DEMAND, SUPPLY AND PARTIAL EQUILIBRIUM ANALYSIS OF TURKISH ELECTRICITY ENERGY PRICING

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ABSTRACT

DEMAND, SUPPLY AND PARTIAL EQUILIBRIUM ANALYSIS OF ELECTRICITY ENERGY PRICING FOR TURKISH MARKET

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Electricity energy is a fundamental commodity for all sectors of the economy. For this reason, estimating the factors and their impacts on electricity consumption and production are important to maintain sustainability in electricity energy market. The aim of the study is to determine the association between main macroeconomic and sectorial indicators with electricity consumption and production. For estimating electricity demand, annual electricity consumption, Gross Domestic Product (GDP), electricity transmission and distribution losses, industry value added, annual average electricity prices and urbanization ratio are used as variables. On the other hand, for estimating electricity supply variables annual electricity production, gross profit and labor supply in electricity sector, electricity transmission and distribution losses, annual average electricity prices, GDP and investments in electricity sector are used. At the first time impact on each series is investigated by using time series approach. Econometric models for both electricity supply and demand are estimated through Ordinary Least Squares (OLS), Generalized Method of Moments (GMM) and Autoregressive Distributed Lags Approach (ARDL) by using annual data for the period from 1970 to 2010. Within ARDL procedure; vector error correction models, impulse-response functions and variance decomposition analyses are performed to detect the degree of association among the variables and their sensitivity to the mean reverting fluctuations. Furthermore, by using estimated demand and supply equations, partial equilibrium analysis are performed and equilibrium annual average electricity prices are extracted and compared to actual prices by using statistical measurement methods.

Keywords: Turkish electricity price, demand and supply, generalized method of moments (GMM), multiple linear regression (OLS), Autoregressive distributed lags (ARDL)

ÖZ

TÜRKİYE ELEKTRİK ENERJİSİ PİYASASINA DAİR ARZ, TALEP VE KISMI DENGE ANALİZİ

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Elektrik enerjisi ekonomide bütün sektörler için önem arz eden kullanımı zorunlu bir maldır. Bu sebeple elektrik üretim ve tüketimi etkileyen faktörleri doğru tahmin etmek enerji sektörünün sürdürülebilirliğini devam ettirmek için önemlidir. Bu çalışmanın amacı, elektrik tüketimi ve üretimini etkileyen makroekonomik ve sektörel değişkenleri tespit etmek ve bunların elektrik tüketimi ve üretimiyle ilişkisini incelemektir. Elektrik talebi tahmininde değişken olarak; yıllık elektrik tüketimi, gayrı safi yurt içi hasıla, elektrik iletim ve dağıtım kaçak kayıpları, endüstri katma değeri, yıllık ortalama elektrik fiyatları ve kentleşme oranı kullanılmıştır. Bunun yanı sıra, elektrik arzı tahmin modelinde değişken olarak, yıllık elektrik üretim miktarı, elektrik sektöründe brüt kar ve işgücü arzı, elektrik iletim ve dağıtım kaçak kayıp miktarları, yıllık ortalama elektrik fiyatları, gayri safi yurtiçi hasıla ve elektrik sektörüne yapılan yatırım miktarları kullanılmıştır. İlk adımda tün değişkenler zaman serileri yöntemleri kullanılarak modellenmiştir. Hem elektrik talebi hem de elektrik arzı; En Küçük Kareler (OLS), Genelleştirilmiş Momentler (GMM) ve Oto Regresif Dağıtılmış Gecikmeler ekonometrik yöntemleriyle 1970-2010 yıllarını kapsayan yıllık veriyle tahmin edilmiştir. Oto Regresif Dağıtılmış Gecikmeler yöntemi içerisinde, Hata Düzeltme Modeli (ECM), Etki-Tepki Fonksiyonları ve varyans ayrıştırma analizleri yapılmıştır. Ayrıca, tahmin edilen talep ve arz fonksiyonları kullanılarak kısmi denge analizleri yapılmış ve bu analizler sonucu ortaya çıkan yıllık ortalama fiyatlar en doğru modeli bulabilmek adına var olan istatistiksel ölçüm metotları kullanılarak fiyatlarla karşılaştırılmıştır.

Anahtar Kelimeler: Türkiye elektrik arzı, talebi ve fiyatı, genelleştirilmiş momentler yöntemi (GMM), çoklu doğrusal regresyon , oto regresif dağıtılmış gecikmeler yöntemi (ARDL)

To my beloved mother

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CHAPTER 1

Introduction

As a consequence of social and economic development in Turkey in last decades, energy demand and especially demand for electricity has increased. In order to meet this increasing demand it has become important to analyze and control reliability and sustainability of electricity supply. The main electricity energy resources in Turkey are coal, lignite and hydro. The oil and natural gas are imported because of scarcity of their reserves in Turkey. Recently, the sun, wind and geothermal energy are encouraged to investors, but they still require planning and investment on the infrastructure. Among these resources the most of the electricity energy is produced by thermal power plants and hydro power plants in Turkey. Strategic planning in electricity energy sector in Turkey aims several targets: to meet long term demand by suitable public and private investments and adding new and renewable energy resources to meet the increasing energy requirements; to encourage research and development activities for increasing efficiency in energy sector by technological developments which leads to minimize the supply cost of electricity; to diversify energy resources and avoid fully dependence on outside sources; to minimize losses in production, transmission, distribution and consumption of electricity; to protect the environment and public health by decreasing negative externalities in energy production. Moreover, Turkey aims to liberalize its energy market for providing competition in domestic market and to become a key transit country and energy hub between Europe, Turkic countries and Middle East.

Economics of electricity market requires understanding the relation among the factors which contributes to the changes in the price, demand and supply to the electricity. The macroeconomic indicators and sectoral variables require a special attention to determine the factors affecting electricity consumption and production in Turkey. It is known that in the microeconomic theory quantity demanded has inverse relationship with the price of the commodity if it is a normal good. Therefore, it can be expected that there should be an inverse relationship between the electricity consumption and the electricity prices. Moreover, for supply side of economy, quantity supplied should increase due to increase in price. However, as electricity is a necessary good and it is continuously produced, the relationship between prices and production could be also negative in accordance with price fluctuations. In addition, a direct relationship between electricity consumption and gross domestic product (GDP) could be expected by the motivation of income effect in the microeconomic theory. It is also valid for electricity production that the relationship between GDP and electricity production should be positive. The increase in the electricity transmission and distribution losses leads to an increase in electricity consumption which makes sense, as unpaid consumption of a basic facility attracts especially low income consumers. On the other hand, it will require increase in production in order to meet increased demand. Industrial value added can be used as a reflection of the total production in the industry at which electricity used mainly as an input. Therefore, a positive relationship between electricity demand and industrial value added could be expected under normal circumstances. However, if industry value added increase due to the technological improvements, in other words, if production increase due to increase in the efficiency, industry value added can increase without increase or even decrease in the electricity consumption. In addition, the urbanization ratio is expected to have an effect on the electricity demand. If urbanization is supported by industrialization as a consequence of economic growth, it is expected that it would positively affect the electricity demand. However, if urbanization caused by increase in migration from rural to urban areas, and as purchasing power parity of these migrated people would be lower in metropolitan cities, it might have a negative effect on the electricity demand. In accordance with microeconomic theory, if profitability increases production will increase so a positive relationship between electricity production and gross profit is expected. In addition, investments in electricity sector are expected to be positively related with electricity production. Mostly, investments include new power plant projects. However, as the constructions of these new power plants require time even investments flowed into these projects, there could be a negative relationship between production and investments within this time delay period until these power plants start to generate electricity.

