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A Time Series Anaylsis Of Autoregressive Distributed Lag (ARDL) To Co Integration Technique: The Results Applications

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Abstract

This research examines Autoregressive Distributed Lag (ARDL) to co integration technique and its theoretical background, advantages, application, interpretation and problems of ARDL to co integration approach. ARDL approach to co integration technique has flexible behavior about variables, can be applied in the presence of same or different stationary order or mutually integrated. This approach has a compulsory condition that none of variable in the model should be at second difference. This technique is applied on time series dataset while time series dataset has to face unit root problems. In the presence of unit roots problems the forecasting model gives the spurious results. The bound test (Wald test) or F-statistics reflects the long run relationship of the variables. The value of F-statistics exceeds the lower and upper limits at 90% and 95% confidence interval represents the co integration among variables exists in long run. In case of low value of bound test shows absence of co integration. Error Correction Mechanism is used for the picture of short run results. The negative value of ecm (-1) represents the model is highly significant and convergence towards equilibrium. The Lagrange Multiplier test for serial correlation and Ramsey Reset test for correct functional form is used in diagnostic test scenario. The value of F-version and LM-version is more than 10% or 5% fulfills all the assumptions of Ordinary Least Square. Pesaran and Pesaran (1977) applied the stability test if the plot of CUSUM and CUSUM sum of square lies in between 5% critical bound limits showed model is stable without structural breaks.

Keywords: ARDL Approach; Bound Test; Error correction Mechanism; Unit Root Tests; Stability

INTRODUCTION

The econometric forecasting of time series model suggests that it can be used for model forecasting. The estimated results are meaningful to formulate the policies purposes. It is possible only when time series is stationary with constant mean and variance and independent from time. Stationary data removes deterministic trend with time and put the model on the path of long run which trend does not depend upon time and co integration of the model becomes possible. But mostly time series dataset has revealed divergence features farther and farther away from their mean over time is called none stationary. Non-stationary data is the problem, unpredicted and cannot be used in model forecasting because none stationary series has no behaviour towards long run deterministic path. The variance of series becomes time dependent in the presence of no stationary series and the results of estimated model may be misleading and spurious. To overcome this problem the ARDL to co integration technique is operated at first difference hence corrects the problem of omitted variable, serial correlation and endogenity and autocorrelation and provides unbiased estimation of parameters. The variables are co integrated in log run and meaningful forecasting becomes possible. Mostly researchers are not well conversant with conditions of ARDL technique to co integration that it is crushed in the presence of I (2) and results and interferences of model forecasting becomes misleading and spurious.

In applied econometric there are three approaches to co integrations names are Engle Granger technique to co integrated, Johnson Likelihood approach to co integration and ARDL technique to co integration. Engle Granger technique includes limited variables only up to two has limited scope in application of model forecasting. Johnson Likelihood approach can be employed only when all variables are at first difference I (1) and efficient on for large sample size. Auto Regressive Distributed Lag (ARDL) technique was first time introduced by Pesaran (1997). Later, the other economists Pesaran and Shin refined and applied it on small and large sample size dataset in 2001. The results of t-tests are more reliable if it is estimated by ARDL technique and it is efficient not in case of small sample size as well as large sample size.

The division of this paper is portioned into five sections. Section one consist of Introduction. Section two, explains the concept of unit root problems and tests in term of stationary and none stationary. Section three reviews the historical background of ARDL approach to co integration. Section four contains bound test (long run), error correction mechanism (short run) and stability test. Section five concise the summary and conclusion of the study.

