APPLICATION OF NONLINEAR UNIT ROOT TESTS AND THRESHOLD AUTOREGRESSIVE MODELS

A THESIS SUBMITTED TO GRADUATE SCHOOL OF SOCIAL SCIENCES
OF THE MIDDLE EAST TECHNICAL UNIVERSITY

BY

ELA UYSAL

IN PARTIAL FULLFILMENT OF THE REQUIREMENTS
FOR THE DEGREE OF MASTER OF SCIENCE IN
THE DEPARTMENT OF ECONOMICS

SEPTEMBER 2012

I certify that this thesis satisfies all the requirements as a thesis for the degree of Master of Science.

Prof. Dr. Meliha Altunışık
Director

I certify that this thesis satisfies all the requirements as a thesis for the degree of Master of Science.

Prof. Dr. Erdal Özmen
Head of Department

This is to certify that we have read this thesis and that in our opinion it is fully adequate, in scope and quality, as a thesis for the degree of Master of Science.

Dr. Dilem Yıldırım
Supervisor

Examining Committee Members

Prof. Dr. Nadir Öcal (METU, ECON) ____________________

Dr. Dilem Yıldırım (METU, ECON) ____________________

Asst. Prof. Dr. Ceylan Yozgatlıgil (METU, STAT) ____________________

I hereby declare that all information in this document has been obtained and presented in accordance with academic rules and ethical conduct. I also declare that, as required by these rules and conduct, I have fully cited and referenced all material and results that are not original to this work.

Name, Last name: Ela Uysal
Signature

ABSTRACT

APPLICATION OF NONLINEAR UNIT ROOT TEST AND THRESHOLD AUTOREGRESSIVE MODEL

Uysal, Ela
M.S. in Economics
Supervisor: Dr. Dilem Yıldırım

September 2012,52 pages

Popularity of nonlinear threshold models and unit root tests has increased after the recent empirical studies concerning the effects of business cycles on macroeconomic data. These studies have shown that an economic variable may react differently in response to downturns and recoveries in a business cycle. Inspiring from empirical results, this thesis investigates dynamics of Turkish key macroeconomic data, namely capacity utilization rate, growth of import and export volume indices, growth of gross domestic product, interest rate for cash loans in Turkish Liras and growth of industrial production index. Estimation results imply that capacity utilization rate and growth of industrial production index show M-TAR type nonlinear stationary behavior according to the unit root test proposed by Enders and Granger (1998).

Key Words: Threshold nonlinear model (TAR), Momentum threshold model (M-TAR), Unit Root Test, Nonlinearity, Turkish Macroeconomic Data

ÖZ

DOĞRUSAL OLMAYAN BİRİM KÖK TESTİNİN VE EŞİK OTOREGRESİF MODELİNİN UYGULANMASI

Uysal, Ela
Yüksek Lisans Tezi, İktisat Anabilim Dalı
Tez Yöneticisi: Dr. Dilem Yıldırım

Eylül 2012, 52 sayfa

Son zamanlarda, iktisadi dalgalanmaların makroekonomik veriler üzerine etkisini konu alan çalışmalar, doğrusal olmayan modellerin ve birim kök testlerinin popülerliğini arttırmıştır. Yapılan çalışmalar bir ekonominin iktisadi dalgalanma boyunca faklı dinamikler sergileyebileceğini göstermektedir. Bu ampirik bulgulardan esinlenerek, tez kapsamında Türkiye makroekonomik verileri, kapasite kullanım oranı, ithalat ve ihracat hacim endeksi büyümesi, gayri safi yurt içi hasıla büyümesi, Türk Lirası üzerinden nakit kredilere uygulanan faiz oranı ve sanayi üretim endeksi büyümesi incelenmiştir. Enders ve Granger'ın (1998) birim kök test sonuçlarına göre kapasite kullanım oranı ve sanayi üretim endeksi büyüme dinamikleri durağanlık göstermekte ve bu dinamikler momentum eşik otoregresif modeli ile açıklanabilmektedir.

Anahtar Kelimeler: Eşik Otoregresif Modeli, Momentum Eşik Otoregresif Modeli, Birim Kök Testi, Doğrusalsızlık, Türkiye Makroekonomik Verileri

To my family…

ACKNOWLEDGEMENTS

Firstly, I would like to thank my supervisor Dr. Dilem Yıldırım for patiently guiding and encouraging me throughout this study.

I render thanks to Prof Dr. Nadir Öcal for allocating his valuable time and effort for reviewing my thesis.

I would also like to express my heartfelt thanks to Can Batkı for his endless love, friendship and encouragements throughout this study and my life. His presence with me makes me always feel confident and safe.

Finally, I want to express my sincere gratitude to my family, İsmet, Vahide and Nuhcan Uysal, for their unconditional love and complete reliance.

TABLE OF CONTENTS

LIST OF TABLES

TABLES

LIST OF FIGURES

FIGURES

1. INTRODUCTION

1.1 Introduction

Time series analysis concerns interpretation of data collected over time, forecasts future values and tests for economic theories. It has various application areas in economics since most of macroeconomic variables are measured over time. For instance, fiscal policies or financial interventions are implemented according to time series analysis.

Despite the popularity of linear time series models, recent empirical studies have shown that economic variables may react differently in response to downturns and recoveries in a business cycle. The reactions of employment and output are the most representative indicators. During recessions, they decrease more sharply than they increase during recoveries. As these different reactions cause asymmetric fluctuations in the structure of time series variables, nonlinear approaches represent these kinds of dynamics more properly than linear approaches. Following this principle, nonlinear models have gained great attention over three decades.

Increasing popularity of nonlinear models has triggered development of unit root tests for asymmetric dynamics because many economists document that power of traditional unit root tests such as Dickey-Fuller (ADF), Phillips Perron (PP) and Kwaitkowski, Phillips, Schmidt and Shin (KPSS) unit root tests decrease substantially when time series has an asymmetric structure.[1] They show tendency to fail to reject the null hypothesis of a unit root in the presence of asymmetric dynamics. Therefore, the results of these tests may be misleading.

[1]See, Pippenger and Goering (1993), Dickey and Fuller (1979), Phillips Perron (1988), Kwaitkowski, Phillips, Schmidt and Shin (1992)

Inspiring from the increasing importance of the recently developed nonlinear models and unit root tests, applications of these procedures on Turkey's key macroeconomic variables constitute the basic motivation of this thesis. It makes contributions to the economic literature in terms of asymmetric researches on Turkish data. Specifically, our aim is to investigate nonlinear stationarity of Turkish macroeconomic series such as capacity utilization rate, growth of import and export volume indices, growth of gross domestic product, interest rate for cash loans (in Turkish Liras) and growth of industrial production index. Second purpose is to describe the structure of these variables with appropriate nonlinear two-regime autoregressive models such as threshold autoregressive model (TAR) and momentum threshold autoregressive model (M-TAR).

In scope of the thesis, a comprehensive literature review is conducted. A review of recently developed nonlinear models and unit root tests are performed. Since TAR and M-TAR models and the unit root test developed by Enders and Granger (1998) are preferred for empirical analyses, representation of these models, their estimation steps and testing procedures are explained in detail. Empirical analyses are composed of four main parts. As standard unit root tests are frequently applied to test the null hypothesis of a unit root even when process is nonlinear, first ADF, PP and KPSS unit root tests are applied in order to test for stationarity of the variables. Since powers of these tests are relatively low when the actual dynamics of a variable is asymmetric, it is found vital to apply another unit root test which considers nonlinear stationarity of a variable. Hence, application of the nonlinear unit root test for this type of a case constitutes the second step of empirical analysis. Enders and Granger (1998) unit root test is preferred as an asymmetric unit root test, because it allows testing the presence of stationarity and asymmetry simultaneously. Furthermore, their procedure uses a suitable form of asymmetric model according to the dynamics of a variable. TAR and M-TAR models are suggested for unit root test. Despite the different models in use, the logic behind these models is quite similar. TAR model uses lag of a variable, whereas M-TAR model prefers previous period's change as a threshold variable. Thirdly, symmetry test proposed by Enders and

Granger (1998) is applied to the series for which stationarity is statistically confirmed at the second step. As a symmetry test, standard F test is employed according to Tong's (1983) study. He proved that least squares estimation of coefficients converges to multivariate normal distribution under the stationarity assumption. Lastly, TAR and M-TAR models are estimated for nonlinear stationary variables. At first step of model construction, super-consistent threshold estimates are determined by adopting Chan's (1993) methodology. Afterwards, estimations of models are performed following the methodology proposed by Tong.

This thesis has considerable importance on the following grounds. Our findings support the theoretically proved fact that traditional unit root tests have tendency to fail to reject the null hypothesis of a unit root. Therefore, in addition to traditional unit root tests, recently developed asymmetric unit root and nonlinearity tests should be employed in order to reveal nonlinearities. Second important inference of this study is about the modeling structure. Linear models with symmetric error distributions are inadequate to describe the dynamics when series is asymmetric. In this study, linear and nonlinear model estimations are compared. Comparison results indicate that nonlinear models allowing for regime switches represent the dynamics better than linear models for asymmetric structures.

The rest of the thesis is organized as follows. Chapter 2 describes nonlinear models and unit root tests developed for asymmetric dynamics. Chapter 3 covers data description part and empirical investigations. Lastly, chapter 4 concludes empirical analyses and the whole study.

1.2 Literature Review

In theoretical aspect, linear models with symmetric error distributions are not adequate enough to capture asymmetric dynamics of a variable. The theoretical deficiency of linear models and different behaviors of economic variables during business cycles have triggered the development of nonlinear time series models.

Widely applied nonlinear models in the literature are mostly based on different regimes according to some distinct notions of the variables. Since they have regime switching behavior, they are more flexible than linear models.

One of the well-known nonlinear models is threshold autoregressive (TAR) model, which is firstly introduced by Tong (1978).[2] Basically a TAR model is an extension of a linear autoregressive (AR) model. It is composed of at least two different AR models based on estimated threshold value(s). The other popular nonlinear model is smooth transition autoregressive (STAR) model proposed by Teräsvirta (1994). Further developments are provided by Teräsvirta (1998) and Potter (1999). A STAR model allows for a smooth shift between different regimes with an estimated smooth transition function rather than a specified threshold variable as in the TAR model. Therefore, the TAR model can be interpreted as an abrupt transition case of the STAR model. In most of recent pragmatic studies, it is observed that nonlinear models mentioned above are used to describe asymmetric dynamics of macroeconomic variables. For instance, Tiao and Tsay (1994) and Potter (1995) conclude that US GNP has an asymmetric structure and implement a TAR model. Enders and Granger (1998) find evidence of nonlinear dynamic adjustments of the US spread of interest rates and perform a special case of the TAR model, which is momentum autoregressive threshold (M-TAR) model. Koop and Potter (1999) study on an asymmetric dynamics of US unemployment rates with a TAR model. Teräsvirta and Anderson (1992) analyze the industrial production indices for Europe and 13 countries, most of which show nonlinear structure and are described by STAR models. Skalin and Teräsvirta (2002) observe substantial asymmetry in many OECD unemployment series and use STAR model to interpret them. Moreover, Nadir Öcal (2001) find evidence of STAR type of nonlinearities in many UK macroeconomic time series, namely industrial production, gross domestic product, prices, retail sales, consumption, savings, personal disposable income, investment, and unemployment. Another commonly used model in the literature is Markov

[2] See, the methodology is enhanced by Tong (1983,1990).

switching model suggested by Hamilton (1989), Engel and Hamilton (1990) and Filardo (1994). In this type of model, movements among regimes are dependent on probabilities instead of fixed threshold value(s) in a TAR model. Hansen (1992) analyze GNP dynamics with Markov switching model. Furthermore, Murray, Nikolsko and Papell (2008) estimate the dynamics of the US inflation rate with Hamilton's procedure.

