ARDL MODEL BOUNDS TEST APPROACH: THE CASE OF TURKEY

ARDL MODELİ SINIR TESTİ YAKLAŞIMI: TÜRKİYE ÖRNEĞİ

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ABSTRACT

ARDL MODEL BOUNDS TEST APPROACH: THE CASE OF TURKEY

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In the econometric literature, ARDL bounds testing approach proposed by Pesaran and Shin [16], improved Pesaran et al. [17], and Toda-Yamamoto causality procedures [12] are widely used in empirical analysis because the outcomes of these tests are more likely to be convincing than their predecessors. The most important distinguishing features of both tests are to necessitate none of prerequisites like stationarity or co-integration analyses. Nevertheless, the number of theoretical studies on these co-integration and causality procedures are not sufficient. The primary purpose of this thesis study is thoroughly to examine the issue in framework of the co-integration analysis and the error correction model within the autoregressive distributed lag model. As a second objective of this thesis, Toda-Yamamoto causality procedure is comprehensively reviewed within a sound theoretical basis. In the empirical part of the thesis, the validity of a level relationship between saving and investment rates for Turkish economy over the period 1970-2015 is analyzed by using ARDL bounds co-integration testing and Toda-Yamamoto causality testing approaches. The result from ARDL bounds testing procedure confirms that there are both long-run and short-run relationship between domestic saving and domestic investment whilst there is no causal relationship neither from saving to investment nor from investment to saving.

Keywords: ARDL Model, Bounds Test, Co-integration, Tado-Yamamoto, Causality, Feldstein-Horioka Hypothesis.

ÖZET

ARDL MODELİ SINIR TESTİ YAKLAŞIMI: TÜRKİYE ÖRNEĞİ

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Bu tezin esas amacı, Gecikmesi Dağıtılmış Otoregresif Modeli (ARDL) – Sınır testi Yaklaşımı ve Toda-Yamamoto nedensellik analizi, istatistiki ve ekonometrik yönüyle incelenmesidir. Bu iki ekonometrik model, uygulamalarda sıkça kullanılmasına rağmen, teorik yapılarını inceleyen çok az çalışma vardır.

ARDL sınır testi yaklaşımı değişkenler arasındaki uzun dönem ilişkilerin araştırılmasında son yıllarda yaygın olarak kullanılan Pesaran ve Shin [16] ve Pesaran ve diğerleri [17] tarafından geliştirilmiş bir eşbütünleşme yöntemidir. Bu yaklaşımının en önemli avantajı değişkenlerin bütünleşme dereceleri dikkate alınmaksızın değişkenler arasında eşbütünleşme ilişkisinin var olup olmadığının araştırılabilmesidir. ARDL sınır testi, modeldeki serilerin ikinci farkı alındığında durağan olmaması kısıtı dışında, bütünüyle düzey halinde durağan ve birinci farkı alındığında durağan ve ya hepsinin karşılıklı eşbütünleşik ve birinci farkı alındığında durağan olup olmadığına bakılmaksızın uygulanabilmektedir [17]. İkinci farkı alındığında durağan olan verilerin kullanılamamasının nedeni ise, ikinci farkı alındığında durağan olmaları halinde, karşılaştırılabilecek kritik değerleri üretilmemiş olmasıdır. Bir diğer avantajı ise, küçük ve sınırlı örneklem kümeleri için oldukça etkin ve yansız tahminler vermesidir. ARDL yaklaşımında kısıtsız hata düzeltme modeli kullanıldığından, diğer klasik eşbütünleşme testlerine göre daha iyi istatistiksel özelliklere sahiptir ve güvenilirdir. ARDL sınır testi yönteminin bir diğer önemli özelliği ise, tek denklemli eşbütünleşme testidir. Yani, açıklayıcı (bağımsız) değişkenler içsel olduğu ve açıklanan (bağımlı) değişkenin ise dışsal olduğu varsayılır. ARDL eşbütünleşme yöntemi, modeldeki uzun ve kısa dönem katsayıları aynı anda tahmin edilebilme özelliğine sahiptir. Örneklem sayısı T olmak üzere, elde edilen kısa dönem katsayılar, tutarlı iken uzun dönem katsayılar ise süper tutarlıdır. Ayrıca, ARDL sınır testi tekniği, her bir değişkenin farklı sayıda gecikme uzunluğuna

sahip olmasına izin verir. Optimal gecikme uzunluğunun seçilmesi önemlidir çünkü bu yolla, içsellik problemi ve hataların otokorelasyon probleminin üstesinden gelinebilir. ARDL sınır testi yaklaşımı temel olarak 3 aşamadan oluşmaktadır. İlk aşamada kısıtsız hata düzeltme modeli (UECM) oluşturulur. İkinci aşama olarak, Akaike veya Schwarz gibi bilgi kriterleri kullanılarak, model için uygun gecikme uzunluğu p değeri bulunur. En küçük değeri sağlayan gecikme uzunluğu, modelin optimal gecikme uzunluğudur. Optimal p değeri hesaplandıktan sonra, eşbütünleşme ilişkisinin yokluğunu ifade eden temel hipotezi, Wald ya da F testi kullanılarak test edilir. Hesaplanan F istatistiği Pesaran vd. [17]'deki tablo alt ve üst kritik değerleri ile karşılaştırılır. Eğer hesaplanan F istatistiği alt kritik sınır değerinden küçükse, seriler arasında eşbütünleşme olmadığına karar verilir. Hesaplanan F istatistiği alt ve üst kritik sınır değerleri arasında ise kesin bir yorum yapılamamaktadır. Hesaplanan F istatistiği üst kritik sınır değerinden büyük ise seriler arasında eşbütünleşme ilişkisinin olduğu sonucuna ulaşılır. Eşbütünleşme ilişkisinin varlığı gösterildikten sonra, uzun ve kısa dönem ilişkiler olup olmadığını belirlemek için ARDL modeli kurulur. ARDL modelinde uzun dönem katsayılarını elde etmek için kullanılacak toplam dinamik model denkleminin sayısının belirlenmesinde, m maksimum gecikme sayısı ve k modeldeki bağımlı ve bağımsız toplam değişken sayısı kullanılarak hesaplanır. Modeldeki gecikme sayısı, bilgi kriterlerinden biri kullanılarak karar verilir. En küçük kareler tekniği kullanılarak uzun dönem ARDL modeli tahmin edilir. Değişkenler arasındaki kısa dönem ilişki ise ARDL modeline dayanan hata düzeltme modeliyle elde edilmektedir. Hata düzeltme modeli ile elde edilen hata düzeltme terimi, ECT, katsayısının istatistiksel olarak anlamlı ve 0 ile -1 arasında olması halinde söz konusu değişkene ait olan ECT katsayısı, kısa dönemdeki dengesizliğin ne kadarının uzun dönemde düzelebileceğini söyler.

Eşbütünleşme analizinin yanı sıra, değişkenler arasındaki nedensellik yapısını anlamak ekonomide önemlidir. Bu yüzden nedensellik analizi de tezde incelenmiştir. Klasik nedensellik analizlerinde en büyük sorun kullanılan değişkenlerin aynı seviye de durağan ve aralarında eşbütünleşme ilişkisi var olması beklenir. Bu sebeple herhangi bir önsel teste ihtiyaç duyulmadan, yani durağan olmayan ve eşbütünleşme ilişkisi olmayan seriler arasındaki nedensellik ilişkinin incelenebilmesi için Toda ve Yamamoto [12] tarafından bir test önerilmiştir. Bu önerilen nedensellik analizi gecikmesi arttırılmış VAR modeline dayanır. Yani, uygun gecikme uzunluğu (k) belirlenmiş standart VAR modeline, değişkenlerin maksimum bütünleşme sırası (dmax) kadar gecikme eklenir. Sonuç olarak, VAR(k+dmax) modeli tahmin edilir. Modelin ilk k parametresi için elde edilen Wald istatistiğinin asimptotik olarak k-serbestlik dereceli ki-kare dağılımına sahiptir. Eğer Wald istatistiği anlamlı bulunursa, değişkenler arasında Granger Nedenselliği olmadığı sıfır hipotezi reddedilir.

Tezin uygulama bölümünde, Türkiye'de Feldstein-Horioka hipotezinin geçerliliği test edilmiştir. Feldstein-Horioka hipotezi [25] kısaca yurtiçi yatırımların, yurtiçi tasarruflara karşı duyarlı olduğunu söyler. İlk kez Feldstein ve Horioka [25] tarafından 1960-1974 yıllarına ait 16 OECD ülkesinin tasarruf ve yatırımları arasındaki ilişkiyi araştırılmıştır. Nihai olarak, yurtiçi yatırımlar ve tasarruflar arasındaki ilişkinin gücü sermaye hareketliliği derecesinin bir göstergesi olduğu sonucuna varılmıştır. Türkiye'de Feldstein – Horioka hipotezinin geçerliliğinin test edildiği bu çalışmada 1970 - 2015 dönemi için yurtiçi yatırım, yurtiçi tasarruf ve gayri safi yurtiçi hasıla yıllık veriler kullanılmıştır. Optimal gecikme uzunluklarının

belirlenmesi sonucu ARDL(1,2) modeli kurulmuştur. Sınır testi sonucu olarak, değişkenler arasında eş bütünleşme ilişkisinin varlığı kanıtlanmıştır. Yurtiçi tasarruflarda yüzde 1'lik artış uzun dönemde yurtiçi yatırımlarda yüzde 0.5912'lik artışa neden olmaktadır. Buradan yola çıkarak uluslararası sermaye hareketliliği 0.5912'dir. Kısa dönemde ise, yurtiçi tasarruflarda yüzde 1'lik artış yurtiçi yatırımlarda yüzde 0.615'lik artışa neden olur. ARDL modeline dayanan hata düzeltme modeli tahmin edilmiştir. Hata Düzeltme katsayısı istatistiksel olarak anlamlı ve -0.722616 değerine eşittir. Buna göre, herhangi bir ekonomik şok olması durumunda bu etkinin bir sonraki yılda yüzde 0.722616 hızla düzeltildiğini göstermektedir. Yani uzun dönem dengeye hızlı bir şekilde ulaşılmaktadır. Sonuç olarak, Feldstein – Horioka hipotezi Türkiye ekonomisi için 1970-2015 dönemleri arasında geçerli olduğu ARDL sınır testi yaklaşımı ile gösterilmiştir. Aynı zamanda bu sonuçtan yola çıkarak, tasarruf ve yatırım arasındaki ilişki, sermaye hareketlerinin düzeyini güçlü bir şekilde açıklayabilir. Daha sonra da, Toda – Yamamoto nedensellik testi uygulanmış, fakat ne yurtiçi tasarruflardan yurtiçi yatırımlara doğru ne de yurtiçi yatırımlardan yurtiçi tasarruflara doğru bir nedensellik ilişkisi olduğu sonucuna varılamamıştır. Değişkenler arasında kısa ve uzun dönemli ilişkiler olmasına rağmen, nedensellik ilişkisi söz konusu olmadığı için, sadece kısa ve uzun dönemli ilişkilerin varlığı göz önünde bulundurularak uygulanan tasarruf teşvik edici politikalardan yeterli ve başarılı sonuç elde edilemeyebilir.

Anahtar Kelimeler: ARDL Modeli, Sınır Testi, Eşbütünleşme, Toda-Yamamoto, Nendensellik, Feldstein-Horioka Hipotezi.

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LIST OF ABBREVIATIONS

ADF	: Augmented Dickey-Fuller
AIC	: Akaike Information Criterion
AO	: Additive Outlier
ARDL	: Autoregressive Distributive Lag
BG	: Breusch-Godfrey
BP	: Breusch-Pagan
BRICS	: Brazil, Russia, India, China, South Africa
C	: Consumption
CLRM	: Classical Linear Regression Model
CUSUM	: The Cumulative Sum of Recursive Residuals
CUSUMSQ	: The Cumulative Sum of Recursive Residuals of Square
DF	: Dickey Fuller
DL	: Dolado-Lütkepohl
DW	: Durbin-Watson
ECM	: Error Correction Model
ELG	: Exportled Growth
F-H Hypothesis (puzzle)	: Feldstein Horioka Hypothesis (Puzzle)
G	: Government Expenditure
GDS	: Gross Domestic Saving
GDI	: Gross Domestic Investment
GDP	: Gross Domestic Product
GNP	: Gross National Product
HJC	: Hatemi Information Criterion
HQ	: Hannan-Quinn Criterion
I	: Investment
ILG	: Import-Lead-Growth
IO	: Innovational Outlier
J-B	: Jarque-Bera
LCU	: Local Currency
LM	: Lagrange Multiplier
M	: Import

MIST	: Mexico, Indonesia, South Korea, Turkey
MPS	: Marginal Propensity to Save
MWALD	: Modified Wald
NARDL	: Non-Linear Autoregressive Distributive Lag
NX	: Net Export
OECD	: Organisation of Economic Cooperation and Development
OLS	: Ordinary Least Squares
OSCE	: Organization for Security and Co-operation in Europe
PP	: Phillips Perron
PSS	: Pesaran, Shin and Smith
RECM	: Restricted Error Correction Model
RESET	: Regression Equation Specification Error Test
S	: Saving
SBC	: Schwarz Bayesian Criterion
TT	: Total Taxes
TO	: Trade Openness
TPS	: Transfers to the Private Sector
T-Y	: Toda-Yamamoto
TYDL	: Toda-Yamamoto and Dolado-Lütkepohl
UECM	: Unrestricted Error Correction Model
VAR	: Vector Autoregression
VECM	: Vector Error Correction Model
WDI	: World Development Indicators
X	: Export
Y	: Output (or Income)
YD	: Disposable Income

1. INTRODUCTION

Economic data sets are in various forms such as cross-sectional data, time series data and panel data, the most common one of which is in the form of time series which is defined a sequence of data points, comprising of consecutive observations on quantifiable variables, depended on a time interval [1]. Time series methods are statistical techniques that make use of past data so as to forecast future pattern or demand especially in the field of economics. It can be mentioned about two major objective of time series analysis, which are determination of the structure of the phenomenon expressed by the series of observed measurements, and the estimation of future values of the time series [2].

In time series, two significant analyses, which are co-integration and causality analyses, are conducted. In general, co-integration theory is a technique to investigate a long-run association between series that are not stationary. Although the time series are non-stationary, linear combination of these series may move together over time as if they are stationary. This case is called as a co-integrated relationship. Furthermore, it can be said that if two or more series are co-integrated, then they have a long-run, or an equilibrium relationship between them exists. As for the causality theory, economists and statisticians draw causal inferences and pay an attention on causality from the outlook of economic regulation assessment since causal parameters and conclusions in the field of finance are motivated by questions concerning economy [3]. The concept of causality connotes that the power of one variable to estimate (and thus cause) the other. That is, more than one variables have a significant impact on one another with distributed lags. And moreover, this causal relationship can be seized through a VAR model [4].

In time series analysis, the initial step is to determine the order of the integration for the time series used. And then, statistical models for time series analysis are selected depending on the order of integration of the used series. The first case is that all series are stationary at level. In this case, classical linear regression model is applied so as to forecast the long-run values of the variables. Another case is that all variables are integrated of order 1. For this case, one of co-integration methods, which is first introduced by Granger [5] and improved further by Engle and Granger [6], Engle and Yoo [7], Phillips and Ouliaris [8], Stock and Watson [9], Phillips [10] and Johansen [11], is applied so as to estimate the long-run relationship among these variables. If there does not exist any co-integrated relation between variables, then VAR model is estimated. If it exists, then error-correction model (ECM) is estimated. The ECM is also classified in two sub-models: ECM for one endogenous variable and VECM for more than one endogenous variables. When the variables are stationary at both first or second difference, the vector autoregressive model is preferred. The other case is that all variables are stationary purely I(0), I(1) or I(0) and I(1), then ARDL bound testing model is applied in order to predict co-integrated relationships between these variables. And finally, in the case that all variables are stationary at I(0), I(1) and I(2), Toda Yamamoto model is used.

The general aim of the study is to investigate ARDL bounds testing approach and Toda-Yamamoto causality procedure in theoretical aspects. And another purpose of the study is to conduct an empirical analysis to determine the relationship between saving and investment of the Turkish economy by using the econometric methods which are analyzed in the first part.

2. LITERATURE REVIEW

The main objective of the literature review chapter is to provide information about both theoretical and empirical literature discussed in this thesis.

The first part of the literature review consists of all theoretical studies related to ARDL model, bounds testing approach and Toda-Yamamoto causality approach. The second part of the literature review comprises of the macroeconomic theory which has been used in the empirical analysis of this thesis. The theory, namely the Feldstein – Horioka hypothesis, which has found wide coverage in literature. In a large and growing econometric literature, all studies on the Feldstein – Horioka hypothesis for Turkish economy by using various econometric methods ranging from traditional co-integration approach to fractional co-integrating procedures, have chronologically been presented.

2.1. Theoretical Literature Review

The earliest discussion on ARDL modelling approach was first introduced by Charemza and Deadman [13]. First of all, the general form of autoregressive distributed lag model was defined and described. Then, they suggested that long-term association among time series could be estimated by means of autoregressive distributed lag model. And for that, unrestricted autoregressive distributed lag model was established. Finally, they came up with the argument that autoregressive distributed lag model and Engle-Granger co-integration method might be the same. The reason for this was explained in the way that these two techniques, initially, determine long-term association, and then, add the deviations from the long-term path, lagged properly, as the error correction procedure in the short-term equation [13].

Pesaran and Shin [14] aimed to analyze both the impacts of financial shocks on co-integrating associations in the framework of a multivariate VAR(p) model and the methods to measure the speed of convergence to equilibrium. Accordingly, they advanced a fundamental framework to examine the short-term and long-term properties of the equilibrium relationships. They preferred the persistence profile approach that was proposed by Lee and Pesaran [15]. This approach estimates the impact of shocks on the equilibrium or the co-integrating relations over time while studying on the various method to characterize the dynamics to converge to equilibrium. They finally concluded that the estimations of the persistence profile were normally distributed.

Pesaran and Shin [16] published a paper in 1995 and revised this paper in 1997. The paper shows how an autoregressive distributed lag model (ARDL) is used to examine long-term relationships. And they prove that the application of ARDL approach to co-integration procedure yields reliable results regardless of whether the underlying variables are I(0), I(1) or a combination of both. In addition to this, they compare the efficiencies and performances of ARDL and Phillips-Hansen procedures in the use of time series econometric modelling.

Pesaran, Shin and Smith [17] developed a new approach to co-integration test, namely the Autoregressive-Distributed Lag Bounds Test, which is practicable regardless of whether the regressor variables are I(0), I(1) or mutually co-integrated. To investigate the presence of a level relationship between variables, the suggested approach is predicated on a Wald or F-statistic to testify the null hypothesis that all coefficients of all lagged variables in a univariate equilibrium correction equation are zero. As well as the F-test, they also tabulated asymptotic critical value bounds of the t-statistic to test whether the coefficient on the lagged variables is statistically significant. They produced two sets of asymptotic critical value bounds for the F-statistic for five conditional ECM model cases according to the way that the deterministic components are specified: no intercept, no trend; restricted intercepts, no trend; unrestricted intercepts, no trend; unrestricted intercepts, restricted trends; unrestricted intercepts, unrestricted trends. And they provide the information on two sets of asymptotic critical values: when all regressors are purely I(1) and others are I(0). Finally, they show that the suggested test is consistent.

Narayan [18] argues that the critical values, based on large sample sizes generated by Pesaran et al. [17], cannot be used for small sample sizes. Therefore, the approximate critical values for the F-test are obtained from Narayan [18] who has re-estimated the lower I(0) and upper I(1) bound critical values suitable for a small sample size.

Hassler and Wolters [19] released a very significant paper conducting a co-integration analysis in the ARDL procedure. In that paper, they proposed to re-examine the parameterization and interpretations which are used for ARDL model. They demonstrated an overall derivation of this error correction model for co-integrated levels variables predicated on ARDL (p+1, q+1) model for the endogenous variable. And, the forecast of a co-integrated vector from an ARDL model was demonstrated to be equivalent to the Error-Correction Models. They finally conducted a Monte-Carlo study. From this study, they reached three important conclusions. The first one is that the power of the t-type co-integration test is similar to that of the F-type test. The second one is related to the case that Δx_t and the regression error have a correlation. In this case, the conditional model achieves an acceptable inference on the co-integrated vector depending on the normal approximation. The last and most significant one is that the conditional EC regression outperforms the unconditional one.

Shin, Yu and Nimmo [20] published a paper to demonstrate the derivation of a co-integrating nonlinear ARDL (NARDL) model. They clearly prove that the model is possible to be estimated by ordinary least square (OLS). And they accomplish to get valid and acceptable long-term inference with this NARDL bounds test approach. Similar to classic ARDL co-integration procedure, NARDL technique ignores the integration orders of the variables. Finally, they establish asymmetric dynamic multipliers that show the traverse between the short- and the long-term nonlinearities in the form of a graph.

McNown, Sam and Goh [21] introduced a bootstrap ARDL testing approach. They claim that many researchers apply this test in environment violating the underlying assumptions of the bounds testing framework, which is the most important disadvantage of this co-integration procedure even though the model has quite a few advantages. As an example of this violation problem of the assumptions, they say that despite the presence of the assumption that there does not exist any feedback at the levels from the dependent variable to independent variables, this assumption is violated because each of the variables is regarded as the dependent variable in a sequence of regressions on the others. Thus, the performance of the test is checked under violation of this assumption. They conduct Monte Carlo experiment, and they find that the violation of this assumption has no impact on the efficiency of the test results. And moreover, they make a comparison of the performance of the bootstrap and asymptotic tests in the ARDL model. In addition to this, they argue the problem concerning size distortions for the t-test on the lagged dependent variable. As an alternative approach, they suggest to use the ARDL test procedures depended on bootstrap simulations. In this way, the size problem is dealt with by re-producing critical values with bootstrap approaches. Finally, they point out the occurrence of degenerate cases.

As for causality analysis, Toda and Yamamoto [12] developed a causality analysis procedure based on VAR model. This new causality approach ignores both the presence of co-integration relationship among variables and the order of integration of the variables. Firstly, they estimate VAR($k+d_{max}$) where d_{max} is the maximum order of integration of variables and k is a lag length which is chosen based on any information criterion such as AIC, SBC or HQ. And they estimate Granger causality test in VAR($k+d_{max}$) framework. And VAR($k+d_{max}$) model guarantees the asymptotic χ^2 distribution of the Wald statistic.

Dolado and Lütkepohl [22] contributed to Toda-Yamamoto causality approach. The application procedure is similar to that of Toda-Yamamoto test, but VAR(k+1) model is estimated by OLS instead of VAR($k+d_{max}$) model. The obtained statistic which is asymptotically distributed as chi-square, and they define this as Modified Wald (MWALD) statistic. And they show the power properties of this modified test.

Hacker and Hatemi-J [23] developed a causality test that is an alternative version of Toda-Yamamoto causality approach. The most remarkable difference between these two approaches is that Hacker-Hatemi-J [23] causality test has a bootstrap distribution.

2.2. Empirical Literature Review

Erden [24] conducted a study on domestic private saving and investment interaction for Turkish economy over the time period of 1963-2002 by means of bivariate time series methods. And, the ratios of gross private investment and saving to GNP were obtained as the variables used in econometric analysis. No co-integration between these variables was found for the period from 1963 to 2002. And it was inferred that the absence of long-run relationship between these variables was the implication of the presence of either a high degree of capital mobility or unsustainability of current account throughout the period 1963-2002. Nonetheless, it was preferred to divide the sample period into two distinct subsamples, pre- and post-1980, because Turkish economists practiced reforms related to liberalization that made Turkish economy relatively open in 1980. As a result, the presence of co-integration is proved in the pre-liberalization period whereas the existence of this co-integration cannot be said for post- liberalization reforms. And accordingly, they conclude that these findings are consistent with the interpretation of the degree of capital mobility based on Feldstein – Horioka hypothesis purposed by Feldstein and Horioka [25].

Iyidogan and Balıkçıoğlu [26] utilized ARDL bounds testing approach to investigate the degree of capital mobility through the domestic saving-investment association. In this analysis, the annual data spans the time period of 1968 to 2008 for Turkey. They conclude that there is no evidence of a long-run saving-investment relationship although %39 of domestic investment is financed by means of the domestic saving in the short-term. In other words, they find that the Feldstein – Horioka puzzle does not exist for Turkey over the time period of 1968-2008.

Altıntaş and Taban [27] empirically explored the validities of the twin deficit hypothesis and Felstein-Horioka hypothesis using the annual data for Turkey from

1974 to 2010 by means of ARDL bounds testing approach and Toda-Yamamoto Granger causality test. Economists mostly utilize the concepts of twin deficits and the Feldstein-Horioka puzzle in order to show the long-run determinants of current account imbalances. The twin deficit hypothesis can be briefly defined as a macroeconomic argument that states the impact of budget deficit on current account deficit. In order to test the twin deficit and Feldstein-Horioka hypothesis, they used these variables like the ratio of current account deficit to GDP as a dependent variable, the ratio of budget deficit and the ratio of investments to the GDP as independent variables. As the result of the co-integration analysis, Turkish economy has a twin deficit problem. Moreover, that the fixed capital investment coefficient has a negative value and it is and less than 1 implies Feldstein-Horioka hypothesis is validated for Turkish economy. In addition to this, it indicates that Turkey could not be stated to achieve a complete integration into the global capital markets. And another important conclusion they reached is that one fifth of the investments are funded through external savings. As for the results of Toda-Yamamoto causality test, there is no causal relationship neither from the current accounts deficit to the budget deficit nor vice versa, which certifies that there is twin deficit in the analyzed period. On the other hand, unidirectional causal associations both from the investment to the budget deficit and from the current account deficit to the investment were demonstrated.

Mangır and Ertuğrul [28] carried out a study in order to find the relationship between domestic saving-investment and capital movements by for 16 OECD industrialized countries, including Turkey, in the years between 1998 and 2010. The domestic saving-investment correlations was assumed to follow decreasing trend in open economies under perfect international capital mobility while domestic investment was largely financed by domestic savings in closed economies without international capital mobility. The study was done by means of Kalman filter approach. Consequently, they proved the high correlation between investment and saving and accordingly, they inferred no perfect capital mobility among these countries. As to Turkish economy, by applying Bounds Test and Kalman filtering approach for the years 1998-2010, a long run relationship between domestic saving and investment was present even though there were decreasing impacts of saving on investment in the short-term and outcomes of Kalman filter implied that there was a capital mobility in Turkey.

Another study on the validity of the Feldstein-Horioka hypothesis was published by Kiran [29]. The study covered the period 1960 to 2010. And the author preferred to use the fractional co-integration approach introduced by Gil Alana (2003) and Caporale and Gil Alana (2004) since the fractional co-integration approach permits residuals to be fractionally integrated instead of stationary. Robinson unit root test (1994) were also conducted since these conventional unit root tests have strict limitations. It was confirmed that the series used in the analysis were at I(1). As to the fractional co-integration analysis, the co-integrated regression between investment and saving was estimated by applying Robinson (1994) test on these residuals obtained from the estimation of co-integration. As a conclusion, there exist a fractional co-integrated relationship between investment rate and savings rate series, which confirms the Feldstein-Horioka hypothesis along with the fact that international capital mobility for Turkey is low.

Guriş [30] analyzed the validity of the Feldstein – Horioka hypothesis for Turkish economy using variables; saving and investment from 1968 to 2012. In order to conduct this analysis, autoregressive Distributed Lag test for threshold co-integration proposed by Li and Lee (2010) was used. And since the relationship between saving and investment exists, the validity of Feldstein – Horioka hypothesis for Turkish economy was proven. Hence, according to Guris [30], it is possible to revive Turkish saving by imposing economical policies that encourage people to make an investment.

Halıcıoğlu and Eren [31] analyzed whether both twin deficit and the Feldstein-Horioka hypotheses were valid for Turkey over the period of 1987-2004 by means of bounds testing approach. After conducting the co-integration analysis, they reached the findings that there was the existence of a long-term association between the current account and budget deficits besides the domestic investments throughout the examined period. That is to say, the presence of twin deficit phenomenon in Turkish economy was verified, and also they found that the validity of Feldstein – Horioka hypothesis was proven in Turkey. Furthermore, they stated that Turkish economy could be count to be an integral part of global capital market with a low degree of capital mobility. Additionally, another finding was that about 20% of investment was funded with foreign saving. As to the results of the Granger-causality, a causal relationship between the current account and budget deficits for both in the short-term and the long-term cannot be stated. In addition to the causality analysis, the results of variance decompositions for post-sample imply that current deficits in the long-term result from the domestic investments.

Dursun and Abasız [32] conducted a study on the validity of Feldstein-Horioka puzzle with such three co-integration approaches as Hansen-Seo, Gregory-Hansen and Hatemi-J models. The data used in the study covered the period from 1968 to 2008 for Turkey. First of all, Feldstein-Horioka hypothesis was examined by the threshold co-integration method suggested by Hansen-Seo, but the variables never showed a nonlinear structure. After obtaining the result that there is a likelihood to exist a linear relationship, they performed following co-integration procedures. As a result of the Gregory-Hansen single-break co-integration test that estimates by regarding the presence of breakpoint in a co-integration vector and detects the breakpoints relying on the observation values in the model, the saving coefficient was found to occur a fall by 1.051 unit later than the year 2000. And also, as it is stated, this result exhibits in the case that the Gregory-Hansen test is conducted that Feldstein-Horioka puzzle is going on. As for the Hatemi-J test, double-break co-integration procedure, the result, which the saving-retention coefficient (0.426) exhibits that there is capital mobility in Turkey and it follows a rise in years, was regarded to be highly acceptable. That is to say, it is found that Feldstein-Horioka hypothesis is invalid for Turkey. Hence, in light of the findings reported, they conclude that the results that are reached with the tests taking into account the assumption of endogenous structural breaks are more sound and dependable in comparison to the tests regarding a fixed parameter assumption.

Bolatoğlu [33] examined whether there existed the co-integrated relationship between domestic saving rate and domestic investment rate by considering the time period from 1970 to 2003 for Turkey. First of all, Bolatogğu [33] obtained the results of co-integration among these variables by carrying out Engle-Granger co-integration procedure. However, since there is a likelihood that the variables include a unit root, he decides that Engle-Granger co-integration procedure cannot be applied. And moreover, instead of Engle-Granger co-integration procedure, to apply the co-integration approach introduced by Pesaran, Shin and Smith [17] gives more reliable results. As a result of Peseran's co-integration procedure, the existence of a long-term effect of domestic saving on domestic investment is confirmed. Furthermore, according to Bolatoğlu's [33] inference, there exists a weak relationship between variables used in the analysis and the degree of weakness makes the result of no international capital mobility statistically insignificant. Thus, even though domestic investments in Turkey can be financed by domestic saving, it may be said that there is also a need for foreign saving.

In the study of Mercan [34], Feldstein-Horioka hypothesis for EU-15 countries and Turkey, is investigated in the time period spanning annual data from 1970 to 2011. The hypothesis was analyzed by applying the new generation dynamic panel data method taking into account the structural breaks. And Mercan [34] used the unit root and co-integration tests taking into account the supposition that financially sudden changes in a country would be experienced and these changes would have an impact on the economies of other countries to some extent. Consequently, it is discovered that although the validity of Feldstein-Horioka hypothesis is confirmed for these 16 countries, there does not exist a strong co-integration association between investment-saving series for the countries. When the countries are separately investigated, the co-integration coefficients of 11 countries are statistically significant. And, the countries, which have the highest level of savings to meet investments, are Turkey, Belgium, Ireland, France, Italy, Denmark, Sweden, Portegue, Finland, England, and Greece, respectively. Nevertheless, when the short-run analysis is considered, it can be inferred that the level of savings to meet investments is lower.