2. UNIT ROOT STOCHASTIC PROCESS

The white noise or random walk Model is as

$$Y_t = \rho Y_{t-1} + u_t \ldots\ldots\ldots$$

Where the value of ρ lies $-1 < \rho < 1$

Without drift, ρ = 1, in this situation time series of random walk is non stationary represents the unit root issue variance Yt is not stationary. Yt becomes stationary only, when $|\rho|<1$ and error term is said to be random walk or white noise. The series is normally distributed with 0 mean and unit variance. In econometric it is expressed as

$$E\,(Yt) = 0 \text{ and } Var\,(Yt) = 1/(1-\rho^2)$$

In the presence of first difference $(\boldsymbol{Y_t + Y_{t-1}})$, the series is non stationary and random walk process face unit root problem. Non-stationary data is the problem, unpredicted and cannot be used in model forecasting because non stationary series has no behaviour towards long run deterministic path. The variance of series becomes time dependent in the presence of non stationary series and the results of estimated model may be misleading and spurious. So to get consistent, reliable and efficient results, the data demands for transforming from non-stationary into stationary. The stationary data converts the variable variance and mean into constant variance and mean i-e independent of time. It also remove deterministic trend with time and put the model on the path of long run which trend does not depend upon time and co integration of the model becomes possible.

3. DICKEY FULLER TEST (DFT)

Let Y_t is random stochastic process

$$Y_t = Y_{t-1} + \varepsilon_t$$

Now the regression model is constructed as

$$Y_t = \rho_1 Yt_{-1} + \varepsilon_t$$

Y_{t-1} subtract on both sides of the equation

$$Y_t - Y_{t-1} = \alpha_1 Y_{t-1} - Y_{t-1} + u_t$$

$$\Delta Y_t = Y_{t-1}(\alpha_1 - 1) + u_t$$

$$\Delta Y_t = Y_{t-1}(\alpha_1 - 1) + \alpha_2 T + u_t$$

Now α_1-1= ρ_1

ΔY_t = First Difference

t = Represents trend

u_t = white noise

$$\Delta Y_t = \rho_1 Y_{t-1} + u_t$$

With drift $\Delta Y_t = \alpha_0 + \rho_1 Y_{t-1} + u_t$

Now if $\rho_1 = 1$ means that the series is no stationary and parameters will be explosive, when $\rho_1 > 0$ and $\rho_1<1$ represents the time series will be stationary with zero mean (Emeka Nkoro and Aham Kelvin Uko, 2016).

If the DF and ADF statistic value is less than critical value represents the time series is no stationary. The calculated value of DF and ADF statistics exceeds the critical values at 1%, 5% and 10 %, the series will becomes stationary. In case of non stationary the null hypothesis cannot be rejected while stationary series rejects the null hypothesis and accepts the alternative hypothesis. These results of DF and ADF can be confirmed by applying the others tests like (Kwaitkowski Phillips-Schmidt-Shin and Perron 1992) and Philips and Philip Perron test, ADF test have same null hypothesis but KPSS has different null hypothesis. KPSS test does not determine the p-value but provides the different critical values. In KPSS the test statistic value is matched with critical values at different significant level. If the KPSS statistic value is more than critical value, null hypothesis can be rejected otherwise not. The ADF test is better than other unit root tests like PP test and KPSS tests and it is used in a wider application of model estimation. The DF and ADF determine the autocorrelation in error term by joining the lagged difference term of dependent variable. While the PP takes in account only autocorrelation in error term but test static of both is the same. However, ADF Test is easy applicable and commonly used in estimation of modelling (Dickey-Fuller test 1979), (Augmented Dickey-Fuller 1981).

4. THEORETICAL BACKGROUND OF AUTOREGRESSIVE DISTRIBUTIVE LAG (ARDL) TECHNIQUE TO CO INTEGRATION

Auto Regressive Distributed Lag technique approach was first time introduced by Pesaran (1996). Later, the other economists Pesaran and Shin (2001) refined and applied it on small and large sample size dataset. This technique is better than other approaches because of many reasons. Engle Granger technique includes limited variables only up to two hence it cannot be applied on this model because it included many of variables. The other two techniques to co integration could be applied if the model was having a numbers of explanatory variables. But theoretical background ARDL Technique confirmed preference of this technique over to Johnson Likelihood approach for many benefits.