1.1. Literature Survey

Literature in electricity demand counts too many recognizable studies with cointegration and Autoregressive Distributed Lags Approach (ARDL) estimation techniques. Chang and Martinez-Chombo (2003) estimate Mexican electricity demand with considering independent variables; income, prices and nonparametric temperature measure. Studies done in energy modeling in Turkey have started during 1970s. However, model based studies are initiated first by the Ministry of Energy and Natural Resources in 1984. The use of time series and cointegration analysis on the Turkish electricity market with respect to the economic indicators are studied by Ucal and Dogan (2005), Maden and Baykul (2012), Erdogdu (2007), Soytas and Sari (2003), Kucukbahar (2008), Halicioglu (2007), Bakirtas et al.(2000). These significant studies consider in part the economic variables which are taken into account in this thesis with respect to different methodologies. There are few studies on cointegration analysis for electricity demand by using ARDL procedure. Sari, Ewing and Soytas (2007) investigated the relationship between energy consumption and industrial production in the U.S. Acaravci and Ozturk (2010) estimate long run relationship between employment, electricity consumption and GDP for Turkey. In the study conducted by Halicioglu (2011) short and long run dynamic casual relationships between aggregate output, energy consumption, exports, capital amount and labor force are analyzed for

Turkey. Fuinhas and Marques (2011) analyze the short and long run relationship with primary energy consumption and growth for the countries Portugal, Greece, Italy, Spain and Turkey through ARDL bounds test approach. In addition, Tatlidil et al. (2002), has analyzed the long run relationship among electricity consumption per capita, GDP per capita and price of electricity with ARDL procedure. There are no significant studies on electricity consumption in Turkey by using ARDL procedure after privatization occurred in 2009 in electricity sector. On the other hand, literature in electricity supply counts less recognizable studies compared to the electricity demand within cointegration and ARDL procedures. Lean and Smyth (2010) examine the causal relationship between economic growth, electricity production, exports and electricity prices. It is found that there is a unidirectional Granger causality running from economic growth to electricity generation. Moreover, Zeshan (2013) reveals the impact of electricity production on economic growth in Pakistan and bounds test for cointegration indicates a long run relationship between them. Abanda F.H et al. (2012) examine the association between renewable energy production and economic growth across different African countries through cointegration analysis. Ghosh (2009) uses ARDL method for investigating the relationship between GDP, electricity supply and employment in India. Bildirici and Kayıkçı (2013) use ARDL approach for estimating the relationship between oil production and economic growth in Eurasian countries including Azerbaijan, Kazakhstan, Russian Federation and Turkmenistan and empirical results indicate that there is a cointegrated relationship between oil production and economic growth in both long and short run. For Turkey, Ozkan et al. (2010), investigate the causal relationship between aggregated and disaggregated levels of energy production, demand, import and GDP through Engle-Granger cointegration method.

There are some significant studies in the literature which mostly use least squares estimation to determine electricity demand and supply. Yau and Tso (2007) presents three different methods, in which one of them is OLS, for estimating electricity consumption and it is claimed that implementing various estimation techniques requires efficiency in data mining approaches because performance of models depends on data acquired. Guven et al. (2001) use multiple linear regression model for estimating annual electricity consumption in Northern Cyprus. It is found that number of customers, price of electricity and number of tourist correlate with annual electricity consumption. In addition, Bianco et al. (2009) use linear regression model for estimating electricity consumption in Italy by considering variables such as electricity consumption, GDP, GDP per capita and population. For supply side of electricity market, Ubi et al. (2012) analyze determinants of electricity supply in Nigeria by using a parametric econometric methodology of least squares. In this study it is found that technology, government funding, and electricity losses have significant effect on electricity supply. In addition, Bremnes (2004) analysis electricity generation from wind power resources in Norway by using local quantile regression estimation technique. Moreover, Boyd and Pang (2000) use regression analysis to estimate the association between electricity power plant productivity, electricity prices and level of production.

In literature, generalized method of moments is also used for determining factors which affect electricity demand and supply. Considine (2000) estimates energy demand with variables such as price, income and weather data by generalized method of moments estimation technique. Filippini (2011) uses GMM for estimating Swiss electricity demand for the period 2000-2006. In addition, White (2005) estimates the factors affecting electricity demand and price elasticity of residential electricity demand by using GMM estimation. Sadorsky (2010) uses generalized method of moments to examine the impact of financial development on energy consumption for 22 emerging economies. For supply side of electricity energy market, studies in the literature are mainly based on the estimation of expected energy production costs rather that determination of variables which affect electricity supply. Toy and Schenk (2007) in their study, use classical method of moments for estimating marginal costs for energy production. Jeremy (1992) calculates a production cost curve of a power system by using method of moments estimation technique. Moreover, Rungsuriyawiboon (2004) estimates cost structure of electricity market in US by using generalized method of moments estimation technique.

1.2. The Aim of the Study

This thesis investigates how sensitive are the electricity demand and supply in Turkey to the macroeconomic and sectoral factors through the years from 1970 to 2010. Additionally, it searches the best possible method to estimate the annual average electricity prices based on partial equilibrium analysis. Therefore, this study can be used as an input for risk management strategy development for electricity sector in Turkey as it reflects the fragility of electricity supply and demand to changes in main macroeconomic and sectoral indicators.

The study on the partial equilibrium analysis for Turkish electricity market is aimed to be an important contribution to the decision makers and investors. Knowing the significant variables and their impact on electricity consumption and production is important in order to maintain sustainability in energy market. Moreover, it is an integrated and comprehensive study in which various econometric modeling techniques are implemented and compared to find which method gives the best estimate. Most of the studies on electricity market are put forward by using monthly, daily or even hourly data. These studies are efficacious for estimating simultaneous electricity prices since they are determined in shorter periods. On the other hand, this study integrates statistical methods with macroeconomic point of view and states the effects of main macroeconomic and sectoral indicators on the functioning of electricity market in Turkey for the period 1970-2010.

This master thesis is comprised of five chapters. Chapter 1 summarizes the literature survey and introduces the purpose of the study. Chapter 2 gives information about the Turkish electricity market and its risk factors. Econometric methodology behind this study is expressed in Chapter 3. Univariate and multivariate time series modeling and econometric methods such as; Ordinary Least Squares (OLS), Generalized Method of Moments (GMM) and ARDL, which are used in the thesis for estimating electricity demand and supply in Turkey are presented thoroughly. Chapter 4 contains empirical results of analysis applied to the Turkish data. In this part estimation results are shown for both electricity supply and demand in Turkey. Chapter 5 presents partial equilibrium analysis and comparison of models within the concept of basic microeconomic theory and statistical measurement methods. Conclusion and comments finalizes this thesis.

1.3. Electricity Sector in Turkey

The first electricity production attempt in Turkey occurred in 1902, with a watermill producing 2kW electricity in Tarsus. The first large scale power plant was established in Istanbul in 1913. In these times electricity service was available in only few cities as Istanbul, Adapazarı and Tarsus. The first electricity company started to produce electricity in 1926. In 1935, government institution was established to control electricity production as 'Electric Power Resources Survey and Development Administration (EIE)'. In 1963, 'The Ministry of Energy and Natural Resources of Turkey (MENR)' has established. After that a law has enacted about the establishment of 'Turkish Electricity Administration Commission (TEK)' which would create a monopoly in electricity sector for a long period as a state run and state-owned entity. In 1987 construction of Karakaya Dam and in 1994 Ataturk Dam has finished. Therefore the share of hydroelectric generation within total electricity production has increased. After 1987, Turkey started importing natural gas for electricity production. It can be said that until 1993 hydroelectric installation was increasing but after that, thermal power plants installation has increased due to construction of natural gas power plants (Ozturk et al. 2007).