Erdem, Köseoğlu and Yücel [35] testified whether the Feldstein-Horioka puzzle was verified for Turkish economy by using time series data over the period of 1960 to 2014. The analysis was conducted by using multiple-break co-integration test proposed by Maki (2012). After deciding all variables are integrated of order one, four models including level shift, regime shift, regime shift with trend and level, trend & regime shift are constructed. As a result of the test, the null hypothesis of no-co-integration between domestic investment and saving was not accepted at the 1% significance level. That is to say, the Feldstein-Horioka hypothesis is valid under structural breaks including the years 1977, 1989, 1994, 1996, and 2001. Moreover, the Error Correction Model is estimated for Feldstein-Horioka equation. As a result of the ECM, the error correction system tends to correct its preceding disequilibrium resulting from financial shocks at an adjustment speed of 91% each year to achieve at the steady state. Finally, they also performed Fully Modified Ordinary Least Squares and Dynamic Ordinary Least Squares estimation methods so as to estimate long-term coefficients once they proved the presence of a co-integrated association between domestic saving under the allowance of endogenous structural breaks. And they reveal the fact that even though the validity of Feldstein-Horioka hypothesis is proven, the Feldstein-Horioka puzzle cannot be said to have a strong form because a saving-retention coefficient is obtained low for Turkey.

In the paper of Akadiri et al. [36], the relationship between savings and investment was examined for Turkey using annual time series data for the periods 1960 to 2014. After determining that the variables were stationary at first difference, the co-integrating likelihood ratio test was conducted. And it was found that there was a long-term relationship between saving/GDP and investment/GDP with a major structural break in 1993. As for the Granger causality, the presence of bi-directional relationships between the series was proven. Finally, they performed the Dynamic Ordinary Least Square co-integration analysis and consequently, the Feldstein-Horioka hypothesis holds for Turkish economy since there exists high capital mobility in Turkey.

Tunçsiper and Biçen [37] aimed to examine the Feldstein-Horioka Puzzle for emerging seven economies (E7) including China, Brazil, India, Indonesia, Mexico, Russia, and Turkey. The dataset consists of annual observations over coverage of 24 years between the periods 1990 to 2014. The hypothesis is investigated by using the Zellner's (1962) Seemingly Unrelated Regression method. As a result of the regression analysis, the hypothesis does not hold for Brazil, Mexico, Russia, and Turkey because each coefficient of these countries' economies is both statistically insignificant and close to zero. Moreover, each coefficient of China, India and Indonesia is not only statistically significant but also close to 1. Therefore, they infer that the investments for these three countries consist of an integral part of savings and that the Feldstein-Horioka puzzle is valid for these three countries.

Demir and Cergibozan [38] conducted a study on the Feldstein-Horioka hypothesis for Turkish Economy over the period from 1962 to 2015 by means of various time series methods. In the period between 1962 and 1989, a strong relationship between domestic investment and domestic saving was demonstrated. It was proven to exist a co-integration among these series over 27-year-time period since 1990. However, the relation after 1990 was not as strong as that of previous period. Furthermore, the period 1990-2015 was also predicted with the Markov Regime Switching Model. From this estimation, different results were reached for pre- and post- 2001 period. The international capital mobility of Turkish economy followed an increasing trend after the year 2001 even though this result was not valid for the pre-2001 period. They ultimately concluded that the international capital mobility of Turkish Economy raised every passing time.

3. ECONOMIC FRAMEWORK

This chapter in which economic framework is described consists of two parts. In the first part, basic terminology of economics which is used in the part of empirical analysis is defined, fundamental equations are derived, and thereafter the concept of Feldstein-Horoika hypothesis is explained. In the second part, Turkish economy is basically discussed in terms of its economic growth, saving and investment levels.

3.1. The Theoretical Analysis of the Macroeconomic Theory

3.1.1. The Basic Terminology of Economics

Gross Domestic Product (GDP): Macro-economy is in general defined as the area of economics investigating the interactions and performance of the whole economy. Gross Domestic product (GDP) is known as one of the most essential elements for macroeconomic analysis because United Nations System of National Accounts has standardized GDP as an economic measure. The common definition of GDP is the value of all final goods and services produced in the country within a given year.

The significant features of GDP can be listed as:

1- The calculation of GDP is done by using market values, but quantities are not used.
2- GDP consists of the market values of final products that are known as the goods bought by a final user.
3- GDP includes only current production that takes place during the indicated time period. In other words, GDP never covers intermediate goods. In this way, the problem of double counting of goods is prevented.

GDP is generally used in order to evaluate the economic performance of nations and to compare them. Besides this purpose, this notion is also used for assessment of living conditions, progress and social welfare between countries although the ultimate aim of GDP is not originally for this.

As to the calculation methods of GDP, there are various ways, such as value added approach, expenditure approach, income approach etc. The value added approach is to add up the gross output of different industries and then subtracts intermediate inputs. The expenditure approach is the most used procedure to compute GDP. And by this approach, GDP equals the total of consumption, investment, government purchases, and net exports. The following formula is used in order that GDP might be calculated with the income approach,

$$\begin{aligned} \text{GDP} = {} & \text{National income} - \text{Income earned from the rest of the world} \\ & + \text{Income earned by the rest of the world} \ + \text{Indirect business taxes} \\ & + \text{Capital consumption allowance} + \text{Statistical discrepancy} \end{aligned} \tag{3.1}$$

Economic Growth: An economic growth rate refers a measure of economic growth from a specified period to successive one in percentage terms. The result of this measure is obtained in nominal terms. The growth rate is computed using the following formula:

$$\text{Percentage Change in Real GDP} = \left(\frac{\text{Real GDP}_{\text{later year}} - \text{Real GDP}_{\text{earlier year}}}{\text{Real GDP}_{\text{earlier year}}}\right) \text{x}100 \tag{3.2}$$

where real GDP is gotten from GDP adjusted for price changes.

Income: Personal income is the total amount of earnings that people in fact make. And it is calculated as follows:

$$\text{Personal Income} = \text{National Income} - (\text{major earned but not received items}) \tag{3.3}$$

where major earned-but-not-received items are known as the sum of an undistributed corporate profits, social insurance taxes, corporate profits taxes, and transfer payments [39].

Disposable income (or known as disposable personal income), which is denoted by YD, is defined as a proportion of personal income that can be used for consumption or saving [39]. And the disposable income is calculated with the following equation:

$$\text{Disposible income} = \text{Personal income} - \text{Personal Taxes} \tag{3.4}$$

Consumption (C): Consumption is defined as the total expenditures of households. It is divided into expenses on goods and services. The linear consumption function is expressed as

$$\mathrm{C} = \mathrm{a} + \mathrm{c}\ \mathrm{YD} \tag{3.5}$$

where C is current entire consumption, YD is current disposable income.

It can be mentioned about the presence of four factors having a considerable impact on consumption expenditures, which are wealth, the interest rate, income taxes, and expectations about future prices and income [39].

Government Expenditure (G): Governmental spending consists of all expenses on the goods and services purchased by government at the federal, state, and municipal levels [39].

Investment (I) and Saving (S): Investment spending covers total spending of households and firms. Firms make an investment on new factories, office buildings machines and additions to inventories and households invest in new houses. The term of saving shows a consumers' decision mechanism to purchase goods or services now or later.

It is mostly known that economic growth, saving and investment are closely interconnected because endogenous growth theory states their strong positive correlation with GDP growth rates [40]. Therefore, there are quite a few economic growth models which explain growth rates in terms of the level of saving and investment. The most important one is the Solow [41] model introduced by neoclassical economists says that the increase in the savings rate accelerates steady-state production by more than its explicit influence on investment. This is because the induced rise in earnings boosts savings, which causes a further rise in investment [42]. In addition to the Solow model, the theory claimed by the economist Lewis [43] who won the Nobel Memorial Prize in Economics highlights that if the increase in savings exists, then economic development explicitly follows an increasing trend. In other words, he said that governments of the developing countries preferred to adopt economic policies promoting the increase in saving level in order to boost GDP growth rates. The underlying reason for this claim is the high rate of domestic saving stimulates the obtainability of loanable funds, which explicitly expands the level of investment which is the component of GDP [44]; [45]. Conversely, there are also growth theories which investigate economic improvement in terms of an increase in investment level. Especially, according to the Keynesian and post-Keynesian approaches, the conventional investment level plays a critical role as a component of total demand. The Harrod-Domar models can be given as an example of Keynesian economists, and this model indicates that investment has a great contribution to economic growth [42]. Furthermore, some economists like Levine and Renelt [46] reveal the fact that investment enable economic development to be sustainable. There are many economic perspectives on this association among investment and economic development. Especially neo-classics emphasize investment plays an integral part of the process of financial development because if investment is used efficiently, then output increases directly.

Export (X), Import (M) and Net Export (NX): The term of export exhibits total amount of goods and services which are produced in one country and purchased by consumers living in another country. Similarly, the term of import refers the total goods and services, which are produced in overseas countries, are purchased by own citizens of a country. Then, net export is calculated by subtracting export from import.

There are various discussions of the roles of export and import on an economic development. The effect of export on economic growth is controversial topic. In the contemporary world, quite a few economists have preferred export-led industrialization to import substitution industrialization. The hypothesis of export-led growth (ELG) emphasizes that the most fundamental determinant of long-term economic growth is the policies and measures that expands export. According to other classical perspectives like Adam Smith, being contingent on international division of labour along with foreign trade, the rise in total factor productivity brings about the growth in total output. Neo-classical economists investigate growth models predicated on the decreasing productivity of production factors; however, they ignore the relationships between technological enhancement and foreign trade. They stress the conclusion that any economy always remains in balance in the long-term. This hypothesis was clarified by Keynesian approach as well. Keynesian economists examined the link between income and consumption. And they concluded that export was a contribution to the economic growth whilst import was regarded as a leakage. Apart from these Keynesian economists, Sharma et al. [47] mention that Keesing, Bhagwati, Krueger, and Srinivasan pioneered the hypothesis of export-led growth as well. The rise in export firstly expands the output level and thus, this offers employment opportunities because of the foreign trade multiplier which algebraically means a function being equal to the sum of marginal propensity to save (MPS) and marginal propensity to import. Secondly, export stimulates the power of competition. The increase in the competition of entering international market brings about the spread of technical information and progress, the acceleration of the cutting edge of production technology and the rise in availability of the high technology. Third and the most important one is that export growth promotes the foreign exchange, which also allows the rise in the import of goods and services. Besides the contribution of export level to the economic growth, some economists argue import-lead-growth models (ILG), and they regard the significance of imports as a connection for foreign technology and knowledge with the territorial economy by the help of endogenous growth models. According to the studies of Lawrence and Weinstein [48], ILG models express that growth in imports could render economic development possible. By the help of endogenous growth models imports can be demonstrated to be a way for a long-term economic growth. The reason for this is that it enables local firms and factories to take advantage of necessary intermediate and foreign technology [49].

Current Account Deficit: The term means that the value of imports of goods, services, and even investment earnings exceed the value of exports. The problem of current account deficit has some adverse effects on economy. These effects may be listed as:

- Because of the problem, foreign investors may refrain from making investment in this country.
- In the case that a current account deficit exists, investors from overseas countries make a growing assertion about their assets, which they could want to be given back whenever they want.
- The problem may result in decreasing enlargement of the export sector.

Capital Mobility: In general, the term means a skill of the private funds to extend over national territories in search of higher returns. The determinants of capital mobility are listed as:

- The effects of tariffs and taxes on capital flows,
- Restrictions on capital flows,
- Some policies and regulations which aim to increase cost of moving capital from one country to another,
- The exchange rate volatility.

There are many studies on the capital mobility. The most important ones of which are Mundell's study [50] on the case of perfect mobility of capital and Fleming´s model [51] on the imperfect mobility. Perfect capital mobility refers that no transaction or other costs in moving capital from one country to another while capital immobility implies the difficulty and expensiveness of the movement of the capital from one country to another. In the today's world, the model introduced by Mundell is more valid in comparison to that of Fleming.

The effects of capital mobility on economics are as follows: [52]

- The capital mobility being high contributes to the rise in investment opportunities,

- If capital mobility is high, then interest rates become higher, and accordingly, this interest rate affects exchange rate to a large extent.
- Capital mobility makes incomes between different countries equal.

3.1.2. The Correlation Between Domestic Savings and Investments

The roles of savings and investment in promoting economic growth have received considerable attention in many countries. Before explaining this correlation, Misztal [53] started with it by defining some equations as follows:

Total demand for domestic output (Y) consists of four components including consumption spending by households (C), investment spending by businesses and households (I), government expenditure (G), and foreign demand for net export (NX).

Then, the equation of fundamental national income is given by

$$\mathrm{Y = C + I + G + NX} \tag{3.6}$$

First of all, consider a simple economy. In a country where has a closed economy, national income can be only equal to the sum of consumption and investment spending.

$$\mathrm{Y = C + I} \tag{3.7}$$

And then, a relation among saving, consumption and GDP should be established. Since a part of all income is spent while the rest of the income is allocated, the income function can be also written as:

$$\mathrm{Y = C + S} \tag{3.8}$$

The combination of the expressions (3.7) and (3.8) is expressed as:

$$\mathrm{C + S = Y = C + I} \tag{3.9}$$

In the expression (3.8), its left hand side represents the allocation of the income whilst its right hand side gives the components of demand. Concerning the expression (3.9), it implies the output manufactured and the output sold are equal to each other; moreover, the value of output manufactured is equal to income earned. And the earned income, in order, is expended on goods or saved [54].

It can be re-written as follows:

$$S = Y - C = I \tag{3.10}$$

The implication of the expression (3.10) is that investment is equal to saving in closed economies.

As for a complex economy which government expenditures and foreign trade exist, the national income is calculated by the Equation (3.6).

To derive the relation between output and disposable income, transfers to the private sector and total taxes are shown respectively by TPS and TT.

$$YD = Y + TPS - TT \tag{3.11}$$

The expression (3.11) is also called "Disposable Income". If the disposable income is allocated to consumption and saving, YD can be re-stated as:

$$YD = C + S \tag{3.12}$$

$$YD = Y + TPS - TT \Rightarrow Y = YD - TPS + TT \tag{3.13}$$

The combination of the expression (3.13) and (3.6) is

$$YD - TPS + TT = C + G + I + NX \tag{3.14}$$

If the equation (3.12) is inserted to the equation (3.14), then we can write

$$(C + S) - TPS + TT = C + G + I + NX \tag{3.15}$$

Accordingly, the equation (3.15) can be re-written as:

$$NX = S - I - (G + TPS - TT) \tag{3.16}$$

According to the expression (3.16), the Feldstein - Horioka hypothesis is interpreted that under the supposition, there is a substantial correlation level between savings and investments in spite of comparatively upward international capital mobility. This correlation must indicate similar alterations in both the budget deficit and the present account deficit [55].

3.1.3. The Theoretical Foundation of Feldstein – Horioka Hypothesis

In economic terminology, the concept of ‘puzzle’ connotes the case that empirical facts or findings are not consistent with their theoretical frameworks. Obstfeld and Rogoff [56] published a paper on the six major puzzles in international economics which were the home-bias-in-trade puzzle by McCallum (1995), the Feldstein-Horioka puzzle by Feldstein and Horioka (1979), the consumption correlations puzzle by Backus, Kehoe, and Kydland (1992), the purchasing-power-parity puzzle by Rogoff (1996), the exchange-rate disconnect puzzle by Dornbusch, (1976) and the neutrality of exchange rate regime puzzle by Baxter-Stockman (1989) [56]. One of the most famous puzzles in economics is that of Martin Feldstein and Horioka [25]. Therefore, in the empirical analysis of this thesis, the Feldstein-Horioka puzzle will be tested for Turkish economy.

In the study published by Feldstein and Horioka in 1979 [25], they analyzed the relationship between saving and investment for 16 OECD (Organisation of Economic Cooperation and Development) countries spanning the period from 1960 to 1974. That is, this work of Feldstein and Horioka [25] is pioneer. They found that the domestic saving was sensitive to the changes in domestic investment. Consequently, they reached the conclusion that international capital mobility was low even though the capital mobility was indeed high in these industrialised countries. Because of this controversy, the Feldstein-Horioka (hereafter F-H) hypothesis is also called the F-H puzzle.

Briefly, Feldstein and Horioka in 1979 proved that investments and savings were highly correlated in developed economies, which also demonstrated low international capital mobility [25]. In other words, the F-H hypothesis says that in a country where the level of capital mobility is perfect, a correlation between domestic savings and investment is low.

To assess this relation, they estimate the following equation:

$$\left(\frac{\mathrm{I}}{\mathrm{Y}}\right)_{\mathrm{t}} = \alpha + \beta\left(\frac{\mathrm{S}}{\mathrm{Y}}\right)_{\mathrm{t}} + \mathrm{e}_{\mathrm{t}} \tag{3.17}$$

where e_t is error term, I is investment, S is saving, and Y is GDP. Here, $\left(\frac{I}{Y}\right)_t$ represents the ratios of gross domestic investment (GDI) to GDP while $\left(\frac{S}{Y}\right)_t$ represents the gross domestic saving (GDS) to GDP observed for the t^{th} country. The parameter β, which is known as saving retention coefficient shows international capital mobility. If the parameter β is statistically significant and its value is close to 0, then high capital mobility can be stated. Conversely, if the parameter β is statistically significant and its value is close to 1, then the capital mobility is said to be low. It is noteworthy that the case that β is equal to zero occurs only when the country has a small economy in comparison to the global economy [37].

Furthermore, Feldstein and Horioka [25] interpreted the cases of the high coefficient β. They explained three reasons related to the high coefficient β. First one is that the most significant deterministic external factor of investment level is population growth rate. In other words, the more population grows, the more investment level increases. However, when Feldstein and Horioka [25] added the effects of population growth in the model, the value of the coefficient β never altered. The second one is the trade openness of a nation. In the economies, where trade openness degree is low, the value of the coefficient β becomes high. When the trade openness is added in the model (3.17), the model is obtained by

$$\left(\frac{\mathrm{I}}{\mathrm{Y}}\right)_{\mathrm{t}} = \alpha + (\beta_0 + \beta_1 \mathrm{X}_{\mathrm{t}})\left(\frac{\mathrm{S}}{\mathrm{Y}}\right)_{\mathrm{t}} \tag{3.18}$$

where X_t represents the trade openness of a country. And the coefficient β_1 is not statistically significant. The final reason is that even if there exists perfect global capital mobility, due to either the regional choices or adequate inflexibilities on capital mobility, rises in domestic saving will have an effect firstly on supplementary domestic investment [25]; [37].

Additionally, the validity of the F-H hypothesis requires the three conditions. First condition is that investment has to rely only on the national rate of return. The second condition is that the domestic real rate of return is equivalent to the global real rate of return. And the final condition is that the global rate of return is exogenous; that is, it may not be impacted by the certain country [57]; [58].

There are various studies and interpretations on the theoretical frameworks of F-H hypothesis which are listed as follows. First of all, Iyidoğan and Balıkçıoğlu [26] say that economic policies, which promote the tendency in investment have an effect on the level of investment and accordingly, economic growth expands. Secondly, if capital mobility is low, domestic and foreign borrowing costs will become different and thus, domestic investment will be financially compensated for domestic saving [59]. Thirdly, Murphy [60] estimated the model (3.17) by using gross national product (GNP) instead of using GDP and it was revealed the fact that the coefficient β was found to display sensitivity toward the changes in population rate. Therefore, Murphy [60] infers that the findings of Feldstein and Horioka [25] cannot be generalized. Moreover, it is stated that the coefficient β actually represents the substitute relationship between domestic and external investments [61]. Finally, it is stated that the coefficient β may denote current account deficit instead of the level of capital mobility. And this view is supported by Bolatoğlu [33] who shows the studies of Tesar in 1991, Coakley et al. in 1996, and Moreno in 1997 as an example in order to highlight the fact that the strong long-term relationship between saving and investment is more related to the sustainability of current account deficit than world-wide capital mobility.

In the literature, it is also mentioned that there exist different criticisms on the F-H hypothesis. Gülay [62] says that a low correlation between the series of saving and investment exists if different methods and different data sets are used, and secondly, the high correlation between saving and investment may cause different inferences [62]. Furthermore, İyidoğan and Balıkçıoğlu [26] argue and stress that the relationship between saving and investment cannot be explained only with the F-H hypothesis; therefore, other remarkable aspects concerning this relationship have better been considered and they evidently explained all aspects as follows. The first aspect is that the separate analysis of the saving-investment interaction for private and public sectors instead of at the domestic levels gives much healthier results while deciding the effectiveness of the economic policies that promotes saving because of the fact that the domestic saving and investment have two components like private and public sectors. As the second aspect, the investigation of the saving - current account balance relation is suggested. The reason for this suggestion is that the existence of co-integration between current account balance and saving possibly shows that the saving-investment relationship is weak. That is, when there exists a long-term association between current account balance and saving, the domestic saving is contributed to the financing of the current account deficits. In this situation, it can be said that the domestic saving boosts economic growth by means of the improvement of current account balance rather than a rise in domestic investment. Finally, whether the saving-investment relationship exists or not depends on the global saving glut from the beginning of the 21st century [26].

3.2. The Economy of Turkey

The economic background of Turkey has been full of difficult periods and financial constraints once the establishment of the Republic in 1923. However, Turkey has become a member of the most important international organizations which are the Council of Europe, OECD, OSCE, G-20 major economies and the 17th- largest economy in the world. And according to the information from World-Bank, it is significant to note that Turkey’s per capita income reached to US$10,500 in 2015, which helps Turkey to join the group of upper-middle-income countries [63].

In the contemporary world, global economic power has been gradually changing and shifting from G7 countries to other developing countries. For example, two important country groups have arisen. First one is BRICS including Brazil, Russia, India, China and South Africa. This term first was grouped by Jim O'Neill in 2001 [64] without South Africa. In 2010, South Africa was joined in this group. Even though Turkey could not be joined to this group, Turkish economy and BRICS economies are always compared. The another one is MIST which consists of

Mexico, Indonesia, South Korea and Turkey. This term emerged in order to describe the next tier of large growing economies by Jim O'Neill [64].

3.2.1. Economic Growth in Turkey

The best way to understand the rate of the economic growth of Turkey is to look at its annual GDP growth as it is given in Figure 1.

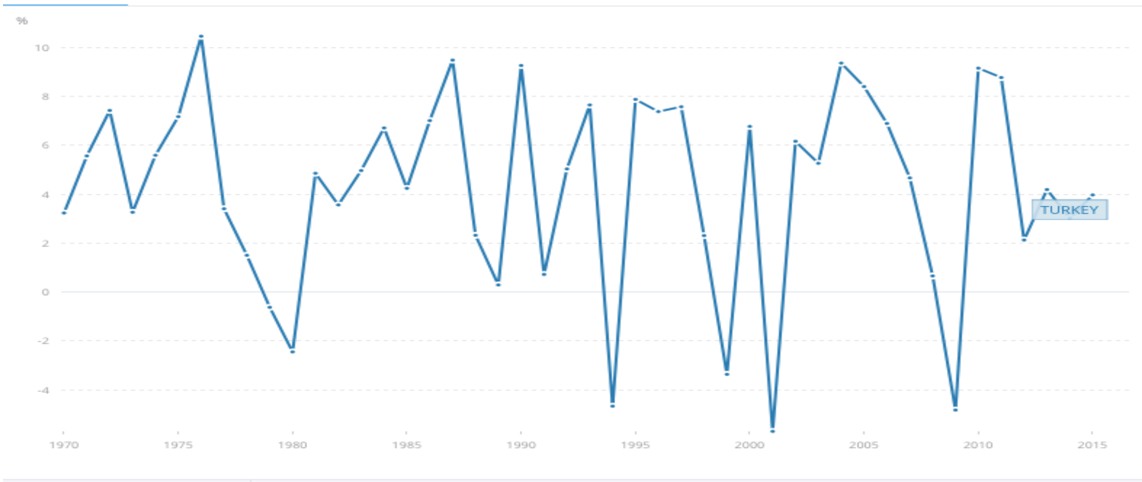


Figure 1. GDP Growth (annual %) (based on constant local currency) in Turkey over the Period 1970-2015

(**Source**: World Bank National Accounts Data)

As it is clearly seen in the Figure 1, the Turkish economy has not had a stable economy since 1970 till the present. Turkish economy has always followed a volatile trend and it faced sharp declines in the years 1994, 2001 and 2009 when three biggest economic crises occurred throughout the Turkish history. The reasons for these crisis are respectively listed as: unsustainable current account deficits for 1994 crisis, the global crisis starting in USA for 2001 crisis and finally, the global crisis for 2008 financial recession. Since 2009 till 2011, Turkish economy has followed increasing trend; nevertheless, the growth has become moderated after 2012 because of election-related uncertainties, geopolitical developments and the like. The percentage of economic growth between the years 2013 and 2014 fell from %4.2 to %2.9 according to the information from World Bank Group [63].

In addition to financial crisis experienced by Turkish economy, there have been many significant economic reforms which strongly affect and alter the economic structure. First of all, the 1980s have been significant years for Turkish economy. Since the beginning of the 1980s, the Turkish ministry of economy has regulated and implemented economic policies and reforms in order not only to limit governmental intervention to the economic activities but also to bring freedom for Turkish market model [66]. By means of the reforms in 1980, Turkish economy achieved to reduce inflation, and to expand savings and exports due to an efficient use of domestic output [67]. Moreover, Turkey internalized an export-led growth strategy in the post-1980.

3.2.2. Domestic Saving in Turkey

Domestic saving rates of Turkey are given in Figure 2. Even though the domestic saving in the period of 1978-80 follows a volatile trend in Figure 2, the 1978–1980 debt crisis caused a fall mainly in investment level rather than in saving level [68]. As it is mentioned in previous part, Turkish economy shifted from an economic regime of import-substituting industrialization to export-led growth accompanied by trade and financial liberalization [69]. And it is obviously seen in Figure 2 that the economic reforms in 1980 leaded to the increase in the domestic saving level after 1980s. As yearly economic growth rate in Turkey was observed to soar in the post-1985 period, public saving started to follows a downward trend whereas private saving was on the rise [68]. In Figure 2, GDS rate attained its highest value since the currency crisis occurred in 1994 resulted in the rise in interest rates by 30% [68]. In the post-2004s, the changes in saving level are as follows. After 2004, public savings started to accelerate even though private savings was observed to decline. As for the period 2005-2008, public savings continued at positive levels; however, global financial crisis in 2008 resulted in the fall in public savings [67].

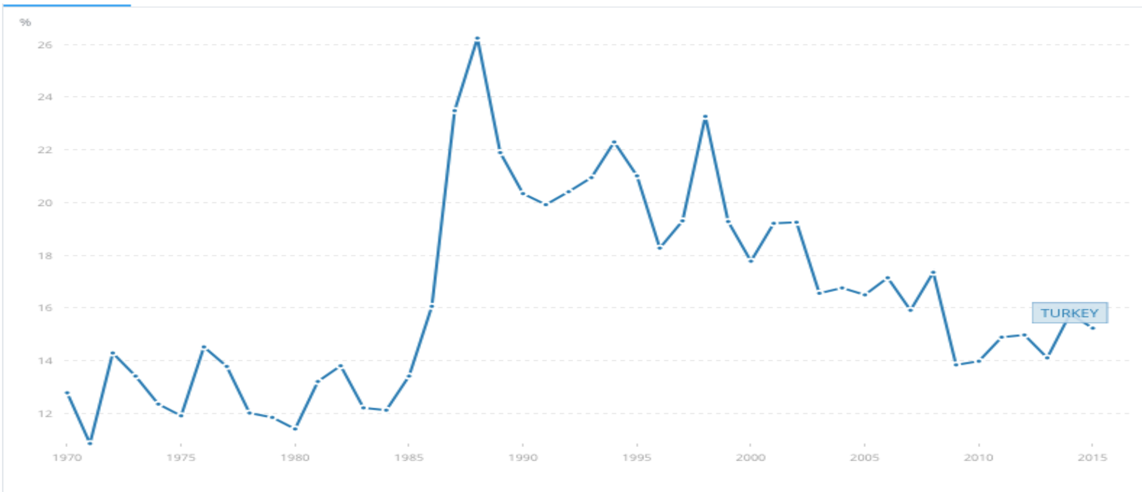


Figure 2. GDS (% of GDP) in Turkey over the Period 1975-2015

(**Source**: World Bank National Accounts Data)

3.2.3. Domestic Investment in Turkey

The investment performance of Turkey is given in Figure 3. The investment spending has shown a considerably remarkable change since 1980 in Turkish economy [69]. The adoption of the economic guidelines and regulations on export-led growth was accomplished for the sake of cost savings on wage labor which were then oriented to export markets through a prosperous export subsidy plan [70]. And as a result, like saving performance of Turkey, Turkish investment performance is volatile as well when Figure 3 is examined in detail. And investment level was affected by the crisis occurred in both 2001 and 2009.

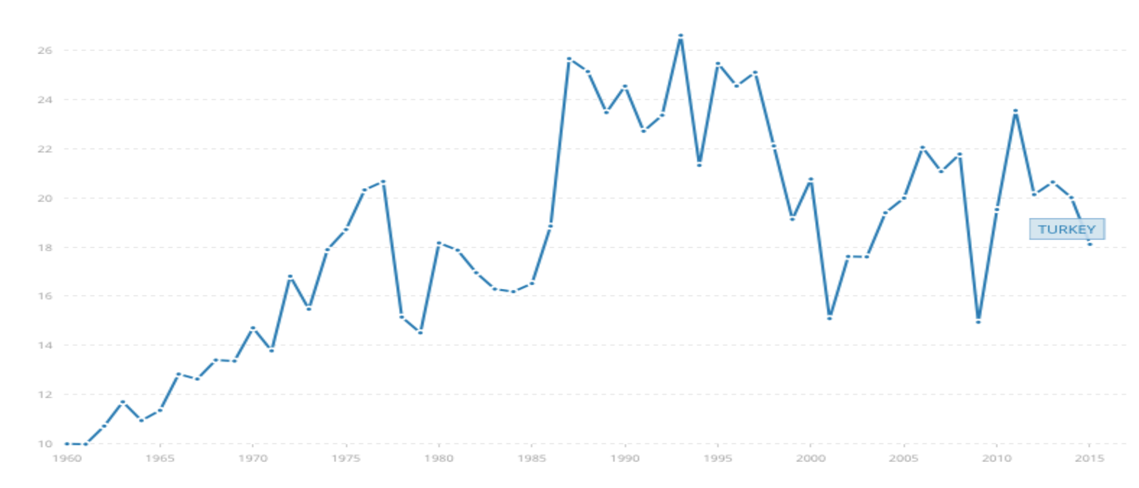


Figure 3. GDI (%of GDP) in Turkey over the Period 1975-2015

(**Source**: World Bank National Accounts Data)

4. THE THEORY OF AUTOREGRESSIVE DISTRIBUTIVE LAG (ARDL) BOUNDS TEST APROACH

In this section, the autoregressive distributed lag model bounds testing procedure, which was introduced with a series of studies by Pesaran and Shin [16] and Pesaran, Shin and Smith [17], is comprehensively explained.

4.1. The Construction of ARDL Model

Distributed lag model for time series data is defined as a model which anticipates the present and the past period impacts of an independent variable on the dependent variables in the model. According to the definition of autoregressive distributed lag model (ARDL henceforth) provided by [15], as well as the present and past values of dependent variables, this model includes lagged value of independent variable, and the model is called as ARDL models. And accordingly, the general form of an infinite distributed lag model is initially expressed as follows:

$$y_t = \alpha + \beta_0 x_t + \beta_1 x_{t-1} + \beta_2 x_{t-2} + \cdots + u_t = \alpha + \sum_{i=0}^{\infty} \beta_i x_{t-i} + u_t \tag{4.1}$$

Many linear distributed lag models are generally classified into rational distributed lag models that can be written in the form of the autoregressive distributed lag models [71].

