-3.26644	1976
4 Consumer Price Index (CPI)	[1]	-6.08997 *	1973
5 Wholesale Price Index (WPI)	[1]	-5.15683 *	1973
6 Exports	[1]	-4.07124	1972
7 Imports	[0]	-4.07435	1974
8 Manufacturing production	[3]	-4.03514	1981
9 Call Money Rate	[0]	-3.39404	1974
10 Total Revenue	[0]	-2.97679	1974
11 Total Expenditure	[0]	-2.50593	1974

The critical values for Zivot and Andrews test are -5.57, -5.30, -5.08 and -4.82 at 1 %, 2.5 %, 5 % and 10% levels of significance respectively.

* denotes statistical significance at 5% level. ** denotes statistical significance at 10% level.

level, while we fail to reject the unit root hypothesis for the remaining 9 series⁴. This result clearly contradicts the results obtained from the unit root test without structural breaks for these two series.

At the same time, the test identifies endogenously the point of the single most significant structural break (\overline{TB}) in every time series examined in this paper. The break-date for each time series is reported in Table 3. This too has important implications. As underlined by Piehl et al., (1999), knowledge of break point is central for accurate evaluation of any program intended to bring about structural changes; such as the tax reforms, banking sector reforms and regime shifts etc.

⁴ For consistency we compare the results from Zivot and Andrews test and the conventional unit root tests at the 5 percent significance level. Interestingly, however, we can also reject the unit root hypothesis for Nominal GDP and M2 at 10 percent significance level in the Zivot and Andrews test.

Generally, the year 1972—the year when the country disunited into two sovereign states, is regarded as the most suitable candidate for a structural break in Pakistani data⁵. The results show that only one of the eleven series studied (i.e., exports) bear witness to the presence of a structural break in 1972. Contrary to prevailing perception, the test identifies a break in the GDP series at 1974. The results also show that the year 1974 emerges as the most significant break-year for call money rate. This can be associated to a deliberate policy shift by the SBP towards interest rate management⁶. Similarly, results show that M2 and reserve money series experienced a one-time break in 1975 and 1976 respectively⁷. A one-time break in imports is detected at 1974, while CPI and WPI attest to the presence of a single break in 1973, perhaps a consequence of the 1973 oil price shock. The break-points in total revenues and total expenditures of the government are detected at 1974, possibly a result of a large nationalization program undertaken by the then government. Finally, results signal a trend-break in manufacturing production in the year 1981.

IV. Conclusion

This paper uses annual data to determine endogenously the most important years when

⁵ Eastern part of the country separated from Pakistan on December 16, 1971 to become Bangladesh. Since all data is in calendar year format, the year 1972 is considered the true candidate for the break point.

⁶ A random survey conducted by State bank of Pakistan (SBP) of the balance sheet of corporate enterprises for 1972 showed that total interest payments amounted to 2.5% of the total cost of production of these enterprises. The study also showed that a 5% increase in interest rate would increase the cost of production by no more than 1.25%. Given the fact that annual price increases during that period were in double digit, even such a sharp increase in interest rates was not expected to affect the demand for bank credit. Realizing that availability of bank credit mattered more than its cost, the SBP authorities became more flexible about interest rates. Since 1972 SBP has actively changed various rates of interest to control the rate of monetary expansion, to bring about a more rational utilization of bank credit and promote savings. For more detail see Janjua, M. A. (2003) History of State Bank of Pakistan (1977-1998), State Bank of Pakistan, pp 175-182.

⁷ The break in M2 and reserve money may be a result of large increase in government budgetary borrowing during that period to finance a large increase in public sector investment and a nationalization program. *ibidem*, chapter 2.

structural breaks occurred and simultaneously test for the unit root hypothesis in the presence of these breaks in eleven macroeconomic variables of Pakistani economy. To this end we utilized the test developed by Zivot and Andrews. Some key conclusions follow the results obtained from this test. First, regarding the mean reversion properties of these series, it is inferred that we can reject the hypothesis of unit root for two series namely CPI and WPI at 5 percent significance level. Interestingly, both these series were inferred as containing a unit root when we used the tests that do not account for the breaks in the data; namely ADF, DF-GLS and PP tests.

Second, this test indicated us the most probable break-points in the data. It is found that almost all the series exhibits structural breaks during 1970's; clustering around 1972 to 1976. The results suggest that a one-time break in call money rate occurred in 1974, which can perhaps be a result of SBP policy shift in interest rate management whereby significant increases in interest rates were allowed to take place. A one-time break in the two price indices examined is detected in 1973 suggesting to the possible impact of first oil price shock on the level of prices. On the other hand, single breaks in monetary aggregates in 1975 and 1976 might have resulted from the growing budgetary borrowings of the government to finance a large increase in public sector investment during that period.