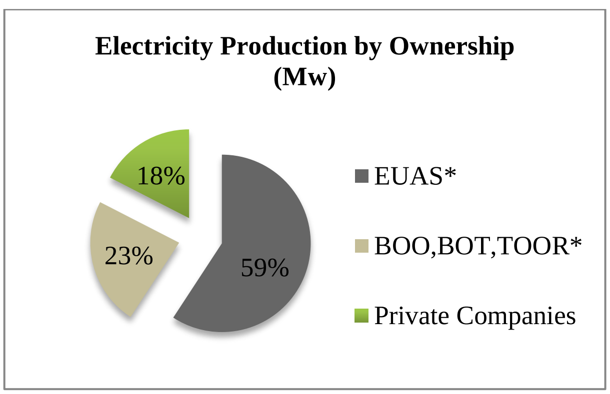
In 1993 privatization studies started to be implemented. The Regulation 85/9799 is published in the Official Gazette in September 1995 (which is about the permission and authorization of the owners who establish electricity production facilities) (Ozturk et al. 2007). The Regulation 96/8007 is published in the Official Gazette at April 1996 demystified who will be authorized to produce electricity, over production and its price and transmission and distribution costs. In February 2001, Turkey passed the 'Electricity Market Law' No. 4628 in line with EU Energy Acquisition, which creates a way for free market conditions in power generation and distribution. With this law; generation, transmission, distribution, wholesale, retail, imports and exports are aimed to be privatized. In September 2002, a new Energy Market Regulatory Authority (EMRA) has issued licenses for electricity generation, transmission and distribution. In March 2003, eligible customers have been free to select their suppliers. In 2005 the state-owned distribution monopoly, Turkish Electricity Distribution Inc (TEDAS), was divided into 20 districts for privatization. The pace of reform in the electricity sector accelerated in 2010 with the government making considerable progress on plans to privatize its generation and distribution assets except the publicly owned transmission (Ozturk et al. 2007).

To provide free market conditions in electricity market, suitable privatizations should be adopted without any financial burden on government budget. For this reason five types of investment models are implemented in Turkey as 'Build Operate and Transfer (BOT) Model', 'Build, Own, Operate (BOO) Model', 'The Auto-producer Model' and 'The Transferring of Operating Rights (TOOR) Model'. By these investment models it is aimed to liberalize electricity market but still transmission mechanism is owned by Turkish Electricity Transmission Company (TEIAS) (Hepbasli, 2005).

Briefly, as a development path Turkish electricity sector can be divided into periods with specific properties as; Foreign investment period (1923-1930), Nationalization (1930-1950), Development Plans (1960-1980), Investment Models (1980- 2000) and Restructuring the Electricity Markey (2000-now) (Hepbasli, 2005).

1.3.1. Structure of Electricity Market in Turkey

For demand side of electricity market, in Turkey, due to economic growth electricity demand has been continuously increasing. On the other hand, for supply side of electricity market in Turkey, state owned generation plants, mainly thermal plants, dominate with a 58.2% share of all generation (Republic of Turkey Prime Ministry, 2010). Electricity wholesale markets are very liquid compared to other markets of commodities in energy sector. However, it is more rational to accept electricity as a service rather than a commodity. Moreover; due to the physical limitations of electricity related to production, consumption and delivery, it is an 'instantaneous' product as it cannot be stored. In addition, as a necessary good, electricity energy could not be stored so demand and supply have to be in perfect balance in order to obtain market equilibrium (Thomsen and Olsen, 2004).



*EUAS: Electricity Generation Company, BO: Build, Own and Operate Model, BOT: Build, Operate and Transfer Model, TOOR: The Transferring of Operating Rights Model

Figure 1.1: Electricity production ownership in Turkey (Source: EUAS, 2010)

Figure 1.1 shows that the ownership of electricity production is shared among three partners: Companies in the form of 'Build Operate and Transfer (BOT) Model', 'Build, Own, Operate (BOO) Model', and 'The Transferring of Operating Rights (TOOR) Model', and private companies having the highest share of the state. It can be seen that in Turkey still state owned enterprises dominates electricity production even privatization process started (Electricity Generation Company, 2010).

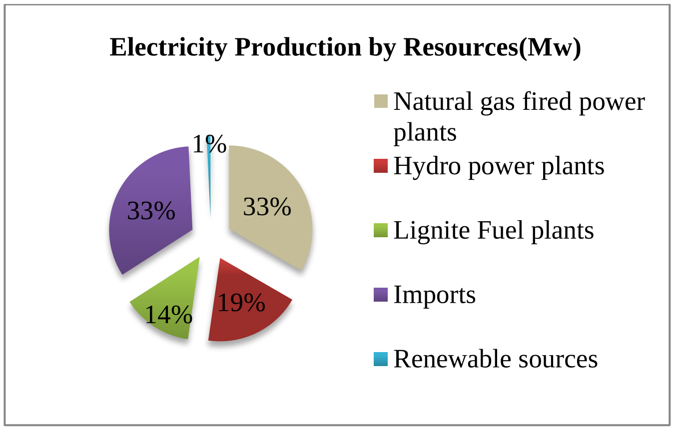


Figure 1.2: Usage of electricity production resources in Turkey

From Figure 1.2, it can be seen that in Turkey electricity mainly produced from natural gas power plants and percentage of electricity imported is high in electricity produced. With these production and consumption properties, Turkey's energy strategy has three main pillars as; (i) To ensure diversified, reliable and cost-effective supply for domestic consumption, (ii) Liberalize the electricity market, and (iii) To become a key transit country and energy hub for oil and gas flowing from Caspian Basin and the Middle East to the world markets.

In Turkey privatizations and reform in electricity sector gain more importance with the enactment of Electricity Market Law (2001). For deregulation process, Electricity Sector Reform and Privatization Strategy Document (High Planning Council) is published at 2004. The aims of the reform are to decrease the cost of the electricity, maintain supply security, and prevent power theft, increase in investments and increase in the utility level for consumers (Yuksek Planlama Kurulu (YPK), 2004). Moreover, reasons for the reform can be sorted as: (i) Rapid increase in electricity consumption, (ii) Problems in supply and demand balance, (iii) Government's vertical integrated structure which was inefficient for making suitable investments and (iv) European Union membership adoption process.

For energy policies of Turkey in detail, it can be said that Turkey has been undergoing privatization of the state enterprises, price liberalization, and integration into the European and global economy both in terms of social development and targeted growth. Moreover, Turkish energy policy endeavors to assure energy supply in a reliable, sufficient and economical manner by considering environmental impacts. Government focused its effort on improvement in domestic production by utilizing public, private and foreign utilities and increasing efficiency by rehabilitation and acceleration of existing construction programs. For global market, Turkey aims to transform itself into a critical energy hub for oil and gas flowing from the Caspian Basin and the Middle East to world markets.

For pricing policies in 2008, Turkey adopted a new system of electricity tariffs to ensure that electricity prices adjust to reflect changes in the cost of inputs. After that, there was not a significant increase in price in following 5 years except two cases. First one was in 2008, pushing retail tariffs up by a total of 50% and the second in October 2008 (High Planning Council, 2004).

1.3.2. Risk Factors in Turkish Electricity Sector

The market mechanism for electricity energy market works in accordance with microeconomic theory. The equilibrium price can be determined by the intersection of supply and demand curve. Demand curve or supply curve can shift by the shocks or developments in main macroeconomic or sectoral indicators and so this would cause fluctuations in equilibrium price. In Turkey demand for electricity has an increasing trend and possibility of the occurrence of demand shock is low. However, in the supply side there are some challenges for security of energy supply as: (i) High dependency on imported fossil fuel, (ii) Reliability of energy suppliers (iii) High energy intensity, (iv) Investment need of the Turkish electricity sector and, and (v) High transmission and distribution losses rates which has been estimated as the highest loss percentage among OECD and EU countries by approximately 16% (YPK, 2004).

There are some risk factors affecting electricity market from either demand or supply side in Turkey. These factors are important that they can cause shocks in electricity demand and supply and so fluctuations in electricity prices.

Table 1.1: Risk assessment components for the Turkish electricity market

Risk Group	Detailed description	Risk group	Detailed description
Market Risk	• Electricity price risk • Energy price risk • Carbon dioxide emission price risk • installed capacity	Financial risk	• Interest rate risk • Foreign exchange risk • Ranking risk • Market failures • Macroeconomic instability
Liquidity Risk	• Risk of liquidity for financing • Risk of the asset liquidity of electricity utility	Counterparty Risk	• Risk of business partners liquidity • Risk of unreliable partners
Operational Risk	• Risk of quality of supply • Technical risk • Personnel risk • Trading risk • Lack of infrastructure and safety conditions	Political and Regulatory Risk	• Political risk • Legislation risk • Humanitarian crisis or terrorism and vandalism • Non-transparency of electricity market in regulation
Strategic risk	• Risk related to business strategy of electricity producer	Business and reputation risk	• Risk of negative publicity • Risk of key factors in business

Based on the summary done by Jukan et al. (2011), Table 1.1 represents the modified risk factors for Turkish electricity market. It can be said that the most important risk factors for Turkish electricity market are the price risk of electricity and energy including raw materials used for producing electricity which is included in market risk part of Table 1.1. It is important to develop an appropriate risk management scheme for trade with full utilization of the multimarket environment in order to maximize participants' benefits and minimize the corresponding risk.