As it is mentioned above, if the lagged values of y_t are added to this distributed lag model, autoregressive distributed lag model is obtained and the general form of the autoregressive distributed lag model (ARDL(p,q) model) can be expressed as follows:

$$y_t + \phi_1 y_{t-1} + \phi_2 y_{t-2} + \cdots + \phi_p y_{t-p} = \alpha_0 + \alpha_1 t + \beta_o x_t + \beta_1 x_{t-1} + \cdots + \beta_q x_{t-q} + u_t \tag{4.2}$$

Or the presentation of the model using the polynomial lag operator L can be expressed in the Equation (4.3).

$$\phi(L)y_t = \alpha_0 + \alpha_1 t + \beta(L)x_t + u_t \qquad ; \forall t = 1, \ldots, T \qquad (4.3)$$

In the Equation (4.3), $\beta(L) = \sum_{k=0}^{q} \beta_k L^k$ and $\phi(L) = 1 - \sum_{k=1}^{p} \varphi_k L^k = 1 - \varphi_1 L - \varphi_2 L^2 - \cdots - \varphi_p L^p$ for L being lag operator such that $Ly_t = y_t - 1$ for an independent variable $\boldsymbol{y_t}$ **,** x_t is defined as kx1 vector of regressors considered to be **I**(1) such that $x_t = x_{t-1} + e_t$ for k-dimensional vector. Pesaran and Shin [16] suggested five assumptions on the basis of general ARDL (p,q) model form in Equation (4.3) as follows:

A.1. The scalar disturbance term u_t follows independently and identically distributed process with zero mean and constant variance i.e. $u_t \sim$iid(0, σ_u^2).

A.2. e_t is a linear multi-variate stationary process.

A.3. u_t and e_t does not have a correlation for all lags and leads in order that x_t is purely exogenous with respect to u_t.

A.4. There is no co-integration between regressors, x_t,.

A.5. (Stability Condition) The inverse root of the autoregressive characteristic polynomial is strictly less than one, |ϕ| < 1, which guarantees the dynamical stability of the model and there exists a long-term association between independent variables x_t and dependent variables y_t. Otherwise, in the case ϕ = 1, the existence of long-term relationship between x_t and y_t would not be mentioned.

4.2. The Adaptation of ARDL Model to Time-Series Analysis

As the result of the decomposition of $\phi(L)$ and $\beta(L)$ that are defined in the expression (4.3), Narayan [18] and Pesaran and Shin [16] started with general ARDL (p,q) model showing a stationary unique long-term association among y_t and x_t.

$$y_t = \alpha_0 + \alpha_1 t + \sum_{i=1}^{p} \phi_i y_{t-i} + \beta' x_t + \sum_{i=0}^{q-1} \beta_i^{*\prime} \Delta x_{t-i} + u_t \qquad (4.4)$$

$$\Delta x_t = P_1 \Delta x_{t-1} + P_2 \Delta x_{t-2} + \cdots + P_s \Delta x_{t-s} + \varepsilon_t = \sum_{j=1}^{s} P_j \Delta x_{t-j} + \varepsilon_t \qquad (4.5)$$

In both Equation (4.4) and (4.5), x_t is defined as the k-dimensional (non-stationary at level) variables that does not have co-integration between themselves, u_t and ε_t represent serially correlated disturbances with zero means and constant variance-co-variances. Also, P_i refers kxk-coefficient matrices in order that a stability can be mentioned in VAR process in Δx_t. In the model (4.4), t is deterministic trend.

Polynomial equation is defined in Equation (4.6). The presence of stability in ARDL model can be stated when all roots of the p^{th} order this equation

$$\phi(z) = 1 + \phi_1 z + \phi_2 z^2 + \cdots + \phi_p z^p = 0 \qquad (4.6)$$

fall outside the unit circle i.e. $|z| > 1$, which implies that it does not consist of unit-root. If $\phi(1) = 0$, then the model is said to have a unit root. When $\phi(z)$ is equal to zero, its one or more roots may fall inside the unit circle. This case is not practical connection to analyze econometric time series [16].

4.3. The Property of Consistency for ARDL Model

Consistency property is usually regarded as a serious problem while constructing a time series model. The concept of consistency is that the parameter estimated by a procedure converges to the correct parameter value as the sample size increases infinitely [4]. This is clearly acceptable when the estimator is not biased. That is to say, the norm of consistency is regarded as the weak form of unbiasedness [72]. And moreover, in general, the most known definition of consistency is that in order for an estimator T of a parameter θ to be consistent, the parameter should converge in probability to the correct value of the parameter i.e. $\operatorname{p}\lim_{n\to\infty} T = \theta$. [72].

Pesaran and Shin [16] examined the property of consistency of ARDL model by considering whether a correlation of u_t and ε_t defined in the models (4.4) and (4.5) exists or not. The conclusive inference of the examination is given in the following two fundamental cases.

Case – 1: When u_t and ε_t are not correlated disturbances with zero means and constant variance-covariance.

In this case, x_t is the k - dimensional I(1) ‘forcing’ variables that are not co-integrated among themselves. So as to handle the undesirable situation of co-integration between x_t, it is required to set k=1.

Then, the OLS-based estimators of long-term coefficients can be obtained by $\delta \coloneqq \alpha_1 / \phi(1)$ and $\theta \coloneqq \beta / \phi(1)$ where $\phi(1) = 1 - \sum_{i=1}^{p} \phi_i$. The long-run coefficients are estimated by using OLS-based estimators of the short-term coefficients α_0 , α_1 , β, $\beta_1^*, \ldots, \beta^*_{q-1}$ and $\phi = (\phi_1, \ldots, \phi_p)$ [16].

The short-term coefficients are $\sqrt{T}$-consistent with the asymptotically singular covariance matrix [16]. That is to say, the short-run parameters converges at the rate $T^{\frac{1}{2}}$ to the correct value for sample size T and for the exact convergence rate 1/2.

This rate of convergence is higher for long-term parameter estimators (δ, θ) in comparison with the short-term (α_1, β) since (α_1, β) and the estimator ϕ have asymptotically perfect collinearity. And δ is $T^{3/2}$ – consistent while θ is T – consistent. In other words, the ARDL estimators of the long-term parameters have the advantage of being super-consistent.

Therefore, well-grounded and cogent conclusion about the long-term parameters, together with the short-term parameters, can be drawn by making use of standard normal asymptotic theory. Accordingly, the ARDL model is used regardless of the regressors are purely I(0) or purely I(1) or even fractionally integrated.

As a result of the first case, Pesaran and Shin [16] show that the estimator using OLS forecasts the ARDL-based short-term parameters as consistent and the ARDL-based long-term ones as super-consistent even if sample size is small.

Case – 2: When u_t and ε_t are correlated.

In this case, appropriate augmentations of the number of lagged alterations in the regressors for the ARDL model are necessary. And the determination of augmentation degree is based on the inequality that q is greater than s + 1 holds.

In order to express the augmented version of the first equation (4.4), we need to define vector **d** as contemporaneous correlation vector between u_t and ε_t. And the expression of the augmented version of the first equation (4.4) is given by:

$$y_t = \alpha_0 + \alpha_1 t + \sum_{i=1}^{p} \phi_i y_{t-i} + \beta' x_t + \sum_{i=0}^{m-1} \pi_i' \Delta x_{t-i} + \varphi_t \quad (4.7)$$

where $m = \max(q, s+1)$; $\pi_i = \beta_i^* - P_i' \mathbf{d}$, $\forall\, 1 \leq i \leq m-1$, β_i^* is equal to zero for I being equal and greater than q, P_i is equal to zero for i being equal and greater than s and also $I_k = [I]_{kxk}$ such that $I_k = P_0$

The reason for re-expressing the equation, which is converted to the augmentation specification form is to make φ_t and ε_t uncorrelated. Accordingly, we can easily get the same result as the above by applying the same way to the OLS short-term and long-term coefficients of the Equation (4.7). Hence, Pesaran and Shin [16] point out that the ARDL approach necessitates adding adequate lags of x_t so as to make y_t endogenous, and then estimation should be performed. In this way, the problems of both serial correlations in the error process and regressor endogeneity might be concurrently handled.

4.4. The Selection of the Order of the ARDL Function

To select “accurate” orders of the ARDL(p,q) model is significant and this order selection procedure is performed in accordance with a two-step strategy.

The first step is the selection of p and q by utilizing information criteria such as AIC, SBC and the like. The smaller the values of AIC and SBC are, the better the model can be obtained. Pesaran and Smith [73] also strictly emphasizes that SBC tends to be preferred to the AIC according to Monte-Carlo evidence. A total of $(m+1)^{(k+1)}$ different ARDL models are predicted, where k and m respectively represent the number of variables in the model and the maximum number of lag to be used. And then, the final (optimal) model is chosen by acquiring those p and q which make the mentioned selection criteria minimum.

In the second step, after selecting the appropriate $ARDL(\hat{p}, \hat{q})$, the short-run parameters are obtained by OLS. By the help of the short-term parameter estimators, the long-term coefficients of the following co-integration relation (4.8) and their standard errors are estimated by making use of the selected ARDL model in the first step.

$$y_t = \mu + \delta t + \theta x_t + \vartheta_t \tag{4.8}$$

Accordingly, the long-run coefficients are calculated by [150]:

$$\hat{\mu} = \frac{\hat{\mu}_0}{(1 - \hat{\phi}_1 - \cdots - \hat{\phi}_p)} \tag{4.9}$$

$$\hat{\delta} = \frac{\hat{\mu}_1}{(1 - \hat{\phi}_1 - \cdots - \hat{\phi}_p)} \tag{4.10}$$

$$\hat{\theta} = \frac{(\hat{\beta}_0 + \hat{\beta}_1 + \cdots + \hat{\beta}_q)}{(1 - \hat{\phi}_1 - \cdots - \hat{\phi}_p)} \tag{4.11}$$

These estimators are called as ARDL-AIC and ARDL-SBC. There is a slight difference between the estimators of ARDL-AIC and ARDL-SBC in terms of small-sample performance because AIC cannot be described as a consistent model selection criterion whilst SBC can be regarded as being a consistent model selection criterion. Moreover, as it is seen in the expressions from (4.9) to (4.11), the long-run coefficients are calculated through the short-run parameters, which indicates that the impacts of the lagged variables can be seized by the long-run coefficients.

As for the standard errors for the ARDL-based long-term coefficient estimates, they are computed by applying the so-called ‘delta’ technique. And similarly, Bewely’s (1979) regression approach is also used to get the asymptotic standard errors [16]. When the both methods are compared, their results are seen to be the same as each other.

4.5. Bounds Test Approach for Co-integration

Pesaran, Shin and Smith [17] (PSS henceforth) introduced bound testing approach which is connoted as PSS bounds testing approach in the econometric literature. This approach perfectly analyzes the presence of co-integration relationship among variables by utilizing ARDL technique in the framework of error correction model.

Bounds testing approach depends on Vector Autoregression (VAR) model and the following five assumptions.

First of all, write a (k+1)-VAR model of order p (VAR(p)):

$$\phi(L)(z_i - \mu - \gamma t) = \varepsilon_t \qquad ; \forall t = 1,2,3,\ldots \tag{4.12}$$

In the Equation (4.12), L is defined as the lag operator, $\{z_t\}_{t=1}^{\infty}$ is a (k+1)-vector random process, μ is unknown (k+1)-vectors of intercept, γ is unknown (k+1)-vectors of trend coefficients. Also $\phi(L)$ is (k+1, k+1) matrix lag polynomial and it is defined as $\phi(L) = I_{k+1} - \sum_{i=1}^{p} \phi_i L^i$ for the (k+1, k+1)-matrices of unknown coefficients.

4.5.1. Assumptions of the Bounds Test

As it is mentioned in the last section, the assumptions which bounds testing approach depends on are given by PSS [17] as follows with their explanations.

A.1. The roots of $|I_{k+1} - \sum_{i=1}^{p} \phi_i z^i| = 0$ are either outside the unit circle |z|=1 or satisfy z=1.

The first assumption ensures that the permission of the elements for $\mathbf{z_i}$ to be purely I(0) or purely I(1) or mutually co-integrated except for the probability of seasonal unit roots.

A.2. The vector error process $\{\varepsilon_t\}_{t=1}^{\infty}$ is $IN(0,\Omega), \Omega$ positive definite.

The second assumption allows $\{\varepsilon_t\}_{t=1}^{\infty}$ to be both a conditionally mean zero and homoscedastic process.

It is important to note that the study of Pesaran, Shin and Smith [17] is established on the base of conditional modelling of the scalar variable y_t given the k-vector $\boldsymbol{x_t}$ and the past values $\{z_{t-i}\}_{i=1}^{t-1}$ and Z_0 where $z_t = (y_t, x_t')'$ is partitioned.

VAR(p) in Equation (4.12) is derived into a system of conditional error correction model (ECM) as follows:

$$\Delta y_t = c_0 + c_1 t + \pi_{y.x}\mathbf{z_{t-1}} + \sum_{i=1}^{p-1} \psi_i' \Delta \mathbf{z_{t-i}} + w'\Delta \mathbf{X_t} + u_t \ ; \ \forall t = 1,2, \dots \qquad (4.13)$$

where the difference operator Δ is defined as $\Delta = 1 - L$, $w \equiv \Omega_{xx}^{-1} w_{xy}$, $c_0 \equiv a_{y0} - w' a_{x0}$, $c_1 \equiv a_{y1} - w' a_{x1}$, the short-run multiplier $\psi' = \gamma_{yi} - w'\Gamma_{xi}$, $\forall 1 \leq i \leq p - 1$, and $\pi_{y.x} \equiv \pi_y - w'\Pi_x$.

Partitioning the error term ε_i with $z_t = (y_t', x_t')'$ as $\varepsilon_t = (\varepsilon_{yt}, \varepsilon_{xt}')'$ and its variance matrix as $\Omega = \begin{pmatrix} w_{yy} & w_{xx} \\ w_{xy} & \Omega_{xx} \end{pmatrix}$. Also ε_{yt} can be conditionally expressed in terms of ε_{xt} as $\varepsilon_{yt} = w_{yx}\Omega_{xx}^{-1} w_{xy} + u_t$ for u_t being independent of ε_{xt}. Moreover, the long-term multiplier matrix Π is partitioned with $z_t = (y_t, x_t')'$ as $\Pi = \begin{pmatrix} \pi_{yy} & \pi_{yx} \\ \pi_{xy} & \Pi_{xx} \end{pmatrix}$.

A3. The k-vector $\pi_{xy} = 0$

The third assumption implies that it cannot be mentioned about the existence of any feedback from the level of y_t in the system of conditional unrestricted error correction of $\boldsymbol{X_t}$, yet parallel constraints on the short-term multipliers in the equations for $\boldsymbol{X_t}$ is never put [74].

$$\mathbf{\Delta X_t} = a_{x0} + a_{x1}t + \Pi_{xx}X_{t-1} + \sum_{i=1}^{p-1}\Gamma_{xi}\Delta z_{t-1} + \varepsilon_{xt} \quad ; t = 1,2,\ldots \tag{4.14}$$

The assumption apparently limits vectors $\mathbf{X_t}$ as forcing variable**s** to the process $\{\boldsymbol{X_t}\}_{\boldsymbol{t=1}}^{\infty}$ as long-run forcing for $\{\boldsymbol{y_t}\}_{\boldsymbol{t=1}}^{\infty}$**.** According to Yan [74], the underlying reason for this assumption is to restrain taking into account the cases of the presence of at most one conditional level relationship among y_t and $\boldsymbol{X_t}$ regardless of the integration order of $\{\boldsymbol{X_t}\}_{\boldsymbol{t=1}}^{\infty}$.

Under the third assumption, the error correction model given in the Equation (4.13) also becomes:

$$\Delta y_t = c_0 + c_1 t + \pi_{yy}y_{t-1} + \pi_{yx.x}x_{t-1} + \sum_{i=1}^{p-1}\psi_i'\,\Delta z_{t-i} + w'\Delta x_t + u_t \;\; ; \; \forall t = 1,2,\ldots \tag{4.15}$$

where $c_0 = -(\pi_{yy}, \pi_{yx.x})\mu + [\gamma_{y.x} + (\pi_{yy}, \pi_{yx.x})]\gamma$ and $c_1 = -(\pi_{yy}, \pi_{yx.x})\gamma$ and $\pi_{yx.x} \equiv \pi_{yx} - w'\Pi_{xx}$.

A4. Rank($\Pi_{xx} = \alpha_{xx}\beta_{xx}'$) = r for $0 \leq r \leq k$, where α_{xx} and β_{xx}' are defined as (k,r) matrices of full column rank.

Up to here, Π has rank r and is given by $\Pi = \begin{pmatrix} 0 & \pi_{yx} \\ 0 & \Pi_{xx} \end{pmatrix}$. Therefore, it is expressed as $\Pi = \alpha\beta'$ where $\alpha = (\alpha_{yx}', \alpha_{xx}')'$ and $\beta = (0, \beta_{xx}')'$ are matrices of full column rank.

A5. a. If rank of Π is r, then the matrix $(a_y^{\perp}, a^{\perp})'\,\Gamma(\beta_y^{\perp}, \beta^{\perp})$ is full-rank k-r+1 for $0 \leq r \leq k$.

b. If rank of Π is equal to r+1, then the matrix $a^{\perp}\Gamma\beta^{\perp}$is full rank k-r for $0 \leq r \leq k$.

In the assumption 5, $(a_y^{\perp}, a^{\perp})$ and $(\beta_y^{\perp}, \beta^{\perp})$ are defined as the columns of (k+1, k-r+1) matrices, where $a_y^{\perp}$, $\beta_y^{\perp}$ and $a^{\perp}, \beta^{\perp}$ are respectively (k+1)-vectors and (k+1, k-r)-matrices, and the columns of $a_y^{\perp}$ and $\beta_y^{\perp}$ denote bases for the orthogonal complements of respectively (a_y, α) and (β_y, β). And here, $a^{\perp\prime}(\alpha_y, \alpha) = 0$ and $\beta^{\perp\prime}(\beta_y, \beta) = 0$. Also, if rank of Π is equal to r, then π_{yy} is not equal to zero and the long multiplier Π can be expressed as $\Pi = \alpha_y\beta_y' + \alpha\beta'$ where $\alpha_y = (\alpha_{yy}, 0')'$ and $\beta_y = (\beta_{yy}, \beta_{yx}{}')'$ are both (k+1) vectors [17].

As a results of these assumptions, these six assumptions allow for the series $\{x_t\}_{t=1}^{\infty}$. When the series is a purely I(0), a_{xx} and β_{xx} are non-singular. Similarly, when the series is a purely I(1), a_{xx} and β_{xx} are null matrices [17].

4.5.2. The Existence of Degenerate Case

Pesaran et al. [17] stated a special case which is called degenerate case. For the case, Pesaran et al. [17] consider the following conditional level relationship between y_t and $\mathbf{X_t}$.

$$y_t \equiv \varphi_0 + \varphi_1 t + \varphi X_t + \nu_t \qquad ; \ t = 1,2, \dots \qquad (4.16)$$

where $\varphi_0 \equiv \pi_{y.x}\mu/\pi_{yy}$, $\varphi_1 \equiv \pi_{y.x}\gamma/\pi_{yy}$, $\varphi \equiv -\pi_{yx.x}/\pi_{yy}$and ν_t is zero mean stationary process.

The case in which $\pi_{yy} \neq 0$ and $\pi_{yx.x} = 0'$ is called first degenerate case. y_t is stationary or $y_t \sim I(0)$ regardless of the value of r. In this degenerate case, the only the lagged dependent variable is remarkable while the lagged independent variables are not [74]. That is, Δy_t which is given in the conditional ECM equation

(4.14), is only relied on its own lagged level y_{t-1}, but it is not dependent on the lagged level x_{t-1} of the independent variable.

The case in which π_{yy} is equal to zero, that is the assumption A5(a) holds, and $\pi_{yx.x} \neq 0'$ is called second degenerate case. In this case, $y_t \sim I(1)$ regardless of the value of r. Unlike the first degenerate case, the second degenerate case considers the condition where lagged independent variables are important whereas lagged dependent variable is not [74].

When both $\pi_{yy} = 0$ and $\pi_{yx.x} = 0'$, there does not exist any level effect in the conditional ECM (4.14) without the likelihood of any association among y_t and $\mathbf{X_t}$., degenerate or otherwise and $y_t \sim I(1)$ regardless of the value of r. Hence, the variables are co-integrated if and only if $\pi_{yy} \neq 0$ and $\pi_{yx.x} \neq 0'$, degenerate cases are not considered as co-integration [74].

4.5.3. The Cases for the Bounds Test

The bounds test uses the basic and essential assumptions of Johansen's five EC multi-variance VAR models. Regarding the existence of constant, time trend, and restricted condition, it was categorized five cases of interest delineated by the specification of deterministic components [17].

Case-1: If there is neither intercept nor trend, that is, c_0 and c_1 are both equal to 0, then the given conditional error correction model (4.14) is modified as:

$$\Delta y_t = \pi_{yy} y_{t-1} + \pi_{yx.x} x_{t-1} + \sum_{i=1}^{p-1} \psi_i' \Delta z_{t-i} + w' \Delta x_t + u_t \;\; ; \; \forall t = 1,2, \ldots \qquad (4.17)$$

since $c_0 = -(\pi_{yy}, \pi_{yx.x})\mu = 0 \;\Leftrightarrow\; \mu = 0$, and $c_1 = -(\pi_{yy}, \pi_{yx.x})\gamma = 0 \Leftrightarrow \gamma = 0$.

Case-2: If there are restricted intercept, but no trend, then the given conditional error correction model (4.14) is modified for all $t = 1,2, \dots$ as:

$$\Delta y_t = -(\pi_{yy}, \pi_{yx.x})\mu + \pi_{yy} y_{t-1} + \pi_{yx.x} x_{t-1} + \sum_{i=1}^{p-1} \psi_i' \Delta z_{t-i} + w' \Delta x_t + u_t \tag{4.18}$$

$$\Delta y_t = \pi_{yy}(y_{t-1} - \mu_y) + \pi_{yx.x}(x_{t-1} - \mu_x) + \sum_{i=1}^{p-1} \psi_i' \Delta z_{t-i} + w' \Delta x_t + u_t \tag{4.19}$$

since $c_0 = -(\pi_{yy}, \pi_{yx.x})\mu$ and $c_1 = -(\pi_{yy}, \pi_{yx.x})\gamma = 0 \Leftrightarrow \gamma = 0$.

Case-3: If there are unrestricted intercepts, but no trend, then the given conditional error correction model (3.14) is modified as:

$$\Delta y_t = c_0 + \pi_{yy} y_{t-1} + \pi_{yx.x} x_{t-1} + \sum_{i=1}^{p-1} \psi_i' \Delta z_{t-i} + w' \Delta x_t + u_t \; ; \; \forall t = 1,2, \dots \tag{4.20}$$

since c_0 is not 0 but $c_0 = -(\pi_{yy}, \pi_{yx.x})\mu$ is ignored and $c_1 = -(\pi_{yy}, \pi_{yx.x})\gamma = 0 \Leftrightarrow \gamma = 0$.

Case-4: If there are unrestricted intercepts and restricted trend, then the given conditional error correction model (4.14) is modified for all $t = 1,2, \dots$ as:

$$\Delta y_t = c_0 - (\pi_{yy}, \pi_{yx.x})\gamma t + \pi_{yy} y_{t-1} + \pi_{yx.x} x_{t-1} + \sum_{i=1}^{p-1} \psi_i' \Delta z_{t-i} + w' \Delta x_t + u_t \tag{4.21}$$

$$\Delta y_t = c_0 + \pi_{yy}\left(y_{t-1} - \gamma_y t\right) + \pi_{yx.x}(x_{t-1} - \gamma_x t) + \sum_{i=1}^{p-1} \psi_i' \Delta z_{t-i} + w'\Delta x_t + u_t \tag{4.22}$$

since $c_0 \neq 0$ but $c_0 = -\left(\pi_{yy}, \pi_{yx.x}\right)\mu$ is ignored and $c_1 = -\left(\pi_{yy}, \pi_{yx.x}\right)\gamma$.

Case-5: If there are unrestricted intercepts and unrestricted trend, then the given conditional error correction model (4.14) is modified for all $t = 1,2, \ldots$ as:

$$\Delta y_t = c_0 + c_1 t + \pi_{yy} y_{t-1} + \pi_{yx.x} x_{t-1} + \sum_{i=1}^{p-1} \psi_i' \Delta z_{t-i} + w'\Delta x_t + u_t \tag{4.23}$$

since $c_0 \neq 0$, $c_1 \neq 0$,but $c_0 = -\left(\pi_{yy}, \pi_{yx.x}\right)\mu$ and also $c_1 = -\left(\pi_{yy}, \pi_{yx.x}\right)\gamma$ are ignored.

4.5.4. The Null and Alternative Hypothesis for Bounding Test Approach

This technique is to assess the presence of a level relationship among pairs of variables having a unit root and no unit root predicated upon standard F test (Wald test) which is required to be jointly significant.

Under the null hypothesis which is defined below, the asymptotic distribution of the standard F statistics (or standard Wald statistic) for checking the joint significance of coefficients on the one-term values of the variables is not standard which relies on:

(i) variables contained in the ARDL model are integrated of order one or level,
(ii) the amount of dependent variables,
(iii) the ARDL model includes an intercept and/or a trend term.

In the unrestricted error-correction model, the testify for the non-existence of a level relationship between y_t and $\mathbf{X_t}$ is conducted with the defined null and alternative hypotheses:

$$H_0 = H_0^{\pi_{yy}} \cap H_0^{\pi_{yx.x}}$$

against

$$H_1 = H_1^{\pi_{yy}} \cup H_1^{\pi_{yx.x}}$$

where

$$H_0^{\pi_{yy}}: \pi_{yy} = 0 \quad ; \quad H_1^{\pi_{yy}}: \pi_{yy} \neq 0'$$

$$H_0^{\pi_{yx.x}}: \pi_{yx.x} = 0 \quad ; \quad H_1^{\pi_{yx.x}}: \pi_{yx.x} \neq 0'$$

The null hypothesis tests the absence of a long-term association among the investigated variables y_t and $\mathbf{X}_t$.

4.5.5. The Calculation of the Wald and F – Statistics

In order to define the F-statistics and the Wald statistics, Pesaran et al. [17] consider the Case 4 and the equation is re-expressed as follows:

$$\Delta y = i_T c_0 + Z_{-1}^{*}\pi_{y.x}^{*} + \Delta Z_{-}\psi + u \tag{4.24}$$

where i_T is a T-vector of ones, $\Delta y \equiv (\Delta y_1, \dots, \Delta y_T)'$, $\Delta\mathbf{X} \equiv (\Delta x_1, \dots, \Delta x_T)'$, $\Delta\mathbf{Z}_{-i} \equiv (\Delta z_{1-i}, \dots, \Delta z_{T-i})'$, $\forall i = 1, \dots, p-1$, $\psi \equiv (w', \psi_1', \dots, \psi_{p-1}')'$, $\Delta\mathbf{Z}_{-} \equiv (\Delta\mathbf{X}, \Delta\mathbf{Z}_{-i}, \dots, \Delta\mathbf{Z}_{1-p})$, $Z_{-1}^{*} \equiv (\tau_T, Z_{-1})$ for $\tau_T \equiv (1, \dots, T)'$, $\mathbf{Z}_{-i} = (z_0, \dots, z_{T-1})'$, $u \equiv (u_1, \dots, u_T)'$ and $\pi_{y.x}^{*} = \begin{pmatrix} -\gamma' \\ \mathbf{I_{k+1}} \end{pmatrix}\begin{pmatrix} \pi_{yy} \\ \pi_{yx.x} \end{pmatrix}$. And also the least squares (LS) estimator of $\pi_{y.x}^{*}$ is given by $\hat{\pi}_{y.x}^{*} \equiv \left(\tilde{Z}^{*\prime}_{-1}\overline{P}_{\widetilde{\Delta Z_-}}\tilde{Z}_{-1}^{*}\right)^{-1}\tilde{Z}^{*\prime}_{-1}\overline{P}_{\widetilde{\Delta Z_-}}\widetilde{\Delta y}$,where $\tilde{Z}_{-1}^{*} \equiv \overline{P}_i Z_{-1}^{*}$, $\widetilde{\Delta Z_-} = \overline{P}_i \Delta Z_-$, $\widetilde{\Delta y} \equiv \overline{P}_i \Delta y$, $\overline{P}_i \equiv \mathbf{I_T} -, \widetilde{\Delta Z_-}\left(, \widetilde{\Delta Z_-}', \widetilde{\Delta Z_-}\right)^{-1}, \widetilde{\Delta Z_-}'$.

The Wald-statistics and F-statistics are calculated, respectively, by

$$\mathrm{W} \equiv \hat{\pi}_{y.x}^{*\prime}\, \tilde{Z}^{*\prime}_{-1}\, \overline{P}_{\widetilde{\Delta Z_-}} \tilde{Z}^{*}_{-1} \hat{\pi}_{y.x}^{*} / \hat{w}_{uu} \text{ and } \mathrm{F} \equiv \frac{\mathrm{W}}{k+2} \tag{4.25}$$

In the Equation (4.25), $\hat{w}_{uu} = (T-m)^{-1} \sum_{t=1}^{T} \tilde{u}_t^2$ for the number of estimated coefficients $m \equiv (k+1)(p+1)+1$ and the least squares residuals $\tilde{u}_t \quad \forall t = 1,2, \ldots$

Theorem 1: Under the conditions that the given assumptions from one to five hold and that the null hypothesis $H_0 = H_0^{\pi_{yy}} \cap H_0^{\pi_{yx.x}}$ is not rejected, the asymptotic distribution of the Wald statistic W of the expression (4.8) can be represented as:

$$\mathrm{W} \Rightarrow z_r' z_r + \int_0^1 dW_u(a) \mathbf{F_{k-r+1}(a)}' \left(\int_0^1 \mathbf{F_{k-r+1}(a)} \mathbf{F_{k-r+1}(a)}' \, da \right)^{-1} \int_0^1 \mathbf{F_{k-r+1}(a)} \mathbf{dW_u(a)} \tag{4.26}$$

where $z_r \sim N(0, \mathbf{I_r})$ and $f(x) = \begin{cases} W_{k-r+1}(a) & for\ Case\ 1 \\ (W_{k-r+1}(a)', 1)' & for\ Case\ 2 \\ \widetilde{W}_{k-r+1}(a) & for\ Case\ 3 \\ \left(\widetilde{W}_{k-r+1}(a)', 1\right)' & for\ Case\ 4 \\ \widehat{W}_{k-r+1}(a) & for\ Case\ 5 \end{cases}$

and $r = 0, \ldots, k$ and $a \in [0,1]$.

The theorem is called as the limiting distribution of W as well.

After giving this theorem, they give the following two corollaries in order that asymptotic critical values are obtained from the corollaries.

The first corollary is about limiting distribution of W when $\{x_t\} \sim I(0)$. Under the given first five assumptions, and if r is equal to k i.e. r=k, such that $\{x_t\} \sim I(0)$, then under the given null hypothesis $H_0^{\pi_{yy}}: \pi_{yy} = 0 \quad ; \quad H_0^{\pi_{yy}}: \pi_{yy} \neq 0'$, as T converges to infinity, the asymptotic distribution of the Wald statistic W of (4.25) can also be represented as follows:

$$W \Rightarrow z_k' z_k + \frac{\left(\int_0^1 F(a) dW_u(a)\right)^2}{(\int_0^1 F(a)^2 da)} \quad (4.27)$$

where $z_k \sim N(0, I_k)$ has an independent distribution of the second term in the Equation (4.26) and it is defined as:

$$F(a) = \begin{cases} W_u(a) & for\ Case\ 1 \\ (W_u(a), 1)' & for\ Case\ 2 \\ \widetilde{W}_u(a) & for\ Case\ 3 \\ \left(\widetilde{W}_u(a), a - \frac{1}{2}\right)' & for\ Case\ 4 \\ \widehat{W}_u(a) & for\ Case\ 5 \end{cases} \quad (4.28)$$

for $r = 0, \dots, k\ and\ a \in [0,1]$.