Presence of an asymmetric structure of a variable brings along another serious problem related with testing the existence of a unit root. Standard unit root tests including augmented Dickey-Fuller (ADF), Phillips Perron (PP) and Kwaitkowski, Phillips, Schmidt and Shin (KPSS) unit tests have considerable power while testing the hypothesis of a linear unit root model against a linear stationary model. However, their powers decrease substantially when the series has an inherent asymmetric structure.[3] One of the main reasons for relatively poor performance of these standard unit root tests stems from the assumption of these tests. The standard unit root tests presume that effects of positive and negative shocks on a variable are identical. Pippenger and Goering (1993) and Balke, Fomby (1997) and Taylor (2001) conduct Monte Carlo experiments to uncover the substantial power changes of ADF test under asymmetric dynamics. Moreover, Gonza'lez and Gonzalo (1997), Enders and Granger (1998), Caner and Hansen (2001), Bec. Ben Salem and Carrasco (2004) and Kapetanios and Shin (2006) underline this issue and develop new unit root tests by using TAR type nonlinearity. These new tests have gained great attention in economic literature. For instance, Henry and Shields (2003) adopt procedures developed Gonza'lez and Gonzalo (1997) and Caner and Hansen (2001) in order to investigate the nonlinear stationarity of US inflation rate and conclude nonstationarity. Basci and Caner (2005) also use Caner and Hansen's methodology for dynamics of real exchange rates for 14 countries, 11 of which are exhibit evidence of partial unit root case. Furthermore, Chi and Su (2009) apply Enders and Granger's (1998) unit root test on spread of Twain's bond interest rates

[3] See, Pippenger and Goering (1993), Balke and Fomby (1997), Taylor (2001)

and conclude nonlinear stationarity. Ewing and Thompson (2007) also perform Enders and Granger's (1998) procedure for corporate profits and find evidence of asymmetric mean reversion. Furtheremore, Coakley and Fuertes investigate asymmetric stationarity of the long run behavior and short run dynamics of quarterly UK real interest rates with the procedure proposed by Enders and Granger (1998) and their findings support the evidence of asymmetric mean reversion. Bohl and Siklos conclude that US stock prices is a stationary process in the long run with asymmetric adjustments by adopting Enders and Granger's (1998) method.

Furthermore, Kilic (2003) and Kapetanios, Shin and Snell (2003) develop different kinds of unit root tests accounting for STAR type nonlinearity under the null hypothesis of a unit root. Several application studies of these procedures are also available in the economic literature. One of which is proposed by Paya and Peel (2006). They apply both tests on dynamics of real Dollar-Sterling exchange rate and find stronger evidence of stationarity. Furthermore, Liew, Baharumshah and Chong (2004) adopt procedure developed by Kapetanios *et al.* (2003) for Asian real exchange rates, most of which reject the null hypothesis of a unit root. Cuestas and Harrison (2010) also perform the same test on inflation rates of Central and Eastern European countries and conclude that more than half of them show evidence of nonlinear stationarity.

2. METHODOLOGY

2.1 Introduction

Over the last three decades, empirical studies have documented that business cycles have substantial asymmetric effects on dynamics of key macroeconomic data such as, gross domestic product, industrial production index, unemployment rate, interest rate and etc.[4] Recent studies on the dynamics of these variables have triggered the popularity of nonlinear models and unit root tests for asymmetric structures. Consequently, economic literature has flourished with many different unit root tests and nonlinear models. The well-known nonlinear models used in the economic literature are threshold autoregressive (TAR) model proposed by Tong (1978), momentum threshold model (M-TAR) suggested by Enders and Granger (1998), smooth transition autoregressive (STAR) model due to Teräsvirta (1994) and Markov switching model produced by Hamilton (1989). On the other hand, for stationarity detection of asymmetric dynamics, Gonza'lez and Gonzalo (1997), Enders and Granger (1998), Caner and Hansen (2001) and Kapetanios and Shin (2006) produce new unit root tests based on TAR models.

In the scope of this chapter, the nonlinear models and the asymmetric unit root tests mentioned above are described. Since TAR and M-TAR models and unit root test proposed by Enders and Granger (1998) are used for empirical analyses, these procedures are explained in detail. The rest of this chapter is divided into two main sections based on descriptions of nonlinear models and asymmetric unit root tests, respectively.

[4]See Tiao and Tsay (1994) and Potter (1995), Koop and Potter (1999), Teräsvirta and Anderson (1992), Skalin and Teräsvirta (2001), Öcal (2001) etc.

2.2 Nonlinear Models

Section 2.2 is divided into two subsections. First subsection describes TAR and M-TAR models, which are the main focus of this study, and the other subsection continues with other well-known nonlinear models which are STAR and Markov switching models.

2.2.1 Threshold Autoregressive (TAR) Model

A TAR model is one of the widely used nonlinear models in econometric literature. It is first developed by Tong (1978) and further maturations are proposed by Tong and Lim (1980), Tong (1983, 1990) and Tsay (1989), respectively. The technique suggested by Tong and Lim is not widely used because they do not consider any diagnostic statistics in order to test necessitate of a threshold model for a given data set. Furthermore, their technique contains intensive computational calculations which make it difficult to apply in practice. Whereas, the technique proposed by Tsay (1989) is relatively easy. It is based on visual investigations of graphs of recursive residuals and estimated t-statistics. He also suggests using misspecification tests in order to find consistent estimates. With the help of TAR model Tiao and Tsay (1994) and Potter (1995) explains the asymmetric dynamics of US GNP, Enders and Granger (1998) describe US spread of interest rates, Koop and Potter (1999) analyze US unemployment rates and Teräsvirta and Anderson (1992) investigate dynamics of industrial production indices for Europe and 13 countries.

2.2.1.1 Representation of a TAR Model

A two-regime TAR model can be considered as a combination of two different AR models. Switches between one regime to the other depend on a threshold variable and a threshold value. If a time series, y_t, is defined as a simple two-regime TAR model with a stationary threshold variable, r_{t-d}, where d is a delay parameter, then

y_t series follows the model[5]:

$$y_t = \begin{cases} \rho_{10} + \rho_{11} y_{t-1} + \dots\dots\dots + \rho_{1p} y_{t-p} + \varepsilon_{t,1} & if \quad r_{t-d} \geq \lambda \\ \\ \rho_{20} + \rho_{21} y_{t-1} + \dots\dots\dots + \rho_{2p} y_{t-p} + \varepsilon_{t,2} & if \quad r_{t-d} < \lambda \end{cases} \tag{2.1}$$

λ is defined as a threshold value and defined as $-\infty < \lambda < \infty$. $\varepsilon_{t,i}$ is a random error term of regime i at time t, $i \neq j$ and $(i, j) = (1, 2)$. Error terms are independent and identically distributed with zero mean and a constant nonzero variance. As it is obvious from the model (2.1), y_t series is described as a combination of two linear AR models and each AR model is defined according to the specific threshold value. If variances of each regime error terms are equal (i.e., $\text{var}(\varepsilon_{t,1}) = \text{var}(\varepsilon_{t,2})$), then the model can be represented in closed form as:

$$y_t = I_t \left(\rho_{10} + \rho_{11} y_{t-1} + \dots.. + \rho_{1p} y_{t-p} \right) + \left(1 - I_t \right) \left(\rho_{20} + \rho_{21} y_{t-1} + \dots.. + \rho_{2p} y_{t-p} \right) + \varepsilon_t \tag{2.2}$$

where I_t is Heaviside indicator function which is defined as:

$$I_t = \begin{cases} 1 & if \quad r_{t-d} \geq \lambda \\ \\ 0 & if \quad r_{t-d} < \lambda \end{cases} \tag{2.3}$$

According the threshold value, series is divided into two sections and these sections are described with different linear AR processes. Different linear models for each regime allow modeling different asymmetric fluctuations. Therefore, TAR model is considered as a piecewise linear AR model in the economic literature. Despite the fact that y_t sequence is described with linear models in each regime, the presence of regime switches in the model leads the entire process to be nonlinear. When coefficients of each regime are identical (i.e., $\rho_{10} = \rho_{20}, \rho_{11} = \rho_{21}, \dots\dots, \rho_{1p} = \rho_{2p}$), the TAR model (2.2) turns into a linear AR model.

[5]A two-regime TAR model can be extended by increasing the number of regimes.

When the threshold variable, r_{t-d}, is defined as a lag of y_t, then the TAR model is called self exciting TAR (SETAR) model. In other words, SETAR model can be basically defined as a special case of TAR model with a lagged dependent threshold variable. In this study, unit root tests and model estimations are based on SETAR model. Therefore, further definitions and procedures explained about nonlinear models use lagged dependent time series, y_{t-d}, as a threshold variable.

Furthermore, a momentum threshold autoregressive (M-TAR) model proposed by Enders and Granger (1998) is quite similar to the TAR model. The only difference between these models is the definition of threshold variables. Regime switches in a TAR model depend on the previous period values, whereas in an M-TAR model they are subject to the lagged period changes. Therefore, the M-TAR model can be defined by (2.2) with an indicator function defined as:

$$L_t = \begin{cases} 1 \quad if \quad \Delta y_{t-d} \geq \lambda \\ 0 \quad if \quad \Delta y_{t-d} < \lambda \end{cases} \tag{2.4}$$

2.2.1.2 Estimation of a TAR Model

The estimation procedure of a TAR model is explained step by step in order to define the process systematically.

Constructing a Basis of a TAR Model:

First step of modeling process is constructing a basis for a nonlinear model. Since a linear AR model is the core of a nonlinear TAR model, construction of an appropriate autoregression for entire observations constitutes the first step. An appropriate AR order can be selected through different methods such as information criteria like Schwarz Bayesian information criteria (SBC), Akaike information criteria (AIC), general to specific method with t-test or elimination of group of coefficients method with F-test.[6] Following Hall (1994) and Ng and Perron (1995), we determine the lag length of AR model by using general to specific approach at the 5% significance level with a maximum autoregressive order of 12 for monthly data and 8 for annual data.[7]

Nonlinearity Test and Selection of a Delay Parameter:

After constructing an appropriate AR model, next step is testing for nonlinearity and selecting an optimum threshold variable if nonlinearity is detected. These steps are fundamentally based on arranged autoregression procedure. It is defined as construction of an autoregression with cases rearranged based on the values of a particular regressor. Tsay (1989) suggests using threshold variable as a basis of an arrangement. His procedure is specifically based on ordering the process ascendingly according to the threshold variable. This way groups all observations in such a way that all data points in a group follow the same linear autoregression model. Hence, the arranged autoregression model is estimated by ordinary least squares estimation (OLS) method. If the process is linear, OLS estimates of coefficients are consistent, and consequently, predictive errors are asymptotically white noise. On the other hand, if the process is nonlinear, some of the predicted errors are biased when process switches from one regime to the other because different regimes require different models. In such a case, predictive residuals contain dynamics of the variable which are not captured by the estimated model. For that reason, the orthogonality assumption between the predicted residuals and the regressors is violated. Following this logic, auxiliary least squares regressions are constructed by regressing predictive residuals of arranged autoregression on regressors for all possible delay parameters. When the sample size is small, standardized form of

[6]See Enders, W. (2010)

[7]Appropriate lag length selection is also carried out by setting significance level at 10%. Since the obtained lag lengths are almost same, we only exhibit the results for 5% significance level.

predictive residuals is preferable rather than a standard form.[8] To detect the nonlinearity of dynamics, significance test is performed to the auxiliary regressions by using F statistics. If F test fails to reject the null hypothesis, the process is concluded to be linear. Otherwise, it is nonlinear. When nonlinearity is detected, optimum threshold variable is selected according to F statistics. Specifically, the selection procedure is based on the selection of the delay parameter that indicates the most significant nonlinearity test result.

Determining Threshold Value:

After detecting the nonlinearity and specifying the delay parameter, next step is to determine the threshold value. Although the graphical methods do not provide statistical inferences, Tsay (1989) suggests to use graphs for this purpose. His procedure is based on scatter plots of a variety of statistics versus the specified threshold variable. For instance, he uses scatter plot of ordinary or standardized predictive residuals of the arranged autoregression model versus determined threshold variable. If the process is linear, the predictive residuals will be asymptotically normal. On the other hand, if the process is nonlinear, then the predictive residuals will be biased at regime changing point(s) because at this point dynamics of data changes and the estimated model becomes inadequate to explain the dynamics. Therefore, this changing point(s) indicates a candidate threshold value(s). Another useful graphical method is the scatter plot of recursive t-statistics of estimated AR coefficients versus threshold variable. The t-statistics exhibit the significance of a particular AR coefficient. When it is significant, statistics gradually converge to a fixed value as the recursion continues. However, if the process is nonlinear, the convergence of t-statistics will be destroyed at the threshold value(s).

After specifying the location of threshold value, sample sizes of each regime should be checked because if there are not enough observations in one regime, estimation results observed from that regime will be unreliable and inefficient. Therefore, the

[8]See, Tsay (1989)

specified threshold value should not be too close to the 0^{th} or 100^{th} percentile in order to divide the regimes rationally.