CHAPTER 2

Econometric Methodology

Many statistical and econometric methods are implemented to estimate the price behavior of electricity market as summarized in the literature survey part of this thesis. The methods which are used to capture the impact of market indicators are applied both in demand and supply variables separately. Univariate time series modeling is useful for determining the behavior of series especially for forecasting purposes. On the other hand, multivariate time series modeling techniques such as ARDL procedure and cointegration, and econometric methods such as; OLS and GMM are applied to determine the joint behavior of the variables selected on demand and supply.

2.1. Univariate Time Series Modeling

A time series can be defined as statistical data set, usually created by collected data for regular frequency in time interval. This stochastic process could be expressed by;

$$\{y(r,t): r\epsilon\mathcal{R}, t\epsilon\mathcal{T}\} \tag{2.1}$$

The main purpose of time series analysis is to develop appropriate mathematical models for a given data set. A stochastic process is said to be weakly stationary, if its mean and variance remains constant over time and covariance between two time periods only depends on lag between this two time periods (Gujarati, 2004) such as:

$$\begin{aligned} &E[y_t] = \mu \\ &E[(y_t - \mu)\left(y_{t-j} - \mu\right)] = \gamma_j\,,\ \forall t, j \in \mathcal{T} \\ &Var[y_t] = E(y_t - \mu)^2 = \sigma^2 \end{aligned} \tag{2.2}$$

Another important feature of stochastic process is ergodicity of time series data which refers asymptotical independence. If autocovariances tend to zero with increasing j, time series data would satisfy the property of ergodicity as follows (Pfaff, 2008):

$$lim_{T\to\infty}\{\tfrac{1}{T}\sum_{j=1}^{T} E[y_t-\mu][y_{t+j}-\mu]\} = 0 \quad (2.3)$$

Moreover, there is a special type of stochastic process namely, a purely random or white noise process having the conditions:

$$\begin{aligned} &E[\varepsilon_t] = 0 \\ &E[\varepsilon_t^2] = \sigma^2 \\ &E[\varepsilon_t \varepsilon_r] = 0 \;\; for\; t \neq r \end{aligned} \quad (2.4)$$

If a time series follows a random walk it is said to be nonstationary. There are two types of random walks: (i) Random walk without drift and (ii) Random walk with drift. If ε_t denotes a white noise error term and μ drift term; respectively, the series is said to fits on random walk with drift when the value of the series at time t is equal to the value of series at previous lag values. If ρ =1, series follows the pattern of random walk with drift it represents unit root problem.

$$y_t = \mu + \rho y_{t-1} + \varepsilon_t \quad (2.5)$$

Series could become stationary by taking first or higher order differences. If a nonstationary time series become stationary by taking difference, it is said to be integrated at order *d*, denoted as $y_t \sim I(d)$ (Gujarati, 2004).

There are several unit root tests implemented in order to determine stationarity of series. The basic idea behind these tests is to determine ρ value in Equation 2.5 by regressing y_t on its lagged value.

$$\begin{aligned} y_t - y_{t-1} &= \rho y_{t-1} - y_{t-1} + \varepsilon_t \\ &= (\rho - 1) y_{t-1} + \varepsilon_t \\ \nabla y_t &= \delta y_{t-1} + \varepsilon_t \end{aligned} \quad (2.6)$$

For theoretical purposes unit root tests have been implemented by estimating δ, represented in Equation 2.6. If $\delta = 0$, this requires $\rho = 1$ meaning that series have unit root and nonstationary.

Dickey-Fuller (DF) Test is one method to detect unit root of data set. Under the null hypothesis of unit root, this test uses τ statistics rather than Student's t distribution and rejecting null hypothesis implies that time series is stationary. Dickey and Fuller calculated τ statistics by Monte Carlo simulations (Dickey, Fuller, 1979). There are three different forms of estimating DF test as: (i) y_t is random walk, (ii) y_t is random walk with drift, (iii) y_t is a random walk with drift around a stochastic trend (Gujarati, 2004). Disadvantage of this test is that it is applicable only if series is an AR(1) process. Therefore; for testing higher order correlations, Augmented Dickey Fuller Test (ADF) could be used. Moreover, in DF Test it is assumed that error terms are uncorrelated but in ADF Test this assumption relaxed (Gujarati, 2004). This test could be implemented by adding lagged values of dependent variable, y_t to three equations in DF Test.

As ADF test follows the same asymptotic distribution with DF Test, the same statistics could be used for testing unit root process. Moreover, PP Test could be another choice for testing unit root as it is a nonparametric test which is a modified version of DF test (Philips, Perron, 1998). In addition, Kwiatowski, Phillips, Schmidt and Shin (KPSS) test differs from other tests by the way that it is assumed to be stationary under the null hypothesis in which critical values are calculated through LM statistics (Kwiatowski, Phillips, Schmidt, Shin, 1991). Moreover, Ng and Perron (NP) Test uses four test statistics based on Generalized Least Squares (GLS) detrended data (Ng, Perron, 2000).

2.1.1. ARIMA (p,d,q) Process

Before determining ARIMA (p,d,q) process as a whole it is important to analyze its AR(p) and MA(q) parts separately.

The autoregressive process of order p is defined in Equation 2.7 in which ϕ_r represents a constant for related lagged value and ε_t is white noise error term. If $|\phi_t| > 1$, this means the process will grow without bound and so nonstationary. Moreover, if $|\phi_t| = 1$,the process would have unit root. Therefore, for providing covariance-stationarity, $|\phi_t|$ should be lower than one (Pfaff, 2008). Basically, AR(p) process can be identified as estimating dependent variable linearly with respect to its lagged values.

$$y_t = \sum_{r=1}^{p} \phi_r \, y_{t-r} + \varepsilon_t \tag{2.7}$$

The moving average process MA(q) is defined in Equation 2.8 where θ_s represents constant with $\theta_0 = 1$ and ε_{t-s} is a sequence of independent random variables as white noise error term (Pfaff, 2008). Basically, it can be said that moving average process is linear modeling of white noise error terms.

$$y_t = \sum_{s=0}^{q} \theta_s + \varepsilon_{t-s} \tag{2.8}$$

In practice it is hard to estimate a pure AR(p) and MA(q) process. Therefore, mixed time series models such as autoregressive moving average process (ARMA(p,q)) should be investigated. Equation 2.9 expresses ARMA(p,q) where. ε_t is white noise error term and process would be stationary for $|\phi| < 1$ and $|\theta| < 1$ (Pfaff, 2008).

$$y_t - \sum_{r=1}^{p} \phi_r \, y_{t-r} = \sum_{s=0}^{q} \theta_s \, \varepsilon_{t-s} \tag{2.9}$$

In equations 2.7, 2.8 and 2.9, AR(p), MA(q) and ARMA(p,q) processes are defined for stationary time series with constant mean, variance and time-invariant covariance. However, as many economic time series are nonstationary, autoregressive integrated moving average ARIMA(p,d,q) process should be estimated where “p”, “q” and “d” represent number of autoregressive terms, number of moving average terms and order of integration, respectively (Gujarati, 2004).

ARIMA(p,d,q) process is estimated by Box-Jenkins Procedure (Box, Jenkins, 1970) including four steps: (i) identification, (ii) estimation, (iii) diagnostic checking and (iv) forecasting.

In identification step, autocorrelation and partial autocorrelation functions are analyzed to determine orders.