The second corollary is also about limiting distribution of W when $\{x_t\}$ ~I(1). Similarly, under the given first five assumptions, and if r is equal to zero such that $\{x_t\}$ is stationary at the first difference, then under the given null hypothesis $H_0^{\pi_{yy}}: \pi_{yy} = 0$; $H_0^{\pi_{yy}}: \pi_{yy} \neq 0'$, as T converges to infinity, the asymptotic distribution of the Wald statistic W of (4.24) can also be represented as follow:

$$W \Rightarrow \int_0^1 dW_u(a) F_{k+1}(a)' \left(\int_0^1 F_{k+1}(a) F_{k+1}(a)'\, da \right)^{-1} \int_0^1 F_{k+1}(a) dW_u(a) \quad (4.29)$$

where $F_{k+1}(a)$ is defined in theorem and $a \in [0,1]$.

4.5.6. The Consistency Property for Bounds Testing Procedure Based on Both F and Wald Statistics

The consistency property for bound testing technique predicated on both Wald statistic and on t-statistic is assured by the following theorems:

Theorem 2: If assumptions from 1 to 4 and 5b are valid, then under the alternative hypothesis $H_1^{\pi_{yy}}: \pi_{yy} \neq 0'$, the Wald statistic W is consistent against $H_1^{\pi_{yy}}: \pi_{yy} \neq 0'$ for the five cases.

Theorem 3: If assumptions from 1 to 5a are valid, then under the null hypothesis $H_0^{\pi_{yy}}: \pi_{yy} = 0$ and the alternative hypothesis $H_1^{\pi_{yy.x}}: \pi_{yy.x} \neq 0$, the Wald statistic W is consistent against $H_1^{\pi_{yy.x}}: \pi_{yy.x} \neq 0$ for the five cases.

4.5.7. The Critical Value of Bounds Test

Instead of the standard critical values, PSS [17] provide two asymptotic critical value bounds which are not only based on whether the intercept and trend are present or not in the model, but also relied on the dimension and co-integration rank, k and r, of the forcing variables $\mathbf{X}_t$. Pesaran et al. [17] especially demonstrate that the critical values take on lower bound when r is equal to k while the critical values take on upper bounds when r is equal to zero. The generation of the critical values for F-test is predicated on two alternative data-generating processes; hence, one case is assumed all variables are I(1). Another case is I(0). The values which are generated with I(0) regressors set up lower bounds to the critical values whilst values which are generated by the I(1) regressors set up upper bounds to the critical values. Therefore, these two sets of critical values supply critical value bounds that comprise entire potential categorizations of into I(0), I(1), and even mutually co-integrated. The PSS [17] of critical value bounds consisting of the cases 1 to 5 are presented in Appendix for the sizes 0.100, 0.050, 0.025, and 0.010.

It is considerably important to note that Pesaran et al. [17] produced critical values relies on sample sizes of 500 observations [75] and 1000 observations [17] and respectively 20,000 and 40,000 replications of a stochastic stimulation [76]. Nevertheless, Narayan [18] claimed that these critical values which were generated by PSS, were not worthy to test for small samples. In order to prove this claim, in the paper of Narayan [18], the new critical values were produced by using 31 observations with 4 regressors and then, the critical values of Narayan (2004) and the critical values of Pesaran et al. [17] were compared. It is found that Narayan's the upper bound critical value at the 5% significance level is 4.13 [18] whereas the corresponding critical value that is reported by Pesaran et al. [17] is 3.49. That is to say, it is obviously seen that the critical value for 1000 observations is 35.5% lower than for 31 observations. Besides the comparison of his critical values with those of Pesaran et al. [17], Narayan [18] made a compassion of Narayan [18]'s critical value for 31 observations to the critical values for 500 observations which is reported by Pesaran and Pesaran [75]. According to this comparison, the upper bound critical value at the 5 percent level is less than that for 31 observations. Because of this reason, Narayan [18] again estimated appropriate critical values for sample size in the interval from 30 to 80 observations for the usual levels of significance by using the same GAUSS code. In this way, he succeeded to obtain a well-founded result concerning co-integration for small sample size.

4.5.8. The Interpretation of the Comparison Results

For the PSS [17] of critical value bounds, PSS suggest the following procedure: When the computed F statistic exceeds the upper bound critical value, i.e. $F>F_U$, then the null hypothesis of no co-integration could not be accepted and it can be concluded that the presence of steady state equilibrium between the variables is found; if the calculated F-value is less than the lower bound critical value, i.e. $F < F_L$, then the null hypothesis of no co-integration can be accepted.

On the other hand, when the computed F-statistics falls inside the lower and upper bound critical value bounds, i.e. $F_L < F < F_U$, a conclusive decision cannot be made. And for that, co-integration rank r of the $\{x_t\}$ process should be proceeded. According to the study of Haq and Larsson [77], in the case that an inclusive conclusion from the F-test is obtained, there may exist a possible solution. And Haq and Larsson [77] highlighted to utilize a negative and significant error correction term in a similar frame for the promotion of co-integration (long-run relationship) under the inconclusive case. For that, Pesaran et al. [17] suggested t-test as an alternative test that is equivalent to F-test. The t-test has a similar null hypothesis and lower and upper bounds to those of the F-test. Briefly, the t-test can be a complementary test when the F-test is inconclusive [17]; [77].

Knowing the integration order of the explanatory variables is essential before drawing any conclusive inference. In the cases that the order of integration of the variables is exactly identified, the decision mechanism is as follows: when all the variables are integrated of order one, the decision is reached predicated on the upper bounds; likewise, when all the variables are stationary at level, the decision is reached predicated on the lower bounds [78].

As for the Narayan's critical values, the interpretation of test results is the same as that of Pesaran et al. [17].

4.6. Error Correction Models Based on ARDL Model

Hassler and Wolters [19] also provided a detailed discussion on ARDL and error correction models.

The ARDL model of order p and q is defined by Hassler and Wolters [19] as follows:

$$y_t = \alpha_0 + \sum_{i=1}^{p} \phi_i y_{t-i} + \sum_{i=0}^{q} \beta_i' X_{t-i} + u_t \qquad (4.30)$$

where α_0 is a constant term, ϕ_i are scalar coefficients, β_i' are row vectors, u_t is a scalar zero mean error term and X_{t-i} is a *K*-dimensional column vector process of explanatory variables, i.e. $X_{t-i} = [x_t, x_{t-1}, \ldots, x_{t-q}]'$. In the equation (4.30), $\sum_{i=0}^{q} \beta_i'$ is the long-run effect over all future periods, which is sometimes denoted as the vector of equilibrium multipliers [79].

Hassler and Wolters [19] omitted the constant term from the model (4.30) in order to shorten it, and accordingly the following equation is re-written.

$$\phi(L)y_t = \beta'(L)\mathbf{X}_t + u_t \tag{4.31}$$

where the lag operator L is implemented to every component of a vector, $L^k X_t = X_{t-k}$ and it is convenient to introduce the lag polynomial $\phi(L) = 1 - \phi_1 L - \cdots - \phi_p L^p$ and the vector polynomial $\beta(L) = \beta_0 + \beta_1 L + \cdots + \beta_q L^q$ as it is defined before. In addition, β_0 is known to show the immediate impacts of changes in the explanatory variable vector $\boldsymbol{X}_t$ [79].

Hassler and Wolters [19] indicate that the expression (4.30) is necessarily converted to dynamic stability in order to interpret parameters in economic aspects even though the expression (4.30) is acceptable for estimation in statistical aspect.

For dynamic stability, Hassler and Wolters [19] maintain that the roots of the characteristic polynomial of ϕ have to lie outside the unit circle, i.e. $\phi(z) = 0$ implies that $|z| > 1$ for $z \in \mathbb{C}$. This condition guarantees the presence of an absolutely summable infinite expansion of the inverted polynomial $\phi^{-1}(L)$ as follows:

$$\phi^{-1}(L) = \frac{1}{\phi(L)} = \sum_{j=0}^{\infty} \phi_j^* L^j \tag{4.32}$$

where $\sum_{j=0}^{\infty} | \phi_j^* |$ is finite, i.e. $\sum_{j=0}^{\infty} | \phi_j^* | < \infty$.

Therefore, it follows from the Equation (4.31) that the inevitability of $\phi(L)$ generates the following representation:

$$y_t = \frac{\beta'(L)}{\phi(L)} X_t + \vartheta_t \tag{4.33}$$

where $\phi(L)\vartheta_t = \varepsilon_t$ and ϑ_t has a stable autoregressive structure of order p. Hence, the following infinite distributed lag representation results from expanding $\phi^{-1}(L)$.

$$y_t = \left(\sum_{j=0}^{\infty} \phi_j^* L^j\right)\left(\sum_{j=0}^{\infty} \beta_j L^j\right)' \mathbf{X_t} + \vartheta_t = \left(\sum_{j=0}^{\infty} \gamma_j' X_{t-j}\right) + \vartheta_t \tag{4.34}$$

where γ_j is defined as the vectors of dynamic multipliers which are derived by the method of undetermined coefficients with the vector of long-term multipliers $\Gamma = \sum_{j=0}^{\infty} \gamma_j = \frac{\beta(1)}{\phi(1)}$.

And then, Hassler and Wolters [19] opt for re-parameterizing the ARDL model given in the Equation (4.30) by re-arranging the **X**'s with $\Delta = 1 - L$

$$y_t = \alpha_0 + \sum_{i=1}^{p} \phi_i y_{t-i} + \phi(1)\Gamma'\mathbf{X_t} - \sum_{i=0}^{q-1}\left(\sum_{j=i+1}^{q} \beta_j\right)' + \mathbf{\Delta X_t} + u_t \tag{4.35}$$

where Hassler and Wolters [19] especially highlighted y_t to be concerning its own past, to contemporaneous $\mathbf{X_t}$ and differences $\mathbf{\Delta X_{t-i}}$.

$$\sum_{i=1}^{p} \phi_i y_{t-i} - y_{t-1} = -\phi(1)y_{t-1} - \sum_{i=1}^{p-1}\left(\sum_{j=i+1}^{p} \phi_j\right)\Delta y_{t-i} + u_t \tag{4.36}$$

By utilizing the expression (4.36) and $\mathbf{X_t} = \mathbf{X_{t-1}} + \mathbf{\Delta X_t}$, the expression (4.35) yields the following equation which is called an error correction representation :

$$\Delta y_t = -\phi(1)(y_{t-1} - \Gamma'\mathbf{X_{t-1}}) - \sum_{i=1}^{p-1}\left(\sum_{j=i+1}^{p} \phi_j\right)\Delta y_{t-i} + \left(\phi(1)\Gamma - \sum_{j=1}^{q} \beta_j\right)' \mathbf{\Delta X_t} - \sum_{i=0}^{q-1}\left(\sum_{j=i+1}^{q} \beta_j\right)' + \mathbf{\Delta X_{t-i}} + u_t \tag{4.37}$$

In this error correction representation, the economic interpretation of parameters depends on the long-term equilibrium relation, i.e. $y_t = \Gamma'\mathbf{X_{t-1}}$, if there exists such a linear combination with $\Gamma \neq 0$. And moreover, the EC mechanism is known to be the adjustment of y_t through $\mu(1)$ to deviations from equilibrium in the preceding period, which is denoted $(y_{t-1} - \Gamma'\mathbf{X_{t-1}})$.

Another version of the error correction representation, which is given in the expression (4.37), is introduced as follows:

$$\Delta y_t = \phi(1)y_{t-1} + \beta'\mathbf{X_{t-i}} + \sum_{i=1}^{p-1} a_i \Delta y_{t-i} + \sum_{i=0}^{q-1} \gamma_i' \mathbf{\Delta X_{t-i}} + u_t \qquad (4.38)$$

for $c = -\phi b$.

Assumptions:

A1. The vector $(y_t, \boldsymbol{X_t'})'$ of length *K+1* is I(1).

A2. The vector $\mathbf{X_t}$ alone is not co-integrated.

A3. $\mathbf{X_t}$ does not adjust to past equilibrium deviations $(y_{t-1} - \Gamma'\mathbf{X_{t-1}})$.

A4. The errors u_t are serially independent with variance σ^2, i.e. $u_t \sim iid(0, \sigma^2)$.

A5. (Exogeneity Assumption) The errors are uncorrelated with Δx_{t+h} $\forall h \in \mathbb{Z}$. This assumption allows Δx_t to be exogenous.

4.7. The Analysis of the Assumptions and Properties by Using ARDL (1,1)

Each type of single-equation model in empirical time series methods is a particular case of an ARDL(1,1) [80]; [81]. Therefore, the following simple bivariate model is considered in order to construct the ARDL(1,1) model specification without the deterministic trend,

$$y_t = \alpha_0 + \alpha_1 y_{t-1} + \alpha_2 x_{t-1} + v_t \qquad (4.39)$$

$$x_t = \omega + \lambda x_{t-1} + \xi_t \tag{4.40}$$

where y and x are defined respectively as the decision variable and the forcing variable. Moreover, the residuals used in the Equations (4.39) and (4.40) have the following distributional properties:

$$\begin{pmatrix} v_t \\ \xi_t \end{pmatrix} \sim \text{iid}(0, \Sigma), \quad \Sigma = \begin{pmatrix} \sigma_{vv} & \sigma_{v\xi} \\ \sigma_{\xi v} & \sigma_{\xi\xi} \end{pmatrix} \tag{4.41}$$

Then, it is modeled the contemporaneous correlation between $v_t$and ξ_t by a linear regression of $v_t$on ξ_t as follows

$$v_t = \left(\frac{\sigma_{v\xi}}{\sigma_{\xi\xi}}\right)\xi_t + u_t \tag{4.42}$$

where u_t is distributed independently from ξ_t.

$$y_t = \alpha_0 + \alpha_1 y_{t-1} + \alpha_2 x_{t-1} + v_t$$

$$y_t = \alpha_0 + \alpha_1 y_{t-1} + \alpha_2 x_{t-1} + v_t = \left(\frac{\sigma_{v\xi}}{\sigma_{\xi\xi}}\right)\xi_t + u_t$$

$$y_t = \alpha_0 + \alpha_1 y_{t-1} + \alpha_2 x_{t-1} + v_t = \left(\frac{\sigma_{v\xi}}{\sigma_{\xi\xi}}\right)(x_t - \omega - \lambda x_{t-1}) + u_t$$

$$y_t = \left(\alpha_0 - \omega\frac{\sigma_{v\xi}}{\sigma_{\xi\xi}}\right) + \alpha_1 y_{t-1} + \frac{\sigma_{v\xi}}{\sigma_{\xi\xi}}x_t + \left(\alpha_2 - \lambda\frac{\sigma_{v\xi}}{\sigma_{\xi\xi}}\right)x_{t-1} + u_t$$

$$y_t = \zeta + \phi y_{t-1} + \beta_0 x_t + \beta_1 x_{t-1} + u_t \qquad ; \forall t = 1,2,\ldots,T \tag{4.43}$$

where $\zeta = \left(\alpha_0 - \omega\frac{\sigma_{v\xi}}{\sigma_{\xi\xi}}\right), \phi = \alpha, \beta_0 = \frac{\sigma_{v\xi}}{\sigma_{\xi\xi}}$ and $\beta_1 = \left(\alpha_2 - \lambda\frac{\sigma_{v\xi}}{\sigma_{\xi\xi}}\right)$. Moreover, y_t is stable and ϕ, β_0 and β_1 are unknown parameters, x_t is I(1) process generated by $x_t = \omega + \lambda x_{t-1} + \xi_t$.

The ECM implied by the ARDL (1,1) in Equations (4.39) and (4.40) can be expressed as

$$y_t - y_{t-1} = \left(\alpha_0 - \omega\frac{\sigma_{v\xi}}{\sigma_{\xi\xi}}\right) + \alpha_1 y_{t-1} - y_{t-1} + \frac{\sigma_{v\xi}}{\sigma_{\xi\xi}}x_t + \left(\alpha_2 - \lambda\frac{\sigma_{v\xi}}{\sigma_{\xi\xi}}\right)x_{t-1} + u_t$$

$$\Delta y_t = \left(\alpha_0 - \omega\frac{\sigma_{v\xi}}{\sigma_{\xi\xi}}\right) - (1-\alpha_1)y_{t-1} + \frac{\sigma_{v\xi}}{\sigma_{\xi\xi}}x_t + \left(\alpha_2 - \lambda\frac{\sigma_{v\xi}}{\sigma_{\xi\xi}}\right)x_{t-1} + u_t$$

$$= \left(\alpha_0 - \omega\frac{\sigma_{v\xi}}{\sigma_{\xi\xi}}\right) - (1-\alpha_1)y_{t-1} + \frac{\sigma_{v\xi}}{\sigma_{\xi\xi}}x_t + \alpha_2 x_{t-1} - \lambda\frac{\sigma_{v\xi}}{\sigma_{\xi\xi}}x_{t-1} + \frac{\sigma_{v\xi}}{\sigma_{\xi\xi}}x_{t-1} - \frac{\sigma_{v\xi}}{\sigma_{\xi\xi}}x_{t-1} + u_t$$

$$= \left(\alpha_0 - \omega\frac{\sigma_{v\xi}}{\sigma_{\xi\xi}}\right) - (1-\alpha_1)y_{t-1} + \left(\alpha_2 + (1-\lambda)\frac{\sigma_{v\xi}}{\sigma_{\xi\xi}}\right)x_{t-1} + \frac{\sigma_{v\xi}}{\sigma_{\xi\xi}}(x_t - x_{t-1}) + u_t$$

$$= \zeta + \gamma y_{t-1} + \rho x_{t-1} + \psi\Delta x_t + u_t$$

(4.44)

where $\zeta\left(\alpha_0 - \omega\frac{\sigma_{v\xi}}{\sigma_{\xi\xi}}\right)$, $\gamma = -(1-\alpha_1)$, $\rho = \left(\alpha_2 + (1-\lambda)\frac{\sigma_{v\xi}}{\sigma_{\xi\xi}}\right)$, and $\psi = \frac{\sigma_{v\xi}}{\sigma_{\xi\xi_0}}$

To confirm the co-integration between variables, the unrestricted ECM (UECM) in Equation (4.44) is estimated. The reason why the ARDL is called an UECM is that the error correction term in the ARDL has no restricted error corrections [82].

According to the assumption A5, the expression which is called the UECM is rewritten and the following equation is further obtained by

$$\Delta y_t = -(1-\alpha_1)[y_{t-1} - \frac{\left(\alpha_0 - \omega\frac{\sigma_{v\xi}}{\sigma_{\xi\xi}}\right)}{(1-\alpha_1)} - \frac{\left(\alpha_2 + (1-\lambda)\frac{\sigma_{v\xi}}{\sigma_{\xi\xi}}\right)}{(1-\alpha_1)}x_{t-1}] + \frac{\sigma_{v\xi}}{\sigma_{\xi\xi}}\Delta x_t + u_t$$

$$\Delta y_t = \gamma(y_{t-1} - \zeta - \rho x_{t-1}) + \psi\Delta x_t + u_t$$

(4.45)

where the expression $[y_{t-1} - \frac{\left(\alpha_0 - \omega\frac{\sigma_{v\xi}}{\sigma_{\xi\xi}}\right)}{(1-\alpha_1)} - \frac{\left(\alpha_2 + (1-\lambda)\frac{\sigma_{v\xi}}{\sigma_{\xi\xi}}\right)}{(1-\alpha_1)} x_{t-1}]$ is the error correction term (equilibrium error). And $(1-\alpha_1)$ is the speed of adjustment. That is, $(1-\alpha_1)$ measures the speed with which Δy_t adjusts towards equilibrium. Equation (4.45) is called restricted error correction model (RECM). And the long-run parameter $b = -\frac{\left(\alpha_2 + (1-\lambda)\frac{\sigma_{v\xi}}{\sigma_{\xi\xi}}\right)}{(1-\alpha_1)} = -\frac{\rho}{\gamma}$.

The values of the speed of adjustment is noteworthy. The value being equal to zero indicates that there exists no long-run relationship. If the value falls the interval between -1 and 0, then there exists partial adjustment. If the value is less than -1, then the model over-adjusts in the current period. And moreover, that the value is positive means that the system moves away from equilibrium in the long-run [83].

Furthermore, Shittu, Yemitan and Yaya [84] review the re-parameterized ARDL model to the ECM. And as a result of the study, they infer that the current change in y_t is the sum of two following components:

- the current change in y_t is proportional to the current change in $\boldsymbol{X_t}$.
- the current change in y_t is a partial correction for the extent to y_{t-1} deviates from the equilibrium values corresponding to $\mathbf{X_{t-1}}$.

Theorem 4: Let's consider the UECM defined in the Equation (4.44),

$$\Delta y_t = \zeta + \gamma y_{t-1} + \rho x_{t-1} + \psi \Delta x_t + u_t \qquad (4.46)$$

Under the assumptions A1 and A5,

(1) The ARDL-based estimators of the long-term parameter, obtained by $\hat{b} = -\frac{\hat{\rho}}{\hat{\gamma}}$, converges to $b = -\frac{\rho}{\gamma}$ as the sample size T goes to infinity and $T(\hat{b} - b)$ has the limiting normal distribution.

(2) The *t-statistics testing* b is equal to b_0 converges to the standard normal distribution.

(3) The OLS estimators of all of the short-run parameters $\gamma, \rho,$ and ψ denoted by $\hat{\gamma}, \hat{\rho}$ and $\hat{\psi}$ are $\sqrt{T}$-consistent and have the asymptotic normal distribution.

4.8. The Advantages of ARDL Bounds Testing Procedure

The ARDL bounds testing approach has quite a few econometric superiorities compared with alternative and traditional co-integration methods.

1- The most important advantages of ARDL bounds test approach is that this approach can be applied even if the variables are not integrated in the same order. That is to say, the ARDL model are possible to be estimated irrespective of whether underlying regressors are purely I(0), purely I(1) or mutually co-integrated [16]. Nonetheless, Johansen's co-integration technique requires that all variables to be stationary at the same order and even they are purely stationary at the first difference I(1). Therefore, Johansen's co-integration is at serious disadvantage compared to the ARDL technique. In this issue, Charemza and Deadman [13] claim that estimating an econometric model using non-stationary data is unreliable; hence, use of the ARDL bound co-integration approach is the best technique in order to overcome problems arising from non-stationary time series.

2- The ARDL-based short-run coefficients estimators are consistent; on the other hand, ARDL estimators of long-run parameters are super consistent and asymptotically normal distributed [16].

3- Due to the fact that ARDL-based short-term and long-term parameters can meet the property of consistency for small sample size, the ARDL method estimates more statistically significant long-run relationships for small data samples while the estimation of co-integrated relationship using Johansen's method is valid if and only if the used data samples are large. As a contribution to this, Haug's study [85] demonstrates that when the ARDL bound testing approach is compared to conventional approaches such as the Engle and Granger [6], the Johansen and Juselius [86] and the Philips and Hansen [87] co-integration tests, the small sample properties of ARDL bound testing approach are more strongly suitable [85].

4- Another significant advantage of ARDL method is that ARDL method does not suffer from the problem of endogeneity unlike other traditional co-integration methods because the ARDL method is able to distinguish dependent and explanatory variables. That is, the ARDL assumes that there is one dependent variable and the rest of the variables are at least weakly exogenous [88]. Thanks to this feature, the ARDL technique usually yields unbiased estimates of the long-term model, and the t-statistic derived from it is valid even though some of the regressors are endogenous [89]. Furthermore, it should not be forgotten that appropriate modification of the orders of ARDL model is considerably sufficient to impede problems resulting from endogenous variables [16].

5- The another side of ARDL model which outweighs that of Johansen's co-integration method is that in ARDL model, a different number of optimal lags is permitted for different variables whilst Johansen's method prohibits this and conversely, it requires a uniform number of lags [90].

6- ARDL method has an edge on the permission for ARDL model to consist of dummy variables unlike the Johansen's method [91]. This is because, utilizing the ARDL a large number of options can be made including decisions concerning the number of independent and dependent variables, if any, for inclusion, the behaviour of deterministic elements, in addition to the order of VAR, and the optimum number of lags in the model [90]; [73]; [91].

7- ARDL model bound testing approach is robust against concurrent equation bias and autocorrelation so long as the orders of the ARDL model are sufficiently chosen on the basis of earlier-information by making use of a model selection procedure such as the AIC or SBC [92].

8- Bentzen and Engsted [93] state that the ARDL bound testing technique simultaneously forecasts the short-term and long-term impacts of one variable on the other variables and it also disjoins the short-term and long-term impacts from one another.

9- The ARDL approach allows the application of general-to-specific modeling approach that is the econometric methodological benchmark pioneered by Davidson et al. [148] so as to forecast consistent parameters of the model [94].

4.9. The Application of ARDL Bounds Test Procedure

In previous sections of this chapter, ARDL bounds test procedure has been discussed in the theoretical aspect. Now, it is briefly explained how to perform ARDL bounds testing procedure in empirical analysis.

- The first step is to check that none of the variables in the model is at I(2).

- The optimal lag lengths are determined by means of such information criteria as AIC, SBC, HQ and the like among the estimated $(m+1)^{(k+1)}$ different ARDL models for the maximum number of lag, m and the number of variables, k.

- With the optimal lags, either F test or t-test for the null hypothesis of no co-integration is carried out. To assess the null hypothesis, the computed F-statistic is compared to the new critical values tabulated by Pesaran et al. [17].

- Once the null hypothesis is rejected, the goodness of fit of the ARDL model should be done through diagnostic tests including serial correlation, normality test, heteroscedasticity, Ramsey RESET test, and CUSUM & CUSUMSQ.

- Another step is to estimate the long-run relationship using the selected ARDL model.

- As the final step, in the situation of the presence of long-term relation between variables, the ECM representation of ARDL model is discussed. By employing ECM version of ARDL model, the speed of adjustment to equilibrium can be obtained.

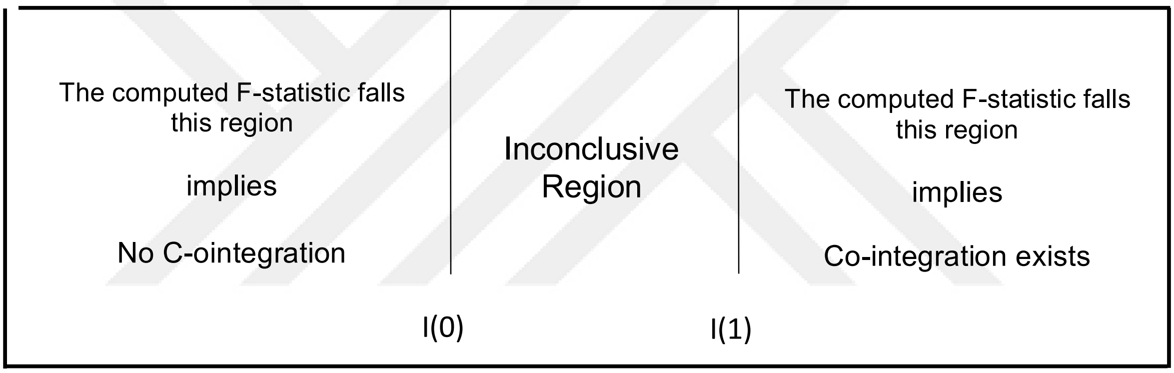


Figure 4. The Determination Table

These steps are also summarized in the Figure 5 that is given by Shakya [95].

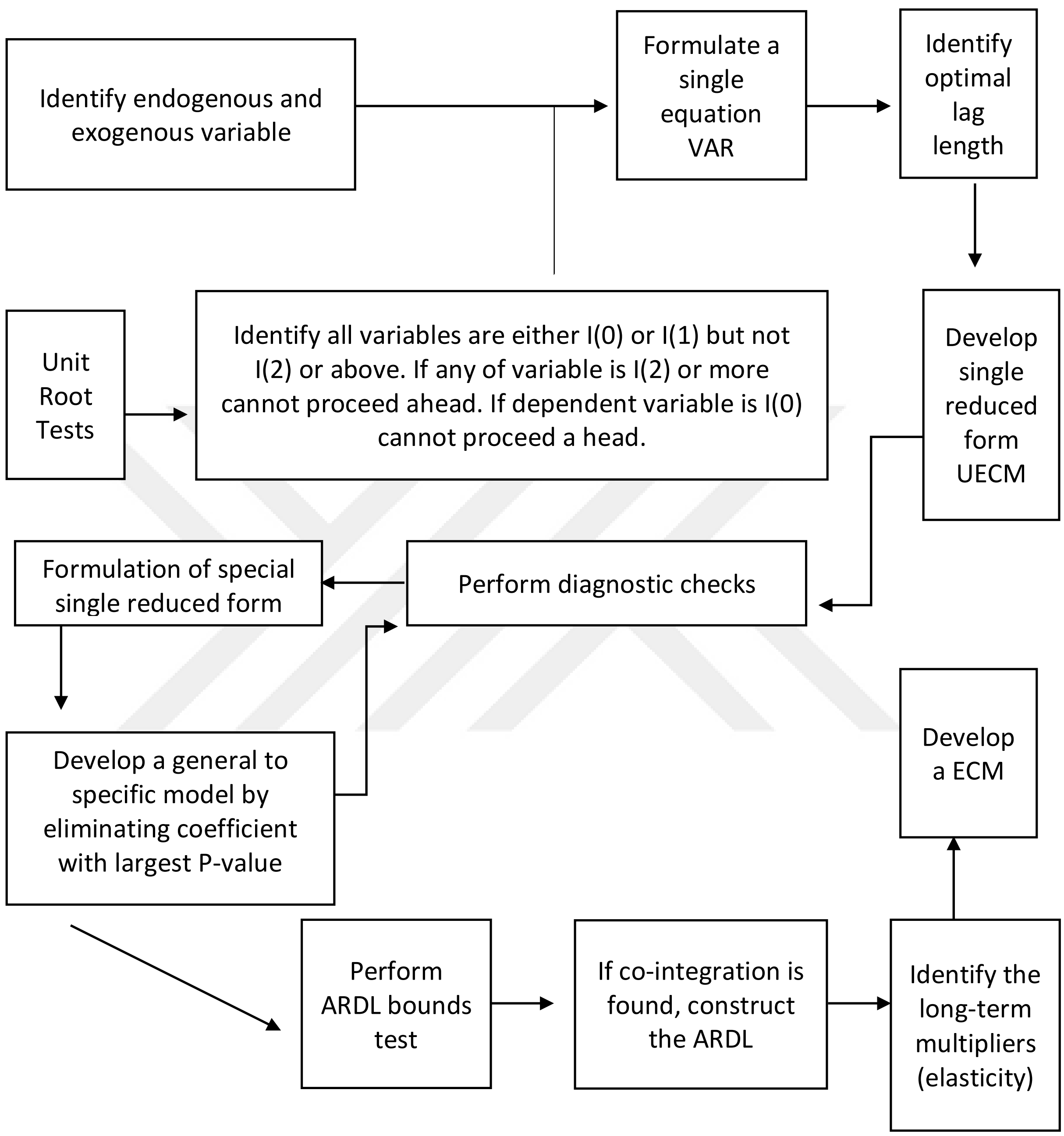


Figure 5. ARDL Bounds Test Procedure [95]

5. CAUSALITY TESTS

It is undoubtedly that testing causality between variables is one of the integral parts of statistics related to time series. Yet it still remains difficult and complicated concept. At first, Granger [96] developed a relatively simple causality test which is called Granger Causality which uses forecast-ability as a criterion. Since Granger causality analysis requires carrying out a zero restriction on the specific parameters in VAR model, test statistics can be obtained by applying Wald or Chi-square tests. That is, the causality test is predicated on calculated F-statistics for the normal Wald test under the condition that all series are stationary [4]. Granger causality test has some conditions as well. The first and most important one is all series should be stationary. Additionally, if there exist a co-integration between the series, then Granger causality test is performed predicated on vector error correction model (VECM) rather than VAR model [97]. Nevertheless, in the cases that there exist non-stationary variables at level in the VAR models, F and Chi-square distribution may be said to have non-standard asymptotic properties. That is to say, Wald tests for Granger causality may lead non-standard limiting distributions predicated on the co-integration features of the model [98].