Lastly, it is important to recognize that the above results are derived through endogenously determining the presence of a single structural break. However, it can be argued that data may contain two structural breaks. Lee and Strazicich (2003) point out that considering only one break when in fact two are present can result in loss of power of the test. Therefore this analysis could be extended for the case of more than one structural break.

Moreover, a further direction of research relates to the proper identification of the source of structural breaks in each time series.

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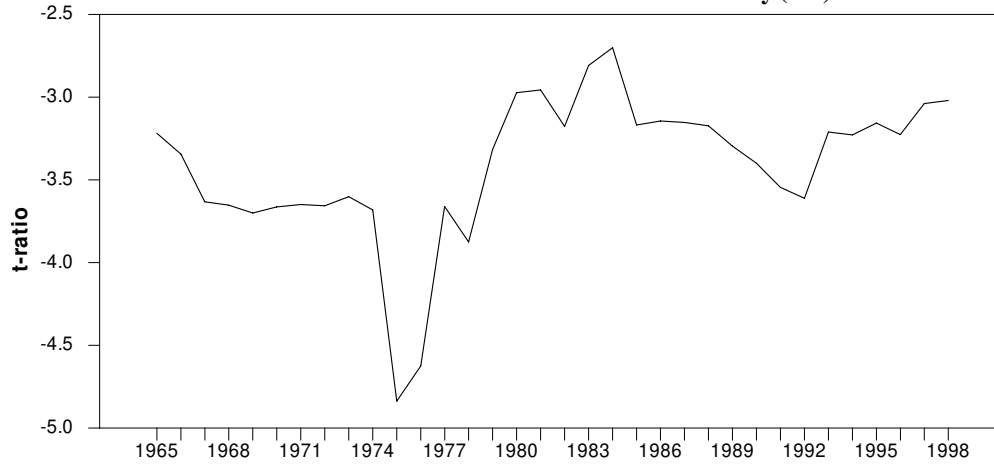
Zivot, E. and D. Andrews, (1992), Further evidence of great crash, the oil price shock and unit root hypothesis, *Journal of Business and Economic Statistics*, 10, 251-270.

Plots of Estimated timing of structural break by Zivot-Andrews procedure

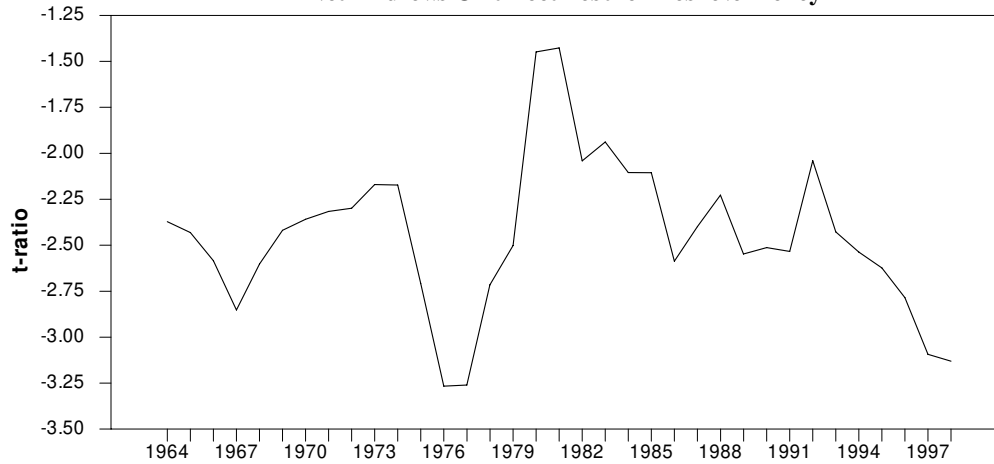
Zivot-Andrews Unit Root Test for Nominal GDP