As an alternative to graphical methods, Chan (1993) suggests a statistical procedure to identify a super-consistent estimate of threshold value(s). He first orders the candidate threshold values ascendingly, and then, eliminates the lowest and highest 10 percent in order to avoid the disorganized dispersion of observations to each regime. Afterwards, TAR models are estimated for all potential threshold values. Each sum of squared residuals of these models is considered as a function of associated threshold value because model is constructed according to the threshold value. Hence, the pattern of sum of squared residuals indicates the presence of nonlinearity. In the absence of nonlinearity, there must be no relationship between threshold values and sum of squared residuals. However, if there is a threshold effect, sum of squared residuals becomes smaller as the threshold value in use is getting closer to the true threshold value. Consequently, the model having the smallest sum of squared residuals will give a consistent estimate of the threshold value. Furthermore, if there is more than one threshold value, the sum of squared residuals will have the same number of local minima.[9]

Estimation of TAR Model:

As mentioned above, a TAR model constitutes of locally linear AR models. Therefore, the notion behind the estimation procedure of a TAR model is similar to that of a linear AR model. Specifically, after detecting the threshold variable and the threshold value(s), the estimation procedure totally turns to the linear AR model estimation procedure. Estimations are performed regime by regime; therefore, the series under investigation is first divided into groups according to the threshold variable and threshold value(s). Since each group exhibits linear dynamics, simple

[9]Chan (1993) suggests scatter plot of sum of squared residuals versus threshold values in order to determine the number of regimes in a TAR model.

OLS technique can be used for estimation of each locally linear AR model.[10]

2.2.2 Other Nonlinear Models

Another popular nonlinear model is smooth transition autoregressive (STAR) model. The logic behind a STAR model is quite similar to a TAR model except the regime switches. Goldfeld and Quandt (1972) propose a cumulative distribution function for regime switches.[11] A two-regime STAR model with a continuous and non-decreasing transition function is defined as:

$$Y_t = \pi_{1i} + \sum_{i=1}^{p} \pi_{1i} Y_{t-i} + \left(\theta_{2i} + \sum_{i=1}^{p} \theta_{2i} Y_{t-i} \right) * F\left(Y_{t-d}; \gamma, c\right) + \varepsilon_t \tag{2.5}$$

where $i = 1, 2, 3, \ldots\ldots, p$ and ε_t should be a martingale difference sequence according to time series $Y_{t-i} = \left(y_{t-1}, y_{t-2}, \ldots\ldots, y_{t-p}\right)$ and their conditional variance is constant. The smooth transition function, $F\left(Y_{t-d}; \gamma, c\right)$, takes values between 0 and 1. According the transition function, the STAR model is defined as the mixture of two AR(p) processes. In economic literature, a transition function can be defined in two different forms: logistic form and exponential form. Luukkonen, Saikkonen and Teräsvirta (1988) and Teräsvirta (1994) focus on the logistic form. The logistic STAR (LSTAR) model is useful for modeling different dynamics of expansions and recessions in a business cycle.[11] First order logistic transition function is described as:

$$F_L(y_{t-d}) = \left\{1 + \exp\left[-\gamma_L \left(y_{t-d} - c_L\right)\right]\right\}^{-1} \tag{2.6}$$

where y_{t-d} is the transition variable, c_L is the threshold parameter and γ_L is the smoothness parameter where $\gamma_L > 0$. LSTAR model is preferred by many

[10]Tong (1983) proved that OLS estimates of coefficients converges to multivariate normal distribution under the stationarity assumption.

[11]Enhancements are performed by Teräsvirta and Anderson (1993) and Skalin and Teräsvirta (2001)

economists because of the flexible structure. Teräsvirta and Anderson (1992), Teräsvirta, Tjostheim and Granger (1994) use LSTAR model to characterize the dynamics of industrial production index. Exponential form of transition function is:

$$F_E(y_{t-d}) = \left(1 - \exp\left(-\gamma_E\left(y_{t-d} - c_E\right)^2\right)\right) \quad (2.7)$$

The exponential STAR (ESTAR) model considers only the distance from the location parameter, and hence, regimes are effectively defined by value close or far from the threshold parameter, c_E. Michael (1997), Satantis (1999) and Taylor (2001) adopt this form of STAR model in order to describe the dynamics of real exchange rates.

Other popular nonlinear model in the literature is Markov switching autoregressive model which is proposed by Hamilton (1989). Further developments are performed by Engle and Hamilton (1990) and Filardo (1994). Apart from the regime switches procedure of TAR model, Markov switching autoregressive model is similar to TAR model. A Markov switching AR(1) model which allows for two states is defined as:

$$Y_t = \mu_{st} + \alpha_{st} + \varepsilon_t \quad (2.8)$$

where ε_t is normally distributed. Regime switches are based on fixed probabilities and follow a first order Markov process with transition probabilities:

$$P\left(s_t = j \mid s_{t-1} = i\right) = p_{ij} \quad \text{where} \quad (i, j) = (1, 2) \quad (2.9)$$

In an empirical analysis, $s_t = 1$ and $s_{t-1} = 2$ can be thought as recession and expansion. So, p_{12} indicates the probability of switching from recession to expansion. The important drawback of Markov model is fixed probabilities between regime switches. Therefore, model cannot take into account whether an economy is at the end or the beginning of a recession or an expansion. Filardo (1994) underlines this issue and improves the model with transition probabilities fluctuating over time.

2.3. Unit Root Tests for Asymmetric Dynamics

In the last two decades there has been a debate on power of linear unit root tests including traditional augmented Dickey Fuller (ADF) (1979), Phillips Perron (PP) (1988) and Kwiatkowski *et al.* (KPSS) (1992) unit root tests since they cannot adequately identify stationarity of series when the series is inherently nonlinear. Pippenger and Goering (1993), Balke and Fomby (1997) and Taylor (2001) focus on this drawback of conventional unit root tests. They document various Monte Carlo simulations in order to show the low power of standard ADF test when a series is stationary but nonlinear. Their studies have triggered the debate on power of conventional unit root tests. As a consequence, many economists have developed new type of unit root tests considering the fact that a series might indicate a nonlinear stationary behavior. For instance, Gonza'lez and Gonzalo (1997), Enders and Granger (1998), Caner and Hansen (2001), Bec., Ben Salem and Carrasco (2004) and Kapetanios and Shin (2006) produce new unit root tests based on TAR model.

Section 2.3 introduces two subsections according to unit root tests based on TAR and M-TAR models. Since Enders and Granger (1998) procedure is adopted for the empirical investigation, first subsection focuses on their procedure in detail. Second subsection defines other asymmetric unit root tests stated above.

2.3.1 Unit Root Test Proposed by Enders and Granger (1998)

Due to the underlying assumption of linearity, a conventional augmented Dickey-Fuller (ADF) test is adequate for detection of stationarity for linear variables. The model used in ADF test is:

$$\Delta y_t = \alpha + \beta t + \rho y_{t-1} + \gamma_1 \Delta y_{t-1} + \cdots\cdots + \gamma_{p-1} \Delta y_{t-p+1} + \varepsilon_t \qquad (2.10)$$

where α is a constant term, β is a coefficient on a time trend t, and ε_t is a white noise error term. The series is stationary if coefficient of y_{t-1} satisfies the necessary condition, $-2 < \rho < 0$. The stationarity detection is tested under the null hypothesis, $H_0 : \rho = 0$. Since ADF test is misspecified for asymmetric adjustments as mentioned before, Enders and Granger (1998) develop a new type of unit root test allowing for an asymmetric adjustment under alternative hypothesis. They prefer using threshold nonlinear models in order to identify the dynamics of asymmetric adjustment. They use augmented TAR model in equation (2.3) with lagged changes such as:

$$\Delta y_t = I_t \rho_1 y_{t-1} + (1 - I_t)\rho_2 y_{t-1} + \sum_{i=1}^{p-1} \rho_i \, \Delta y_{t-i} + \varepsilon_t \tag{2.11}$$

with Heaviside indicator function:

$$I_t = \begin{cases} 1 & if \quad y_{t-1} \geq \lambda \\ 0 & if \quad y_{t-1} < \lambda \end{cases}$$

For the determination of optimum lag length which is necessary to be included in the model, various methods are suggested. Diagnostic checks of residuals such as correlogram of residuals and Ljung-Box Q test, are some of the useful ways because it is known that diagnostics are violated when a model is not adequate enough to represent the dynamics of series. Furthermore, information criteria such as, Akaike information criterion (AIC) and Schwartz Bayesian information criterion (SBC), is another way of lag length determination. Tong (1983) recommends using model selection criteria for this purpose.

As it is obvious from the equation (2.11) that model shows an asymmetric adjustment if the condition $\rho_1 \neq \rho_2$ satisfies. The sequence, y_t has a tendency to decay at a rate ρ_1 if the threshold variable is above the threshold value (i.e., $y_{t-1} \geq \lambda$), and at a rate ρ_2 if the threshold variable is below the threshold value (i.e., $y_{t-1} < \lambda$). The sequence, y_t, is stationary when coefficients satisfy the condition $-2 < (\rho_1, \rho_2) < 0$, and then, long run equilibrium occurs around the threshold value, λ. For the series dispersing around a trend line, the threshold value, λ, can be defined as a linear attractor such as $a_0 + a_1 t$. Hence, the long run equilibrium for trend stationary series occurs around the trend line if the series is stationary.

Enders and Granger (1998) also discuss different type of asymmetric adjustment that enables to characterize the deepness type of asymmetry. This model is called momentum threshold autoregressive (M-TAR) model and uses a different form of a threshold parameter. The Heaviside indicator function of M-TAR model is constructed according to the previous period changes in y_{t-1} such that:

$$I_t = \begin{cases} 1 \quad if \quad \Delta y_{t-1} \geq \lambda \\ \\ 0 \quad if \quad \Delta y_{t-1} < \lambda \end{cases} \tag{2.12}$$

where λ is a threshold value and could be defined in the linear form of an attractor such as $a_0 + a_1 t$ or a distinct value, a_0. The M-TAR model is appropriate especially for the sequences exhibiting more momentum in one direction than other. For instance, $|\rho_1| < |\rho_2|$ and $\lambda = 0$, then the increment of positive divergences from threshold value will be more persistent than that of negative divergences. This property of model enables to capture steepness of the asymmetry.

The unit root test proposed by Enders and Granger (1998) has similarities to the traditional ADF test. In both procedures, the critical values depend on the existence of deterministic regressors such as, a_0 and a_1. Since these deterministic regressors are estimated before the construction of the indicator function, it is not possible to test the existence of deterministic elements and unit root simultaneously. Following this fact, Enders and Granger suggest eliminating the effect of deterministic elements on the series by demeaning and detrending the series. Demeaning is performed by regressing the data on a constant such as, $y_t = a_0 + \varepsilon_t$. On the other hand, detrending is performed by regressing the data on a constant and a trend term such as, $y_t = a_0 + a_1 t + \varepsilon_t$ where t is time. It is obvious that studying with the residuals of these models, ε_t, turns the associated attractor into the attractor, $\lambda = 0$. Sometimes the form of deterministic components is not clearly observed. For this case, Enders and Granger suggest using demeaned series because the unit root test statistics for series including deterministic regressor (i.e., a_0) and the test statistics for the series not including deterministic regressor are reasonably close. Therefore, an inappropriately included deterministic regressor has not substantially effect on the unit root test statistics.

For testing the null hypothesis of a unit root, $H_0 : \rho_1 = \rho_2 = 0$, Enders and Granger use not only F statistics but also t statistics for separate null hypotheses, $H_0 : \rho_1 = 0$ and $H_0 : \rho_2 = 0$. They record the most and the least significant t statistics as t-Max and t-Min in order to compare the powers. According to Monte Carlo experiment, the power of F statistics shows better performance than that of t-Max and t-Min. Therefore, in practice they recommend using F statistics for an asymmetric unit root test. Since F statistics has nonstandard distribution under the null hypothesis, decision making should be undertaken with specifically derived critical values by Monte Carlo experiments. Six different critical values depend on deterministic components (i.e., critical values for no deterministic components, critical value for estimated constant attractor and critical value for estimated trend attractor) are tabulated for TAR and M-TAR models. The values for test statistics are reported at 10%, 5% and 1% significance levels.

After stationarty detection, the possible existence of nonlinearity should be tested under the null hypothesis, $H_0 : \rho_1 = \rho_2$. Since Tong (1983) proved that OLS estimates of ρ_1 and ρ_2 converge to a multivariate normal distribution, a standard F statistics and critical values can be used for asymmetry test.

2.3.2. Other Unit Root Tests Based on TAR and M-TAR Models

This section covers brief descriptions of recently developed unit root tests based on TAR models. One of them is developed by Gonza'lez and Gonzalo (1997). They focus on the idea that some variables can be best represented by a model with a unit root such as:

$$y_t = \alpha_1 I(r_{t-d} \leq \lambda) + \alpha_2 I(r_{t-d} > \lambda) \; y_{t-1} + \varepsilon_t \quad (2.13)$$

where r_{t-d} is stationary threshold variable, $\alpha_i = 1$ and $|\alpha_j| < 1$, $i \neq j$, $(i, j) = (1, 2)$ and λ is a threshold value defined by the approach proposed by Chan (1993). Model (2.13) is rearranged as:

$$\Delta y_t = \rho y_{t-1} + \gamma I(r_{t-d} \leq \lambda) + \varepsilon_t \qquad (2.14)$$

where $\rho = \alpha_2 - 1$ and $\gamma = \alpha_1 - \alpha_2$. The null hypothesizes of no threshold $H_0: \gamma = 0$, is proposed to test by the supremum of square t statistic over the range of λ and null of a unit root is tested by Wald statistics with tabulated critical values.