There are also several variants of this Granger causality test including the Sims [99] causality test, Dolado and Lütkepohl [22] causality approach, and the Toda and Yamamoto [12] test.

The first alternative causality test developed by Sims [99] utilizes the notion of causality is that it is impossible for the future to cause the present. And also, for non-stationary series, the Wald statistics never converges Chi-square distribution. Because of these reasons, test results may be invalid [4]. That is to say, Toda and Yamamoto [12] claim that F-statistic used to test for traditional Granger causality has a highly likelihood to be invalid as the test does not have a standard distribution in the case that the time series data are neither integrated nor co-integrated [100]. In order to overcome this problem, Toda and Yamamoto [12] and Dolado and Lütkepohl [22] propose a causality approach which is more applicable in comparison to others.

5.1. Toda Yamamoto Causality Test

In 1995, Toda and Yamamoto proposed a new method which is a modification of the standard Granger causality test on the non-stationary series. A causality procedure proposed by Toda and Yamamoto [12] is seen to be complementary to the Sims et al. [99] method since it permits causal inference predicated on augmented level VAR with integrated and co-integrated processes [101].

5.2. The Advantages of Toda-Yamamoto Causality Test

The advantages of Toda-Yamamoto test (TY) is found to be superior to those of other causality tests.

1- The first and main advantage of TY test is that in the case there does not exist any co-integrated relationship between the variables, the causality procedure should be carried out on a VAR in differenced series [12].
2- This causality test avoids potential bias associated with the presence of unit roots because it is possible to be employed irrespective of whether a series is I(0), I(1) or I(2).
3- In spite of the presence of additional lagged variables to the vector auto-regression which are not restrictive while conducting the Granger causality test, TY causality procedure gives rise to slight loss of power in comparison with alternative of causality testing the restrictions on a VECM that places co-integrating limitations [102].

5.3. The Disadvantages of Toda-Yamamoto Causality Test

As well as the advantages of TY causality test which are listed above, there are major drawbacks.

1- In the cases that sample size is considerably small, it is apparently proven that the asymptotic distribution is possible to poorly approximate to the distribution of the test statistic [103]; [104].
2- Some loss of power might result from that the VAR model is intentionally over-fitted [12]; [104].

5.4. The General Model of Toda-Yamamoto Causality Approach

As it is mentioned, Toda-Yamamoto approach is predicated on VAR model. Toda-Yamamoto causality test is briefly explained as follows:

First of all, n-vector time series $\{y_t\}_{t=-k+1}^{\infty}$ is generated with the function as

$$y_t = \beta_0 + \beta_1 t + \cdots + \beta_q t^q + \eta_t \tag{5.1}$$

where for known k, $\{\eta_t\}$ contains an order of integration equal to *d*, i.e. $\{\eta_t\}\sim$*I(d)*, that comes from the following k-th order vector autoregressive process:

$$\eta_t := J_1\eta_{t-1} + J_2\eta_{t-2} + \cdots + J_k\eta_{t-k} + \epsilon_t \tag{5.2}$$

In the Equation (5.2), $\{\epsilon_t = (\epsilon_{1t}, \ldots, \epsilon_{nt})'\}$ is assumed to be an i.i.d. sequence of $N(0, \Sigma_\epsilon) > 0$ such that $\Sigma\epsilon > 0$ and $E|\epsilon|^{2+\delta} < \infty$ for some $\delta > 0$.

From the Equation (5.1), the expressions can be derived by

$$\eta_t = y_t - \beta_0 - \beta_1 t - \cdots - \beta_q t^q \tag{5.3}$$

$$\eta_{t-1} = y_{t-1} - \beta_0 - \beta_1(t-1) - \cdots - \beta_q(t-1)^q$$

$$\eta_{t-2} = y_{t-2} - \beta_0 - \beta_1(t-2) - \cdots - \beta_q(t-2)^q$$

$$\vdots$$

$$\eta_{t-k} = y_{t-k} - \beta_0 - \beta_1(t-k) - \cdots - \beta_q(t-k)^q \tag{5.4}$$

By substituting the Equation (5.4) into the Equation (5.2), we obtain

$$\eta_t = y_t - \beta_0 - \beta_1 t - \cdots - \beta_q t^q$$

$$= J_1\left(y_{t-1} - \beta_0 - \beta_1(t-1) - \beta_2(t-1)^2 - \cdots - \beta_q(t-1)^q\right)$$

$$+J_2\left(y_{t-2}-\beta_0-\beta_1(t-2)-\beta_2(t-2)^2-\cdots-\beta_q(t-2)^q\right)$$
$$+\cdots+J_k\left(y_{t-k}-\beta_0-\beta_1(t-k)-\beta_2(t-k)^2-\cdots-\beta_q(t-k)^q\right)+\epsilon_t \quad (5.5)$$

After some calculations, $y_t$is obtained as follows:

$$y_t=\gamma_0+\gamma_1 t+\cdots+\gamma_q t^q+J_1 y_{t-1}+\ J_2 y_{t-2}+\cdots+J_k y_{t-k}+\epsilon_t \quad (5.6)$$

where $\gamma_i(i=0,1,\ldots,q)$ is a function of $\beta_i\ (i=1\,,2,\ldots,q)$ and $J_h\ (h=1\,,2,\ldots,k)$.

5.5. The Establishment of TY Hypotheses

In the general case, the null hypothesis can be defined as follows:

$$H_0\colon f(\phi)=0 \quad (5.7)$$

where the parameter $\phi=\mathrm{vec}(\Phi)$ of the second model in (5.2), where $\Phi=(J_1,\ldots,J_k)$ and $f(.)$ is defined as m-vector valued function. And this function fulfills the assumption that $f(.)$ is a twice continuously differentiable function with $\mathrm{rank}\left(F(.)\right)=m$ in a neighborhood of the correct parameter value for $F(\theta)=\partial f(\theta)/\ \partial\theta'$.

It is important to note that Toda and Yamamoto [12] take into account the significance of coefficient of lagged y_t whereas they ignore whether the process y_t is integrated, co-integrated or stationary. Therefore, the null hypothesis is formulated about the parameters of model (5.3) as follows:

$$H_0\colon J_{k+1}=J_{k+2}=\cdots=J_p=0 \quad (5.8)$$

for $t=1,\ldots,T$ and $p\geq k+d$.

The mentioned restrictions on the parameter of equation (5.6) are implemented and the parameter is estimated at levels of series in VAR by ordinary least squares as follows:

$$y_t=\hat{\gamma}_0+\hat{\gamma}_1 t+\cdots+\hat{\gamma}_q t^q+\hat{J}_1 y_{t-1}+\cdots+\hat{J}_k y_{t-k}+\cdots+\hat{J}_p y_{t-p}+\hat{\epsilon_t} \quad (5.9)$$

where the terms have been defined before, $t = 1, \ldots, T$ and $p \geq k + d$.

The parameters of the added lags should be remained unlimited in the null hypothesis so as that the efficiency of the asymptotic Chi-square values is guaranteed in the case that the assumption of normality is satisfied in the VAR model [12]; [105]. Thus, the expression (5.9) can be re-written in the matrix format as follows:

$$Y' = \hat{\Gamma}\mathcal{F}' + \hat{\Phi}X' + \hat{\psi}Z' + \hat{\mathscr{f}}' \tag{5.10}$$

where $\hat{\Gamma} = (\hat{\gamma}_0, \ldots \hat{\gamma}_q)$, $\mathcal{F} = (\tau_1, \ldots, \tau_T)'$ for $\tau_t = (t^0, t^1, \ldots, t^q)'$,

$X = (x_1, \ldots, x_T)'$ for $x_t = (y'_{t-1}, \ldots, y'_{t-k})'$,

$Z = (z_1, \ldots, z_T)'$ for $z_t = (y'_{t-k-1}, \ldots, y'_{t-p})'$,

$\hat{\Phi} = (\hat{J}_1, \ldots, \hat{J}_k)$ and $\hat{\psi} = (\hat{J}_{k+1}, \ldots, \hat{J}_p)$.

And, by using the expression (5.10), the estimation of the unrestricted regression can be derived so as to obtain a vector of estimated residuals by computing the variance-covariance matrix of the residuals [105].

5.6. The Establishment of Test Statistics

In order to testify the null hypothesis given in the expression (5.8), the modification version of a standard Wald statistic *W* based on augmented Vector Autoregressive $VAR(p + d)$ was formulated as follows:

$$MWALD = f(\hat{\phi})'[F(\hat{\phi})\{\hat{\Sigma}_\epsilon \otimes (X'QX)^{-1}\} F(\hat{\phi})']^{-1} f(\hat{\phi}) \tag{5.11}$$

where $\hat{\Sigma}_\epsilon = T^{-1}\hat{\mathscr{f}}'\hat{\mathscr{f}}$, $Q = Q_\tau - Q_\tau Z(Z'^{Q_\tau}Z)^{-1}Z'Q_\tau$ and $Q_\tau = I_T - \mathcal{F}(\mathcal{F}'\mathcal{F})^{-1}\mathcal{F}'$ with TxT-identity matrix I_T . And here, F denotes an indicator matrix $p \times n(1 + (p + d))$

indicating zero value parameters, the Kronecker product shown by the symbol ⊗ represents a matrix multiplication of an element by all elements [105].

Toda and Yamamoto demonstrated the fact that the Wald statistics given in the expression (5.11) has an asymptotic Chi-square distribution when the degree of freedom is under the given null hypothesis in the circumstances that $p \geq k + d$. They accordingly said that the determination of the maximal order of integration d_{max} is the crucial step. And, this step is completed through the estimation of a model that is intentionally over-fitted with additional d_{max} lags; that is, $p = k + d_{max}$.

5.7. The Selection of Lag Length

As it is widely known, the reason why to determine the optimal lag order is essential is that all inference in the VAR model is predicated on the selected lag order. The optimal lag order in the VAR model is able to be selected by utilizing a new information criterion proposed by Hatemi-J [106]. The Hatemi-J [106] criterion is defined as the following:

$$\mathrm{HJC} = \ln(|\Omega_z|) + z + v^2 \left(\frac{\ln N + 2\ln(\ln N)}{2N}\right) \qquad ;\ z = 0, \ldots, p \qquad (5.12)$$

where HJC is the Hatemi information criterion, *ln* is natural logarithm, $|\Omega_z|$ denotes the lag order of z determinant of the estimated white noise variance-covariance matrix in the VAR framework, v and N show the number of variables and observations used in the VAR model respectively. According to Hatemi-J [106], it is noteworthy that HJC exhibits great performance particularly when variables are not stationary.

5.8. Dolado and Lütkepohl Causality Test

Dolado and Lütkepohl [22] published a study in 1996 so as to improve TY causality approach. The fundamental difference between Toda Yamamoto approach and

Dolado- Lütkepohl (DL) approach is that Toda and Yamamoto define VAR model as VAR(k+d) whilst Dolado and Lütkepohl [22] define the same model as VAR(k+1) since d_{max} being equal to 1 shows better performance in comparison to other integration orders [107]; [108]. Like Toda and Yamamoto's causality approach, the main aims of Dolado and Lütkepohl [22] are to deal with some difficulties and problems related to causality tests in a regression without any importance whether variables are co-integrated or not.

The testing technique covers two steps. Initially, a VAR (p) is constructed by one of AIC, SBC and HJC. For that, the determination of the optimal lag length is an integral part of the DL test procedure by means of these information criteria owing to the fact that results of causality test can be affected quickly by the lag added. Secondly, after the estimation of a VAR (p +1), the standard Wald test is implemented on the first p lags. The important point for the DL approach is that for Granger causality test, standard Wald tests ought to be applied on the first p coefficient matrix. In this way, for VAR(p+1) model, the null hypothesis of no causality relationship from X_t to Y_t, i.e. $H_0 = \alpha_{2i} = 0$, can be defined and the Wald (F) test can be applied.

The VAR (p +1) model is expressed as follows:

$$\mathrm{Y_t = \alpha_0 + \sum_{i=1}^{p+1} \alpha_{1(i+1)} Y_{t-(i+1)} + \sum_{i=1}^{p+1} \alpha_{2(i+1)} Y_{t-(i+1)} + \varepsilon_{1t}} \quad (5.13)$$

$$\mathrm{X_t = \beta_0 + \sum_{i=1}^{p+1} \beta_{1(i+1)} Y_{t-(i+1)} + \sum_{i=1}^{p+1} \beta_{2(i+1)} Y_{t-(i+1)} + \varepsilon_{2t}} \quad (5.14)$$

It is important to note that there is no restriction on the parameters related to d lag values.

5.9. The Boostrapping Methods to Produce Critical Values

According to Toda and Yamamoto [12], the defined model allows for the use of asymptotic distribution theory. However, with Monte Carlo evidence, Hacker and Hatemi-J [109] demonstrate that Wald test has a probability to violate the assumption of biasedness in statistical inference for small sample sizes when non-normality and autoregressive conditional heteroskedasicity (ARCH) impacts are found in the error term that is generally the case with financial data. Moreover, Hacker and Hatemi-J [109] prove that the implication predicated on the Toda-Yamamoto test statistic is more accurate when bootstrap distributions are preferred rather than asymptotic χ^2 distributions [97]. Thus, the implementation of the more correct and sound distribution theories like leverage distribution theory is recommended in order to eliminate the problems of size distortion and spurious regression results in finite sample sizes.

5.9.1. Leverage Bootstrapping Process – Based Toda-Yamamoto (1995) Causality

The one of the best ways to produce own critical values is Leverage Bootstrap procedure with employing the program procedure developed by Hacker and Hatemi-J [109] in GAUSS [105]. The generated critical values are predicated upon the underlying empirical data by means of bootstrap simulation.

The method to carry out Leverage Bootstrap simulation is summarized by Umar and Dahalan [105] and Bayat, Kayhan and Senturk [110] as follows.

First estimate

$$y_t^* = \hat{\Gamma} f_t + \hat{\phi} x_t + \hat{\psi} z_t + \not{f}^* \tag{5.15}$$

where $\not{f}^*$ represents the bootstrap residuals that are estimated on the basis of N random draws with replacement from Equation (5.15) having modified residuals with the probability of 1/N in every case. The reason for this modification is to make sure that the mean value of the bootstrapped residuals is equal to zero. The forecast of the equation is made with limitations of no Granger causality, and the data that is used for simulation is generated for every bootstrap simulation. The leverage adjustment is applied in order to adapt the modification of the regression's raw residuals to have constant variance.

The modified residual via leverage adjustment for Y_{it} is expressed by Hacker and Hatemi-J [111] as:

$$\hat{e}_{it}^{m} = \frac{\hat{e}_{it}}{\sqrt{1 - h_{it}}} \tag{5.16}$$

where $\hat{e}_{it}$ represents the ordinary residuals derived from the y_{it} regression for $i = 1,2,3,4$. h_{it} also represents t[th] element of h_i and it is the raw residual from the regression for y_{it} for $i = 1,2,3,4$.

$T \times 1$ leverages vector for y_{it} and y_{jt} is respectively assigned as $h_1 = \mathrm{diag}(Y_1(Y_1'Y_1)^{-1}Y_1')$ and $h_j = \mathrm{diag}(Y(Y_1'Y_1)^{-1}Y')$ for $i = 1,2,3,4$ and for $j = i - 1$, where Y_1 is used to show a regression matrix of independent variables that identify y_{1t} without any Granger causality restriction and Y displays a set of the regression matrix of regressors that explain y_{jt} containing the lags of all variables in the estimation.

Then, the bootstrap simulation is done and also, the MWALD t-statistics are computed subsequent to every iteration in order that the bootstrap critical values are computed by Hacker and Hatemi-J [23]. In this way, the upper $(\alpha)^{th}$ quantile of the bootstrapped distribution of the MWALD t-statistics is evaluated in order to generate 1%, 5% and 10% bootstrapped critical values. Lastly, the raw data rather than the bootstrapped one is preferred for the computation of the MWALD statistics. The null hypothesis of the absence Granger causal relationship cannot be accepted if the MWALD statistics, which is computed by means of the original data, is higher than the bootstrapped critical values.

5.10. The Application Steps of Toda Yamamoto Procedure

The process to apply TY causality approach is step by step summarized by Giles [112].

- The first step is to identify whether there exists a unit root in the used variables and if exists, the order of integration must be known by employing a unit root test.

- The second step is to determine the maximum integration order. For that, it is assumed that the test results imply that the variables have different order of integration; let's say the maximum order of integration is d_{max}. For example, if there are two time-series and one is found to be stationary at level and the other is stationary at the second difference, then d_{max}= 2.

- The third step is to set up a VAR model in the levels of the data, regardless of the degree of sationarity of the time series.

- The fourth step is to specify the maximum lag length for the variables in the VAR model, say p, by the help of the well-known information criteria such as AIC, SBC etc.

- The fifth step is to confirm the VAR that is well-identified in terms of AR unit root graph, VAR residual serial correlation LM-stat, VAR residual normality tests.

- The sixth step is to take the estimated VAR model and to add in d_{max} additional lags of each of the variables into each of the equations. And the VAR system will estimate at the level with the total k+d_{max} lags.

- The seventh step is to practice causality depending on VAR(k+d_{max}). And then, it should be testified whether the estimated results are statistically significant or not for k lags of the series.

The working steps of the Toda-Yamamoto and Dolado-Lütkepohl causality approach are apparently given by Shakya [95] as it is seen in Figure 6.

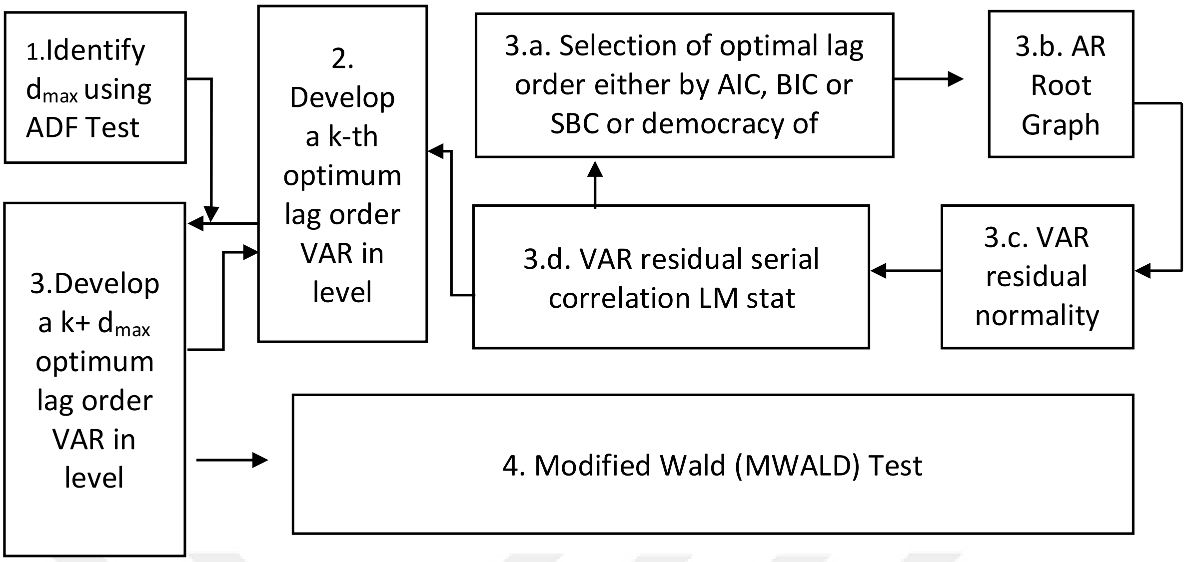


Figure 6. TYDL Test Procedure

6. SOME TESTS USED IN BOTH COINGRATION AND CAUSALITY ANALYSIS

In this chapter, prerequisite tests and diagnostic tests are presented. First of all, even though stationary analysis is not pre-condition for both co-integration and causality analysis, since the integration orders of variables are necessary to use in conducting both procedures, some unit root tests are initially explained. And then, diagnostic tests for both ARDL bounds testing approach and Toda-Yamamoto causality methods are thoroughly discussed.

6.1. Unit Root Tests

According to the clearest definition of non-stationarity term in the statistical literature, the recent observed data in the time series may be stochastically relying on the preceding observed data, which those variables whose means, variance and co-variances alter in the process of time because of trend, random walk, or both [95]. This case is known as variables being non-stationary. To estimate regression equation of time series having unit-root have many drawbacks. For example, the most known drawback is that misleading inferences may be obtained [113] because **u**nless the series are stationary, the estimated regressions with non-stationary series can cause the spurious regression because of this dependency. Spurious regression leads a high R^2 even if the two variables having trend over time are totally unrelated.

Even though the ARDL bounds testing procedure never require all variables to be stationary at the same order, the ARDL procedure is not applicable for the series being stationary at I(2). Similarly, even though the integration order of the variables is not important for Toda-Yamamoto causality approach, stationary analysis should be performed in order to identify the maximum order of integration of the series, $d_{max.}$

There exist many approaches to examine the stationarity of time series. Since this thesis used traditional unit root tests: the Augmented Dickey-Fuller (ADF) test proposed by Dickey and Fuller [114], Phillips-Perron test (PP) proposed by Phillips and Perron [115], and finally breakpoint unit root test offered by the latest version of E-views 9 Beta, these three tests are explained.

6.1.1. ADF Unit Root Test

ADF unit root test is conventionally and frequently performed so as to identify the order of integration of the series. The theoretical explanation of the ADF test is summarized in this section. For details, please see Asteriou and Hall [4].

Standard Dickey-Fuller (DF) test is mostly and formally used to detect non-stationarity condition. To do Standard DF, the error terms are supposed to be random and homogenous so that the assumptions of the time-series Gauss-Markov Theorem are met [149]. And DF test is performed by OLS estimator of the variables in the model.

Dickey and Fuller [114] start with the simplest case where the deterministic trend is zero. Since the DF test is sound and applicable only for AR(1), the random process AR(1) model is constructed in order to be representative of a variable y as follows:

$$y_t = \phi y_{t-1} + u_t \tag{6.1}$$

where $y_0 = 0$ and $u_t = \psi(L)\epsilon_t$ for $\epsilon_t \sim i.i.d.(0, \sigma_\epsilon^2)$ and $\psi(L) = \sum_{j=0}^{\infty} \psi_j L^j$ is a lag polynomial whose coefficient $\{\psi_j\}$ satify $\sum_{j=1}^{\infty} j|\psi_j| < \infty$. And moreover, here, the null hypothesis is described as H_0: $\varphi = 1$, i.e. $y_t \sim I(1)$ whereas the alternative hypothesis is H_1: $\varphi < 1$, i.e. $y_t \sim I(0)$.

Let

$$\hat{\phi} = \frac{\sum_{t=2}^{T} y_{t-1} y_t}{\sum_{t=2}^{T} y_{t-1}^2} \tag{6.2}$$

indicate the OLS estimator of ϕ and let's describe the t-statistic to test for the given unit root hypothesis as

$$t_{\hat{\phi}} = \frac{\hat{\phi} - 1}{s/\sqrt{\sum_{t=2}^{T} y_{t-1}^2}} \qquad \text{and} \qquad s^2 = T^{-1}\sum_{t=2}^{T}\left(y_t - \hat{\phi}y_{t-1}\right)^2 \tag{6.3}$$

Or similarly, under the null hypothesis, y_t and y_{t-1} are not stationary; thus, the t-statistic may be inflated and unreliable. Instead, $y_{t-1}$is subtracted from the both sides.

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

$$\Delta y_{t-1} = (\phi - 1)y_{t-1} + u_t$$

$$\Delta y_{t-1} = \gamma y_{t-1} + u_t$$

(6.4)

Then, the null hypothesis is $H_0: \gamma = 0$, and the alternative hypothesis is $H_1: \gamma < 0$

The latest version of the test is conveniently used. Dickey-Fuller Test also consists of two alternative regression equations for testing the existence of a unit root. The first one is

$$\Delta y_{t-1} = \alpha_0 + \gamma y_{t-1} + u_t \tag{6.5}$$

having a constant term and stochastic trend. If γ = 0, this exhibits a definite trend in the series. The case is very important for macroeconomic variables. The second one is

$$\Delta y_{t-1} = \alpha_0 + \alpha_2 t + \gamma y_{t-1} + u_t \tag{6.6}$$

having both a constant term and stochastic and deterministic trends together. If the assumption on the random and homogenous error terms is not hold, then the Augmented Dickey Fuller test (ADF) is used. There are three forms of ADF, which are

$$\Delta y_{t-1} = \gamma y_{t-1} + \sum_{i=1}^{p} \beta_i \Delta y_{t-i} + u_t \qquad (6.7)$$

$$= \alpha_0 + \gamma y_{t-1} + \sum_{i=1}^{p} \beta_i \Delta y_{t-i} + u_t \qquad (6.8)$$

$$= \alpha_0 + \gamma y_{t-1} + \alpha_2 t + \sum_{i=1}^{p} \beta_i \Delta y_{t-i} + u_t \qquad (6.9)$$

The difference between them is the same as that of DF test. In these models, the lag length is determined by Akaike Information Criterion (AIC), or Schwartz Bayesian Information Criterion (SBC), or Hannan-Quinn Criterion (HQ). Also we need to check whether the residuals are white noise. For both standard DF test and ADF, the normal t distribution table is not used. Instead of this, DF [114] τ table critical values are used.

6.1.1. Phillips-Perron Unit Root Test

Phillips and Perron [115] developed the most frequently used nonparametric unit root test as an alternative to the Augmented Dickey-Fuller procedure. It is undoubtedly that the worthiest feature of Phillips-Perron unit root test is to overcome serial correlation and heteroskedasticity in the errors, which do not suffer from the same degrees of freedom loss as the ADF test, by modifying the Dickey –Fuller (DF) statistic before comparing it to the relevant critical values. [147]. The procedure of Phillips and Perron (1988) unit root test is shortly described in this sub-section.

The Phillips-Perron (PP) test involves fitting the regression:

$$\Delta y_t = \alpha D_t + \pi y_{t-1} + u_t \qquad (6.10)$$

where, OLS residual u_t is I(0) and may be heteroskedastic. The null hypothesis for testing the existence of unit root is $H_0\colon \pi = 0$. There are two statistics, Z_t and Z_π, computed, respectively, as

$$Z_t = \sqrt{\frac{\hat{\sigma}^2}{\hat{\lambda}^2}}\, t_{\pi=0} - \frac{1}{2}\left(\frac{\hat{\lambda}^2-\hat{\sigma}^2}{\hat{\lambda}^2}\right)\left(T * \frac{SE(\hat{\pi})}{\hat{\sigma}^2}\right) = \sqrt{\frac{\hat{\sigma}^2}{\hat{\lambda}^2}}\, t_{\pi=0} \frac{\hat{\lambda}^2-\hat{\sigma}^2}{2\sqrt{\hat{\lambda}^2 T^{-2}\sum_{t=2}^{T} y_{t-1}^2}} \quad (6.11)$$

$$Z_\pi = T\hat{\pi} - \frac{1}{2}\frac{T^2 SE(\hat{\pi})}{\hat{\sigma}^2}\left(\hat{\lambda}^2 - \hat{\sigma}^2\right) = T\,\hat{\pi} - \frac{\hat{\lambda}^2 - \hat{\sigma}^2}{2T^{-2}\sum_{t=2}^{T} y_{t-1}^2} \quad (6.12)$$

where $\sigma^2 = \lim_{T\to\infty} T^{-1}\sum_{t=1}^{T} E[u_t^2]$, and $\lambda^2 = \lim_{T\to\infty}\sum_{t=1}^{T} E[T^{-1}s_T^2]$ for the innovation error variance $s_T^2 = \sum_{t=1}^{T} u_t$. Additionally, in expressions (6.11) and (6.12), $SE(\hat{\pi})$ denotes coefficient standard error [4]. Any serial correlation and heteroskedasticity in the errors u_t of the test regression are eliminated owing to the modification of the test statistics $T_{\pi=0}$ and $T\,\hat{\pi}$. And these modified statistics are denoted as Z_t and Z_π. And also, it is important to note that the Newey-West long-run variance estimate of u_t using $\hat{u}_t$ is known to be a consistent estimate of λ^2. As a result, under the given null hypothesis, the PP, Z_t and Z_π statistics, have the same asymptotic distributions as the ADF t-statistic and normalized bias statistics [116]. That is to say, in order to adjust undefined serial correlation and heteroskedasticity in disturbances, the modification of Dickey-Fuller test statistics is calculated via Newey-West standard errors.

An edge of the test is to be a non-parametric test; in other words, it is supposed not to be functional form for the error process of the variable. This signifies that it is relevant to a broad range of problems. On the other hand, a disadvantage for the test is that it relies on asymptotic theory, which means that the test has been shown to perform well unless sample size is small [117]. The main problem of the ADF and PP tests is that both have some deficiency in detecting the presence of unit roots. According to Maddala et al. [118], data frequencies that is lower than quarterly should be used so as not to obtain useless results.

6.1.2. Testing Stationarity in the Presence of Structural Breaks

The existence of structural breaks especially in macroeconomic variables is generally expected. Traditional unit root tests that disregard the presence of structural breaks in the series may give biased and inappropriate results. In the literature, there are a variety of unit root tests regarding the existence of structural break. At first, Perron [119] proved that quite a few perceived non-stationary series were actually found not to have a unit root under the presence of a structural break in time series. Perron [119] developed a procedure to testify the presence of a unit root in a series under a single exogenous break by employing asymptotic distribution theory. Perron [119] applies a modified Dickey-Fuller unit root test that consists of dummy variables to account for one known, or exogenous structural break [113]. The most common unit root test is Zivot and Andrews [120] unit root test. Because of some restrictions of Perron [119] models, Zivot and Andrews [120] purposed an enhancement over the Perron [119] test where they presume that the exact break point is unknown and endogenise the break date diagnosis. A data dependent algorithm is applied to proxy Perron’s subjective technique in order to identify of the break points endogenously [121].

As well as these unit root tests, a breakpoint unit root test is newly offered in the Beta release of EViews 9. Since the unit root test is also applied in the empirical analysis of the thesis, the theoretical background of this unit root test is summarized according to the website of Eviews-9 Beta [122].

First of all, a model ought to be established in order to conduct the breakpoint unit root test. For that, the model is classified into two categories in accordance with the break dynamics like the innovational outlier (IO) model and the additive outlier (AO) model. As for the features of IO model and AO model, these two models differ slightly from one another in terms of the occurrence speed of break. As the first model, rather than the break occurring at a single point in a time, an alteration in the level and trend of the data may exist throughout a time period. In other words, the breaks take place step by step and follow the same dynamic path as the innovations. This model is called as an innovational outlier. Alternatively, in the cases the breaks occur instantly, the additive outlier (AO) model is offered. These two versions of a model also have own sub-models according to the existence of a change in level and/or in trend. The sub-models consist of four basic models for time series data with a one-time break, which are a one-time change in level for non-trending data

(Model A), a change in level for trending data (Model B), a change in both level and trend (Model C) and a change in trend (Model D).

The following three models are adapted in order to conduct the suggested unit root test under the presence of structural break.