In estimation step, by using "p", "d" and "q" values determined, model parameters of autoregressive and moving average terms are estimated. If the time series process $\{Y_t\}$ is not stationary, first difference or second difference could be taken in order to determine stationarity of series which is expressed in Equations 2.10 as first difference and second difference of series Y_t, respectively.

$$dy_t = \nabla y_t = y_t - y_{t-1} \tag{2.10}$$
$$d^2 y_t = \nabla^2 y_t = \nabla(\nabla y)_t = y_t - 2y_{t-1} + y_{t-2}$$

Therefore, a series $\{y_t\}$ is said to ARIMA(p,d,q) process, if $dy_t = \nabla^d y_t$ is an ARMA(p,q) process.
In diagnostic checking step, estimated model is tested through statistical analysis and it is decided that whether model provides a good fit or not. The forecasting step, the model is checked to make a reasonable forecast and ARIMA(p,d,q) model is a good choice in forecasting purposes.

2.2. Multivariate Time Series Modeling

Multivariate time series models analyze the system of series and consider the association among series and their lagged values. Vector Autoregression (VAR), cointegration, vector error ARDL procedure are most commonly used methods in the literature.

2.2.1. Vector Autoregression (VAR) Modeling

VAR can be defined as a system such that each variable is expressed in terms of other variables and their lagged values. It requires the stationarity of all variables included. Equation 2.11 is the general representation of p-th order VAR model in which y_{t-k} represents k-th lag of y.

$$y_t = c + \sum_{k=1}^{p} A_k \, y_{t-k} + \varepsilon_t \tag{2.11}$$

VAR is useful as it does not require determining variables as endogenous or exogenous. Estimation of model is simple and forecast results performed better than more complex and specific models (Gujarati, 2004).

2.2.2. Cointegration Procedure

Two variables are said to be cointegrated if there is a long-term equilibrium relationship between them. The idea behind cointegration is to determine a linear relationship between I(d) variables, which yields a relationship at lower order of integration. By definition from Engle and Granger (1987), the components of the vector x_t are said to be cointegrated of order "d, b", if all components of x_t are I(d) and there exist a vector α ($\neq 0$) so that $z_t = \alpha' x_t \sim I(d-b)$ where the vector α is called as the cointegrating vector. In other words, if cointegration exists among variables the error term which is obtained from regression as equilibrium error would be stationary.

There are three methods of testing for cointegration. These methods can be specified as; The Engle-Granger Method (Engle and Granger, 1987), The Phillips-Quliaris residual-based tests (Phillips-Quliaris, 1988) and Johansen's multivariate cointegration test which uses maximum likelihood method rather than OLS estimation (Johansen and Juselius, 1988).

Engle-Granger method estimates cointegrating relation in two steps. In the first step, regression for I(1) variables used in the model is established as;

$$y_t = \beta_1 x_{t,1} + \beta_2 x_{t,2} + \cdots + \beta_K x_{t,K} + \varepsilon_t \quad for\ t = 1,2,3,..,T \qquad (2.12)$$

Cointegration vector, $\hat{\alpha}$, is equal to $\hat{\alpha} = (1 - \widehat{\alpha^*})'$ where $\widehat{\alpha^*} = (\widehat{\beta_1}, \widehat{\beta_2}, \dots, \widehat{\beta_K})$. By this process cointegrated vector is normalized to regressand. After that, residuals from this cointegrating regression should be tested in order to determine its stationarity through unit root tests. If residuals are found to be stationary, I(0), error correction model could be estimated as second step in Engle-Granger method in accordance with Engle-Granger representation theorem as:

$$\begin{aligned}\Delta y_t &= \varphi_0 + \xi_1 \varepsilon_{t-1} + \textstyle\sum_{i=1}^{K} \varphi_{1,i}\, \Delta x_{t-i} + \sum_{i=1}^{M} \varphi_{2,i}\, \Delta y_{t-i} + z_{1,t} \\ \Delta x_t &= \delta_0 + \xi_2 \varepsilon_{t-1} + \textstyle\sum_{i=1}^{K} \delta_{1,i}\, \Delta y_{t-i} \sum_{i=1}^{M} \delta_{2,i}\, \Delta x_{t-i} + z_{2,t}\end{aligned} \qquad (2.13)$$

In Equations 2.13 'ε' represent error term for the regression line expressed in Equation 2.12. In addition, '$z_{1,t}$' and '$z_{2,t}$' reflects white noise error term. Moreover, y_t and x_t are two time series which are found to be cointegrated. Equation 2.13 express that changes in dependent variables are explained by their own history, lagged changes in dependent variables and error from the long run equilibrium for the previous period. The coefficient $'\xi'$ represents error correction term and value of this coefficient reflects speed of adjustment. The advantage of this method is its ease to implementation but estimation results depends on how long run relation equation is specified.

Phillips-Quliaris Test (1990) present residual based cointegration test for multivariate time series. There are two types of tests used in this method as variance ratio and multivariate trace statistics. The advantage of the test over Engle-Granger method is that variables are taken as endogenous providing the model is invariant to normalization (Pfaff, 2008).

$$\varepsilon_t = \widehat{\Pi}\varepsilon_{t-1} + \hat{x}_{i_t} \quad (2.14)$$

$$\widehat{P_u} = \frac{T\widehat{w_{11,2}}}{T^{-1}\sum_{t=1}^{T}\widehat{u_t^2}} \quad (2.15)$$

In Equation 2.15, $\widehat{w_{11,2}}$ expresses conditional covariance and $\widehat{u_t}$ represents error term of the long run equation which is extracted from the equation; $y_t = \widehat{\beta}' x_t + \widehat{u_t}$. Within this method variance ratio statistics reflects the size of residuals from cointegrating relationship of y_t on x_t against conditional variance of y_t given x_t (Pfaff, 2008).

$$\widehat{P_z} = tr\left(\widehat{\Omega}E_{zz}^{-1}\right).T \quad (2.16)$$

In Equation 2.16, $\widehat{\Omega}$ expresses partitioned covariance matrix and $E_{zz} = t^{-1}\sum_{t=1}^{T}\varepsilon_t\varepsilon_t'$. Trace (tr) statistics is used for testing the null hypothesis of no cointegration and critical values could be found in Phillips-Quliaris (1990) (Pfaff, 2008).

If cointegration relations between more than two variables are questioned, Johansen's multivariate cointegration test should be implemented. In this method, there are two different likelihood ratio tests proposed as; the trace test and the maximum eigenvalue test (Ssekuma, 2011).

$$\Delta y_t = \Pi y_{t-1} + \sum_{i=1}^{p-1}\Gamma_i\, y_{t-i} + \varepsilon_t \quad (2.17)$$
$$\Pi = \sum_{i=1}^{p} A_i - I \text{ and } \Gamma_i = \sum_{j=i+1}^{p} A_j\, \Pi = \sum_{i=1}^{p} A_i - I$$

According to Granger's representation theorem; if the coefficient matrix Π has reduced rank; $r < k$, then there exists $k \times r$ matrices α and β each have rank r such that $\Pi = \alpha\beta'$ and $\beta' y_t$ is I (0). In this case r can be determined as the number of cointegration relations and each column of β represent the cointegrating vector.

First step in this method is to determine cointegration rank through trace or maximum eigenvalue statistics. Trace statistics for the null hypothesis of "at most r" cointegrated relations are computed by the equation 2.18.

$$LR_{tr}(r/k) = -T\sum_{i=r+1}^{k} log(1-\lambda_i) \quad (2.18)$$

Where λ_i represents the i-th largest eigenvalue of the matrix Π represented in Equation 2.17. In addition, maximum eigenvalue statistics under the null hypothesis of r cointegrating relations against the alternative of r+1 cointegrating relations is computed as:

$$LR_{max}(r/r+1) = -Tlog(1-\lambda_{r+1}) = LR_{tr}(r/k) - LR_{tr}(r+1/k) \quad (2.19)$$

Therefore, by using these widely used methods for cointegration, a long run dynamic relationship between I(1) variables in level form could be found. Implementing cointegration procedure requires that all variables should be at the same order of integration. However, even one variable has different order of integration cointegration is inapplicable and ARDL approach should be used in order to determine the association between variables.