Caner and Hansen (2001) also develop a new unit root test based on a two-regime TAR model with a stationary threshold variable such as:

$$\Delta y_t = \theta_1' X_{t-1} I\left(r_{t-1} < \lambda\right) + \theta_2' X_{t-1} I\left(r_{t-1} \geq \lambda\right) + \varepsilon_t \text{ for } t = 1,2,\ldots,T \qquad (2.15)$$

where $X_{t-1} = \left(y_{t-1},\ d_t', \Delta y_{t-1}, \ldots\ldots, \Delta y_{t-k}\right)'$, d_t is a vector of deterministic components. $\theta_i = \left(\rho_i\ \ \beta_i\ \ \alpha_i\right)'$ where $i = 1, 2$ is slope vector of y_{t-1}, d_t, and $(\Delta y_{t-1}, \ldots\ldots, \Delta y_{t-k})$, respectively. $r_t = y_t - y_{t-m}$ is a threshold parameter for $m \geq 1$ and ε_t is an iid error term. Threshold value, λ, is defined by considering number of observations in each regime. The alternative hypothesis of a stationarity against the null hypothesis of a unit root, $H_0: \rho_1 = \rho_2 = 0$, is $H_1: \rho_1 < 0 \ \textit{and} \ \rho_2 < 0$. Caner and Hansen also interest in another alternative hypothesis which defines the stationarity as a partial unit root case such that $H_{1'}: \rho_1 < 0 \ \textit{and} \ \rho_2 = 0$ or $\rho_1 < 0 \ \textit{and} \ \rho_2 = 0$. For unit root test, one-sided Wald statistics, $R = t_1^2 I\left(\hat{\rho}_1 < 0\right) + t_2^2 I\left(\hat{\rho}_2 < 0\right)$ is suggested and the asymptotic null distributions are derived with bootstrap approximation. To discriminate the stationary regimes, individual t-statistics of estimated coefficients, $\hat{\rho}_1$ and $\hat{\rho}_2$, are suggested.

The procedure suggested by Kapetanios and Shin (2006) is based on three-regime SETAR model such as:

$$y_t = \begin{cases} \phi_1 y_{t-1} + \varepsilon_t & if \quad y_{t-d} \leq \lambda_1 \\ \phi_0 y_{t-1} + \varepsilon_t & if \quad \lambda_1 < y_{t-d} \leq \lambda_2 \\ \phi_2 y_{t-1} + \varepsilon_t & if \quad y_{t-d} > \lambda_2 \end{cases} \quad \text{where } t = 1, 2, 3, \ldots, T \tag{2.16}$$

where ε_t is an iid error term, λ_1 and λ_2 are threshold parameters satisfying $\lambda_1 < \lambda_2$. d is a delay parameter chosen to maximize goodness of fit over $d = 1, 2, \ldots, d_{\max}$ where $d_{\max}$ is the maximum lag length. Since Kapetanios and Shin (2006) assume that the process follows a random walk model in the middle regime, they impose $\phi_0 = 1$. Hence, model (2.16) can be written as:

$$\Delta y_t = \rho_1 y_{t-1} I_{y_{t-d} < \lambda_1} + \rho_0 y_{t-1} I_{\lambda_1 < y_{t-d} \leq \lambda_2} + \rho_2 y_{t-1} I_{y_{t-d} > \lambda_2} + \varepsilon_t \tag{2.17}$$

where $\rho_0 = \phi_0 - 1$, $\rho_1 = \phi_1 - 1$ and $\rho_2 = \phi_2 - 1$. Following the assumption mentioned above, the null of a unit root is defined as $H_0 : \rho_1 = \rho_2 = 0$. For test statistics, they suggest using exponential average Wald tests because they find that it has relatively high power compared to the supremum and average Wald tests according to by Monte Carlo experiments. For critical values, they derive asymptotic distributions due to the unidentified threshold problem under the null hypothesis.

A unit root test suggested by Bec, Ben Salem and Carrasco (2004) is similar to the one proposed by Kapetanios and Shin (2006). The fundamental difference is related to the assumption of the corridor regime. They do not impose any assumption for the corridor regime. Therefore, their null hypothesis covers all regime parameters such that $H_0 : \rho_0 = \rho_1 = \rho_2 = 0$ for the model (2.17). As a testing procedure, supremum Wald test is suggested because they proved that sup-Wald statistics allows for an unknown threshold value and has asymptotic distribution which does not depend on a nuisance parameter.

Among the unit root tests, the procedure proposed by Enders and Granger (1998) is preferred because of three basic reasons. First of all, their procedure is easy to apply.

There are no complicated calculations. Second important reason for the preference is that it allows testing the presence of stationarity and asymmetry, simultaneously. There is no need to construct different models for different tests. Lastly, their procedure allows using suitable form of asymmetric model according to the dynamics of variable while testing the stationarity.

3. EMPIRICAL ANALYSIS

3.1 Introduction

This chapter covers empirical investigation of Turkish key macroeconomic data which are capacity utilization rate, growth of import and export volume indices, growth of gross domestic product, interest rate for cash loans[12] (in Turkish Liras) and growth of industrial production index. Three basic reasons play active roles in selection of these macroeconomic variables. The sufficient volume of sample sizes constitutes the first basic reason. Another factor for selection is that these macroeconomic variables are expected to have an asymmetric dynamics based on the empirical results presented in the literature. For instance, Enders and Granger (1998) document that dynamics of interest rate has an asymmetric adjustment, Tio and Tsay (1994) and Potter (1995) discuss on the asymmetric dynamics of GNP series and Teräsvirta and Anderson (1992) report the asymmetry of industrial production index. Furthermore, these Turkish series under investigation have not been studied before by using the methodology of Enders and Granger (1998). Observing this fact has also triggered our desire to study on these macroeconomic variables.

For the first step of empirical analysis, conventional unit root tests including augmented Dickey Fuller (1979), Phillips Perron (1988) and Kwiatkowski, Phillips, Schmidt and Shin (1992) unit root tests are applied. Then, Enders and Granger (1998) TAR and M-TAR based unit root test is applied to specify integration orders of the variables. According to the test results, TAR or/and M-TAR models are constructed for the variables which provide significant empirical evidence for

[12]Interest rate for cash, vehicle, housing and commercial loans are analyzed. Since all series show the similar results we only propose results of interest rate for cash loans.

nonlinear stationarity. Nonlinear models are performed by replicating the methodology proposed by Chan (1993). In order to find the best fitted model, we also construct liner AR models for these variables and compare their performances with the nonlinear ones. Akaike (1974) information criteria (AIC), sum of square residuals and variance of residuals are investigated for comparison of estimated models.[13] Lastly, diagnostic checks such as skewness, kurtosis, autocorrelation, heteroscedasticity and normality test are performed for the estimated models. To detect the residual correlations, Ljung-Box Q test (1978) is applied. For heteroscedasticity test of residuals, ARCH LM test with maximum lag length of 12 for monthly data and 8 for quarterly data is performed. As a normality test, a well-known Jarque-Bera (1980) normality test is applied.

This chapter is divided into three sections. First section covers the data description part. It exhibits visual analysis and statistical descriptions of data such as mean, standard deviation, skewness and kurtosis. Second section provides the results of unit root tests. These results cover the standard unit root tests together with the asymmetric unit root tests proposed by Enders and Granger (1998).[14] Last section provides the estimated models long with their diagnostic checks.

3.2 Data Descriptions

Capacity utilization rate, growth of import and export volume indices, growth of gross domestic product, interest rate for cash loans and growth of industrial production index are analyzed in this thesis.[15] As it is widely experienced from

[13]AIC is calculated by weighting the residual variance by the number of parameters. Therefore, the smallest AIC value indicates the better fitting model. For its use in nonlinear time series models, see Tong (1983).

[14]For details of conventional unit root tests proposed by Dickey Fuller (1979), Phillips Perron (1988), and Kwiatkowski, Phillips, Schmidt and Shin (1992) see related papers. In empirical analyzing, these tests proposed are denoted by ADF, PP and KPSS, respectively.

[15]In empirical analyzing, capacity utilization rate, growth of import and export volume indices, growth of gross domestic product, interest rate for cash loans and growth of industrial production index are denoted by CUR, GIMP, GEXP, GGDP, INT. RATE, GIP, respectively.

empirical analyzes, most of macroeconomic variables are subjected to seasonality. Therefore, seasonal adjustment should be performed for the necessary variables. Moreover, most of the economies have experienced many economic and financial crises which result in outliers in macroeconomic series. For that reason, in order to avoid the misleading effects of outliers, they should be corrected. Seasonally adjusted data with crisis effects being corrected is obtained from the database of Central Bank of Turkey.[16]

The data sets of capacity utilization rate, industrial production index, import and export volume indices cover the period from January 1994 to October 2011 at monthly frequency. Import and export volume indices' base year is 2003, whereas industrial production index's base year is 2005. The gross domestic product is at quarterly frequency and covers the period from 1995:Q1 to 2011:Q3. It is calculated by expenditure approach with 1998 prices in Turkish Liras (TL). Interest rate for cash loans covers the period from January 2002 to December 2011 at monthly frequency. The period beginning from 2002 is preferred for interest rate since Central Bank of Turkey started to use inflation rate as a political tool at 2002[17] and the deep effects of 2001 financial crisis is eliminated through 2002.

To obtain a general overview for the data set, basic statistics such as sample mean, standard deviation, skewness, kurtosis and Jarque-Bera normality test statistics are presented in Table 1.

[16]In order to obtain deseasonalized series, we assume a deterministic trend and eliminate the seasonality with seasonal dummies. However, we observe significant 4th and 12th lags in estimated models and concluded that the assumption of deterministic trend is not suitable for these series. Therefore, we use the deseasonalized series of Central Bank of Turkey. TRAMO SEAT program is used for seasonality adjustment and outlier effect correction.

Table 1. Basic Statistics

Data	Sample Mean	Std. Error	Skewness	Kurtosis	Jaque-Bera
CUR	77.624	4.219	-0.921 [0.000]	0.313 [0.357]	31.169 [0.000]
GIMP	0.697	6.371	-0.456 [0.006]	4.617 [0.000]	196.639 [0.000]
GEXP	0.684	7.043	-0.404 [0.016]	1.656 [0.000]	30.148 [0.000]
INT. RATE	27.346	13.590	1.323 [0.000]	1.028 [0.025]	40.304 [0.000]
GGDP	0.009	0.027	-1.671 [0.000]	3.997 [0.000]	71.285 [0.000]
GIP	0.280	2.543	-0.215 [0.203]	2.276 [0.000]	47.629 [0.000]

Basic statistics show that distributions of capacity utilization rate, growth of import and export volume indices, interest rate for cash loans and growth of logarithmic gross domestic product are skewed and growth of import and export volume indices, interest rate for cash loans and growth of logarithmic gross domestic product exhibit excess kurtosis. Even though we study with the series whose crises effects are eliminated by Central Bank of Turkey, all distributions of data do not satisfy normality according to Jarque-Bera test statistics.[17] For visual inspection, graphics of each data is presented in Figures 1, 2, 3, 4, 5, 6.

[17] We also impose dummy variables in order to eliminate the crises effects, the results do not change.

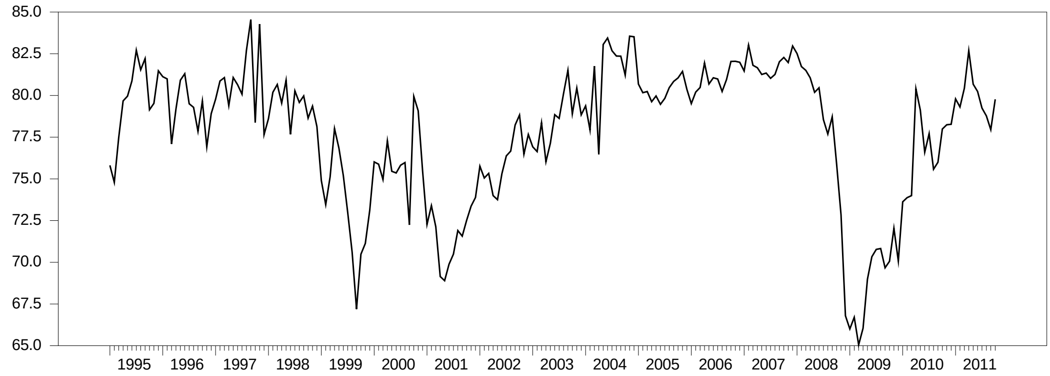

Figure 1. Seasonality Adjusted Capacity Utilisation Rate

Even though crisis effects are corrected, Figure 1 exhibits that capacity utilization rate sharply decreases around crisis times at 2001 and 2008. After crises, it slowly increases because of the continuous effects of crises. For instance, the rate decreases abruptly in 3 months and returns to its former level in 12 months at 2001 crisis. On the other hand, at 2008 crisis the rate falls down deeply in 6 months and the recovery takes 24 months. These different movements observed on data before and after the crisis times may induce an asymmetry in the dynamics of capacity utilization rate.