Secondly, before the construction of these models, let us define some variables used in the models. DU_t captures implies shift occurring at every possible break-date (TB) while DT_t is equivalent to trend shift variable. And,

$$\mathrm{DU_t} = \begin{cases} 1 & \text{for } \mathrm{t} > \mathrm{TB} \\ 0 & \text{otherwise} \end{cases} \text{, and} \quad \mathrm{DT_t} = \begin{cases} \mathrm{t} - \mathrm{TB} & \text{for } \mathrm{t} > \mathrm{TB} \\ 0 & \text{otherwise} \end{cases} \tag{6.13}$$

In addition, break variables are also defined. A particular break date is demonstrated by T_b and 1(.) is used as an indicator function that assigns the value 1 if the argument (.) is true, and 0 if not. An intercept break variable $DU_t(T_b) = 1(t \geq T_b)$ that assigns the value 0 for all dates previous to the break, and 1 henceforward. A trend break variable $DT_t(T_b) = 1(t \geq T_b).(t - T_b + 1)$ that assigns the value zero for all dates in advance of the break, and is a break date re-based trend for all successive dates. And finally, a one-time break dummy variable is defined as $D_t(T_b) = 1(t = T_b)$ that assigns the value of 1 only on the break date and 0 or else. Furthermore, β is trend coefficient, γ is trend break coefficient, θ is break coefficient and ω is dummy break coefficient.

Thirdly, for the innovational outlier (IO) model,

Model-A: for non-trending data with intercept break,

$$\mathrm{y_t} = \mu + \theta\ \mathrm{DU_t(T_b)} + \omega \mathrm{D_t(T_b)} + \alpha \mathrm{y_{t-1}} + \sum\nolimits_{\mathrm{i}=1}^{\mathrm{k}} \mathrm{c_i}\ \Delta \mathrm{y_{t-i}} + \mathrm{u_t} \tag{6.14}$$

Model-B: for trending data with intercept break,

$$y_t = \mu + \beta t + \theta\, DU_t(T_b) + \omega D_t(T_b) + \alpha y_{t-1} + \sum_{i=1}^{k} c_i\, \Delta y_{t-i} + u_t \tag{6.15}$$

Model-C: for trending data with intercept and trend break,

$$y_t = \mu + \beta t + \theta\, DU_t(T_b) + \gamma DT_t(T_b) + \omega D_t(T_b) + \alpha y_{t-1} + \sum_{i=1}^{k} c_i\, \Delta y_{t-i} + u_t \tag{6.16}$$

Model-D: for trending data with trend break,

$$y_t = \mu + \beta t + \gamma DT_t(T_b) + \alpha y_{t-1} + \sum_{i=1}^{k} c_i\, \Delta y_{t-i} + u_t \tag{6.17}$$

That is, the first model A permits a one-time alteration in the level of the series, the second model B permits a one-time alteration in the slope of the trend function, and the third model C incorporates one-time alterations in the level and the incline of the trend function of the series [123]. As to the null hypothesis for IO model, it is defined as

$$y_t = y_{t-1} + \beta + \psi(L)(\theta D_t(T_b) + \gamma DU_t(T_b) + \epsilon_t) \tag{6.18}$$

where the lag polynomial $\psi(L)$ denotes the dynamics of the stationary and the break variables are in the model with the identical dynamics to ϵ_t associated with i.i.d. innovations. The alternative hypothesis for IO model is also defined as

$$y_t = y_{t-1} + \beta t + \psi(L)(\theta DU_t(T_b) + \gamma DT_t(T_b) + \epsilon_t) \tag{6.19}$$

In this expression, a trend stationary model with breaks in the intercept and trend is supposed. The incorporation of these two hypotheses is also done as follows:

$$y_t = \mu + \beta t + \theta DU_t(T_b) + \gamma DT_t(T_b) + \omega D_t(T_b) + \alpha y_{t-1} + \sum_{i=1}^{k} c_i \Delta y_{t-i} + u_t \qquad (6.20)$$

Next, for the additive outlier (AO) model, The AO model has a two-step procedure. The first step is to obtain the detrending series via OLS by adding the intercept, trend and breaking variables. For that, four different models are defined as follows:

For non-trending data with intercept break, Model 1 is constructed as

$$y_t = \mu + \theta DU_t(T_b) + y_t^* \qquad (6.21)$$

For trending data with intercept break, Model 2 is established as

$$y_t = \mu + \beta t + \theta DU_t(T_b) + y_t^* \qquad (6.22)$$

For trending data with intercept and trend break, Model 3 is constructed as

$$y_t = \mu + \beta t + \theta DU_t(T_b) + \gamma DT_t(T_b) + y_t^* \qquad (6.23)$$

For trending data with trend break, Model 4 is established as

$$y_t = \mu + \beta t + \gamma DT_t(T_b) + y_t^* \qquad (6.24)$$

The second step is that the resulting Dickey Fuller unit root test equation is set up for the residuals y_t^* got from the de-trending equation.

For Models 1, 2, and 3:

$$y_t^* = \sum_{i=0}^{k} \omega_i D_{t-i}(T_b) + \alpha y_{t-1}^* + \sum_{i=0}^{k} c_i \Delta\, y_{t-1}^* + u_t \qquad (6.25)$$

For Model 4:

$$y_t^* = \alpha y_{t-1} + \sum_{i=0}^{k} c_i \Delta\, y_{t-1}^* + u_t \qquad (6.26)$$

The null hypothesis for AO model is also written as

$$y_t = y_{t-1} + \beta + \theta D_t(T_b) + \gamma DU_t(T_b) + \psi(L)\epsilon_t \quad (6.27)$$

where β refers a drift parameter, the lag polynomial $\psi(L)$ presents the dynamics of the stationary and the break variables are into the model with the identical dynamics to ϵ_t associated with i.i.d. innovations. The alternative hypothesis for a trend stationary model with potential breaks in the intercept and break is defined as:

$$y_t = \mu + \beta t + \theta DU_t(T_b) + \gamma DT_t(T_b) + \psi(L)\epsilon_t \quad (6.28)$$

In order to evaluate the null hypothesis, t-statistic is used. In all models, k represents a number of lags. And moreover, in order to identify k, the prospective or potential date T_b is better to be specified. Lag selection methods involve established techniques which are observation-based suggestion, t-test, F-test, and known information criterion. The choose of break date can be altered according to the minimization of the Dickey-Fuller t-statistic, the minimization or maximization of θ t-statistic, the maximization of $|\theta|$ t-statistic, the minimization or maximization of γ t-statistic, the maximization of $|\gamma|$ t-statistic and the maximization of (θ, γ) F-statistic.

6.2. Diagnostic Tests

In this section, some diagnostic tests which are used in both ARDL bounds testing model and Toda-Yamamoto causality model, are explained. These tests are respectively Jarque-Bera test for normality, Breusch-Godfrey LM test for autocorrelation, Breusch-Pagan test for heteroskedasticity, CUSUM and CUSUMQ tests for consistency and stability, recursive coefficient tests, and Ramsey RESET test.

6.2.1. Jarque-Bera Normality Test

The Jarque-Bera (J-B) normaility test introduced by Jarque and Bera [124] is a goodness of fit test in accordance to sample data owing the skewness and kurtosis since both skewness and kurtosis are associated with normal distribution. That is to say, the validity of the various goodness-of-fit statistics is confirmed in the only circumstances that the error term is distributed normally. Normal and non-normal distributed data are exhibited in Figure 7.

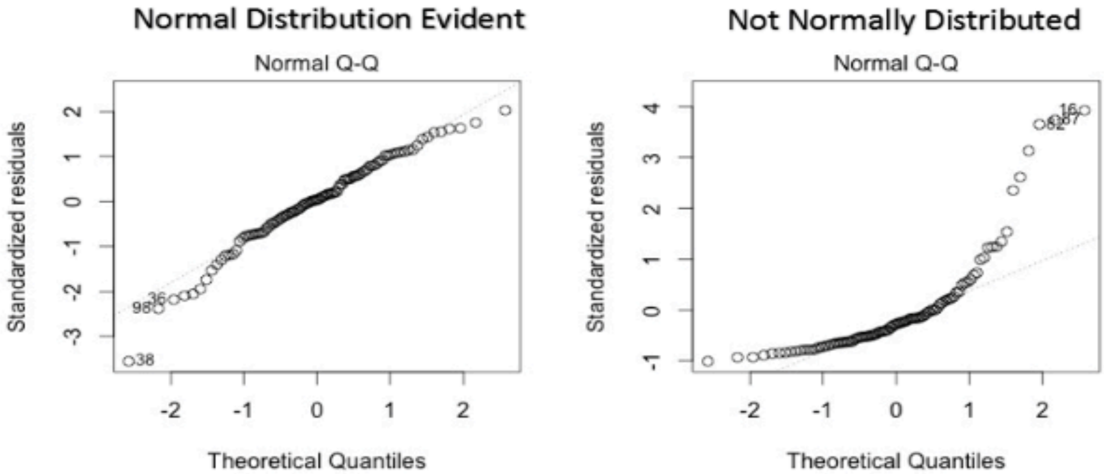


Figure 7. Normally and Non-Normally Distributed Data [125]

It is well-known that the skewness, which gauges to what extent the observations, is symmetric about the mean. It is measured by $S = \frac{[E(X-\mu)^3]^2}{[E(X-\mu)^2]^3}$. And similarly, the kurtosis, which is used as a measurement to determine the heaviness the tails of a distribution, is calculated by $K = \frac{E(X-\mu)^4}{[E(X-\mu)^2]^2}$

And it is remarkable to note that if the distribution is normal, then $S = 0$ and $K = 3$.

The null hypothesis for J-B normality test is defined as H_0: normal distributed (skewness is zero and excess kurtosis is zero) against the alternative hypothesis as H_1: non-normal distributed.

Jarque-Bera Test Statistics is computed as:

$$JB = \frac{(T-k)}{6}\left[S^2 + \frac{(K-3)^2}{4}\right] \quad (6.29)$$

where S and K respectively refer skewness, and kurtosis, T is the number of observations and k shows the number of variables. It turns out that this test statistic can be compared with a Chi-square distribution with 2 degrees of freedom. The null hypothesis of normality cannot be accepted if the calculated test statistic is higher than a critical value of the χ_2^2 distribution.

6.2.2. Breusch-Godfrey LM Test

Initially, the concept of autocorrelation is defined. The OLS estimators of classical linear regression model (CLRM) have six assumptions, one of which is that the covariance and correlations between different disturbances are all zero:

$$cov(u_t, u_s) = 0 \qquad ; \forall\, t \neq s$$

It means that the errors are independently distributed. As a result of the violation of the assumption, the disturbances can be said to be pairwise auto-correlated.

$$cov(u_t, u_s) \neq 0 \qquad ; \forall\, t \neq s$$

The implication of the expression is that an error happening at period t is possible to be correlated with one at period s. The reasons, why auto-correlation problem is experienced, are classified as follows: [4]

- The omission of variables
- The misspecification of model
- The presence of systematic errors in measurement.

The following results arise if the auto-correlation is ignored.

- The variance of the estimated coefficients is obtained to be less than the real variance.
- R^2 is obtained to higher than its actual value.
- The confidence interval, which is estimated, is not reliable.

The outcomes of the ignorance of the problem are also exhibited in Figure 8.

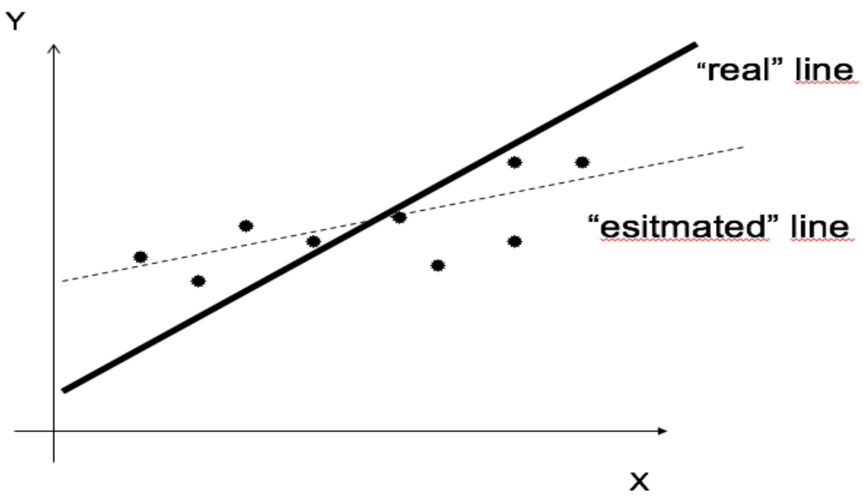


Figure 8. The Result of Autocorrelation Problem [126]

Second of all, let's consider the multiple regression model:

$$y_t = b_0 + b_1 x_{1t} + \cdots + b_k x_{kt} + u_t \tag{6.30}$$

where the current observation of the error term u_t is a function of the past observation of the error term u_{t-1} ,i.e. $u_t = pu_{t-1} + e_t$ for the parameter p providing the functional association between observations of the error terms u_t and a latest error term e_t which is identically independently distributed.

The parameter p demostrates the strong of serial correlation.

- $p = 0 \Rightarrow \exists$ no serial correlation since $\mathrm{u_t} = e_t$ and an iid error term.
- $p \rightarrow 1 \;\Rightarrow \exists$ positive serial correlation
- $p \rightarrow 1 \;\Rightarrow \exists$ negative serial correlation

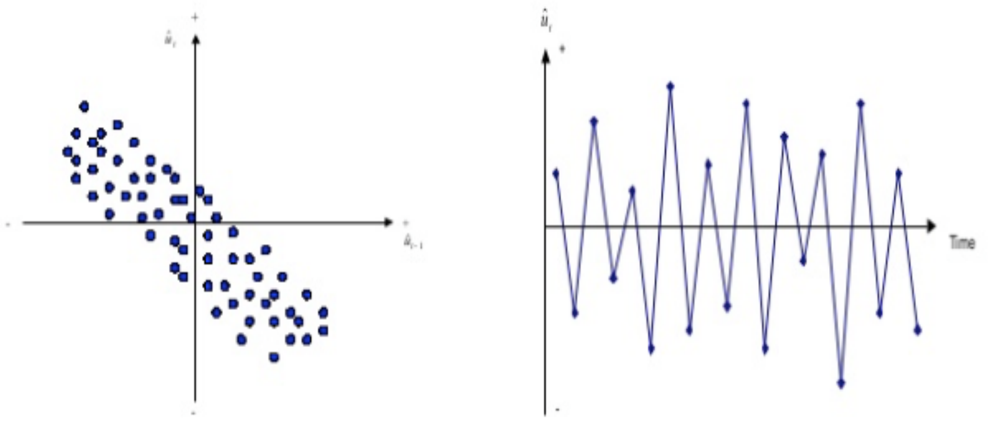


Figure 9. Negative Serial Correlation [127]

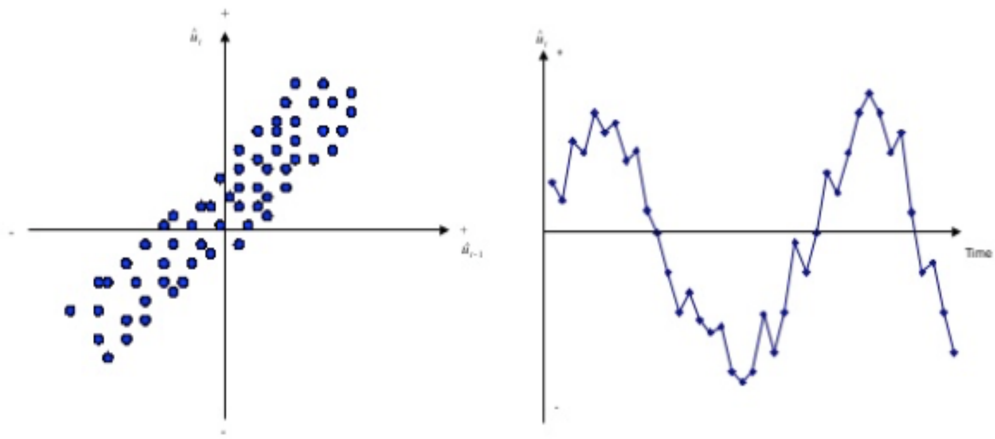


Figure 10. Positive Serial Correlation [127]

There are many methods to catch autocorrelation, such as the graph method, the Durbin-Watson test [128], Breusch-Godfrey LM test [129] & [130], and so on.

As for the Breusch-Godfrey LM test, the test is developed by Breusch and Godfrey [129] & [130]. And this test is an LM test. In order to explain its all steps, consider the following model:

$$y_t = b_0 + b_1 x_{1t} + \cdots + b_k x_{kt} + u_t \tag{6.31}$$

where $u_t = p_1 u_{t-1} + p_2 u_{t-2} + \cdots + p_p u_{t-p} + e_t$.

The first step is to estimate the Equation (6.31) by OLS and to obtain $\widehat{u_t}$.

The second step is to obtain the following regression model with p being determined by the order of serial correlation.

$$\widehat{u_t} = a_0 + a_1 x_{1t} + a_R x_{Rt} + a_{R+1}\, \hat{u}_{t-1} + \cdots + a_{R+p}\, \hat{u}_{t-p} \tag{6.32}$$

The third step is to establish the null and alternative hypothesis as:

$$H_0: p_1 = p_2 = \cdots = p_p = 0$$

$$H_1: \text{at least one } p_j \text{ is not zero}$$

The null hypothesis represents the absence of auto-correlation while the alternative hypothesis says the presence of serial correlation.

The third step is to compute the LM test statistic with the formula $LM = (n-p)R^2$

The final step is to interpret the obtained results. If $LM > \chi_p^2$, then the null hypothesis is rejected.

Breusch-Godfrey LM test has much more advantageous than other autocorrelation tests like Durbin-Watson test (DW). The reasons for this claim are listed as follows. The major drawback of DW test is that this test cannot be used if the regression model does not involve a constant and lagged dependent variables. Moreover, DW test disregards MA process whereas Breusch-Godfrey LM test regards both AR and MA processes. And finally, DW test is only applied for the errors in a regression model which are produced by a first-order autocorrelation.

6.2.3. Breusch-Pagan Test for Heteroskedasticity

The term of homoscedasticity is that the distributions have an equal variance that is separate from *i*. The mathematical representation of this term is $var(u_i|x_{1,i},\dots,x_{k,i}) = \sigma^2$ for the the simple regression model with two variables as

$$\mathrm{y_i = a + b_1x_{1,i} + b_2x_{2,i} + \cdots + b_kx_{k,i} + u_i} \tag{6.33}$$

Heteroskedasticity is known as the circumstance of the infringement of the assumption of homoscedasticity. That is, the variance of the error terms relies on completely observations, i.e. $var(u_i|x_{1,i},\dots,x_{k,i}) = \sigma_i^2$ for $i = 1,\dots,n$.

It is important to note that the problem of heteroskedasticity occurs generally while studying with micro-econometrical data sets. This is because micro-economic data are engaged with the observations collected from either people or households. In addition to micro studies, it cannot be ignored that heteroskedasticity is common in macro variable as well. The scatter plot in Figure 11 is given in order to compare the cases of homoscedasticity and heteroskedasticity.

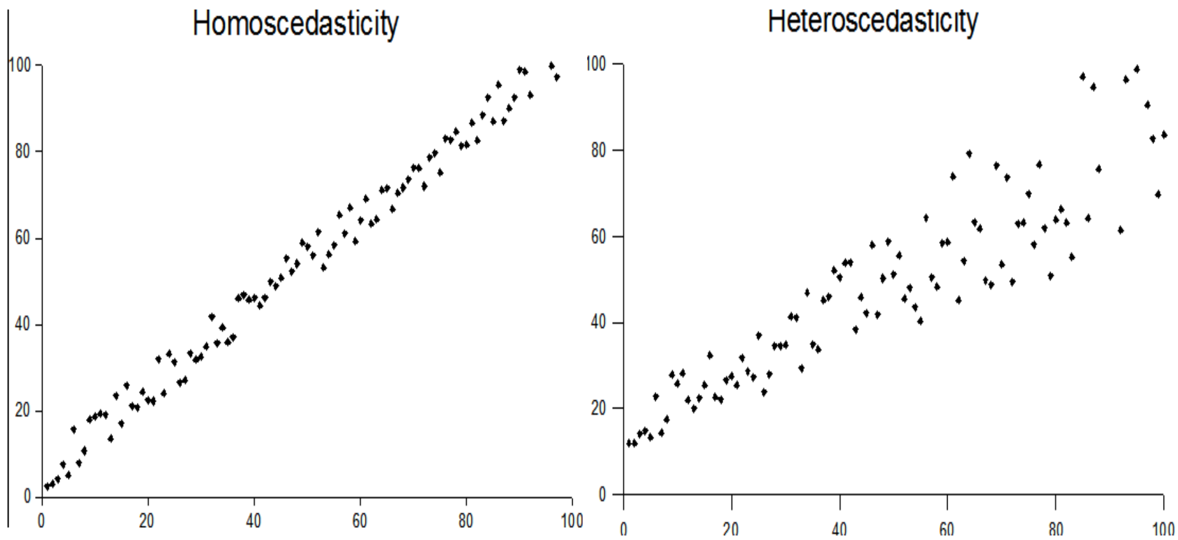


Figure 11. The Scatter Plots for Both Homoskedasticity & Heteroskedasticity [131]

The adverse effects of the presence of heteroskedasticity on the OLS estimators can be listed as follows: [4]

- It cannot be stated that there is a correlation between all explanatory variables and the error term since the assumptions of unbiasedness and consistency hold for the OLS estimators. Therefore, the problem of heteroskedasticity in the model is corrected, and then more accurate results are received by all estimates.
- Heteroskedasticity has an impact on the distribution of the estimators that causes the rise in the variance of the distribution. Hence, this gives rise to obtaining inefficient estimators due to the violation of the assumption of minimum variance.
- Heteroskedasticity also has an effect on the variance as well as on the standard errors of the estimated coefficients. That the problem of heteroskedasticity arises in a model, gives rise to the OLS method not to overestimate both the variances and the standard errors causing greater than anticipated values of t and F statistics. That is to say, the problem of heteroskedasticity has a strong negative effect on hypothesis tests.

There are many methods detecting the problem of heteroskedasticity, some of which are the Breusch-Pagan LM test (1979), the Glesjer LM test (1969), the

Harvey-Godfrey LM test (1976), the Park LM test (1966), the Goldfeld-Quandt test (1965), White's test (1968) and so on [4].

In the thesis, the Breusch-Pagan LM test [132] is preferred. Breusch and Pagan LM test (BP test) is a heteroskedasticity test in a linear regression model based on a Lagrange Multiplier (LM) statistics.

In order to explain theoretical analysis of the BP test, consider the standard OLS model as

$$y_i = b_0 + b_1 x_{1i} + b_2 x_{2i} + \cdots + b_k x_{ki} + u_i \tag{6.34}$$

where $var(u_i) = \sigma_i^2$. The BP test steps are described as follows:

The first step is to estimate the model (6.34) and to obtain the $\hat{u_i}$ as

$$\hat{u_i}^2 = a_0 + a_1 z_{1i} + a_2 z_{2i} + \cdots + a_p z_{pi} + e_i \tag{6.35}$$

where z_{ki} is a set of variables to determine the variance of the error term.

The second step is to express the null and the alternative hypotheses.

$$H_0: a_1 = a_2 = \cdots = a_p = 0$$

The null hypothesis implies that heteroskedasticity does not exist while the alternative hypothesis indicates that at least one of the a's is different from zero and that at least one of Z's has an influence on the variance of the residuals which will be different for distinct t.

The third step is the calculation of LM statistic. LM statistic is calculated by multiplying the the number of observations n and the coefficient of determination R^2, i.e. $LM = nR^2$. LM statistic follows the Chi-square distribution with *p-1* DF. As it is seen, the degrees of freedom of the distribution have to alter the number of independent variables in the model. If the p-value does not exceed the significance level, the null hypothesis cannot be accepted.

6.2.4. CUSUM and CUSUMQ Tests

As suggested by Pesaran and Pesaran [75], the cumulative sum of recursive residuals (CUSUM) and the CUSUM of square (CUSUMSQ) tests proposed by Brown et al. [133] are able to be implemented to the residuals of the estimated ECM to testify parameter constancy and the stability of the long-term parameters together with the short-term movements for the equations. In order to detect the presence of structural changes in econometric studies, CUSUM and CUSUMSQ tests as well as the most known Chow test are also used. These tests are graphical tests which are predicated on recursive residuals.

In order to express these tests mathematically, consider

$$Y_t = X_t \beta_t + \epsilon_t \qquad ; \ \forall t = 1, \dots, T. \tag{6.36}$$

Then the estimator of β_t can be calculated by $\widehat{\beta_t} = (X_t' X_t)^{-1} X_t' Y_t \quad$ for all $t = K, \dots, T$. Similarly, the estimator for the previous term is able to be calculated by $\hat{\beta}_{t-1} = (X_{t-1}' X_{t-1})^{-1} X_{t-1-1}' Y_t \quad$ for all $t - 1 > K$.

Then, if $\widehat{\beta_t}$ can be expressed in terms of $\hat{\beta}_{t-1}$, the following expression is obtained.

$$\widehat{\beta_t} = \hat{\beta}_{t-1} + (X_{t-1}' X_{t-1})^{-1}. x_t . \frac{y_t - x_t' \hat{\beta}_{t-1}}{1 + [x_t' (X_{t-1}' X_{t-1})^{-1} x_t]} \tag{6.37}$$

is obtained. Here, $x_t = (x_{1t}, \dots, x_{Kt})$. We consider

$$e_t = x_t'(\beta_t - \hat{\beta}_{t-1}) + \epsilon_t \tag{6.38}$$

where $E(e_t) = 0$, and $var(e_t) = \sigma_\epsilon^2[1 + [x_t'(X_{t-1}'X_{t-1})^{-1}x_t]]\sigma_e^2$. These predicted errors are uncorrelated.

$$e_t = x_t'(\beta_t - \hat{\beta}_{t-1}) + \epsilon_t = \epsilon_t - x_t'(X_{t-1}'X_{t-1})^{-1}\sum_{j=1}^{t-1} x_j\epsilon_j \tag{6.39}$$

where $E(e_t\, e_m) = 0 \quad \text{and} \quad \forall t = 1, \dots, T.$

And then, the recursive residuals are

$$w_t := \frac{e_t\,\sigma_\epsilon}{\sigma_e} = \frac{y_t - x_t'\hat{\beta}_{t-1}}{\sqrt{1 + [x_t'(X_{t-1}'X_{t-1})^{-1}x_t]}} \tag{6.40}$$

If β_t is constant till *t* is equal to *m* and differs after *t* is greater than *m,* then the recursive residuals w_t will have a null average till *t* is equal to *m* and an average differs to zero for the successive period. That is, if β_t changes in the consecutive period then the forecast error will not have mean zero, i.e. $E(w_t) = 0 \;\; for\; t = 1, \dots, m$ and $E(w_t) \neq 0 \;\; for\; t > m$ [136].

Brown et al. [133] suggested two tests, namely CUSUM and CUSUMQ, by using the recursive residuals w_t.

Firstly, CUSUM test is described as follows:

$$W_t = \sum_{t=K+1}^{m} \frac{w_t}{\hat{\sigma}_m} \tag{6.41}$$

where $\hat{\sigma}_m^2 = \frac{1}{T-K-1}\sum_{t=K+1}^{m}(w_t - \bar{w})^2$ and $\bar{w} = \frac{1}{T-K}\sum_{t=K+1}^{m} w_t$ for $m = K + 1, \dots, T$.

Under the null hypothesis of $H_0: \beta_1 = \beta_2 = \cdots = \cdots = \beta_T = \beta$, W_m must be inside the interval $(-\frac{a(2m+T-3K)}{\sqrt{T-K}}, \frac{a(2m+T-3K)}{\sqrt{T-K}})$ where a = 1.143 for level α = 1%, a = 0.948 for level *α* = 5% and a = 0.85 for level *α* = 10%. Moreover, Baltagi [134] suggests that it would be better to check whether W_t crosses a pair of straight lines (see the Figure 12 given in Baltagi's book [134]) that pass through the points $(K, \pm a(\sqrt{T-K})$ and $(K, \pm 3a(\sqrt{T-K})$ for *a* depending upon the chosen significance level *α*.

Also, it is important to note that each variance is equal to 1 and independent [135]. If W_t cuts the interval, then the null hypothesis cannot be accepted. These results can be interpreted that if the coefficients are not stable over time, then there may be a disproportionate number of recursive residuals W_t with the same sign which requires W_m exiting out of the interval [136].

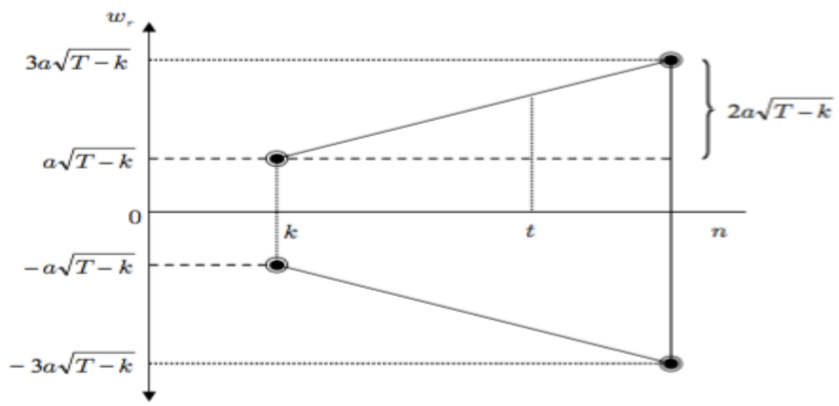


Figure 12. CUSUM Critical Values [134]

Secondly, the CUSUMSQ test is described as follows. This test is predicated on the square of recursive residuals as

$$s_m = \frac{\sum_{t=K+1}^{m} w_t^2}{\sum_{t=K+1}^{T} {w_t}^2} = \frac{S_m}{S_T} \tag{6.42}$$

where s_m follows a Beta distribution with $E(s_m) = \frac{m-K}{T-K}$. And the confidence interval is defined as $(E(s_m) - c,\ E(s_m) + c)$ where c refers the Kolmogorov-Smirnov statistic. If s_m appears the corridor at the period that t is equal to m, then there exists an arbitrary rupture unveiling the evidence that the coefficients are unstable for this time [136].

Harvey and Collier [137] suggested a test statistics based on mean for CUSUMSQ. Under the same null hypothesis, $\bar{w}$ has a normal distribution with zero mean and the variance $\frac{\sigma^2}{T-K}$. And they claim that this test statistic belongs to t-test family since $E(w_t) = 0$.

The method is as follows: [135]

$$t[T-K-1] = \frac{\sqrt{T-K}}{s} \tag{6.43}$$

where $s^2 = \frac{1}{T-K-1} \sum_{r=K+1}^{r=T} (w_t - \bar{w})^2$

And some remarkable notes on CUSUM and CUSUMSQ tests are summarized as: [138]

- The CUSUM test can be established with OLS residuals instead of recursive residuals [139],
- CUSUM Test is a test to catch instability in intercept alone.
- CUSUM Test has a power only in direction of the mean regressors.
- CUSUMSQ has power for changing variance.

6.2.5. Recursive Coefficient Tests and Curves

The Recursive Coefficient test is conducted via a graph that consists of all of the coefficients. This graph gives information on the stability of coefficients as the sample size increases from its minimum to the last observation [140].

6.2.6. Ramsey RESET Test

The Regression Equation Specification Error Test (RESET) test was proposed to detect general functional form misspecification by Ramsey [141].

The RESET test is designed to check for the following types of errors: [140]

- Omitted variables
- Simultaneous-equation bias
- Incorrect use of lagged dependent variables
- Nonlinear functional forms.

The theoretical background of the test is clearly explained by Asteriou and Hall [4].

First of all, consider the true model which is called restricted model as:

$$y = b_1 + b_2 x_2 + b_3 x_2^2 + u \tag{6.44}$$

The wrong estimation of the model become the following:

$$y = b_1 + b_2 x_2 + \hat{u}^* \tag{6.45}$$

where the variable x_2^2 is erased owing to the fact that it is unknown what the real nature of u is.

Then the first step is to estimate the Equation (6.44) and to obtain the fitted values of the dependent value $\hat{y}$.