1) The variables which are having different orders like at level or first difference I (0) and I (1) or both mixed, the ARDL technique can be applied on them. But Johnson Likelihood approach can be employed on specific order of first difference I (1). ARDL technique has the characteristic of flexibility in ordering.
2) ARDL approach IS more consistent, accurate and reliable results in case of small sample size as well as large sample size than Johnson Likelihood approach. Further results of t-test are more reliable if it is estimated by ARDL technique. Johnson technique is efficient only in case of large sample size.
3) ARDL technique is better in performing and efficient in estimating for co efficient and keeps us at distance from the problems caused by serial correlation and endogenity. It also overcomes the problem of omitted variable and autocorrelation and provides unbiased estimation of parameters.

So because of such major qualities ARDL technique to co integration is preferred to other techniques in the model.

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5. PRECONDITIONS FOR OPERATING ARDL TO CO INTEGRATION TEST

(1) In ARDL model, pretesting of variables whether they are at I(0) or I(1) classification of into level or first difference is not necessary when underlying variables are showed in single equation. The compulsory condition for application of ARDL is that none of variable in specified model should not be at 2^{nd} difference. Otherwise it can be applied.

(2) When sample size is finite or small and large long run relationship among variables exist the Bound Test (Wald Test) is applied. Further the error correction reflection becomes more efficient than others estimation.

(3) In the presence of multiple long run relationship, ARDL gives the spurious or misleading results. If dependent variable of single equation is sourcing feedback effect from other variables the case will be tackled with multiple long run relationship. Hence alternative method to estimate the co integration is Johansen co integration test introduced by Juselius (1990).

(4) If there exists single long run relationship with maximal Eigen value, ARDL approach is appropriate for application otherwise, the alternative method of multi variation co integration will be applied

6. AUTO REGRESSIVE DISTRIBUTED LAG MODEL / DYNAMIC MODEL

In time series analysis when regression model involves the present value (x_t) and previous value of explanatory variables (x_{t-1}), the model is called distributed lag model. Further if model includes lagged values of dependent variable as explanatory variable the model form is constructed Auto Regressive Distributed Lag model. It is written as

$$Y_t = \beta_0 + \beta_1 X_t + \eta Y_{t-1} + u_{1t} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

The model is first order auto regressive distributed lag model AR (1). If the model includes two lags values of dependent variables the model is called 2nd order distributed lag model expressed as

$$Y_t = \beta 0 + \beta 1 X_t + \eta Y_{t-1} + ƛ Y_{t-1} + u_{2t} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (2)$$

Where t = 1, 2…... k

The model is 2^{nd} order auto regressive distributed lag model AR (2) or finite lag model. K is the length of the lag and it depicts the time path of dependent variables in the form lags.

Now we estimate the model with ARDL technique where pre testing of unit root test are not necessary. It is not pre requisite condition for ARDL approach but here the compulsory condition for ARDL that none of variable should be at second difference. It can be used or applied when all variables are at first difference I (1) or at level I (0) or mixed. It is an appropriate for small and large sample size and gives reliable and efficient modelling analysis (Narayan 2005).

$$y_t = \gamma_1 y_{t-1} \ldots\ldots . \gamma_m y_{t-m} + ƛ_0 x_t + ƛ_1 x_{t-1} \ldots\ldots + \eta_1 x_{t-m} + u_{1t} \quad \ldots\ldots(1)$$

$$x_t = \gamma_2 x_{t-1} + \ldots + \gamma_m x_{t-m} + ƛ_0 y_t + ƛ_1 y_{t-1} + \ldots + \eta_1 y_{t-m} + u_{2t} \ldots\ldots(2)$$

t= 1, 2, 3…..T

Here η, $ƛ_0$ and $ƛ_1$ are parameters in unknown nature, x_t or (y_t) is first difference from which process is created by

$$x_t = x_{t-1} + e_t$$

$$y_t = y_{t-1} + u_t$$

Here the error terms u_t and e_t are not correlated with each other in any time period or lag. So x_t or y_t are exogenous with respect error terms u_t and e_t, the case of linear stationary process.