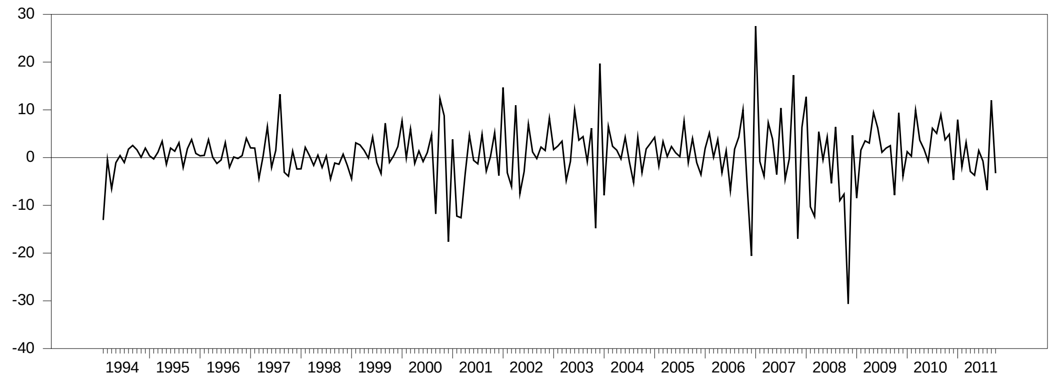

Figure 2. Growth of Seasonally Adjusted Volume Index (base year 2005)

Figure 2 shows the growth of import volume index without seasonality and crisis effects. Despite the correction of crises effects, there are still sharp negative changes in the middle of 2001 and at the end of 2008. As it is seen from the graph, the growth fluctuates around zero. Moreover, fluctuations are getting larger over the years. This property of data probably causes a heteroscedasticity problem in the empirical investigation. On the other hand, Figure 3 shows the growth of export volume index, which shows a similar pattern with the growth of import volume index. It fluctuates around zero and the magnitudes of fluctuations are getting larger over the years. Compared to the growth size of import volume index, the growth size of export volume index is larger.

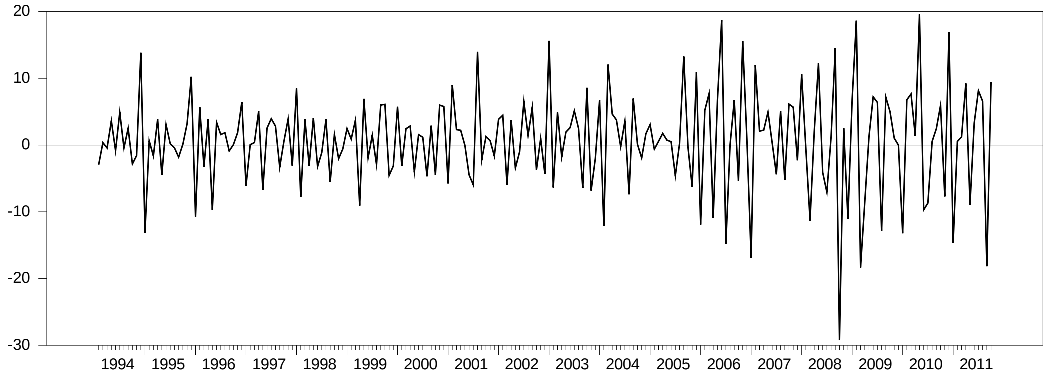

Figure 3. Growth of Seasonally Adjusted Export Volume Index (base year 2005)

Figure 4 describes the interest rate for cash loans. It is seen from the Figure 4 that there is no seasonal patterns in the dynamics of interest rates. In other words, it can be interpreted that there is no seasonality effect on interest rate for cash loans. At the beginning of 2002 the rate is around 70%, and then starts to decrease slowly through the years. This decrease stems from the effect of Central Bank's new monetary policy starting at 2002. It executes inflation targeting policy and uses short term interest rate as a tool of monetary policy in order to achieve the target inflation rate for a stable economy. Hence, this new monetary policy has an effect on interest rates. The downward slope observed in Figure 4 probably stems from the new policy because Central Bank targets to reduce the inflation rate after 2002. To achieve the target, it decreases the short term interest rate from 62% to 14.24% regularly between 2002 and 2005. After 2005, the interest rate becomes smoother. Although these two different characteristics of the series before and after 2005 may indicate the evidence of nonlinearity, visual inspection shows that there might be a structural break as well. Therefore, in addition to the conventional ADF test, Perron's type of unit root test (1989) which is robust to the structural changes is also performed.

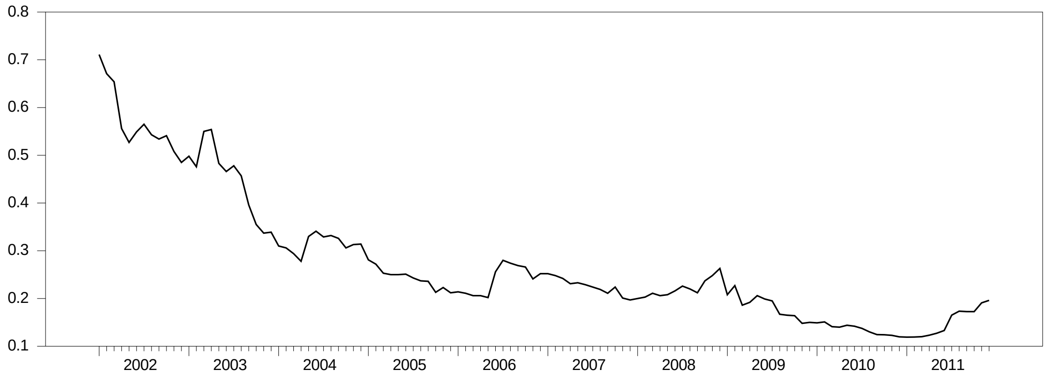

Figure 4. Interest Rate for Cash Loans

Figure 5 presents the growth of logarithmic gross domestic products. Although, there are negative growths around crisis times, 2001 and 2008, the growth of GDP fluctuates around zero.

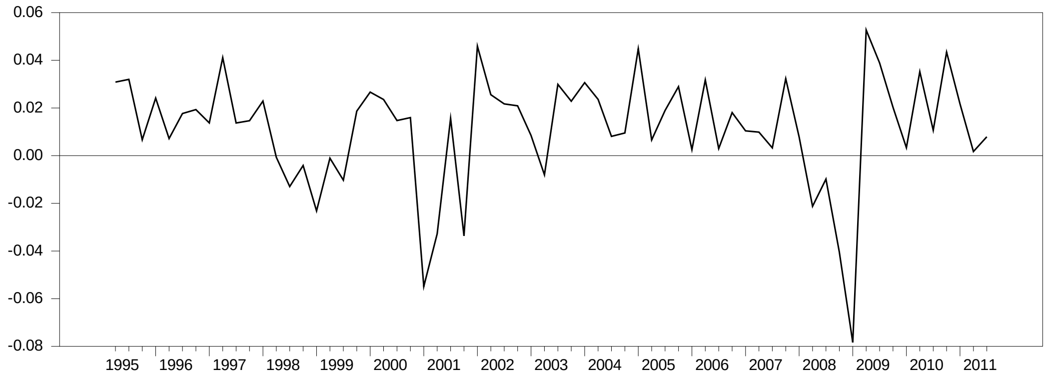

Figure 5. Growth of Logarithmic GDP (fixed 1998 prices)

Lastly, Figure 6 exhibits the growth of seasonally adjusted industrial production index. The growth rate is fluctuating around zero and not changing through the time. Even though, it is difficult to get a clear picture about the negative effects of 2001 and 2008 financial crises in Figure 6, those effects can be easily seen from the graph of the level form.[18] Under these crises effects on dynamics, the growth index may exhibit nonlinearity.

[18] See Appendix for level graph of seasonally adjusted industrial production index

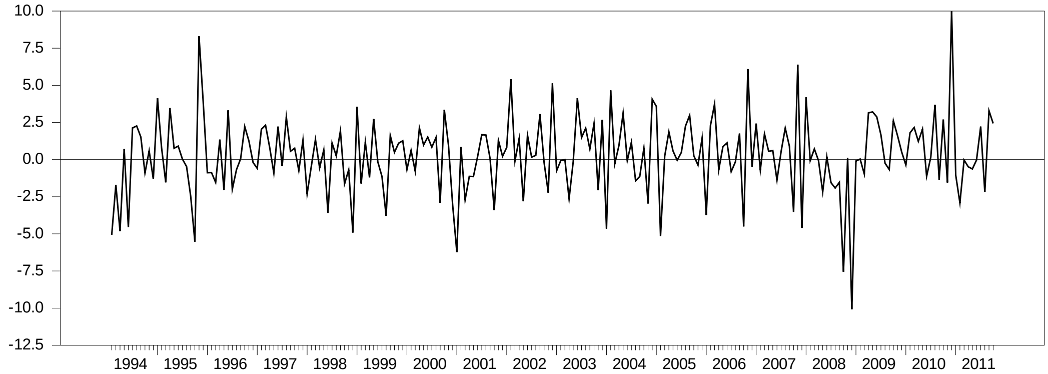

Figure 6. Growth of Seasonally Adjusted Industrial Production Index (base year 2005)

3.3 Unit Root Test Results

This section is divided into two subsections according to the types of unit root tests applied to Turkish macroeconomic data described above. First subsection presents the results observed from the standard unit root tests (i.e., ADF, PP and KPSS) whereas the second subsection provides the results obtained from Enders and Granger's unit root test (1998) designed to account for threshold type nonlinearities.

3.3.1. Results of Linear Unit Root Tests

In order to apply ADF test, an appropriate order of ADF regression equation (2.10) is specified by general to specific approach with t-statistics.[19] AR model is constructed by allowing maximum 12 lags for monthly data, and 8 lags for quarterly data. On the other hand, bandwidth specification for PP and KPSS unit root tests is performed by Andrews – Monahan (1992) procedure following the study proposed by Cheung and Lai (1997). The results for conventional unit root tests are given in Table 2.

[19] Hall, Alastair (1994)

Table 2. Conventional Unit Root Tests

DATA	LINEAR UNIT ROOT TESTS		
	ADF	PP	KPSS
CUR	-2.414 [0.139]	-0.405 [0.715]	0.118
GIMP	-4.420* [0.000]	-18.824* [0.000]	0.095*
GEXP	-3.835* [0.003]	-31.981* [0.000]	0.500
INT. RATE	-3.617* [0.007]	-4.029* [0.002]	1.064
GGDP	-4.442* [0.001]	-8.617* [0.000]	0.054*
GIP	-8.423* [0.000]	17.676* [0.000]	0.114*

Note: ** specifies stationarity of a variable.*

The values given in brackets are p-values. As it is observed from Table 2, test results show the evidence that growth of import and export volume indices, interest rate for cash loans, growth of logarithmic gross domestic product and growth of industrial production index are stationary at 1% significance level, whereas capacity utilization rate has an evidence of a unit root. When applying the conventional unit root tests on a nonlinear series, low test powers indicating the increase in failure of rejecting the null hypothesis of a unit root may arise. Therefore, following subsection covers the results of unit root test developed especially for nonlinear dynamics.

3.3.2. Results of Asymmetric Unit Root Tests

The unit root properties of Turkish macroeconomic data are examined by applying the method suggested by Enders and Grangers (1998). Tests are performed by using not only TAR but also M-TAR models. For the first step of unit root test, series are demeaned.[20] Then, TAR and M-TAR models are constructed with a zero threshold

[20]Demeaned and detrended series are also examined. Since trend terms are statistically insignificant, we only exhibit the demeaned test results.

value. Lag length for each model is specified by detecting autocorrelation between residuals with Ljung-Box Q test as suggested by Enders and Granger. After the construction of nonlinear models, unit root tests are performed under the null hypothesis of a unit root, $H_0 : \rho_1 = \rho_2 = 0$. For testing procedure, F test and tabulated critical values for TAR and M-TAR models are used as suggested by Enders and Grange (1998).[21] If the null hypothesis is rejected, then the series is concluded to be statistically stationary and linearity test is performed. Symmetric versus asymmetric adjustment of dynamics is tested under the null hypothesis, $H_0 : \rho_1 = \rho_2$. Since Tong (1983) proved that least squares estimations of slope coefficients, ρ_1 and ρ_2, converge to a multivariate normal distribution when the sequence is stationary, a standard F statistic is used for asymmetry test. Table 3 proposes the asymmetric unit root and linearity test results for each variable.