2.2.3. Vector Error Correction (VECM) Modeling

If variables included in the model are nonstationary but there exist a cointegrating relation between them vector autoregression (VAR) model could not be used in order to express the relation among them. Instead VECM model could be described as a special case of VAR model for the variables stationary in their differences. In other words, VECM can be described as a restricted VAR, used for cointegrated nonstationary variables. VECM is useful for determining short term dynamics between variables by restricting long run behavior of variables. It restricts long run relationships through their cointegrating relations and error correction term represents the deviation from long run equilibrium. If a cointegration relation exists between two time series such that:

$$y_{2,t} = \beta y_{1,t} \tag{2.20}$$

Corresponding VEC model could be constructed as:

$$\begin{aligned} \Delta y_{1,t} &= \alpha_1 (y_{2,t-1} - \beta y_{1,t-1}) + \varepsilon_{1,t} \\ \Delta y_{2,t} &= \alpha_2 (y_{2,t-1} - \beta y_{1,t-1}) + \varepsilon_{2,t} \end{aligned} \tag{2.21}$$

Equation 2.21 represents VEC model in most basic form. Right-hand side of equations represents error correction terms which converge to zero in long run equilibrium and α_i represents speed of adjustment of variables in the model towards long run equilibrium (Engle, Granger, 1987).

2.2.4. Autoregressive Distributed Lags (ARDL) Approach

In regression analysis of macroeconomic time series data, the relations between variables usually are not found to be instantaneous. Instead, variables are related to each other with a lapse of time. There are three reasons to use lags in the model constructed. Firstly, it is a psychological reason that can be named as force of habit. Usually people do not have incentive to change their habits therefore especially for consumption data using lags is important. Secondly, there are technological reasons to use lags in time series models. There could be market failure as imperfect knowledge and technological improvements could require time period for adaptation. Therefore, especially for modeling production side of economy using lags is meaningful. Thirdly; for sectors which include contractual obligations or government intervention it is meaningful to use lags in the time series model (Gujarati, 2004).

In regression analysis if model includes both current and lagged values for independent variables it is called distributed lags model and if model also includes lagged values of dependent variable it is called as autoregressive model (Gujarati, 2004).

ARDL method allows us to express cointegrated behavior of variables which have different order of integration. ARDL procedure is irrespective whether variables used in model are I(0), I(1) or mutually cointegrated (Peseran et al., 2001). ARDL(p,q) model used in estimation process is expressed in Equation 2.22.

$$y_t = \alpha_0 + \alpha_1 t + \sum_{i=1}^{p} \phi_i \, y_{t-i} + \beta' x_t + \sum_{i=0}^{q-1} \beta_i^{*\prime} \, \Delta x_{t-i} + \varepsilon_t \qquad (2.22)$$
$$\Delta x_t = P_1 \Delta x_{t-1} + P_2 \Delta x_{t-2} + \cdots + P_s \Delta x_{t-s} + \varepsilon_t$$

In Equation 2.22 x_t represents k-dimensional I(1) variables which are not cointegrated, P_i is coefficient matrix which makes autoregressive process stable and ε_t represents white noise error term (Peseran et al., 2001).

Cointegration test for ARDL method is applied through bound testing procedure. In this test there are two sets of asymptotic values which assume that all variables are I(1) in one set and I(0) in another. These two sets provide critical value bounds for cointegration for both I(1) and I(0) data sets. For applying ARDL procedure 3 steps are required as: (i) applying bounds testing procedure for detecting cointegration ranks between variables, (ii) estimating long run relationship coefficients with respect to cointegration relations estimated in first step and (iii) estimating short run dynamic coefficients through vector error correction modeling.

$$DY_t = \phi + \sum_{i=1}^{\alpha} a_{1,i} DX_{v,t-i} + \sum_{i=1}^{\alpha} c_{1,i} DY_{t-i} + \delta_{1,v} X_{v,t-1} + \delta_{1,v} Y_{v,t-1} + \varepsilon_t \qquad (2.23)$$

In Equation 2.23 which is first differenced combined form of Equation 2.22, α represent appropriate lag length selected through Schwarz Information Criteria, $a_{1,i}$ and $c_{1,i}$ represent short run coefficients, δ expresses relative long run coefficients and ε_t is white noise error term (Engle and Granger, 1987).

Bounds test which seeks cointegration relation between variables could be expressed through the hypothesis:

$$H_0: \delta_{1,v} = 0 \qquad (2.24)$$
$$H_1: \delta_{1,v} \neq 0 \;;\; v = 1,2,3,4,5,6$$

Test on the null hypothesis of no cointegration is represented through an F-statistics and the critical values are calculated by Peseran et al. (2001). It is assumed that lower bound critical values could be used for I(0) variables and upper bound critical values are suitable for I(1) variables. Therefore, if computed F-statistics is less than lower bound critical values the null hypothesis is rejected that there is no long run relationship between variables. On the other hand, if computed F-statistics is greater than the upper bound value, it could be claimed that variables used in the model are cointegrated. Moreover, if computed F-statistic falls between the lower and upper bound values, then the test results are inconclusive (Peseran et al. 2001).

2.3. Estimation Methods for Regression Models

Generally, there are three methods of parameter estimation namely: least squares, maximum likelihood and generalized method of moments. In this thesis, both least squares and generalized method of moments estimation techniques are used in order to determine partial equilibrium prices in electricity market by estimating electricity supply and demand.

2.3.1. Least Squares Estimation

In general, least squares estimation technique is used in multiple linear regression model represented as:

$$Y_t = \beta_0 + \sum_{i=1}^{k} \beta_{it} X_{it} + u_t \quad \textit{for } k=1,2,3,\ldots \tag{2.25}$$

In Equation 2.25, Y_t is dependent variable and X_{it} represents independent variables, β_{it} could be expressed as partial regression coefficients which imply the change in mean value of dependent variable with respect to per unit change in related independent variable and u_t is stochastic error term (Gujarati, 2004).

For k-variable multiple linear regression case using matrix notation would be more useful. Therefore, from Equation 2.25 a system of equations could be created as:

$$\begin{bmatrix} Y_1 \\ \vdots \\ Y_T \end{bmatrix} = \begin{bmatrix} 1 X_{11} & \cdots & X_{k1} \\ \vdots \ \vdots & \ddots & \vdots \\ 1 X_{1T} & \cdots & X_{kT} \end{bmatrix} \begin{bmatrix} \beta_0 \\ \vdots \\ \beta_k \end{bmatrix} + \begin{bmatrix} u_1 \\ \vdots \\ u_T \end{bmatrix} \tag{2.26}$$

In k-variable case OLS estimators could be obtained by minimizing squared error term (Gujarati, 2004).

$$\sum \hat{u}_t^2 = \sum (Y_t - \hat{\beta}_0 - \hat{\beta}_1 X_{1t} - \hat{\beta}_k X_{kt})^2 \tag{2.27}$$

where the term $\sum \hat{u}_t^2$ is equal to $\hat{u}'\hat{u}$ in matrix notation. Error term could be expressed in matrix notation as:

$$\hat{u} = y - X\hat{\beta} \tag{2.28}$$

Therefore, residual sum of squares (RSS) term could be written in the form:

$$\widehat{u'}\hat{u} = \left(y - X\hat{\beta}\right)'\left(y - X\hat{\beta}\right) = y'y - 2\hat{\beta}X'y + \hat{\beta}X'X\hat{\beta} \tag{2.29}$$

The unknown parameters are estimated such that they minimize RSS, such that

$$(X'X)\hat{\beta} = X'y \tag{2.30}$$

2.3.2. Generalized Method of Moments Estimation

Many estimation methods used in econometrics such as least squares and instrumental variables are derived from method of moments estimation technique (Wooldridge, 2001). GMM can be accepted as a generalization of classical method of moments. In this thesis Hansen's two step generalized method of moments procedure is implemented. If x_t be an vector of variables observed at time 't', $'\beta'$ denotes unknown parameter matrix and $u_t = u(x_t, \beta)$ denotes covariance stationary vector values function as expectation of u_t is equal to zero, $u(x_t, \beta)$ forms moment or orthogonality conditions for the model (Hansen, 1982). Given $g_T(\beta)$ denotes the sample average:

$$\begin{aligned} g_T(\beta) &= \frac{1}{T}\textstyle\sum_{t=1}^{T}[m(x_{t+i}, \beta)' z_t] \\ &= \frac{1}{T}\textstyle\sum_{i=1}^{T} u(x_t, \beta) \\ &= \frac{1}{T}\textstyle\sum_{i=1}^{T} u_t \end{aligned} \tag{2.31}$$