7. LONG RUN RELATIONSHIP OF PARAMETERS / BOUND STATISTICS

For long run relationship we calculate the value of F-statistic or bound test for existence of co integration among variables. Pesaran and Pesaran devised two set of critical tabulated values but critical values of the bound test have different standard distribution. The upper critical value of bound test implies that all variables are at first difference I (1) while lower critical value of bound test explains that all variables at level I (0). If critical value of bond test exceeds from upper limit of critical value then null hypothesis Ho is rejected and represents the presence of Long Run co integration among variables whether the variables are at first difference or level. If calculated value is lower from critical bounds then H_0 cannot be rejected and co integration between variables is absence. If the value of bound test lies between lower critical bound and upper critical bound values the F-test is inconclusive. Critical values are made by Pesaran and Pesaran (1997) for large samples up to 500 observations.

The test is applied on each of endogenous while others consider as the exogenous variables. To test the long run relationship among forcing variables, the ARDL model postulate the hypothesis to test the long run relationship among variables. During this process the current values of given variables are omitted from ARDL model of co integration.

$$y_t = \gamma_1 y_{t-1} \ldots\ldots \gamma_m y_{t-m} + \lambda_0 x_t + \lambda_1 x_{t-1} \ldots\ldots + n_1 x_{t-m} + u_{1t} \quad \ldots\ldots(1)$$

$$x_t = \gamma_2 x_{t-1} + \ldots + \gamma_m x_{t-m} + \lambda_0 y_t + \lambda_1 y_{t-1} + \ldots + n_1 y_{t-m} + u_{2t} \ldots\ldots(2)$$

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t= 1, 2, 3…..T

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Here , λ_0 and λ_1 are parameters in unknown nature, x_t or (y_t) is first difference from which process is created by

$$x_t = x_{t-1} + e_t$$

$$y_t = y_{t-1} + u_t$$

Here the error terms e_t and u_t are not correlated with each other in any time period or lag. So x_t or y_t are exogenous with respect error terms u_t and e_t, the case of linear stationary process. The stability condition of co integration which the absolute value $\eta < 1$ reflects the stability of the model and shows that there is strong long run relationship between y_t (x_t) and x_t (y_t). The stationary assumption of first order AR (1) is similar to co integration test. The ARDL

Approach to Co Integration Test is as

$$\Delta X_t = \omega_{0i} + \sum_{i=1}^{n} \propto_i \Delta X_{t-1} + \sum_{i=1}^{n} \propto_2 \Delta Y_{t-i} + \omega_1 X_{t-1} + \omega_2 Y_{t-1} + u_{1t}$$

$$\Delta Y_t = \omega_{0i} + \sum_{i=1}^{n} \propto_1 \Delta Y_{t-1} + \sum_{i=1}^{n} \propto_2 \Delta X_{t-i} + \omega_1 Y_{t-i} + \omega_2 X_{t-1} + u_{1t}$$

In ARDL model n represents the number of maximum laps or lags. The calculated value of F-Statistics can be applied on the null and alternative hypothesis if the coefficients of lagged variables $(\omega_1 X_{t-1} \omega_1 Y_{t-1})$ or $(\omega_1 Y_{t-1}(\omega_1 X_{t-1})$ are equal to zero, the difference $\omega_1 - \omega_2$ reflects long run relationship while the difference $\propto_1 - \propto_2$ *shows* the short run relationship of the time series model.

Now test the hypothesis of the coefficients that their lag values are zero or not we apply the null and alternative hypothesis. The null hypothesis represents the nonexistence long run relationship among parameters while the alternative hypothesis expresses the presence of long run relationship of variables of the model. Now we postulate hypothesises of my research are as

The governance base model the hypothesis is manipulated is as.