[21] For critical values, see Enders and Granger (1998), Table 1

Table 3. Asymmetric Unit Root and Linearity Tests

	CUR		***GIMP***		***GEXP***		***INT. RATE***		***GGDP***		***GIP***	
	TAR	***MTAR***	***TAR***	***MTAR***	***TAR***	***MTAR***	***TAR***	***MTAR***	***TAR***	***MTAR***	***TAR***	***MTAR***
ρ_1	-0.141** (-2.537)	-0.165** (-3.685)	-1.136** (-6.786)	-1.055** (-6.240)	-1.628** (-11.464)	-1.617** (-11.313)	-0.069** (-3.870)	-0.066** (-2.806)	-0.692** (-2.874)	-0.633** (-2.635)	-0.919** (-6.985)	-0.794** (-5.834)
ρ_2	-0.100** (-2.426)	-0.051 (-1.022)	-1.082** (-7.387)	-1.118** (-7.667)	-1.469** (-10.446)	-1.506** (-10.674)	-0.008 (-0.341)	-0.037*** (-1.911)	-0.812** (-4.899)	-0.834** (-5.041)	-1.138** (-9.593)	-1.183** (-10.418)
p	3	3	2	2	3	3	1	1	1	1	1	1
Ø	5.819** [0.003]	7.191** [0.001]	30.754** [0.000]	30.792** [0.000]	66.172** [0.000]	65.429** [0.000]	7.576** [0.000]	6.048** [0.003]	13.455** [0.000]	13.730** [0.000]	51.355** [0.000]	55.511** [0.000]
$\rho_1 = \rho_2$	0.354 [0.552]	2.956* [0.087]	0.159 [0.689]	0.217 [0.641]	1778 [0.183]	0.869 [0.352]	3.692* [0.057]	0.905 (0.343)	0.221 [0.639]	0.611 [0.437]	2612 [0.107]	8.247*** [0.004]
Q(.)	17.185 [0.142]	17.744 [0.123]	10.697 [0.554]	11.413 [0.493]	12.757 [0.386]	12.243 [0.426]	13.820 [0.312]	13.649 [0.323]	9.233 [0.322]	9.254 [0.321]	3.655 [0.988]	3.502 [0.990]
AIC	1406.099	1403.455	1880.427	1880.368	1868.737	1869.662	730.710	733.514	-222.668	-223.074	1511.925	1506.355

Note: ρ_1 and ρ_2 are coefficients of first lag values of each regimes and the below values in parentheses are *t*-statistics. *p* shows the number of lags in models, *Ø* refers the *F*-statistics for the null hypothesis $Ho{:}\rho1 = \rho2 = 0$; the values related to $\rho_1 = \rho_2$ shows the *F*-statistics for the null hypothesis $Ho{:}\rho_1 = \rho_2$; *Q(.)* is the *Ljung-Box Q* statistiscs and values in brackets are *p* valeus of corresponding test values. *AIC* is the Akaike Information Criteria calculated as $T*log(SSR) + 2*n$.

*** ,** and * specify significance at 1%, 5% and 10% significance levels, respectively.

As it is observed from Table 3, all of the series reject the null hypothesis of a unit root at 5% significance level for both TAR and M-TAR models. This means that all of the variables are stationary. After observing stationarity, the next step is to test for symmetric versus asymmetric adjustment (i.e., the null hypothesis is $H_0 : \rho_1 = \rho_2$). According to the test results, capacity utilization rate and growth of industrial production index exhibit M-TAR type asymmetric adjustment, whereas cash interest rate shows TAR type asymmetry. According to the graph of capacity utilization rate, Figure 1, it decreases sharply at 2001 and 2008 when Turkey experienced big financial crises. As it is observed, slope of decreases is stepper than the slope of increases at these years. It means that capacity utilization rate has experienced rapid decreases during crises but slow increases during recovery. These different effects between recession and expansion may be the reason for asymmetric behaviours. Growth of industrial production index is another variable that shows evidence of nonlinear stationarity. Even though it is difficult to observe asymmetric effects of crises from the graph of growths at Figure 7, it can be clearly discovered from the level graph.[22] Its dynamics behaves like capacity utilization rate. It decreases sharply when the economy experiences a recession and increases slowly when there is a recovery. The cash interest rate is the other stationary variable that exhibits TAR type asymmetry at 10% significance level. As it is observed from Figure 4, the rate decreases stepper from 2002 to the end of 2005. However, after 2005, the movement of interest rate becomes flatter (reasons are stated in data descriptions part). These different slopes between time periods probably cause asymmetry in the dynamics of variable. However, according to visual inspection, this asymmetric dynamics may stem from a structural break because graph of interest rate visualizes these different movements before and after a time break. Therefore, we also apply Perron's unit root test considering the existence of a structural break.[23] At 5% significance level, test rejects the unit root when end of 2003 is defined as the break

[22] See, Figure 10 in appendix for level graph of industrial production index

[23] See, Perron (1989)

time.[24] Other macroeconomic variables, growth of export and import volume indices, growth of logarithmic GDP exhibit no evidence in favor of nonlinearity. As seen in Table 3, the sizes of estimated coefficients (i.e., ρ_1 and ρ_2) for these series are quite close.

Comparison of asymmetric and conventional unit test results for growth of import and export volume indices, growth of GDP and growth of industrial production index exhibit consistent results. However, capacity utilization rate results are contradictory. Conventional tests provide evidence of a unit root, while asymmetric test finds evidence of stationarity. This contradiction probably stems from the low power of conventional unit root tests for asymmetric dynamics since capacity utilization rate shows nonlinear stationariry.

Moreover, results of interest rate of cash loans are also noteworthy. Conventional tests show the evidence of linear stationarity, however; asymmetric unit root test supports the nonlinear stationarity. According to the visual inspection, it is observed that the investigated nonlinearity stems from a structural break. Therefore, Perron's unit root test which is robust to structural breaks is applied on series and concludes that the series is indeed linear stationarity. In the following part, we construct the models of the macroeconomic variables which show evidence of nonlinear stationarity according to test results above.

3.3.3. Explaining the Asymmetric Dynamics of Variables

In this section, we construct TAR and M-TAR models for the series found to be nonlinear stationarity according to Enders and Granger's unit root test results.[25] In

[24]Perron's test statistics for unit root is -3.808 and tabulated critical value at level 5% is -3.77

[25]For the variables which show evidence of linear stationarity, i.e. growth of import and export volume indices and growth of GDP, linear AR models are constructed. Since the main motivation of this thesis is investigating the nonlinear stationary dynamics, we only express the estimated models for nonlinear stationary variables.

order to find the best fitted model, linear AR models are also constructed for these variables. Many statistics, such as sum of squared residuals, variance of residuals and Akaike information criteria, are calculated for comparison of models. Moreover, Jarque-Bera normality test, ARCH LM heteroscedasticity test and Ljung-Box Q autocorrelation test is applied for diagnostic checks. To examine seasonality, autocorrelation is checked up to lag 8 for quarterly data and up to lag 12 for monthly data.

According to the unit root tests in part 3.3.2, capacity utilization rate, interest rate of cash loans and growth of industrial production index have asymmetric dynamics. However, we do not estimate a nonlinear model for the interest rate of cash loans since its asymmetric structure stems from a structural break. Therefore, only nonlinear dynamics of capacity utilization rate and growth of industrial production index are modeled in this section.

The linear AR model for capacity utilization rate is constructed by allowing maximum 12 lags. Final model is obtained by eliminating the most insignificant coefficients from the model one by one. Estimated AR model for capacity utilization rate is given in Table 4.

Table 4. Estimated Linear AR Model for Capacity Utilization Rate

$$Z_t = \underset{(0.006)}{7.823} + \underset{(0.000)}{0.708}Z_{t-1} + \underset{(0.013)}{0.186}Z_{t-2} + \underset{(0.018)}{0.177}Z_{t-6} - \underset{(0.013)}{0.173}Z_{t-7} + \varepsilon_t \qquad (3.1)$$

JB = 45.143 (0.000)	$SSR = 661.340$	$\mu_{\text{residual}} = 0.000$
Q(12) = 11.478 (0.488)	AIC = 1276.382	Kurtosis = 2.235
ARCH(12) = 1.475 (0.138)	$\sigma^2_{residuals} = 2.408$	Skewness = - 0.374

Note: Z_t refers to capacity utilization rate at time t. The values in parenthesis are *p*-values. Z_t and ε_t denotes capacity utilization rate and residual at time *t*, respectively. *JB* is Jarque-Bera test for normality of the residuals. Q(12) and ARCH(12) specify Ljung-Box Q statistics and ARCH LM test results, respectively. SSR and AIC are sum of squared residuals and Akaike Information Criteria.

As it is observed from the Table 4, all the coefficients are significant at 1% significance level. In order to find the best fitted model, AIC, SSR and variance of residuals are compared with that of nonlinear models. Related values for linear AR model are 661.340, 1276.382 and 2.408, respectively. According to the p-values of Ljung-Box Q statistics for residual autocorrelation and ARCH LM test for homoscedasticity, there is no autocorrelation and heteroscedasticity problem in residuals. However, residuals do not satisfy the normality assumption because of the erratic movements of data especially at crisis times. According to Enders and Granger unit root and symmetry test results, dynamics of capacity utilization rate is stationary and shows an M-TAR type of nonlinearity. In order to estimate M-TAR model, equation (2.2) is used with Heaviside indicator function (2.5). We first specify AR model with maximum 12 lags. General to specific method is adopted in order to find the optimum lag length for the AR model. Lags are eliminated one by one according to t-statistics at 5% significance level until the first significant lag is found. For capacity utilization rate, 4 lags are eliminated. Hence, threshold variable is selected from the rest of 8 lags by using Chan's (1993) methodology and estimation of M-TAR model is performed allowing for maximum 8 lags. Insignificant lags are eliminated (starting from the most insignificant one) one by one according to the t-statistics at 5% significance level. Final estimated M-TAR model with misspecification tests is given in Table 5.

Table 5. Estimated M-TAR model for Capacity Utilization Rate

$$Z_t = I_t\,(\underset{(0.000)}{9.188} + \underset{(0.000)}{0.716}Z_{t-1} + \underset{(0.012)}{0.165}Z_{t-3}) + \qquad (3.2)$$

$$(1-I_t)*(\underset{(0.026)}{25.029} + \underset{(0.000)}{1.763}Z_{t-2} - \underset{(0.000)}{0.761}Z_{t-3} - \underset{(0.008)}{0.566}Z_{t-5} + \underset{(0.006)}{0.814}Z_{t-6} - \underset{(0.009)}{0.605}Z_{t-7})$$

$$I_t = \begin{cases} 1 \quad if \quad \Delta Z_{t-1} \geq -1.824 \\ 0 \quad if \quad otherwise \end{cases}$$

$\text{JB} = 28.219\,(0.000)$	$SSR = 559.365$	$\mu_{resid} = 0.000$
$\text{Q}(12) = 9.466\ (0.662)$	$\text{AIC} = 1251.726$	$\text{Kurtosis} = 1.545$
ARCH(12) = 0.987 (0.463)	$\sigma^2_{resid} = 2.083$	Skewness = -0.521

Note: Z_t refers to capacity utilization rate at time t and ΔZ_{t-1} denote the change of first lag of capacity utilization rate. For other notations, see the note of Table 4.

Misspecification tests conclude that residuals are uncorrelated and homoscedastic. However, they are not coming from a normal distribution according to Jarque-Bera test statistics. Since distribution of residuals coming from linear AR model has same normality problem, we ignore this problem while comparing the models. According to SSR, AIC and variance of residuals, M-TAR model fits better than AR model because estimated M-TAR model has smaller SSR, AIC and variance of residuals.

According to model (3.2), regime changes in capacity utilization rate depend on whether the change in capacity utilization rate in previous month is above or below a certain level. The estimated threshold variable of model (3.2) is $\Delta Z_{t-1} = Z_{t-1} - Z_{t-2}$ and the threshold value is -1.824. This means that capacity utilization rate behaves as a piecewise linear model according to the threshold value. If threshold variable, ΔZ_{t-1} is below -1.824, the estimated model follows regime 1 and includes 167 observations, if ΔZ_{t-1} is above -1.824, the estimated model follows regime 2 and includes 28 observations.