For estimating β correctly, expected value of $g_T(\beta)$ should be equal to zero. If number of instruments used are greater than number of coefficients in the model, the main aim in GMM for estimating $\hat{\beta}$ given β_0 is to find a β value which minimizes the Equation 2.31. In other words, if the number of parameters is equal to number of moment conditions, objective function which is minimized in order to estimate parameters, is constructed as $g_T(\beta) = 0$. On the other hand, if there are more orthogonality conditions than parameters, how close the $g_T(\beta)$ is to zero depends on weighting matrix (Hamilton, 1994). Therefore, the main purpose in GMM is to minimize the function expressed in Equation 2.32, in order to estimate parameters used in the model.

$$Q(\beta) = g_T(\beta)' W^{-1} g_T(\beta) \tag{2.32}$$

where $g_T(\beta)'$ represents matrix transposition and W is the weighting matrix which determines how each moment condition weighted in accordance with their importance in model. W should be symmetric positive definite matrix so that it provides consistent estimates of parameters. However, even it provides consistent estimators they could not be efficient. Hence, Hansen (1982) presented a two-step procedure for GMM which provides asymptotically efficient estimates for the coefficients and weighting matrix is defined in Equation 2.33 (Hayashi, 2000).

$$W = Var[\textstyle\sum_{t=1}^{T} g_T(\beta, w_t)] \tag{2.33}$$

In GMM method it is important to estimate optimal weighting matrix. There are four ways for estimating optimal weighting matrix by using: (i) two stage least squares, (ii) White (iii) HAC-Newey West and (iv) constructing own specified weighting matrix (Hayashi, 2000). If $\hat{\beta}$ is estimated correctly, $g_T(\beta)$ would be strictly stationary with zero mean and its autocovariance matrix is expressed as:

$$\Gamma_v = E\{[g_T(\beta, w_t)][g_T(\beta, w_{t-v})]'\} \qquad (2.34)$$

With the assumption that autocovariances are summable, ‘S’ could be defined as the asymptotic variance of sample mean $g_T(\beta)$:

$$S = \sum_{v=-\infty}^{\infty} \Gamma_v \qquad (2.35)$$

If there is heterocedasticity and autocorrelation, it is needed to modify covariance matrix and to prevent heterocedasticity and autocorrelation White (1980) offers heteroskedastic consistent estimator for weighting matrix which is represented as:

$$S = \Gamma_0 = \frac{1}{T}\sum_{t=1}^{T} E\{[g_T(\beta, w_t)][g_T(\beta, w_{t-v})]'\} \qquad (2.36)$$

In this case weighting matrix can be estimated by using any consistent estimator of model’s parameters and by substituting expected value of squared residuals by actual residuals. However, if autocorrelation exists, it is not possible to use expected value of squared residuals and so weighting matrix is not consistent in the mean squared error. Therefore, class of estimators which prevent autocovariances growing with the sample size should be selected (Hayashi, 2000).

$$W = \sum_{j=-(T-1)}^{(T-1)} w_j \Gamma(j) \qquad (2.37)$$

The weighting matrix represented in Equation 2.37 belongs to class of kernel (spectral density) estimator evaluated at frequency zero In equation 2.37, w_j is named as ‘lagged window generator’ which is equal to $k(\frac{j}{b_t})$ where k(z) is kernel with b_t as bandwidth parameter (Matyas, 1999). With this manner, HAC matrix estimation could be expressed by:

$$\widehat{W} = \hat{\Gamma}(0) + \sum_{j=1}^{p} k(j/b_T)[\hat{\Gamma}(j) + \hat{\Gamma}(-j)] \qquad (2.38)$$

In optimal matrix estimation there are two kernels as quadratic and Barlett. For bandwidth parameter selection Newey and West (1987) offers using Barlett which guarantees positive defineteless and so positive variance (Hayashi, 2000). In addition, pre-whitening could be applied to any kernel and it fits a VAR model to residuals as:

$$\hat{\varepsilon}_t = \hat{c}\varepsilon_{t-1} + \hat{\mu}_t \qquad (2.39)$$

In computing optimal weighting matrix, there is a dilemma that before estimating β matrix S should be estimated and in order to find optimal weighting matrix an estimate of β is needed. Therefore, in practice firstly an initial estimate of β is obtained by an identity weighting matrix as; $W_T = I$. After that, initial estimate of parameter $'\beta'$ is used to form residuals from estimated parameter and with this residuals long run covariance matrix can be constructed. With this covariance matrix optimal weighting matrix S is established and it is aimed to minimize this within an iterative process which continues until the estimation of β becomes stable (Hamilton, 1994).

If number of moment conditions is greater than number of parameters, model is suspected of overidentification. Therefore, J-Test could be used in order to determine the validity of the model within GMM estimation procedure (Hansen, 1982). Formally, hypothesis for J-Test is constructed by

$$\begin{aligned} H_0 &= g_T(\beta) = 0 \\ H_1 &= g_T(\beta) \neq 0 \end{aligned} \tag{2.40}$$

In Equation 2.40, null hypothesis claims that model fits the data well and so the model is valid. Moreover, validity of instruments is met with approval through J-Test. Therefore J-Statistics is estimated as:

$$J \equiv T\left(\frac{1}{T}\sum_{t=1}^{T} g_T(\beta)\right)' \widehat{W_t}\left(\frac{1}{T}\sum_{t=1}^{T} g_T(\beta)\right) \xrightarrow{d} \chi^2_{k-l} \tag{2.41}$$

In Equation 2.41, β is GMM estimator of parameter β_0, 'k' is the number of moment conditions used and 'l' is the number of estimated parameters. With this test statistics H_0 is rejected when calculated J-Statistics is higher than χ^2_{k-l} for a given confidence level (Hansen, 1982).

CHAPTER 3

Empirical Analysis

Turkey specific data has been collected from different sources to determine the impact of the selected factors on demand and supply leading to the evaluation of the equilibrium price.

Data set contains macroeconomic indicators and sectoral variables for Turkish electricity market between years 1970-2010. Annual electricity consumption (CONS) in kWh received from the Turkish Electricity Transmission Company (TEIAS), Gross domestic product (LNGDP) in USD$ cents (World Bank), urban population (URB) (World Bank), the electricity power transmission and distribution losses (LOS) in kWh (TEIAS) the industry value added (IND) in USD$ cents (World Bank) the average annual electricity prices (PRC) in cent/kWh (TEIAS) the Turkish Population (POP) (World Bank), total annual electricity production (PRD) in kwh (TEIAS), labor supply in electricity sector (LBR) (TEIAS), gross profit for Turkish electricity market (PRF) in cent/kwh (TEIAS) and investments in Turkish electricity sector (INV) in USD$ cents (TEIAS) are collected. All the observations are modified to per capita by adjusting each data set to population except the prices and gross profit.