Ho: $\delta 1 = \delta 2 = \delta 3 = \delta 4 = \delta 4 = \delta 5 = 0$ (No co integration among variables exist)

H1: $\delta 1 = \delta 2 = \delta 3 = \delta 4 = \delta 4 = \delta 5 \neq 0$ (Co integration among variables exist)

In my study I prefer ARDL-Schwartz Information Criterion to choose the order of ARDL technique in the long run. Because in Pesaran and Shin (1997) conduct research for comparison SIC and AIC in Monte Carlo empirical study and found that ARDL & AIC provide the same result in case of small sample size . But they concluded that ARDL-SIC gives better results than ARDL-AIC in case of large sample size. Hence it is said ARDL technique is considered consistent, unbiased and reliable in efficient modelling.

In ARDL technique the diagnostic test like serial correlation, normality, functional form and hetroscedacity are also displayed by software and require satisfying the classical assumptions of least square because ARDL is also OLS.

Brown, Durbin and Evans (1975) constructed a test for confirmation of stability of short run variables as well as long run coefficients. Pesaran and Pesaran (1977) applied the stability of parameters test practically and confirm if the plot of CUSUM and CUSUM sum of square lies in between 5% critical bound.

8. ERROR CORRECTION MODEL/ SHORT RUN RELATIONSHIP OF THE MODEL

Error correction model analysis of regression conveys the information of short run relationship of coefficients. But here the concept of co integration and ECM becomes more important in error correction model of co integration because it resolves the short run and long run analysis incorporated with help of error correction model. In ARDL model when without stationary variables are regressed they may give spurious results. So this problem can be resolved by taking first difference of the data which confirms the stationary problem of the data.The spurious results of regression may be corrected and meaningful model will be achieved. ARDL technique is attached with unrestricted error correction model. The model form can also be written in first difference and lagged forms of y_t.

$$\boldsymbol{y_t = \Delta y_t + y_{t-1}}$$

$$y_{t-1} = y_t - \sum_{m=1}^{s-1} \Delta y_{n-m}$$

S= 1, 2, 3,……. p

In same way

$$\boldsymbol{w_t = \Delta w + w_{t-1}}$$

$$\boldsymbol{x_t = \Delta x_t + x_{t-1}}$$

$$x_{1t-s} = y_{it-1} - \sum_{m=1}^{s-1} \Delta x_{it-j}$$

S=1,2,3……p

Substituting these in this equation

$$\eta(L,p)y_t = y_t - \sum_{i=1}^{k} \Delta x_{it+} \lambda w_t + u_t$$

$$\Delta y_t = \eta(1-p)ECM_{t-1} + \sum_{i=1}^{k} \boldsymbol{\beta_{i0}} \Delta x_{it} + \boldsymbol{\lambda_j \Delta_{t-j}} - \sum_{i=1}^{k} \sum_{j=1}^{p-1} \boldsymbol{\beta_{ij}} \Delta x_{i,1-j} + u_t$$

Error correction equation is defined and written as

$$EC_t = \mathcal{E}_t = y_t - \sum_{i=1}^{k} \Delta \theta x_{it-j} - \eta w_t$$

The $\eta(L,p) = 1-\hat{}\eta_1-\hat{}\eta_2-\hat{}\eta_3\ldots\ldots\ldots-\hat{}\eta_p$ informs the usefulness of the error term. The other parameter λ_j *and* β_{ij} conveys dynamics of short run model which converge to equilibrium. The residuals of error are calculated from the estimated model of co integration 1 and 2above. OLS technique can also measure the ARD and error correction model.(Reference)

Juselius introduced error correction model to investigate the short run co integration of the variables. If the coefficient ECM is negative short run co integration of parameters exists and such relationship is highly significant and ECM also shows the adjustment coefficient.