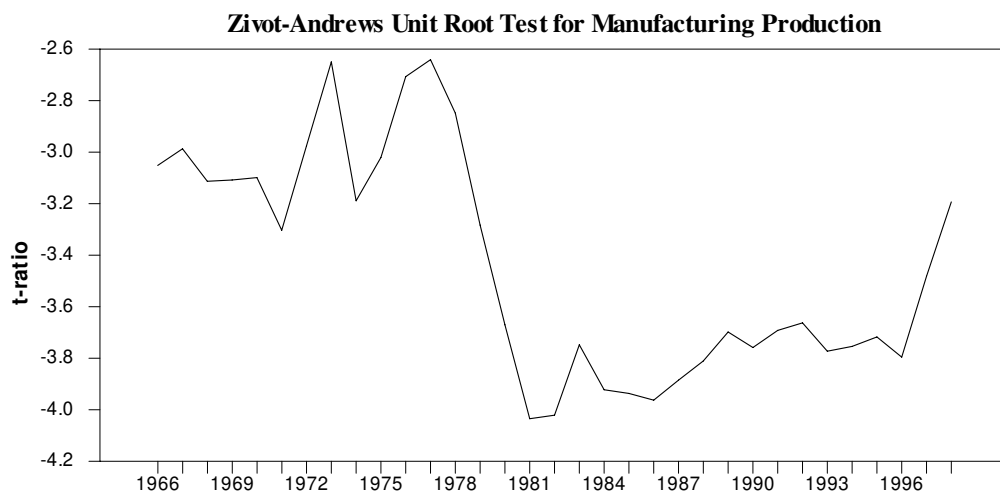
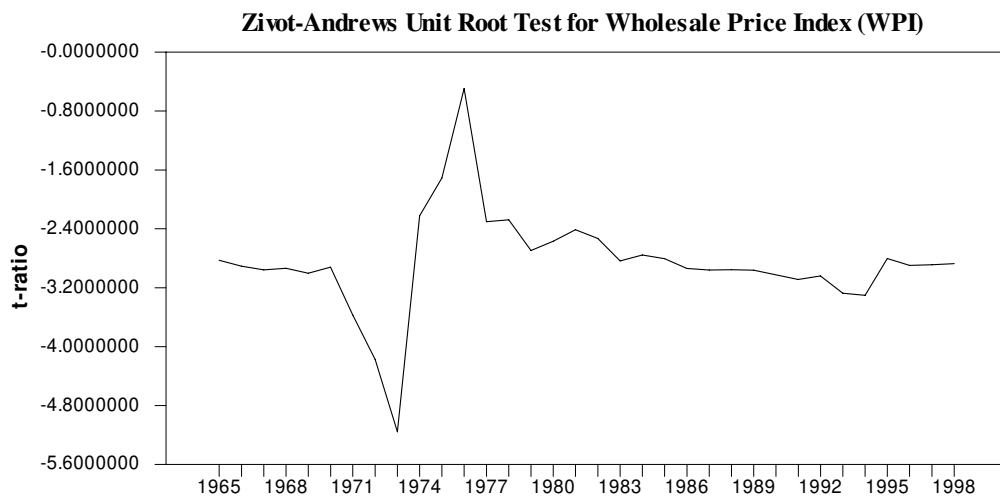
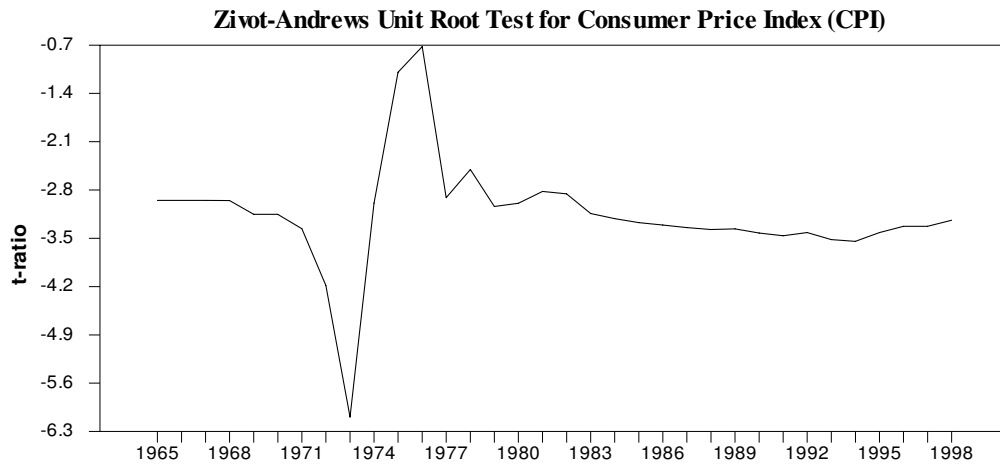
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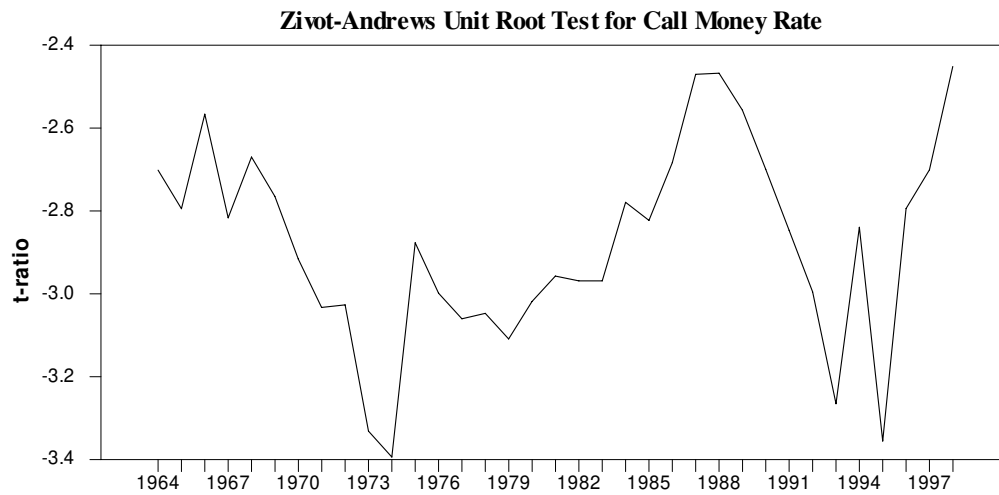
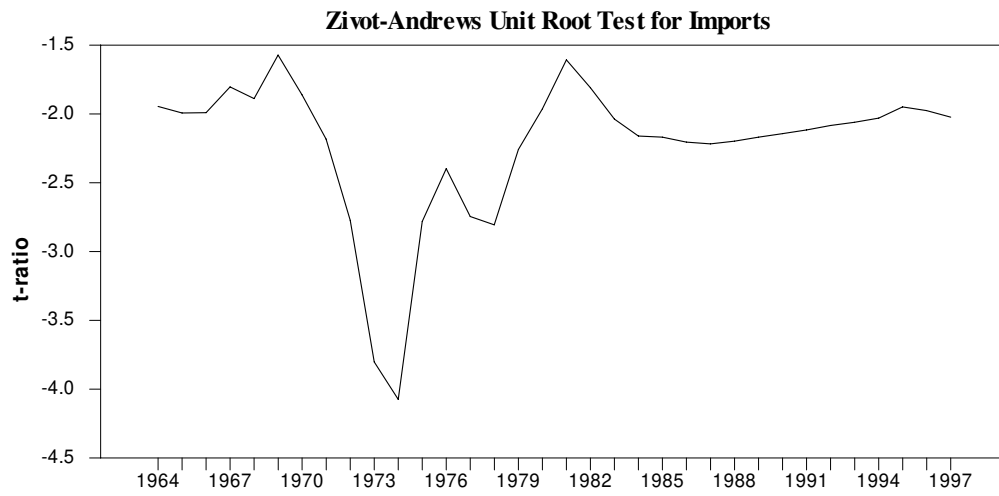
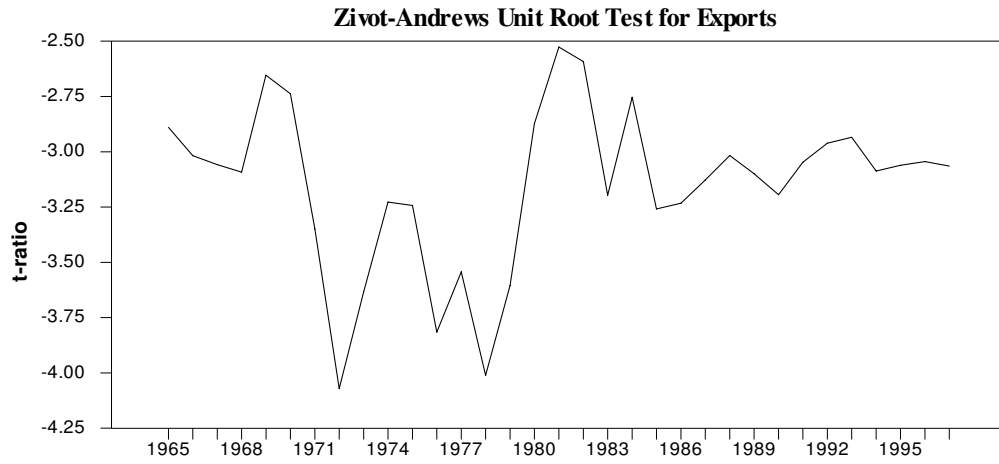
Zivot-Andrews Unit Root Test for Resreve Money



Plots of Estimated timing of structural break by Zivot-Andrews procedure



Plots of Estimated timing of structural break by Zivot-Andrews procedure



Plots of Estimated timing of structural break by Zivot-Andrews procedure

Zivot-Andrews Unit Root Test for Total Revenue



Zivot-Andrews Unit Root Test for Total Expenditure