Growth of industrial production index is another nonlinear stationary variable according to Enders and Granger unit root test. Modeling cycle is started by finding the appropriate lag length of linear AR model which allows maximum 12 lag lengths. Lags are eliminated by using general to specific method according to t-statistics at 5% significance level and the appropriate lag length is found to be 2.

Table 6. Estimated Linear AR Model for Growth of Industrial Production Index

$$Z_t = \underset{(0.041)}{0.334} - \underset{(0.009)}{0.166} Z_{t-1} + \underset{(0.086)}{0.117} Z_{t-2} + \varepsilon_t \qquad (3.3)$$

JB = 38.908 (0.000)	$SSR = 1273.220$	$\mu_{resid} = 0.000$
Q(12) = 3.984 (0.985)	AIC = 1514.503	Kurtosis = 2.038
ARCH(12) = 1.268 (0.240)	$\sigma^2_{resid} = 6.062$	Skewness= -0.260

Note: Z_t refers to growth of industrial production index at time t. For notations, see note of Table 4

According to *p* values, all coefficients are significant. Even though, second lagged growth of industrial production index is not significant at 5% significance level but significant at 10% significance level, we include it according to AIC. Misspecification tests show that residuals only have normality problem as it is experienced in capacity utilization rate.

For the nonlinear M-TAR model, threshold variable is selected from two candidate lagged variables. By using Chan (1993) methodology, optimum threshold variable is determined as ΔZ_{t-1} and optimum threshold value is found -0.359. The estimated model is proposed at Table 7.

Table 7. Estimated M-TAR model for Growth of Industrial Production Index

$$Z_t = I_t\,(0.104 + 0.226 Z_{t-2}) \; + \; (1 - I_t) * (0.368 - 0.353 Z_{t-1}) \qquad (3.4)$$

$$\qquad (0.692) \quad (0.034) \qquad\qquad\qquad (0.180) \quad (0.002)$$

$$I_t = \begin{cases} 1 \quad \textit{if} \quad \Delta Z_{t-1} \geq -0.359 \\ 0 \quad \textit{if} \quad \textit{otherwise} \end{cases}$$

JB = 26.603 (0.000)	$SSR = 1204.440$	$\mu_{\text{resid}} = 0.000$
Q(12) = 3.629 (0.989)	AIC = 1504.785	Kurtosis = 1.668
ARCH(12) = 3.629 (0.989)	$\sigma^2_{resid} = 5.735$	Skewness = -0.246

Note: Z_t refers to growth of industrial production index at time t and ΔZ_{t-1} denote the change of first lag of growth of industrial production index. For other notations, see the note of Table 4.

According to misspecification tests, there is no autocorrelation and heteroscedasticity problem but there is a normality problem. The estimated model (3.4) follows regime 1 when the magnitude of previous month change is above -0.359 and 108 observations are observed in regime 1, whereas when the magnitude of previous month change is below -0.359, model (3.4) follows regime 2 and it includes 104 observations. Compared to the linear AR model, SSR, AIC and variance of residuals support the nonlinear M-TAR model. In other words, it means that estimated nonlinear model describes the dynamics of industrial production index better that the linear model.

4. CONCLUSION

Over three decades nonlinear models have gained great attention due to the inadequate capacity of linear models in capturing the asymmetric movements of variables. Nonlinear models can capture asymmetries more properly by analyzing series regime by regime. Therefore, nonlinear approaches become more preferable and popular in empirical investigations. Furthermore, studies indicating asymmetric structures of many macroeconomic variables in response to downturns and recoveries in a business cycle have also strengthened the popularity of nonlinear approaches. Furthermore, intensive investigations on nonlinear dynamics also trigger the development of asymmetric unit root tests. Various studies prove the fact that traditional unit root tests are inadequate to investigate stationarity for asymmetric dynamics. They only consider the linear stationarity case. Moreover, their powers decrease substantially for asymmetric structures. Therefore, development of a new unit root test which considers the existence of nonlinear stationarty becomes essential for asymmetric dynamics. Hence, developments of asymmetric unit root tests have gained considerable velocity as the nonlinear models become popular in econometric literature.

The increasing interest on nonlinear approaches and asymmetric unit root tests has raised our desire to study on these procedures. Therefore, this thesis defines the most prominent nonlinear models and asymmetric unit root tests. The explained nonlinear approaches are TAR, SETAR, M-TAR, STAR and Markov switching autoregressive models. Since we use SETAR and M-TAR models in empirical investigations, these models are explained in detail. On the other hand, the procedures of asymmetric unit root tests proposed by Enders and Grander (1998), Gonza'lez and Gonzalo (1997), Caner and Hansen (2001), Bec. Ben Salem and Carrasco (2004) and Kapetanios and Shin (2006) are explained. Since the methodology developed by Enders and Granger is easy to apply and allows testing for stationarity and asymmetry simultaneously, we prefer their method for empirical analyses and discuss it in detail.

In the scope of this study, we analyze Turkish macroeconomic data which are capacity utilization rate, growth of import and export volume indices, growth of gross domestic product, interest rate for cash loans and growth of industrial production index which are seasonally adjusted with crises effects being corrected. To mimic the usual approach, first conventional unit root tests are performed, and then asymmetric unit root test proposed by Enders and Granger is applied in order to test for stationarity. Traditional and asymmetric unit root tests support consistent stationarity results for growth of import and export volume indices and growth of GDP. For growth of industrial production index and interest rate for cash loans, traditional unit root tests show the evidence of linear stationarity whereas asymmetric unit root test exhibits nonlinear stationarity. Since visual inspection of interest rate raises a doubt that a structural break in the structure may cause the nonlinearity, Perron's unit root test which is robust to the structural changes is applied in order to determine the stationarity. Since the calculated test statistics supports the evidence of stationarity, we conclude that interest rate shows a linear stationarity. On the other hand, contradictive unit root test results are observed for capacity utilization rate. Conventional unit root tests support nonstationarity whereas asymmetric unit root test exhibits the evidence of stationarity. This difference between test results stems from the low power of conventional unit root tests for asymmetric dynamics since nonlinearity is observed in the structure of capacity utilization rate. For nonlinear stationary variables (i.e., growth of industrial production index and capacity utilization rate), we estimate M-TAR models since their dynamics shows M-TAR type of adjustment according to the symmetry tests. We also constructed linear AR models for these variables in order to find the best fitted model. Nonlinear models exhibit better performance than the linear ones for both variables according to Akaike information criteria, sum of squared residuals and variance of residuals of estimated nonlinear models. In other words, nonlinear approaches represent the dynamics of both variables more properly than the linear ones.

In conclusion, three important inferences are deduced in this study. First, an extensive investigation is performed on Turkish macroeconomic data and great knowledge is gained about their dynamics. Capacity utilization rate and growth of industrial production index show nonlinear stationary dynamics, whereas, growth of import and export volume indices and growth of GDP exhibit linear stationary dynamics. Furthermore, a structural break is observed in the dynamics of interest rate for cash loans. Another inference of this study is that conventional unit root tests sometimes conclude different results than the asymmetric ones. Our findings on dynamics of capacity utilization rate promote the theoretically proved fact that traditional unit root tests have tendency to fail to reject null hypothesis of a unit root. Therefore, in addition to traditional unit root tests, recently developed asymmetric unit root tests are intensively suggested for detection of stationarity. The last and most important deduction of this thesis is that constructing linear model for nonlinear series is inadequate in order to explain the asymmetric dynamics. Nonlinear approaches allowing for regime switches represent the asymmetries better than linear approaches according to our model comparisons based on sum of squared residuals, Akaike information criteria and variance of residuals.

REFERENCES

Akaike, H. (1974), 'A new look at the statistical model identification', IEEE Transaction on Automatic Control, AC-19, 716-723.

Andrews, D. W. K. and Monahan, J.C. (1992), 'An Improved Heteroskedasticity and Autocorrelation Consistent Covariance Matrix Estimator', Econometrica, 60, 953-966.

Andrews, D. W. K., and Ploberger, W. (1994), 'Optimal Tests When a Nuisance Parameter is Present Only Under the Alternative', Econometrica, 62, 1383-1414.

Balke, N.S., Fomby, T.B. (1997), 'Threshold Cointegration', International Economic Review, 38, 627–645.

Basci, E. and Caner M. (2005), 'Are Real Exchange Rates Nonlinear or Nonstationary? Evidence From a New Threshold Unit Root Test', Studies in Nonlinear Dynamics and Econometrics, Berkly Electronic Press, 9 (4), 2.

Berben, R., van Dijk, D. (1999), 'Unit Root Tests and Asymmetric Adjustment: A Reassessment.', Unpublished manuscript, Tinbergen Institute, Erasmus University of Rotterdam.

Beveridge, S. and Nelson, C.R. (1981), 'A New Approach to Decomposition of Economic Time Series into Permanent and Transitory Components with Particular Attention to Measurement of the 'Business Cycle', Journal of Monetary Economics, 7, 151 – 174.

Bohl, M and Siklos, P. (2004), 'The present value model of US Stock Prices Redux: A New Testing Strategy and Some Evidence', The Quarterly Review of Economics and Finance, 44, 208-223.

Caner, M., Hansen, B.E. (2001), 'Threshold Autoregression with a Near Unit Root', Econometrica, 69, 1555–1596.

Chan, K. S. (1993), 'Consistency and Limiting Distribution of the Least squares Estimator of a Threshold Autoregressive Model', The Annals of Statistics, 21, 520-533.

Chan, K. S., Tong, H. (1986), 'On Estimating Thresholds in Autoregressive Models', Journal of Time Series Analysis, 7, 179-190.

Cheung, Y. W., Lai, K. S. (1997), 'On Cross-country Differences in the Persistence of Real Exchange Rates', University of California, Santa Cruz, Discussion Paper, 372.

Chi and Su W. (2009), 'An Empirical Study of Twain's Bond Market Based on the Nonlinear Dynamics', Applied Financial Economics, 19, 563-574.

Coakley, J. and Fuertes, A. (2002), 'Asymmetric Dynamics in UK Real Interest Rates', Applied Financial Economics, 12(6), 379-387.

Cuestas, J. C., Harrison, B. (2010), 'Further Evidence on the Real Interest Rate Parity Hypothesis in Central and East European Countries: Unit Roots and Nonlinearities', Emerging Markets Finance and Trade, 46(6), 22-39.

Dickey, D. A., Fuller, W.A. (1979), 'Distribution of the Estimators for Autoregressive Time Series with a Unit Root', Journal of the American Statistical Association, 74, 427–431.

Enders, W. (2009), ' Applied Econometric Time Series, 3rd Edition', New York: John Wiley.

Enders, W., Granger, C.W.J. (1998), 'Unit Root Tests and Asymmetric Adjustment with an Example Using the Term Structure of Interest Rates', Journal of Business and Economics Statistics, 16, 304–311.

Engel, C. R., Hamilton, J.D. (1990), 'Long Swings in the Dollar: Are They in the Data and Do Markets Know It?', American Economic Review, 80, 689-713.

Ewing, B. T., Thompson M. A. (2007), 'Asymmetric Mean Reversion in Corporate Profits', Applied Economics Letters, 14(13), 935-938.

Filardo, A. J. (1994), 'Business-cycle Phases and Their Transitional Dynamics', Journal of Business and Economic Statistics, 12, 299-308.

Granger, C. W. J., Teräsvirta, T. (1993), 'Modeling Nonlinear Economic Relationships', Oxford University Press.

Gonzalez, M. and Gonzalo, J. (1997), 'Threshold Unit Root Models', Working Paper, U. Carlos III.

Goldfeld, S. M. and Quandt, R. E. (1972), 'Nonlinear Methods in Econometrics', Amsterdam: North-Holland.

Hall, A. (1994), 'Testing for a Unit Root in Time Series with Pretest Data-based Model Selection', Journal of Business and Economic Statistics, 12, 461-470.

Hamilton, J. D. (1989), 'A New Approach to the Economic Analysis of Nonstationary Time Series and the Business Cycle', Econometrica, 57, 357-384.

Hansen, B. E. (1992), 'Likelihood Ration Test Under Nonstandard Conditions: Testing the Markov Switching Model of GNP', Journal of Applied Economics, 7, 61-82.

Hansen, B. E. (1996), 'Inference When a Nuisance Parameter is not Identified Under the Null Hypothesis', Econometrica, 64, 413–430.

Henry, Ó. T., Shields, K. (2004), 'Is there a unit root in in‡ation?', Journal of Macroeconomics 26(3), 481-500.