The RESET test for such misspecified model is hinged on the fitted values of y which is obtained from regression (6.45) as $\hat{y} = \widehat{b_1} + \widehat{b_2}\, x_2$.

The RESET test involves including various powers of $\hat{y}$ as proxies of x_2^2 that can seize possible non-linear relations.

In order to start to apply this test, it is important to identify the number of terms that ought to be involved in the expanded model. Let the expanded model as

$$y = b_1 + b_2 x_2 + \mu_1 \hat{y}^2 + \mu_2 \hat{y}^3 + e \tag{6.46}$$

Next, it is required that the significances of $\hat{y}^2$ and $\hat{y}^3$ are tested by F-type test.

The F-statistic is calculated by

$$F_{stat} = \frac{(R_{ur}^2 - R_r^2)/m}{(1 - R_{ur}^2)/(n-k)} \tag{6.47}$$

If F-statistic > F-critical, then the null hypothesis of correct specification is rejected and it is concluded that the model is misspecified.

6.2.7. Inverse Roots of AR Characteristic Polynomial

The inverse roots of AR characteristic polynomial demonstrate the dynamical stability of VAR model. It is necessary to test whether the residuals of the estimated model suffer from autocorrelation because if there exists a problem of autocorrelation, this problem causes the deviation of the estimated parameters as it is expressed in previous sections. For this aim, the inverse root of the estimated model should be examined. If the residuals are not auto-correlated, then the values of inverse roots have to be fall inside unity [142]. That is to say, the inverse roots of AR characteristic polynomial have to lie inside the unit circle so as for the VAR model to be dynamically stable.

6.2.8. VAR Residual Serial Correlation LM Test

VAR Residual Serial Correlation LM test gives the multivariate LM test statistics for residual serial correlation at most the selected order. This test is performed so as that serial independence of residuals is endorsed [143].

7. EMPIRICAL ANALYSIS

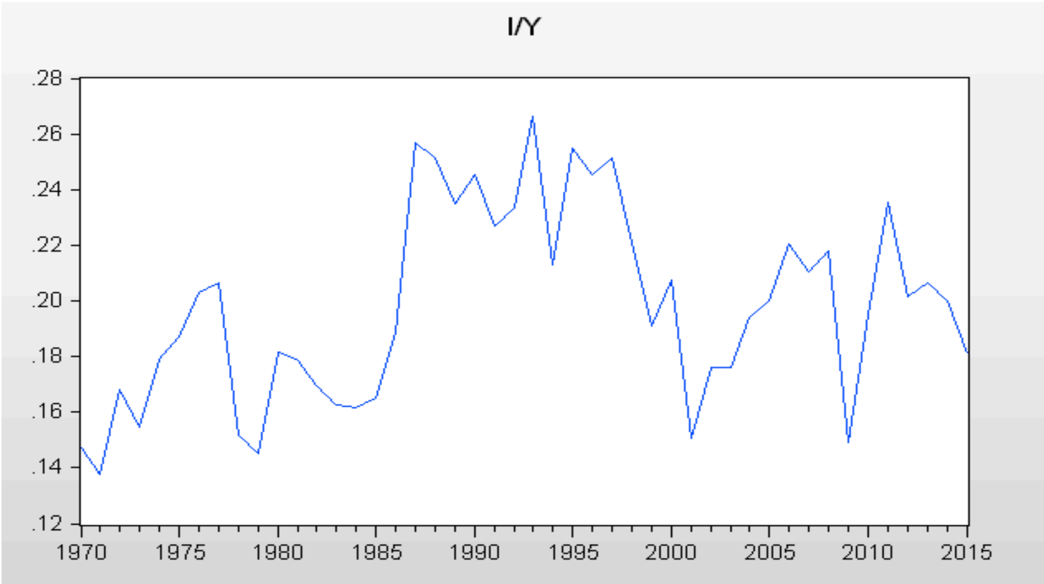
7.1. Data

7.1.1. Data Description

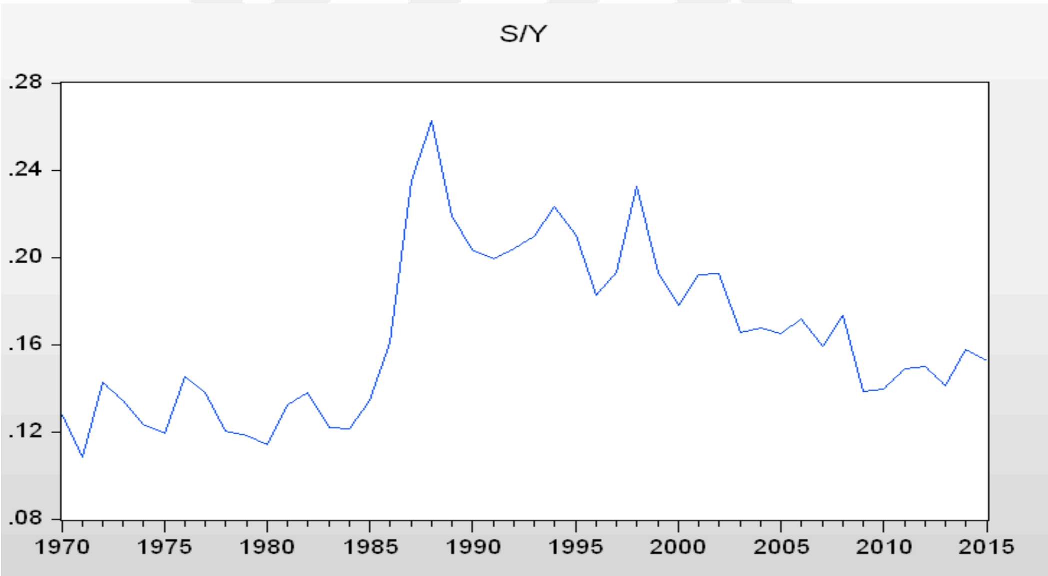
The data used in the study comprises of annual time series for Turkey over the sample periods ranging from 1970 to 2015. The variables in the study are formed by using these data such as gross domestic investment (GDI), gross domestic saving (GDS), and gross domestic product (GDP). All data in current local currency (LCU) are obtained from World Development Indicators (WDI) database of the World Bank. The details of all data are given on World Bank website as follows: the computation of GDS is that GDP less final consumption expenditure, GDI comprises expenses on the fixed assets supplementation of the economy and net variation in the level of inventories, and GDP at purchaser's prices is obtained by adding gross value added by all inhabitant producers in the economy and any product taxes, and then any subsidies not involved in the value of the goods is subtracted from the obtained sum [144].

In the study, the ratio of GDI to GDP (I/Y) and the ratio of GDS to GDP (S/Y) are calculated and these variables are converted to natural logarithmic forms in order to streamline the data. This conversion is standard to begin the analysis by the investigating time series properties of the data used in the study. The reasons for the use of natural logarithm are that it both lessens correlations between the variables and enables the elimination of heteroscedasticity because of the compression of the scale where variables are estimated [145].

All econometric analysis is performed by using the econometric program E-views 9 SV. The time series plots of the variables are demonstrated in Figure 13 and Figure 14 to provide an overview of the data set.

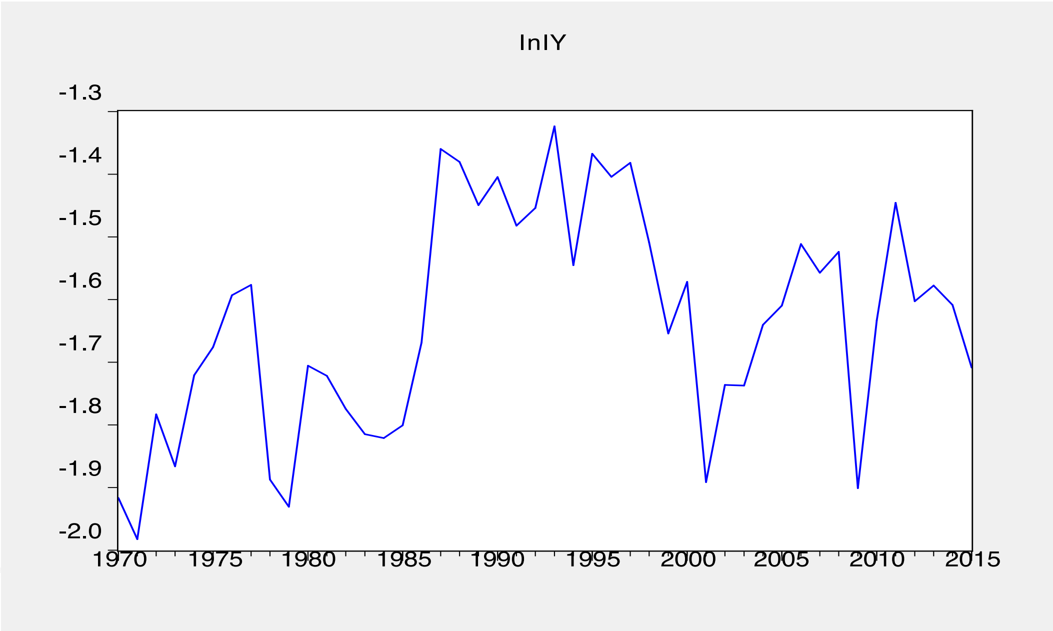


(a)

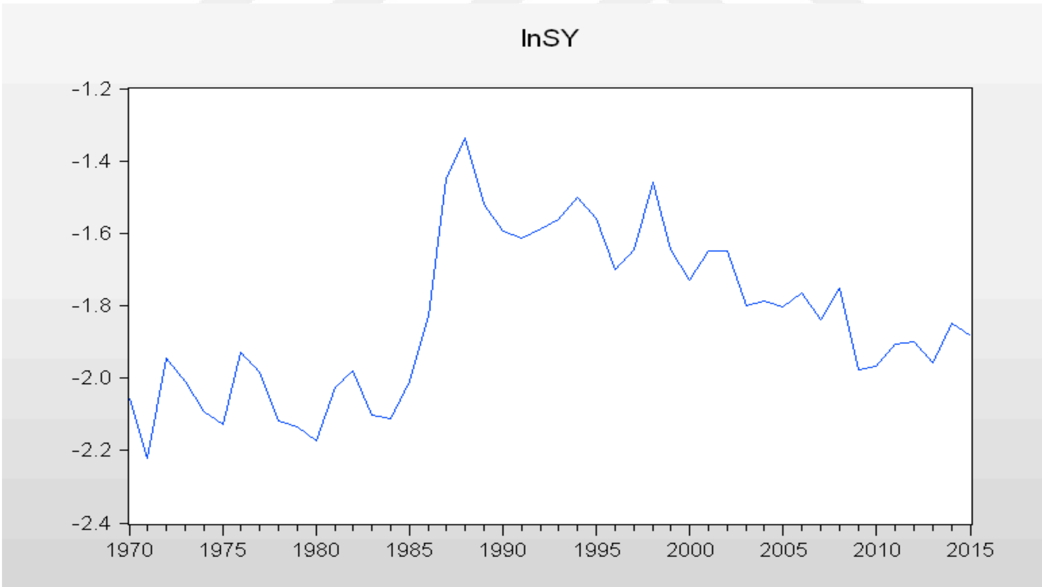


(b)

Figure 13. Plots of **(a)** I/Y and **(b)** S/Y



(a)



(b)

Figure 14. Plots of Logarithm Forms of **(a)** I/Y and **(b)** S/Y

7.1.2. Descriptive Statistics

Table 1 reports the summary statistics for the annual series I/Y, S/Y, ln(I/Y) and ln(S/Y) which are used in the empirical analysis. As for the interpretation of results of summary statistics for the series ln(I/Y) and ln(S/Y), all variables exhibit a negative mean. Both variables have similar standard deviation; however, the variable ln(S/Y) follows a volatile pattern with comparatively high standard deviation. As for skewness, the variables ln(I/Y) has a long left tail because of the fact that it is negatively skewed. And finally, The Jarque-Bera normality test fails to reject the assumption of normality for both variables as the P-values are greater than 5% level of significance.

Table 1. Summary statistics for the annual series I/Y, S/Y, ln(I/Y) and ln(S/Y)

	I/Y	S/Y	ln(I/Y)	ln(S/Y)
Mean	0.197887	0.164288	-1.635208	-1.831067
Median	0.197565	0.158374	-1.621757	-1.842807
Maximum	0.266156	0.262437	-1.323672	-1.337744
Minimum	0.137732	0.108454	-1.982446	-2.221433
Std. Dev.	0.034645	0.037738	0.176695	0.224326
Skewness	0.174641	0.581436	-0.095932	0.229613
Kurtosis	2.057347	2.499404	2.053458	2.068573
Jarque-Bera	1.936968	3.072161	1.787776	2.067018
Probability	0.379658	0.215223	0.409062	0.355756
Sum	9.102810	7.557262	-75.21957	-84.22906
Sum Sq. Dev.	0.054012	0.064086	1.404944	2.264503
Observations	46	46	46	46

Table 2 is a correlation matrix table. The P-value is shown in the parenthesis. The correlation between ln(I/Y) and ln(S/Y) is positive and this correlation is statistically significant since P-value of 0.0000 is less than 5% level of significance.

Table 2. Correlation Matrix

	ln(I/Y)	ln(S/Y)
ln(I/Y)	1.000000	0.748679 (0.0000)
ln(S/Y)	0.748679 (0.0000)	1.000000

7.2. Results of Unit Root Test

Before employing both ARDL bounds test and Toda-Yamamoto causality test, it is essential to determine the order of integration of the variables. Even though it is not crucial that the order of integration of all the variables for both econometric analysis, performing the unit root test is required so as to ensure that the variables are not integrated of the second order i.e. I(2) in the ARDL model, and to determine the maximum integration order of the variables for T-Y test. Thus, the integration properties of these two variables must be verified by employing ADF and Phillips-Perron test, which examines the null hypothesis of non-stationarity.

Table 3. Unit Root Test Results

Variables	ADF	PP	Breakpoint Unit Root Test	
			2001	2008
LN(I/Y)	0.0242 (0) [-3.237935]	0.0296 (0) [-3.153935]	< 0.10 (0) [-3.245919]	< 0.10 (0) [-3.168091]
LN(S/Y)	0.2783 (0) [-2.018082]	0.3245 (5) [-1.910937]	>=0.10 (0) [-2.033843]	>=0.10 (0) [-2.078656]
Δ(LN(S/Y)	0.0000 (0) [-6.671518]	0.0000 (13) [-6.995703]	< 0.01 (1) [-5.759903]	< 0.01 (1) [-5.958958]

The results are reported at Table 3 where Δ represents the first difference of the variable ln(S/Y). The number of lags used for the augmented Dickey–Fuller (ADF) and Phillips–Perron (PP) regression models are shown in parentheses. t-statistic values for both ADF and PP tests are also shown in square brackets. Since neither I/Y nor S/Y appeared to be trended, only constant was chosen as an exogenous regressor for both ADF and PP tests. Similarly, trend specification and break specification determined as intercept only for breakpoint unit root test. The lags for ADF are automatically determined based on Schwarz information criteria.

In order to check whether the residuals are white noise or not, the correlogram of the residuals for both variables are used. When both correlogram reported in Figure 15 and Figure 16 is investigated, it is obtained that P-values of residuals are all higher than 0.05 of significance level. Thus, the residuals are white noise. That is to say, the results obtained from unit root tests can be said to be reliable.

ADF Unit Root Test

	AC	PAC	Q-Stat	Prob
1	0.068	0.068	0.2164	0.642
2	-0.293	-0.299	4.3510	0.114
3	-0.130	-0.093	5.1846	0.159
4	0.101	0.033	5.6987	0.223
5	-0.025	-0.109	5.7312	0.333
6	0.191	0.254	7.6790	0.263
7	-0.010	-0.080	7.6849	0.361
8	-0.205	-0.115	10.052	0.261
9	-0.148	-0.090	11.322	0.254
10	0.193	0.081	13.540	0.195
11	0.063	-0.021	13.786	0.245
12	-0.099	-0.083	14.401	0.276
13	-0.016	0.063	14.418	0.345
14	0.030	-0.008	14.479	0.415
15	0.003	0.062	14.480	0.489
16	0.093	0.050	15.106	0.517
17	-0.041	-0.111	15.232	0.579
18	-0.078	0.042	15.711	0.613
19	-0.039	-0.053	15.837	0.668
20	0.020	-0.061	15.870	0.725

PP Unit Root Test

	AC	PAC	Q-Stat	Prob
1	0.068	0.068	0.2164	0.642
2	-0.293	-0.299	4.3510	0.114
3	-0.130	-0.093	5.1846	0.159
4	0.101	0.033	5.6987	0.223
5	-0.025	-0.109	5.7312	0.333
6	0.191	0.254	7.6790	0.263
7	-0.010	-0.080	7.6849	0.361
8	-0.205	-0.115	10.052	0.261
9	-0.148	-0.090	11.322	0.254
10	0.193	0.081	13.540	0.195
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16	0.093	0.050	15.106	0.517
17	-0.041	-0.111	15.232	0.579
18	-0.078	0.042	15.711	0.613
19	-0.039	-0.053	15.837	0.668
20	0.020	-0.061	15.870	0.725

Break Point Unit Root Test (Date=2001)

	AC	PAC	Q-Stat	Prob
1	0.029	0.029	0.0398	0.842
2	-0.013	-0.014	0.0478	0.976
3	-0.171	-0.170	1.4612	0.691
4	0.011	0.021	1.4673	0.832
5	-0.085	-0.093	1.8385	0.871
6	0.244	0.230	4.9496	0.550
7	-0.072	-0.098	5.2285	0.632
8	-0.120	-0.142	6.0243	0.645
9	-0.265	-0.201	10.026	0.348
10	0.142	0.141	11.208	0.342
11	0.050	0.049	11.357	0.414
12	-0.090	-0.261	11.864	0.457
13	-0.069	-0.014	12.172	0.514
14	-0.111	-0.102	12.988	0.527
15	-0.239	-0.189	16.927	0.323
16	0.078	-0.033	17.367	0.362
17	0.030	-0.130	17.434	0.425
18	-0.009	-0.029	17.440	0.493
19	0.011	0.052	17.449	0.559
20	0.027	-0.052	17.509	0.620

Break Point Unit Root Test (Date=2008)

	AC	PAC	Q-Stat	Prob
1	0.101	0.101	0.4696	0.493
2	-0.028	-0.038	0.5058	0.777
3	-0.120	-0.115	1.2055	0.752
4	0.020	0.044	1.2260	0.874
5	-0.049	-0.063	1.3470	0.930
6	0.228	0.234	4.0548	0.669
7	-0.043	-0.099	4.1562	0.762
8	-0.115	-0.106	4.8872	0.770
9	-0.223	-0.161	7.7108	0.564
10	0.114	0.136	8.4741	0.583
11	0.051	0.030	8.6288	0.656
12	-0.058	-0.172	8.8362	0.717
13	-0.023	0.059	8.8690	0.783
14	-0.105	-0.114	9.5982	0.791
15	-0.264	-0.192	14.417	0.494
16	0.049	0.034	14.590	0.555
17	0.006	-0.105	14.593	0.625
18	-0.048	-0.037	14.773	0.678
19	-0.010	0.039	14.780	0.736
20	-0.038	-0.085	14.902	0.782

Figure 15. Correlogram of RESID for the Series ln(S/Y) ~ I(1)

ADF

Unit Root Test

Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob
		1	-0.099	-0.099	0.4729	0.492
		2	0.031	0.021	0.5202	0.771
		3	0.041	0.047	0.6054	0.895
		4	-0.073	-0.066	0.8824	0.927
		5	0.057	0.041	1.0517	0.958
		6	0.034	0.046	1.1145	0.981
		7	0.059	0.070	1.3064	0.988
		8	0.052	0.055	1.4621	0.993
		9	-0.220	-0.216	4.3174	0.889
		10	-0.002	-0.051	4.3176	0.932
		11	0.014	0.027	4.3299	0.959
		12	-0.162	-0.150	6.0153	0.915
		13	0.041	-0.028	6.1244	0.942
		14	-0.242	-0.247	10.128	0.753
		15	0.074	0.065	10.510	0.787
		16	-0.038	-0.001	10.613	0.833
		17	-0.085	-0.057	11.161	0.848
		18	0.102	0.034	11.980	0.848
		19	-0.057	-0.013	12.241	0.875
		20	0.031	0.085	12.323	0.905

PP

Unit Root Test

Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob
		1	-0.099	-0.099	0.4729	0.492
		2	0.031	0.021	0.5202	0.771
		3	0.041	0.047	0.6054	0.895
		4	-0.073	-0.066	0.8824	0.927
		5	0.057	0.041	1.0517	0.958
		6	0.034	0.046	1.1145	0.981
		7	0.059	0.070	1.3064	0.988
		8	0.052	0.055	1.4621	0.993
		9	-0.220	-0.216	4.3174	0.889
		10	-0.002	-0.051	4.3176	0.932
		11	0.014	0.027	4.3299	0.959
		12	-0.162	-0.150	6.0153	0.915
		13	0.041	-0.028	6.1244	0.942
		14	-0.242	-0.247	10.128	0.753
		15	0.074	0.065	10.510	0.787
		16	-0.038	-0.001	10.613	0.833
		17	-0.085	-0.057	11.161	0.848
		18	0.102	0.034	11.980	0.848
		19	-0.057	-0.013	12.241	0.875
		20	0.031	0.085	12.323	0.905

Break Point

Unit Root Test

(Date=2001)

Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob
		1	-0.074	-0.074	0.2630	0.608
		2	-0.048	-0.054	0.3780	0.828
		3	0.041	0.033	0.4608	0.927
		4	-0.040	-0.037	0.5423	0.969
		5	0.128	0.127	1.4076	0.923
		6	0.124	0.141	2.2398	0.896
		7	0.030	0.070	2.2892	0.942
		8	-0.020	-0.008	2.3118	0.970
		9	-0.147	-0.154	3.5817	0.937
		10	0.078	0.037	3.9453	0.950
		11	0.016	-0.022	3.9603	0.971
		12	-0.171	-0.197	5.8284	0.924
		13	0.068	0.018	6.1332	0.941
		14	-0.193	-0.176	8.6845	0.851
		15	0.114	0.150	9.6041	0.844
		16	-0.070	-0.097	9.9602	0.869
		17	-0.137	-0.090	11.369	0.837
		18	0.071	0.069	11.761	0.859
		19	-0.110	-0.056	12.753	0.851
		20	0.012	0.040	12.765	0.887

Break Point

Unit Root Test

(Date=2008)

Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob
		1	-0.067	-0.067	0.2159	0.642
		2	0.014	0.010	0.2257	0.893
		3	0.023	0.025	0.2534	0.969
		4	-0.068	-0.065	0.4928	0.974
		5	0.055	0.046	0.6541	0.985
		6	0.022	0.030	0.6800	0.995
		7	0.094	0.100	1.1676	0.992
		8	0.042	0.048	1.2663	0.996
		9	-0.219	-0.215	4.0882	0.906
		10	-0.009	-0.045	4.0936	0.943
		11	-0.006	0.007	4.0958	0.967
		12	-0.179	-0.184	6.1521	0.908
		13	0.018	-0.045	6.1731	0.940
		14	-0.240	-0.254	10.096	0.755
		15	0.063	0.045	10.373	0.796
		16	-0.037	-0.003	10.472	0.841
		17	-0.072	-0.046	10.863	0.864
		18	0.111	0.056	11.833	0.856
		19	-0.042	0.022	11.977	0.887
		20	0.042	0.088	12.125	0.912

Figure 16. Correlogram of RESID for the Series ln(I/Y) ~ I(0)

For the variable ln(I/Y), it is stationary at level as the P-value is less than the 5% critical value; whereas, the series ln(S/Y) is not stationary at level. After difference, the unit root tests show that the series becomes stationary and integrated of order 1. Nevertheless, the drawback on unit root test is that these tests do not take into consideration the structural breaks. The existences of structural breaks at the years 2001 and 2008 obviously appear in the plot of ln(I/Y) even though the presence of such breakpoints in the plot of ln(S/Y) cannot be said. In addition to this, Turkish economy severely experienced financial crisis at the years 2001 and 2008. In such a case, the unreliable and biased results may be obtained because of the application of such unit root tests as ADF and PP. Hence, the unit root test with breakpoints introduced by the new version of E-views 9 should be implemented as well. As a result of this test, ln(I/Y) and ln(S/Y) respectively conform to I(0) and I(1) by regarding of the time breaks at 2001 and 2008. Since the ARDL model bounds testing approach permits to test for co-integration even when all variables are I(0) or I(1) or a mix of them and none of the variables is integrated of order 2 or above is guaranteed, this approach is the most suitable method for our study.

7.3. Results of ARDL Bounds Test

7.3.1. The ARDL Model Selection and Estimation

After getting assured about that the variables are not integrated at second difference, the next step is to testify the presence of the co-integration relationship between the variables. In order to investigate the existence of co-integration or the long-term relationship among variables, ARDL bounds testing procedure based on the joint F-statistics of the coefficients of the lagged levels of variables ought to be implemented. Before applying bounds testing approach, Unrestricted Error Correction Model (UECM) should be formed at first. UECM specification for our study is demonstrated as follows:

$$\Delta \ln\left(\frac{I}{Y}\right)_t = \alpha_0 + \alpha_{DUMMY}BREAK + \Sigma_{i=0}^{k}\alpha_{1i}\Delta \ln\left(\frac{S}{Y}\right)_{t-i} + \Sigma_{i=1}^{k}\alpha_{2i}\Delta \ln\left(\frac{I}{Y}\right)_{t-i}$$

$$+\alpha_3 \ln\left(\frac{I}{Y}\right)_{t-1} + \alpha_4 \ln\left(\frac{S}{Y}\right)_{t-1} + \varepsilon_t$$

(7.1)

where Δ indicates difference operator, BREAK is dummy variable to capture the structural break stemming in the series, and ε_t is residual term assumed to have normal distribution with zero mean and finite variance. It is noticed that it is constructed a dummy variable, BREAK, that takes the value 1 for the structural break dates (in 2001 and in 2008) and zero everywhere else. Furthermore, the reason why conditional ECM with an unrestricted intercept and no trend is utilized for bounds testing technique is that any trend pattern in the variables cannot be observed.

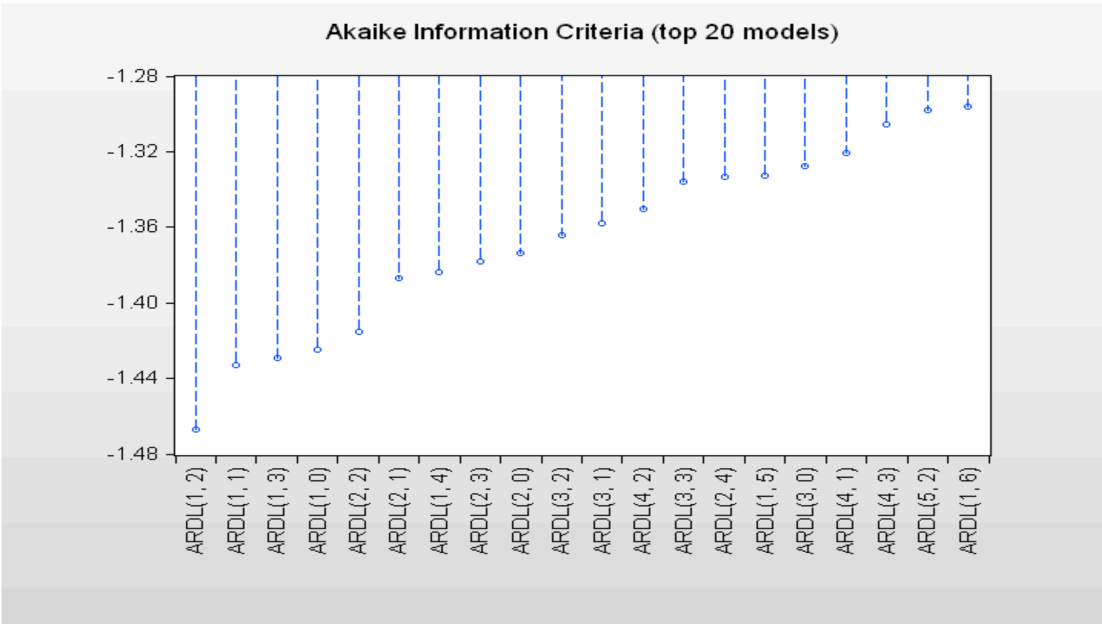


Figure 17. The Top 20 ARDL Models based on AIC

As mentioned, the maximum lag length is selected to be 8 and the optimal lag length is determined to be 8 based on the AIC criterion. As for the ARDL model selection, ARDL model is again selected based on the AIC criterion. All ARDL models with their AIC criterion values are shown in Figure 17. As it is seen in Figure 17, ARDL(1,2) is chosen as an optimal model because that model has the lowest AIC value. Once the existence of co-integrating relationship is proven, the mentioned equation is estimated by using the following ARDL(1,2) specification. The results of the estimated ARDL model are reported in Table 4.

In Table 4, dependent variable is LN(I/Y). We used the ARDL model with an unrestricted intercept and no trend to obtain the estimates of F- and t-statistics. The maximum number of lags for both the dependent variable and the principal regressor was set to be 8. AIC was selected as the basis for determining the lag orders for the regressors. Intercept and BREAK dummy variable were included as (fixed) regressors.

Table 4. ARDL Model: Selected Model: ARDL (1, 2)

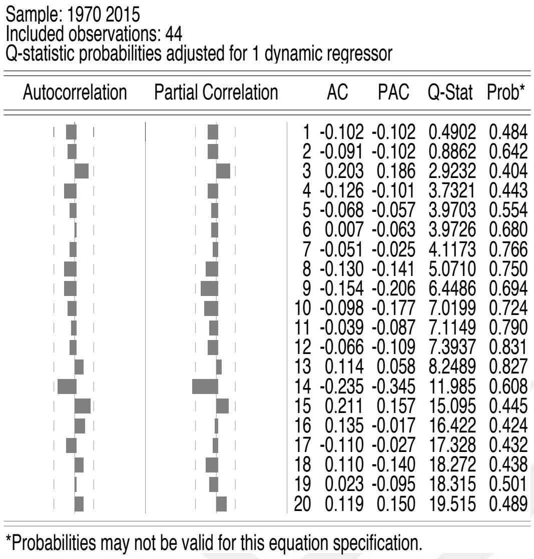
Variables	Coefficient	Std. Error	t-Statistics	Prob.
LN(I/Y)(-1)	0.358187	0.140163	2.555504	0.0147
LN(S/Y)	0.618277	0.143757	4.300865	0.0001
LN(S/Y)(-1)	-0.453112	0.201565	-2.247969	0.0305
LN(S/Y)(-2)	0.214275	0.136516	1.569597	0.1248
BREAK	-0.198025	0.079340	-2.495904	0.0170
C	-0.340455	0.166224	-2.048165	0.0475
R-Squared	0.641418	**AIC**	-1.520136	
Adj. R-squared	0.594236	**SBC**	-1.276837	
Log likelihood	39.44299	**Prob (F)**	0.000000	

7.3.2. Diagnostic Test Results of ARDL Model

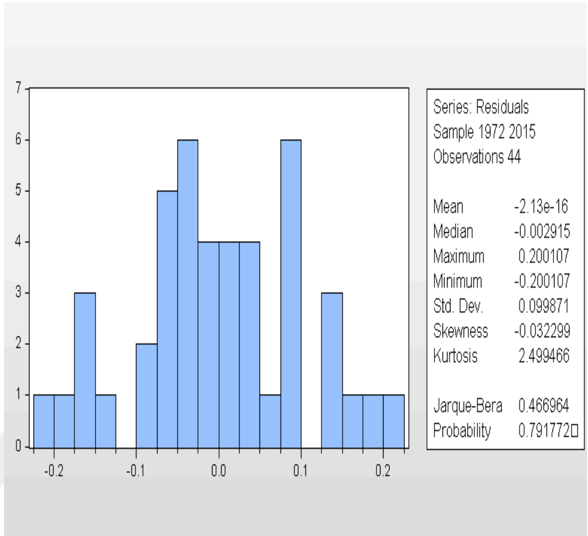
The validity and robustness of the estimated equations are confirmed by employing such relevant diagnostic tests, such as the Jarque–Bera normality test, the Breusch–Godfrey serial correlation LM test, the Ramsey RESET test for model specification and plot of cumulative sum of recursive Residuals (CUSUM).