Short run dynamic can be explained by ECM and negative value of error correction model represents the highly significant and existent of co integration. It also shows long run seasonally effect. The negative symbol of the adjustment coefficient also provide guarantee of stability of the model in short run and long run equilibrium.

Feedback effect or error correction term of adjustment parameter is obtained the errors term of 1and 2 model of co integration and their coefficient are on X_t and Y_t. Error correction dynamic reflects that how adjustment of disequilibrium is corrected. The positive value of adjustment coefficient represents the divergence of disequilibrium and negative value of this coefficient is the sign of convergence. If the estimated value of ECM (-1) confirms 100% adjustment takes place within the same period and it will be instantaneous. If the value of ecm (-1)is .05, the 50% adjustment from disequilibrium to equilibrium will take place in the model. In case the ecm(-1) = 0 shows no adjustment of the model and long run relationship will become spurious.

These specified variables can be tested in the model and are represented as

FX (X1│Y1. . . . . ….Yn)

Fy (Y1│X1,. . . . . ….. Xn)

Where n represents the maximum number of lag

The first step in ARDL approach to co-integration is to examine long-run relationship among the variables by carrying out familiar F-statistic on the differenced variables. To create error correction mechanism in this equation, first lag of the level of each variable is added to the equation and variables Addition Test is conducted by calculating F-test on the joint significance of all the added lagged level variables.

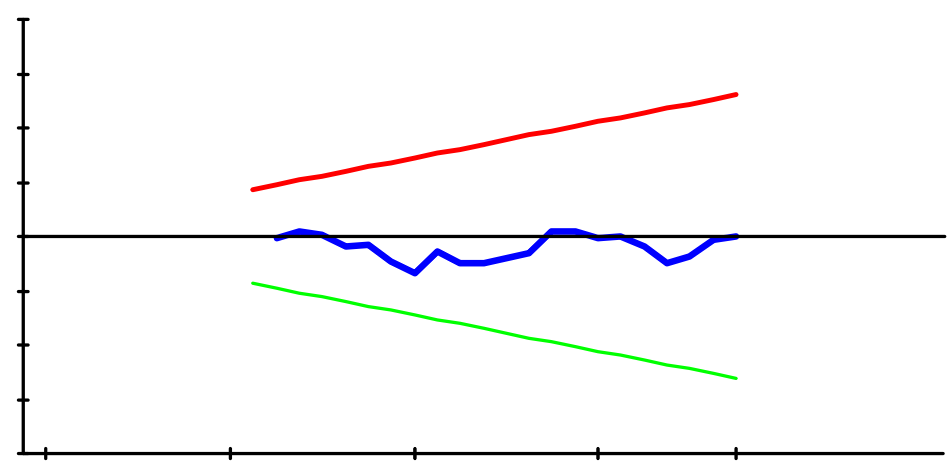
Pesaran and Pesaran (1997) construct two sets of critical tabulated value with different standard distribution. The upper critical value of bound test explains that variables are at first difference I (1) while lower critical value of bound test implies that all variables at level I (0). If critical value of bond test is above from upper limit of critical value then null hypothesis Ho is rejected and represents the presence of Long Run co integration among variables exist whether the variables are at first difference or level. If calculated value of F- statistics is lower from critical bounds then H_0 cannot be rejected and co integration between variables is not present. If the value of bound test lies between lower critical bound and upper critical bound values the F-test is inconclusive.

9. STABILITY TEST

Brown, Durbin and Evan (1975) purposed stability test for confirmation structural stability of the model in short run variables as well as long run coefficients. Pesaran and Pesran (1977) employed the test practically, if Cumulative Sum of Recursive Residuals line lies in between 5% critical bound limits and the graph of CUSUM sum of square line also lies in between 5% critical bound limits which confirms the absence of breaks of the model and confirms structural stability of the model in short run as well as long run.