Kapetanios, G. (2003), 'Threshold Models for Trended Time Series', Empirical Economics, 28, 687–707.

Kapetanios, G. and Shin, Y. (2006), ‘Unit Root Tests in Three-Regime SETAR Models’, Technical Report.

Kapetanios, G. and Shin, Y. and Snell, A. (2003), ‘Testing for a Unit Root in the Nonlinear STAR Framework’, Journal of Econometrics, 112, 359–79.

Kılıç, R. (2003), ‘A Testing Procedure for a Unit Root in the STAR Model’, Working Paper, Georgia Institute of Technology.

Koop, G. and Potter, S. M. (1999), ‘Dynamic Asymmetries in U.S Unemployment’, Journal of Business and Economic Statistics, 17, 298–312.

Koustas, Z., Lamarche, J. F. (2007), ‘Evidence of Nonlinear Mean Reversion in the Real Interest Rate’, Applied Economics, 42(2), 237-248.

Kwiatkotwiski, Phillips, D.,P. C. B., Schmidt, P. and Shin, Y. (1992), ‘Testing the Null Hypothesis of Stationarity Against the Alternative of a Unit Root: How Sure Are We That Economic Time Series Have a Unit Root?’, Journal of Econometrics, 54, 159-178.

Liew, V.K., Baharumshah A. Z., Chong T. T. (2004), ‘Are Asian Real Exchange Rates Stationary?’, Economic Letters, 83, 313-316.

Luukkonen, R., Saikkonen, P. And Teräsvirta, T. (1988a), ‘Testing Linearity in Univariate Time Series Models’, Scandinavian Journal of Statistics, 15, 161-165.

Michael, P., Nobay, A.R., Peel, D.A. (1997), ‘Transaction Cost and Nonlinear Adjustment in Real Exchange Rates: An Empirical Investigation’, Journal of Political Economy, 105, 862-879.

Murray, C. J., Nikolsko, A., Papell, D. H. (2008), ‘Inflation Persistence and the Taylor Principle’, Houston, University of Houston.

Nelson, C. R., and Plosser, C. I. (1982), ‘Trends and Random Walks in Macroeconomic Time Series: Some Evidence and Implications’, Journal of Monetary Economics , 10, 139-62.

Ng, S. and Perron, P. (1995), ‘Unit Root Tests in ARMA Models with Data-dependent Methods for the Selection of the Truncation Lag’, Journal of the American Statistical Association, 90, 268-281.

Öcal, N. (2001), ‘Nonlinear Models for UK Macroeconomic Time Series’, Studies in Nonlinear Dynamics and Econometrics 4(3), 123-135.

Paya, I., Peel, D. A. (2006), ‘A New of the Determinants of the Real Dollar-Sterling Exchange Rate: 1871-1994’, Journal of Money, Credit and Banking, 38, 1971-1990.

Phillips, P. C. B., Perron, P. (1988), ‘Testing for a Unit Root in Time Series Regression’, Biometrika, 75, 335–346.

Pippenger, M. K., Goering, G.E. (1993), ‘A Note on the Empirical Power of Unit Root Tests Under Threshold Processes’, Oxford Bulletin of Economics and Statistics, 55, 473–481.

Potter, S. M. (1995), ' A Nonlinear Approach to US GNP', Journal of Applied Econometrics, 10, 109-125.

Potter, S. M. (1999), 'Nonlinear Time Series Modeling: An Introduction', Journal of Economic Surveys, 13, 5.

Seo, M. (2003), ‘Unit Root Test in a Threshold Autoregression: Asymptotic Theory and Residual Based Block Bootstrap’, Manuscript, University of Wisconsin-Madison.

Shin, D. W. and Lee, O. (2001), ‘Test for Asymmetry in Possibly Non-stationary Time Series Data’, Journal of Business and Economic Statistics, 19, 233–44.

Sichel, D. E. (1993), ‘Business Cycle Asymmetry: A Deeper Look’, Economic Inquiry, April, 224-236.

Skalin, J. and Teräsvirta, T. (2002), ‘Modeling Asymmetries and Moving Equilibria in Unemployment Rates’, Macroeconomic Dynamics, 6, 202-254.

Taylor, M. P., Sarno, L. (2001), 'Real Exchange Rate Dynamics in Transition Economies: A Nonlinear Analysis', Studies in Nonlinear Dynamics and Econometrics, 5, Issue 3.

Teräsvirta, T. (1994), 'Specification, Estimation and Evaluation of Smooth Transition Autoregressive Models', Journal of American Statistical Association, 89, 425.

Teräsvirta, T. (1998), 'Modeling Economic Relationships with Smooth Transition Regressions.' In A. Ullah and D. E. A. Giles, Handbook of Applied Economic Statistics, New York: Marcel Dekker, 507–552.

Teräsvirta, T., Anderson, HM. (1992), 'Characterizing Nonlinearities in Business Cycles Using Smooth Transition Autoregressive Model', Journal of Applied Econometrics, 7, 119-136.

Teräsvirta, T., Tjostheim, D. and Granger, C. W. J. (1994), 'Aspects of Modelling Nonlinear Time Series.' In R. F. Engle and D. L. McFadden (eds.), Handbook of Econometrics, 4. Amsterdam: Elsevier Science, 2917–2957.

Tiao, G. C. and Tsay, R. S. (1994), 'Some Advances in Nonlinear and Adaptive Modeling in Time Series', Journal of Forecasting, 13, 109-131.

Tong, H. (1978), 'On a Threshold Model', In Pattern Recognition and Signal Processing.

Tong, H. (1983), 'A Note on a Delayed Autoregressive Process in Continuous Time', Biometrika, 70, 710-712.

Tong, H. (1990), 'Non-Linear Time Series: A Dynamical Systems Approach', Oxford University Press.

Tong, H., and Lim, K. S. (1980), 'Threshold Autoregression, Limit Cycles and Cyclical Data', Journal of the Royal Statistical Society, Ser. B, 42, 245-292.

Tsay, R. S. (1989), 'Testing and Modeling Threshold Autoregressive Processes', Journal of American Statistical Association, 84, 405.

APPENDICES

Appendix A :

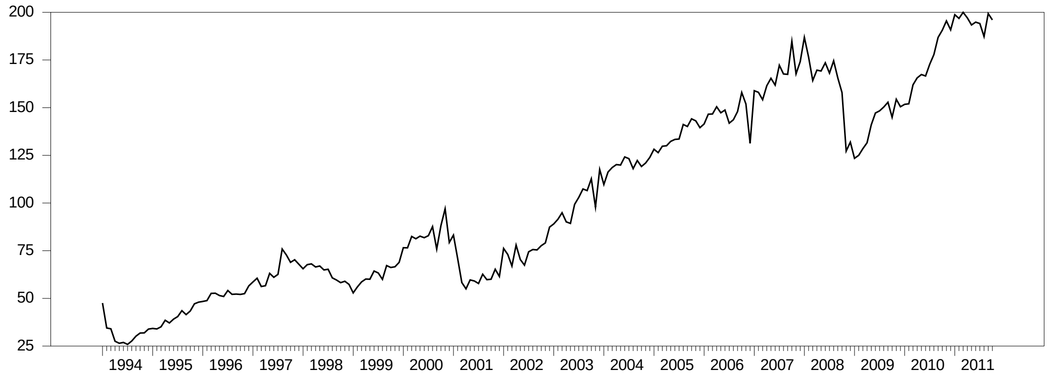

Figure 7. Seasonally Adjusted Import Volume Index (base year 2003)

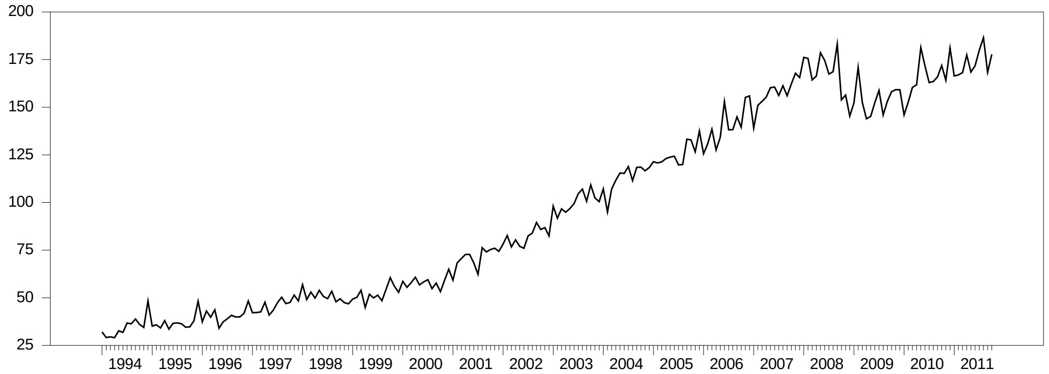

Figure 8. Seasonally Adjusted Export Volume Index (base year 2003)

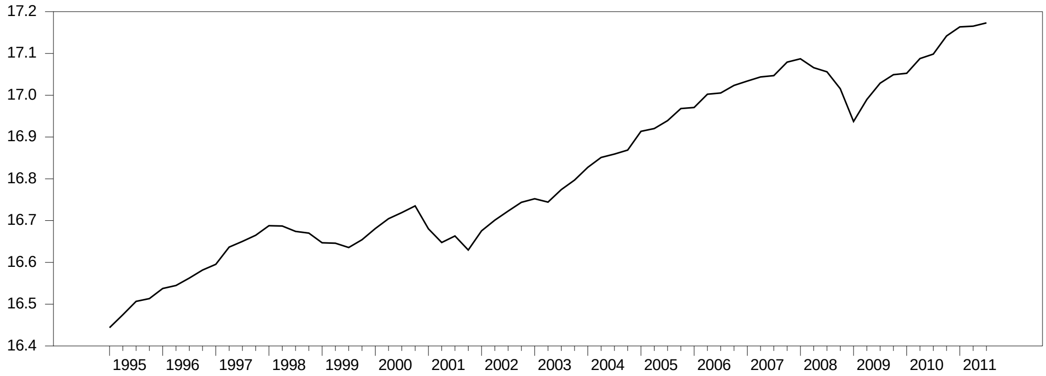

Figure 9. Seasonally Adjusted Export Volume Index (base year 2003)

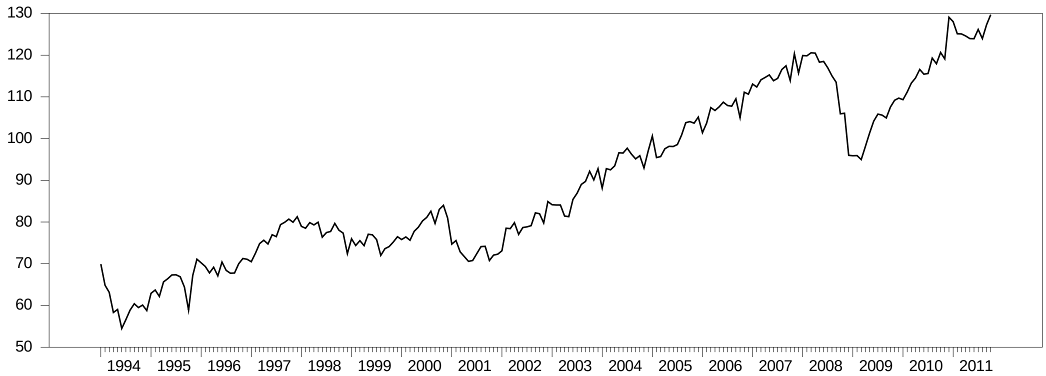

Figure 10. Seasonally Adjusted Industrial Production Index (base year 2005)

Appendix B

TEZ FOTOKOPİSİ İZİN FORMU

<u>ENSTİTÜ</u>

Fen Bilimleri Enstitüsü

Sosyal Bilimler Enstitüsü

Uygulamalı Matematik Enstitüsü

Enformatik Enstitüsü

Deniz Bilimleri Enstitüsü

<u>YAZARIN</u>

Soyadı : UYSAL

Adı : Ela

Bölümü : İktisat

<u>TEZİN ADI</u> : Application of Nonlinear Unit Root Tests and Threshold Autoregressive Models

<u>TEZİN TÜRÜ</u> : Yüksek Lisans Doktora

1. Tezimin tamamından kaynak gösterilmek şartıyla fotokopi alınabilir.

2. Tezimin içindekiler sayfası, özet, indeks sayfalarından ve/veya bir bölümünden kaynak gösterilmek şartıyla fotokopi alınabilir.

3. Tezimden bir bir (1) yıl süreyle fotokopi alınamaz.

<u>TEZİN KÜTÜPHANEYE TESLİM TARİHİ</u>: 05.09.2012