Firstly, in Figure 18, the correlogram of residuals for the estimated ARDL(1,2) model and its normality test results along with its histogram are presented. The Jarque–Bera statistic confirms the normality behavior of the estimated residual series of the equations since P-value of 0.791772 is higher than the significance level 5%.

Secondly, all diagnostic tests including the Breusch-Pagan test, Breusch-Godfrey Serial Correlation LM Test and Ramsey RESET test results are given in Table 5.



(a)



(b)

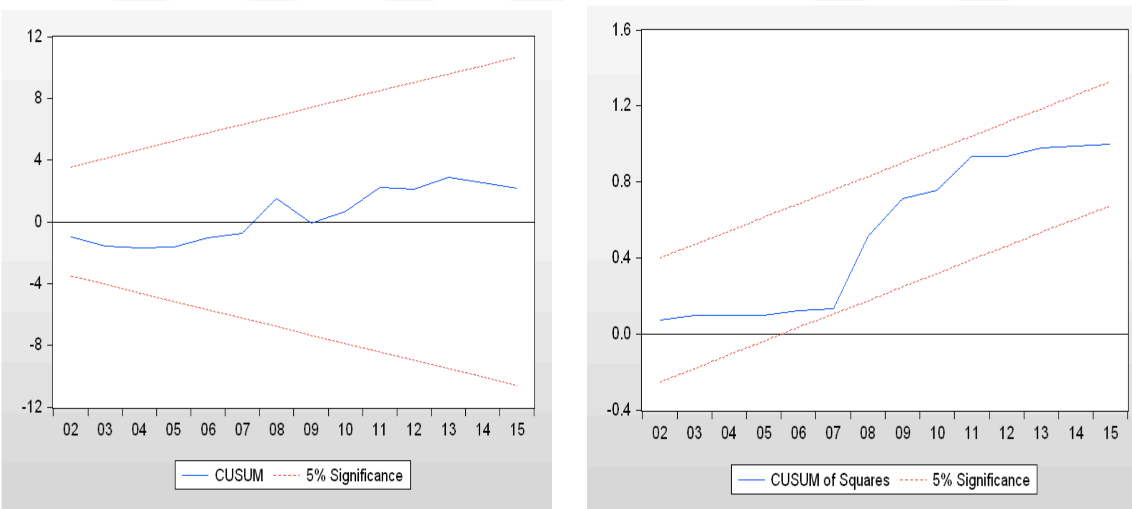
Figure 18. (a) Correlogram of Residuals**, (b)** Histogram-Normality Test for Residuals

Test 5. Some Diagnostic Test Results for ARDL (1,2) Model

Heteroskedasticity Test: Breusch-Pagan-Godfrey			
F-statistic	3.989732	**Prob. F(5, 38)**	0.0052
Obs*R-squared	15.14687	**Prob Chi-Square(5)**	0.0098
Scaled Explained SS	8.470155	**Prob Chi-Square(5)**	0.1322
Breusch-Godfrey Serial Correlation LM Test:			
F-statistic	1.472823	**Prob. F(1, 37)**	0.2326
Obs*R-squared	1.684415	**Prob Chi-Square(1)**	0.1943
Ramsey RESET Test			
	Value	**df**	**Probability**
t-statistic	0.375426	37	0.7095
F-statistic	0.140945	(1, 37)	0.7095

The serial correlation of the estimated ARDL model is tested by using the Breusch-Godfrey test. The test reports the P-value as 0.1943, which indicates to fail to reject the null hypothesis of no serial correlation at all conventional levels of significance. The result from the Breusch-Pagan Test for heteroskedasticity has LM statistic with a P-value as 0.1322 demonstrating that the LM statistic is insignificant at 5 percent level of significance. That is, since the null hypothesis of constant variance is not rejected, it is evidently concluded that homoskedasticity assumption is valid in the model. The RESET test verifies the correct functional form of the equations.

The plots of parameter stability test namely Cumulative Sum (CUSUM) and cumulative sum of squares (CUSUMSQ) are given in Figure 19. When CUSUM plot was found to be within the 5% critical bound, the null hypothesis of the stability of the parameters cannot be rejected. As it is clearly shown from the Figure 19, the CUSUM plot is within the 5% critical bound. That is, the estimated parameters do not have structural instability over the time period of the study, so they are constant or stable within the sample considered.



(a) **(b)**

Figure 19. The plot of (a) CUSUM and (b) CUSUMSQ

Overall, the diagnostic tests suggest that the estimated equation has desired statistical properties**.**

7.3.3. Bounds Test Results

So as to confirm the presence of co-integration relationship, bounds test is applied. The null hypothesis that there is no co-integration relationship between the variables $(H_0: \alpha_3 = \alpha_4 = 0)$ is tested against alternative hypothesis that there is co-integration relationship between the variables $(H_1: \alpha_3 \neq \alpha_4 \neq 0)$. The result of bounds test is presented in Table 6. The optimal lag length in Equation (7.1) is determined by using AIC criteria. And so as to select the optimal lag length, the maximum lag length is set to be equal to 8. The bound test results show that F-statistic (10.48492) is well beyond the upper bound critical value (5.73) at 5% significance level, which strictly implies the presence of long-run relationship among the variables in the case that ln(I/Y) is dependent variable.

Table 6. ARDL(1,2) Bounds Test Result
Null Hypothesis: No long-run relationships exist

Test Statistics	Value	k
F-statistic	10.48492	1
Critical Value Bounds		
Significance	**I0 Bound**	**I1 Bound**
10%	4.04	4.78
5%	4.94	5.73
2.5%	5.77	6.68
1%	6.84	7.84

7.3.4. Long-run Estimates based on the Estimated ARDL model

The result of the estimated long-run coefficients are reported in Table 7. Similarly, based on these results, the long-term equation is written as follows:

$$\ln\left(\frac{\mathrm{I}}{\mathrm{Y}}\right) = 0.591200 \ln\left(\frac{\mathrm{S}}{\mathrm{Y}}\right) - 0.308540\ \mathrm{BREAK} \tag{7.2}$$

The value of saving-retention coefficient is 0.5912 in the long-term. And this coefficient is statistically significant since P = 0.0000 < 0.05. The parameter of the variable ln(S/Y) is known as F-H coefficient at the same time and this measures the degree of the international capital mobility. According to Feldstein-and Horioka [25], if this coefficient is not equal to 1 but it is near to 0, then the international capital of the country is perfectly mobile. That is, F-H coefficient is 0.5912 in our study and accordingly, the degree of international capital mobility for Turkey can be said to be equal to 0.5912. Thus, it cannot be said that the degree of international capital mobility for Turkey is quite high. Along with the international capital mobility level, about 1% increase in the ratio of domestic saving to GDP leads to rise in the ratio of domestic investment to GDP by 0.5912% in the long-run economy for Turkey.

Table 7. ARDL Long Run Coefficients - Selected Model : ARDL(1, 2)

Variables	Coefficient	Std. Error	t-Statistics	Prob.
LN(S/Y)	0.591200	0.123965	4.769096	0.0000
BREAK	-0.308540	0.144496	-2.135280	0.0392

7.3.5. Error Correction Model (ECM) based on the Estimated ARDL model

The error correction representation of the ARDL model is initially estimated as it is given in Table 8. Based on these results given in Table 8, all coefficients are statistically significant except for ln(S/Y)(t-1).

Table 8. Error Correction Representation for the Selected ARDL Model
Selected Model : ARDL(1, 2)

Variables	Coefficient	Std. Error	t-Statistics	Prob.
D(LN(S/Y))	0.581988	0.129896	4.480418	0.0001
D(LN(S/Y)(-1))	-0.166694	0.126450	-1.318262	0.1953
D(BREAK)	-0.130557	0.053828	-2.425478	0.0201
C	-0.405022	0.074065	-5.468455	0.0000
CointEq(-1)	-0.762752	0.135363	-5.634860	0.0000

Therefore, it is preferred to re-estimate this representation after removing this term ln(S/Y)(t-1). The new ECM is called Parsimonious Error Correction Representation. And the outcomes of parsimonious ECM is given in Table 9.

Table 9. Parsimonious Error Correction Representation for the Selected ARDL Model   Selected Model : ARDL(1, 2)

Variables	Coefficient	Std. Error	t-Statistics	Prob.
D(LN(S/Y))	0.615228	0.125231	4.912723	0.0000
D(BREAK)	-0.179942	0.074056	-2.429792	0.0196
C	0.011012	0.015448	0.712838	0.4800
CointEq(-1)	-0.722616	0.135994	-5.31595	0.0000

According to the results in Table 9, the short-run dynamics of growth equation associated with the long-run relationships are written as follows:

$$\Delta \ln\left(\frac{\mathrm{I}}{\mathrm{Y}}\right) = 0.011012 + 0.615228\,\Delta \ln\left(\frac{\mathrm{S}}{\mathrm{Y}}\right) - 0.179942\ \mathrm{BREAK} - 0.722616\ \mathrm{Cointeq}_{t-1} \tag{7.3}$$

The estimated coefficients of ln(S/Y) and dummy variable break are statistically significant. And the sign of the coefficient of ln(S/Y) is positive. The value of saving-retention coefficient is 0.615. Thus, if 1% increase in domestic saving rates occur, then domestic investment rates rises up to 0.615% in the short-term. Furthermore, the saving-retention coefficient also shows the degree of international capital mobility. The presence of international capital mobility can be mentioned because this coefficient is not statistically significant. Since this coefficient is found to be between 0 and 1, it can be concluded that the degree of international capital mobility is moderate.

The equilibrium error correction coefficient, estimated -0.722616 (0.0000) is statistically significant at 1% significance level, has negative sign as required, and implies a considerably high speed of adjustment to equilibrium (1 / 0.722616 = 1.384 years) after experiencing a financial shock or changes. 0.7226% of disequilibrium from the previous year's financial shock converges back to the long-run equilibrium in the present year.

Overall, regarding the effects of significant financial crises occurred both in 2001 and in 2008, the existence of short-run and long-run relationships between domestic saving and investment can be mentioned in the period of 1970-2015.

7.4. Toda-Yamamoto Test Results

As it is explained in Chapter 5 briefly, Toda-Yamamoto causality test is implemented in level VARs regardless of whether the variables are stationary and co-integrated, or not. This study employs Toda-Yamamoto methodology based on the augmented VAR (p+d_{max}) model to investigate the causal relationship between ln(I/Y) and ln(S/Y). In order to test T-Y Granger causality, the following steps are conducted.

7.4.1. Identification of Maximum Order of Integration (d)

The first step is to determine the maximum order of integration (d_{max}) of the variables in the model. According to the unit root testing procedure performed in previous sections, since ln(S/Y) is integrated of order 1 and ln(I/Y) is stationary at level, the maximum order of integration in the VAR system, d_{max}=1.

7.4.2. Optimum Lag Length Selection

The next step is that the optimal lag, k, has to be identified so as to perform causality tests. To select optimal lag length, VAR Lag Order Selection Criteria that is applied as it is seen in Table 10. The most common information criteria are AIC; SBC and HQ, but it is important to point out that SBC and HQ are preferable for large sample sizes although AIC is outperformed for small sample size. In this study, along with AIC, other information criteria imply lag length as 1. Thus, the lag length of VAR model is chosen as 1 based on the least values of AIC. i.e. k=1.

Table 10. VAR Lag Order Selection Criteria

Lag	LogL	AIC	SBC	HQ
0	34.82099	-1.641049	-1.556605	-1.610517
1	63.00865	-2.850433*	-2.597101*	-2.758836*
2	64.33132	-2.716566	-2.294346	-2563905
3	67.18764	-2.659382	-2.068274	-2.445656
4	69.14861	-2.557430	-1.797435	-2.282640
5	69.36779	-2.368390	-1.439506	-2.032535
6	71.23742	-2.261871	-1.164099	-1.864951

* indicates lag order selected by the criterion.

As the next step, the VAR(1) model is set up in order to check for some deterministic tests. The estimated VAR(1) model is shown in Table 11.

Table 11. Vector Autoregression Estimates for VAR(1)

	ln(I/Y)	ln(S/Y)
ln(I/Y)(-1)	0.453107 (0.16673) [2.71756]	0.191978 (0.15208) [1.26239]
ln(S/Y)(-1)	0.193371 (0.13115) [1.47445]	0.725783 (0.11962) [6.06746]
C	-0.534911 (0.18524) [-2.88760]	-0.184283 (0.16896) [-1.09069]
R-squared	0.457157	0.729714
Adj. R-squared	0.431307	0.716843
Sum sq. resids	0.718657	0.597860
S.E. equation	0.130809	0.119310
F-statistic	17.68519	56.69546
Log likelihood	29.23102	33.37162
AIC	-1.165823	-1.349850
SBC	-1.045379	-1.229406
Mean depedent	-1.628950	-1.826028
S.D. dependent	0.173459	0.224214

Determinant resid covariance (dof adj.)	0.000177
Determinant resid covariance	0.000154
Log likelihood	69.83325
AIC	-2.837033
SBC	-2.596145

Note that: Standard errors in () and t-statistics in [].

7.4.3. VAR Residual Serial Correlation LM Tests of T-Y Model

The VAR residual serial correlation LM test demonstrates that the null hypothesis of no serial correlation cannot be rejected up to 11 lags. The conclusion is that there is no serial correlation in the residuals. The VAR Residual Serial Correlation LM test results are given in the Table 12.

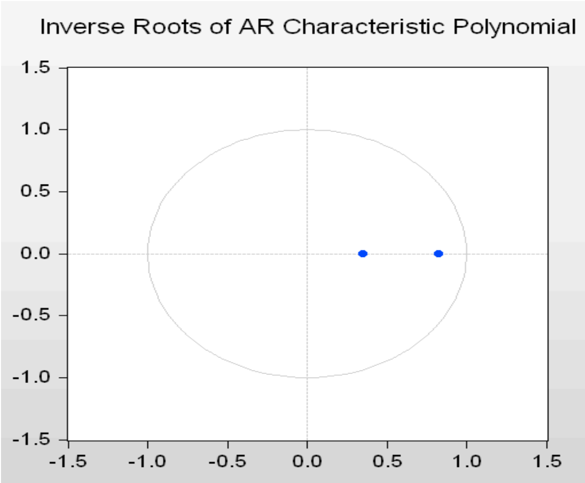
Table 12. The VAR Residual Serial Correlation LM Test Results

Lags	LM-stat	Prob
1	1.478624	0.8304
2	2.354094	0.6709
3	3.877417	0.4228
4	1.571613	0.8139
5	3.727216	0.4442
6	1.761880	0.7794
7	1.243344	0.8709
8	3.086567	0.5434
9	6.207098	0.1842
10	0.639721	0.9585
11	6.079513	0.1933

7.4.4. Inverse Roots of AR Characteristic Polynomial of T-Y Model

In the case that the inverse roots of AR characteristic polynomial lie inside the unit circle, the obtained VAR is said to be stable; in other words, it is stationary.

Figure 20 shows that none of roots of characteristic polynomial lies outside of the circle and thus, the estimated VAR model fulfills the condition on stability. This result is supported by test results as well.



(a)

Root	Modulus
0.825477	0.825477
0.353413	0.353413

No root lies outside the unit circle.
VAR satisfies the stability condition.

(b)

Figure 20. (a) The Inverse Roots of AR Characteristic Polynomial and **(b)** Test Results

7.4.5. VAR Residual Normality Tests of T-Y Model

Normality condition of the VAR residuals is highly desirable. Therefore, normality test is conducted and its results for the VAR residuals are shown in Table 13. The p-value corresponding to the Jarque-Bera test statistic is indicating that the joint null hypothesis of normality of residuals is accepted at the %5 level significance.

Table 13. VAR Residual Normality Tests of T-Y Model

Component	Jarque-Bera	df	Prob.
1	2.874665	2	0.2376
2	5.530118	2	0.0630
Joint	8.044782	4	0.0778

7.4.6. Results of Toda-Yamamoto Test

In order to examine the causal relationship between ln(I/Y) and ln(S/Y), VAR model is constructed, consisting of two variables in levels, of order $p=k+d_{max}=1+1=2$ since $d_{max}=1$ and $k=1$. The results of testing two-variate VAR(2) model are given in Table 14.

Table 14. Vector Autoregression Estimates for VAR(d_{max}+k) = VAR(2)

	ln(I/Y)	ln(S/Y)
ln(I/Y)(-1)	0.437717 (0.18257) [2.39759]	0.180867 (0.16569) [1.09159]
ln(S/Y)(-1)	0.097659 (0.19946) [1.48962]	0.794222 (0.18102) [4.38743]
C	-0.578013 (0.18219) [-2.83164]	-0.299918 (0.18526) [-1.60272]
ln(I/Y)(-2)	-0.067023 (0.18219) [-0.36787]	-0.117106 (0.16535) [-0.70822]
ln(S/Y)(-2)	0.143205 (0.18490) [0.77448]	-0.017527 (0.16781) [-0.10444]
R-squared	0.437657	0.730019
Adj. R-squared	0.379981	0.702328
Sum sq. resids	0.672605	0.554017
S.E. equation	0.131325	0.119187
F-statistic	7.588169	26.36360
Log likelihood	29.54400	33.81119
AIC	-1.115636	-1.309600
SBC	-0.912887	-1.106851
Mean dependent	-1.620916	-1.817042
S.D. dependent	0.166780	0.218454
Determinant resid covariance (dof adj.)		0.000182
Determinant resid covariance		0.000143
Log likelihood		69.91448
AIC		-2.723386
SBC		-2.317888

Note that: Standard errors in () and t-statistics in [].

By applying the model of seemingly unrelated regression (SUR) for a VAR(2), the following equation is estimated:

$$\begin{bmatrix} ln\left(\frac{I}{Y}\right)_t \\ ln\left(\frac{S}{Y}\right)_t \end{bmatrix} = a_0 + a_1 \begin{bmatrix} ln\left(\frac{I}{Y}\right)_{t-1} \\ ln\left(\frac{S}{Y}\right)_{t-1} \end{bmatrix} + a_2 \begin{bmatrix} ln\left(\frac{I}{Y}\right)_{t-2} \\ ln\left(\frac{S}{Y}\right)_{t-2} \end{bmatrix} + \begin{bmatrix} \varepsilon_{ln(I/Y)} \\ \varepsilon_{ln(S/Y)} \end{bmatrix}$$

(7.4)

The Granger non-causality hypotheses can be tested by utilizing MWald test on the following sets of restrictions:

$$\mathrm{H}_0: \mathrm{a}_{12}^{(1)} = \mathrm{a}_{12}^{(2)} = 0 \ \rightarrow ln\left(\frac{S}{Y}\right) \text{does not Granger cause } ln(\frac{I}{Y})$$

Alternatively,

$$\mathrm{H}_1: \mathrm{a}_{12}^{(1)} \neq \mathrm{a}_{12}^{(2)} \neq 0 \ \rightarrow ln\left(\frac{S}{Y}\right) \text{does Granger cause } ln(\frac{I}{Y})$$

And,

$$\mathrm{H}_0: \mathrm{a}_{12}^{(2)} = \mathrm{a}_{12}^{(1)} = 0 \ \rightarrow ln\left(\frac{I}{Y}\right) \text{does not Granger cause } ln(\frac{S}{Y})$$

Alternatively,

$$\mathrm{H}_1: \mathrm{a}_{12}^{(2)} \neq \mathrm{a}_{12}^{(1)} \neq 0 \ \rightarrow ln\left(\frac{I}{Y}\right) \text{does Granger cause } ln(\frac{S}{Y})$$

where $\mathrm{a}_{12}^{(\mathrm{i})}$ are the coefficient of a_{t-i} for $i = 1, 2$.

That causality exists is verified if it is rejected that the null hypothesis in case of MWald statistic test that is statistically significant at 1%, 5% or 10% significance level.

And finally, the Granger non-causality test is obtained. As it is seen in Table 15, the degrees of freedom are set to be 1 in every part of this table; in other words, the right lag length p is equal to 1. Yet, the additional 2nd lag has not been involved in the tests [112].

Since the P-value of 0.6244 is greater than the significance level 0.10, the null hypothesis that ln(S/Y) does not Granger cause ln(I/Y) is not rejected, which means that causal association in Granger sense from ln(S/Y) to ln(I/Y) cannot be obtained. Similarly, since the P-value of 0.2750 is greater than the significance level 0.10, the null hypothesis that ln(I/Y) does not Granger cause ln(S/Y) is not rejected, which means that there is no causality in Granger sense of the direction from ln(I/Y) toward ln(S/Y). Briefly, any causal relationship between the ln(I/Y) and ln(S/Y) cannot be found.

Table 15. Toda-Yamamoto Causality Test Results

VAR Granger Causality/Block Exogeneity Wald Tests			
Dependent Variable: ln(I/Y)			
Excluded	**Chi-sq**	**df**	**Prob.**
ln(S/Y)	0.239729	1	0.6244
All	0.239729	1	0.6244
Dependent Variable: ln(S/Y)			
Excluded	**Chi-sq**	**df**	**Prob.**
ln(I/Y)	1.191564	1	0.2750
All	1.191564	1	0. 2750

8. CONCLUSION

A variety of methods are available for performing the co-integration test. Although co-integration techniques, introduced by Engle and Gragner [6] and by Johansen and Joselius [86], are commonly used methods, these procedures have some inflexible features especially like the requirement of all variables being integrated in same order. Because of similar problems and the low power associated with these test methods, the OLS based autoregressive distributed lag (ARDL) approach to co-integration has become popular in recent years [146]. However, there is a few studies to investigate ARDL co-integration model in theoretical aspects even though there are numerous empirical studies based on ARDL technique. In this thesis, the theoretical and statistical background of ARDL co-integration approach is thoroughly and clearly explained. As a result of the theoretical examination of the model, several advantages of the model have been determined. The first and most remarkable one is, as it is mentioned, that the co-integration procedure based on ARDL model eliminates the precondition of integration order of the variables which is required in traditional co-integration methods. Secondly, the ARDL-based estimators of the long-run and short-run coefficients are respectively $\sqrt{T}$ – consistent and T – consistent (super consistent) despite the small sample size T. What is more, the ARDL co-integration technique permits different variables to have different number of lags unlike other co-integration methods. Putting in sufficient lags of the 'forcing variables' is essential to endogenise y_t. In this way, the problems of endogenous regressors and residual autocorrelation are corrected. In addition to these superiorities, the short-run dynamics integrated with the long-run equilibrium can be obtained without losing long-run information from the ECM that can be derived from ARDL through a simple linear transformation. The first four remarkable features can be listed as above. Therefore, the co-integration technique can be perfectly suggested for econometric analysis unless one of the variables is integrated at the second difference.

As for causality analysis, the existence of co-integration alone does not imply causation; therefore, a theory on causal mechanisms was developed initially by Engle and Granger [6]. Toda and Yamamoto [12] developed a new simple method for causal inference. Similar to the ARDL bounds testing approach, T-Y causality approach is widely utilized in empirical analysis, whereas there are too few studies on the investigation of theoretical background of this causality procedure. The main reason why this method is used widely is that this method does not require pre-tests for unit roots and co-integration. In this thesis, the theoretical background of the causality method is comprehensively explained. First of all, the general form of T-Y process, including VAR model, T-Y testing statistics, Modified Wald test statistics construction and the lag length selection, is explained.

In the empirical analysis of this thesis, it is preferred to analyze the validity of Feldstein-Horioka hypothesis for Turkish economy because saving rate is considered to play a crucial role in economic growth particularly through its association with investment. Feldstein and Horioka [25] first have built and estimated a basic equation that shows the relationship between domestic savings and domestic investments to investigate whether domestic savings are retained for domestic investment or flows to international capital mobility.

The presence of F-H puzzle for Turkey is proven over the time period from 1970 to 2015. As a result of ARDL (1,2) model, 1% increase in saving affects the rise in investment by 0.5912% which explicitly contributes to economic development in the long-run. Accordingly, it can be said that the degree of international capital mobility for Turkey is 0.5912. As for short-run relationship, 1% increase in domestic saving is linked with 0.615% increase in domestic saving. Furthermore, 0.7226% of disequilibrium from the previous year's financial shock converges back to the long-run equilibrium in the present year. On the other hand, according to Toda-Yamamoto causality results, any causality relationship among the variables cannot be found.

As a conclusion, whilst there are no findings on casual relationships among domestic investment and saving, co-integrated relationship among these variables exists, which implies that the economic policies aiming to spur economic growth through the stimulation of domestic saving may be thought to be efficient. Hence, it is very important to point out that two conditions are compulsory in order to realize the success of saving-promoting policies according to the arguments of Erden [24]. Initially, domestic saving is the primary flow of fund existing for domestic investment because of the restricted international capital mobility. The another condition is that as well as the presence of a close relationship between local saving and investment, the causal direction among these two variables ought to be from saving to investment [24].

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APPENDIX

A1. Critical Value Bonds of F-Statistic [151]

Case I: no intercept and no trend

	90%		95%		97.5%		99%	
k	I(0)	I(1)	I(0)	I(1)	I(0)	I(1)	I(0)	I(1)
0	3.016	3.016	4.136	4.136	5.347	5.347	7.381	7.381
1	2.458	3.342	3.145	4.153	3.893	4.927	5.020	6.006
2	2.180	3.211	2.695	3.837	3.258	4.458	3.939	5.341
3	2.022	3.112	2.459	3.625	2.901	4.161	3.372	4.797
4	1.919	3.016	2.282	3.474	2.618	3.924	3.061	4.486
5	1.825	2.943	2.157	3.340	2.481	3.722	2.903	4.261
6	1.760	2.862	2.082	3.247	2.367	3.626	2.744	4.124
7	1.718	2.827	2.003	3.199	2.288	3.536	2.595	3.909
8	1.678	2.789	1.938	3.133	2.198	3.445	2.481	3.826
9	1.640	2.774	1.873	3.072	2.122	3.351	2.396	3.725
10	1.606	2.738	1.849	3.026	2.076	3.291	2.319	3.610

Case II: intercept and no trend

	90%		95%		97.5%		99%	
k	I(0)	I(1)	I(0)	I(1)	I(0)	I(1)	I(0)	I(1)
0	6.597	6.597	8.199	8.199	9.679	9.679	11.935	11.935
1	4.042	4.788	4.934	5.764	5.776	6.732	7.057	7.815
2	3.182	4.126	3.793	4.855	4.404	5.524	5.288	6.309
3	2.711	3.800	3.219	4.378	3.727	4.898	4.385	5.615
4	2.425	3.574	2.850	4.049	3.292	4.518	3.817	5.122
5	2.262	3.367	2.649	3.805	3.056	4.267	3.516	4.781
6	2.141	3.250	2.476	3.646	2.823	4.069	3.267	4.540
7	2.035	3.153	2.365	3.553	2.665	3.871	3.027	4.296
8	1.956	3.085	2.272	3.447	2.533	3.753	2.848	4.126
9	1.899	3.047	2.163	3.349	2.437	3.657	2.716	3.989
10	1.840	2.964	2.099	3.270	2.331	3.569	2.607	3.888

Case III: intercept and trend

	90%		95%		97.5%		99%	
k	I(0)	I(1)	I(0)	I(1)	I(0)	I(1)	I(0)	I(1)
0	9.830	9.830	11.722	11.722	13.503	13.503	16.133	16.133
1	5.649	6.335	6.606	7.423	7.643	8.451	9.063	9.786
2	4.205	5.109	4.903	5.872	5.672	6.554	6.520	7.584
3	3.484	4.458	4.066	5.119	4.606	5.747	5.315	6.414
4	3.063	4.084	3.539	4.667	4.004	5.172	4.617	5.786
5	2.782	3.827	3.189	4.329	3.573	4.782	4.011	5.331
6	2.578	3.646	2.945	4.088	3.277	4.492	3.668	4.978
7	2.410	3.492	2.752	3.883	3.044	4.248	3.418	4.694
8	2.290	3.383	2.604	3.746	2.882	4.081	3.220	4.411
9	2.192	3.285	2.467	3.614	2.723	3.898	3.028	4.305
10	2.115	3.193	2.385	3.524	2.607	3.812	2.885	4.135

A2. Critical Value Bonds of Wald-Statistic [151]

Case I: no intercept and no trend

	90%		95%		97.5%		99%	
k	I(0)	I(1)	I(0)	I(1)	I(0)	I(1)	I(0)	I(1)
0	3.016	3.016	4.136	4.136	5.347	5.347	7.381	7.381
1	4.916	6.684	6.291	8.307	7.786	9.853	10.040	12.011
2	6.541	9.632	8.086	11.512	9.774	13.374	11.816	16.023
3	8.086	12.449	9.836	14.501	11.603	16.645	13.489	19.189
4	9.593	15.078	11.412	17.370	13.092	19.622	15.305	22.429
5	10.949	17.657	12.940	20.042	14.888	22.330	17.417	25.565
6	12.323	20.036	14.575	22.729	16.566	25.385	19.207	28.866
7	13.742	22.616	16.025	25.590	18.301	28.290	20.759	31.272
8	15.100	25.105	17.444	28.196	19.779	31.003	22.325	34.434
9	16.405	27.738	18.730	30.724	21.215	33.509	23.958	37.245
10	17.671	30.116	20.339	33.289	22.839	36.203	25.507	39.715

Case II: intercept and no trend

	90%		95%		97.5%		99%	
k	I(0)	I(1)	I(0)	I(1)	I(0)	I(1)	I(0)	I(1)
0	6.597	6.597	8.199	8.199	9.679	9.679	11.935	11.935
1	8.085	9.576	9.867	11.528	11.552	13.463	14.114	15.630
2	9.546	12.378	11.380	14.566	13.211	16.571	15.864	18.926
3	10.844	15.199	12.875	17.512	14.907	19.591	17.540	22.460
4	12.124	17.868	14.252	20.247	16.460	22.591	19.085	25.612
5	13.569	20.205	15.896	22.831	18.339	25.601	21.097	28.689
6	14.989	22.751	17.330	25.520	19.760	28.486	22.868	31.783
7	16.279	25.223	18.920	28.421	21.322	30.965	24.215	34.367
8	17.601	27.766	20.448	31.021	22.797	33.774	25.634	37.136
9	18.993	30.466	21.634	33.488	24.368	36.574	27.158	39.891
10	20.238	32.609	23.087	35.967	25.640	39.262	28.673	42.766

Case III: intercept and trend

	90%		95%		97.5%		99%	
k	I(0)	I(1)	I(0)	I(1)	I(0)	I(1)	I(0)	I(1)
0	9.830	9.830	11.722	11.722	13.503	13.503	16.133	16.133
1	11.299	12.670	13.212	14.847	15.286	16.902	18.126	19.571
2	12.616	15.326	14.710	17.617	17.017	19.661	19.561	22.752
3	13.936	17.831	16.264	20.477	18.423	22.989	21.259	25.655
4	15.316	20.420	17.694	23.335	20.022	25.861	23.085	28.932
5	16.690	22.963	19.135	25.971	21.441	28.692	24.066	31.984
6	18.047	25.521	20.614	28.617	22.942	31.443	25.678	34.844
7	19.282	27.936	22.013	31.065	24.354	33.984	27.347	37.553
8	20.611	30.443	23.432	33.715	25.940	36.727	28.979	39.697
9	21.924	32.846	24.666	36.138	27.225	38.985	30.280	43.050
10	23.262	35.126	26.240	38.760	28.682	41.928	31.738	45.482

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