Stability Test

Diagram



Stability Test

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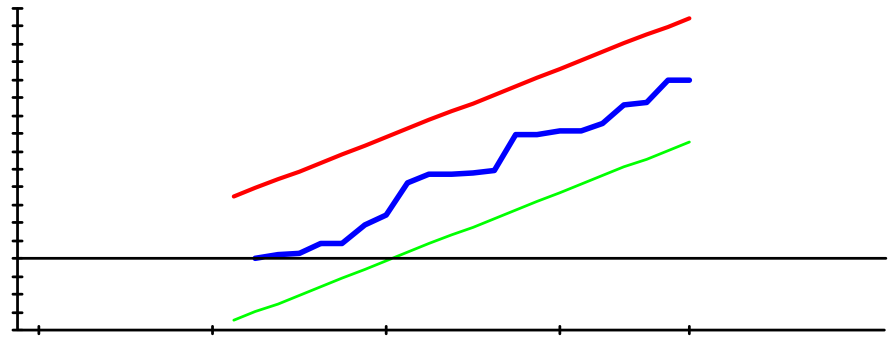
TABLE 4.1.3



10. CONCLUSION

The Engle Granger technique to co integration and Johansen technique to co integration technique has many drawbacks. So against this background, Pesaran and Shin (1999) and Pesaran et al (1996b) introduced ARDL approach to co integration or F-Statistics or Bound Test for long run co integration among variables. Some major deficiencies in these techniques were as. The Engle Granger technique to co integration includes only two variables in application and Johansen technique to co integration technique can be applies when one co integration vector exists or having stationary order of I (I). The ARDL approach to co integration can be applied when variables are all at level I (0) or at first difference I(I) or both of mixed. Pretesting condition of the unit root test is not compulsory but it crashes in the presence of I (2). The ARDL technique to co integration has many superior features than other techniques and is interpreted as:

1. The variables which are having different orders like at level or first difference I (0) and I (1) or both mixed, the ARDL technique can be applied on them.
2. ARDL approach results are more consistent, accurate and reliable in case of small sample size as well as large sample size while Johnson technique is efficient only in case of large sample size.
3. ARDL also overcomes the problem of omitted variable and autocorrelation and provides unbiased estimation of parameters.
4. Pesaran and Pesaran has devised two set of critical tabulated values, the upper critical value of bound test implies that all variables are at first difference I (I) while lower critical value of bound test explains that all variables at level I (0). If critical value of bond test exceeds from upper limit of critical value then null hypothesis Ho is rejected and represents the presence of Long Run co integration among variables
5. When sample size is finite (n≤ 30) or small and large long run relationship among variables exist the Bound Test (Wald Test) is applied. Further the error correction reflection becomes more efficient than others estimation.
6. Error Mechanism reflects the picture of short run results and negative Value of ecm(-1) is the sign of convergence of the model towards equilibrium with highly significance.
7. In the presence of multiple long run relationship, ARDL gives the spurious or misleading results. Hence alternative method to estimate the co integration is Johansen co integration test introduced by Juselius (1990).
8. However, to avoid crashing of the ARDL technique and, effort in futility, it is advisable to tests for unit roots since variables that are integration of order I (2) leads to the crashing of the technique.
9. Pesaran and Pesaran (1977) applied the stability of parameters test practically and confirm if the plot of CUSUM and CUSUM sum of square lies in between 5% critical bound limits. The model will be stable and no structural breaks in the model.
10. If the trace or Maximal Eigen value or the F-statistics establishes that there exists a single long-run relation among the variables (i.e underlying variables), ARDL approach can be applied rather other than not applied.

This research work on ARDL approach to co integration is leading knowledge for the coming researchers. To handle time series model this technique is the biggest discovery of 21th century. The study will avoid the young researchers from wrong application, interpretation and estimation of modeling. The ARDL co integration technique will also be proved helpful in applying, estimating and interpreting the results of time series analysis.

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