Table 3.1: Descriptive Statistics of the variables

	CONS	LNGDP	IND	LOS	PRC	URB	PRD	INV	LBR	PRF
Mean	1085.25	12.361	851.777	187.372	3.216	0.556	1260.21	1300.42	0.0005	0.073
Median	926.117	12.326	723.983	123.424	3.439	0.592	1063.04	1137.12	0.0003	0.142
Maximum	2477.06	13.844	2518.49	415.409	8.445	0.704	2903.11	3146.05	0.001	1.945
Minimum	218.699	10.711	101.962	24.447	0.000	0.383	243.146	101.757	0.000	-3.728
Std. Dev.	686.656	0.814	651.489	139.917	2.080	0.105	828.267	1001.08	0.0004	0.959
Skewness	0.563	0.0045	1.065	0.359	0.263	-0.305	0.533	0.367	0.738	-1.632
Kurtosis	2.093	2.487	3.290	1.447	2.665	1.586	1.982	1.617	1.963	8.000
Jarque-Bera	3.576	0.449	7.899	5.002	0.664	4.050	3.714	4.191	5.560	61.07
Probability	0.167	0.798	0.019	0.081	0.717	0.131	0.156	0.122	0.062	0.000
c.o.v.	0.632	15.185	0.764	0.746	0.646	0.190	0.657	0.769	0.800	13.068

In Table 3.1 descriptive statistics for variables are expressed. Variables such as; annual electricity consumption per capita (CONS), mean adjusted annual average electricity prices (PRC), urbanization ratio (URB), annual electricity production per capita (PRD), the logarithm of Gross domestic product (LNGDP) and investments per capita in electricity sector (INV) are found to be normally distributed according to Jarque-Bera Test results. All variables except urbanization ratio and gross profit are positively skewed which means for urbanization ratio and gross profit variables there are frequent large values and few small values. To illustrate, for gross profit, number of observations within the range [-1,-4] is relatively small even range is relatively large and most of the observations cumulated within the range [0, 0.5]. Moreover, large kurtosis value for gross profit implies that future values for profit can be either extremely large or small. Additionally, coefficient of variation (c.o.v.) is unitized risk coefficient as a dimensionless number. From Table 3.1 it can be seen that c.o.v. values are high for all variables which indicate fluctuations in values of them.

The annual average electricity prices in Turkey in years 1970-2010 show a pattern reflecting the impact of exogenous factors such as economic crises, regulation changes, government influence and international markets. An increasing pattern reflecting the influence of the financial crises continues till 1995 and then, experiences sharp falls twice in its history. This pattern which results in structural breaks in the original data does not allow a robust model. The Chow-test to justify the existence of structural breaks indicates that there exist structural breaks for the years 1994, 2000 and 2002. These breaks fit to the history of the price policy over the years, as 1994 and 2000 experienced two economic crises which recessed Turkish economy severely and 2001 dates back to the electricity market liberalization policy. For this reason, annual average electricity prices data is transformed so that structural breaks are eliminated and data became more stable. The prices are transformed to the mean adjusted forms which shrink down the pikes and shift the prices up after 2000. Figure 3.1 illustrates the original prices (red line) and adjusted prices (blue line).

Figure 3.1: The original and mean adjusted annual average electricity prices (TEIAS)

3.1. Univariate Time Series Modeling

The analyses are performed on all the variables separately. For each data set appropriate time series model is estimated by using the steps of Box-Jenkins procedure.

3.1.1 Electricity Demand

Electricity consumption variable is determined as equivalent to electricity demand. As GDP is main indicator of income and economic growth, it is chosen as one of the independent variables. Industry value added is chosen for reflecting industrial part of economy on electricity consumption. Moreover, as Turkey is a developing country and it is thought that consumption in electricity differs from rural to urban areas urbanization ratio is chosen as another variable affecting electricity demand. In addition, annual electricity prices and electricity losses are determined as sectoral independent variables in demand side of the electricity.

In Figure 3.2 time series plots for all variables related to electricity demand are expressed in original and first differenced forms. It seems even annual electricity consumption, urbanization ratio and electricity losses have more smooth increasing trends, electricity prices, industry value added and GDP have fluctuations with increasing trend due to economic turndowns, crisis and recessions during the period from 1970 to 2010. Moreover, it can be seen that trend vanishes when first difference of each data set is taken.

As we observe a significant trend in each variable, unit root test is employed to the original (level) and the differenced data sets. The results of unit root test for variables are summarized in Table 3.2.

Table 3.2: Unit root test results for electricity demand and its components

		ADF Statistic	Lag			ADF Statistics	Lag
CON	Intercept	2.02547	9	DCON	Intercept	1.1436^{a}	8
CON	Intercept and Trend	-0.38719	9	DCON	Intercept and Trend	-1.8372^{a}	9
LOS	Intercept	-1.4943	2	DLOS	Intercept	-2.6026	1
LOS*	Intercept and Trend	-1.2098	2	DLOS*	Intercept and Trend	-2.9302	1
LNGDP	Intercept	-0.8842	0	DLNGDP	Intercept	-6.4706^{a}	0
LNGDP	Intercept and Trend	-2.4203	0	DLNGDP	Intercept and Trend	-6.8522^{a}	0
IND	Intercept	1.4517	0	DIND	Intercept	-6.4182^{a}	0
IND	Intercept and Trend	-4.1001^{b}	3	DIND	Intercept and Trend	-6.7716^{a}	0
PRC	Intercept	-2.9244^{c}	0	DPRC	Intercept	-6.3431^{a}	0
PRC	Intercept and Trend	-2.6347	0	DPRC	Intercept and Trend	-6.5158^{a}	0
URB	Intercept	-1.4757	1	DURB	Intercept	-1.7407	0
URB*	Intercept and Trend	-1.7268	1	DURB*	Intercept and Trend	-2.04071	0

Superscripts a, b and c represents significance level at 1%, 5% and 10%, respectively. Lag lengths are determined by Schwarz Information Criterion (SIC). * Integrated with respect to Phillips Perron, KPSS, NP and DF-GLS tests.

According to Augmented Dickey Fuller (ADF) test results displayed in Table 3.2, annual electricity consumption (CON), logarithm of GDP (LNGDP), and industry value added (IND) are accepted as first differenced stationary. Moreover, mean adjusted annual average electricity prices data is stationary in its level form. Even, with respect to ADF test results claims nonstationarity for urbanization rate and electricity transmission and distribution losses, other unit root tests such that; DF-GLS, PP, KPSS and NP suggests that they are stationary at I(1) level, by the dominance of other test results.

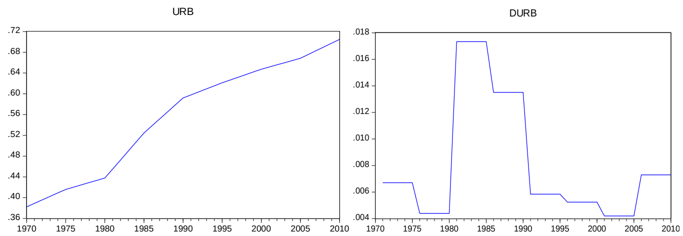


Figure 3.2: Time series plots of original and first differenced electricity demand variables

Each variable is modeled with respect to the orders which are firstly selected based on the correlagram plots, and then selecting the one yielding the smallest AIC, SIC values and required residual analysis. For each variable the same procedure is applied and the estimated models are expressed in Table 3.3 and diagnostic indicators are presented in Appendix for space purposes. The estimated model output illustrates the best fitting model correspondingly. The summary of estimated models and its components are expressed in Table 3.3.

Table 3.3: Estimation results for electricity consumption and its components

Variable	Model	Parameters of	t-stat	p-value	AIC	SIC
Annual electricity consumption per capita	White Noise	C =56.45906	6.690178	0.0000	10.81719	10.85941
Log GDP per capita	White noise	C=0.075944	2.870158	0.0066	-0.7128	-0.6705
Industry Value Added per Capita	ARIMA(2,1,2)	C=55.67247	1.724856	0.0939	13.50745	13.72292
		AR(1)=-1.5537	-6.4911	0.0000		
		AR(2)= -0.669322	-3.116786	0.0038		
		MA(1)= 0.618413	6.158658	0.0000		
		MA(2)=- 0.892038	13.04222	0.0000		
Electricity Transmission and distibution losses	ARIMA(0,1,2)	C=10.24809	3.403174	0.0016	7.364752	7.491418
		MA(1)= 0.121646	1.787166	0.0821		
		MA(2)=- 0.929248	19.48438	0.0000		
Annual electricity prices	AR(1)	C=3.0962	3.384441	0.0052	3.164196	3.248640
		AR(1)=- 0.857384	9.516360	0.0000		
Urbanization Rate	AR(1)	C=0.008176	3.279158	0.0062	-9.0728	-8.9875
		AR(1)= 0.837607	9.352078	0.0000		

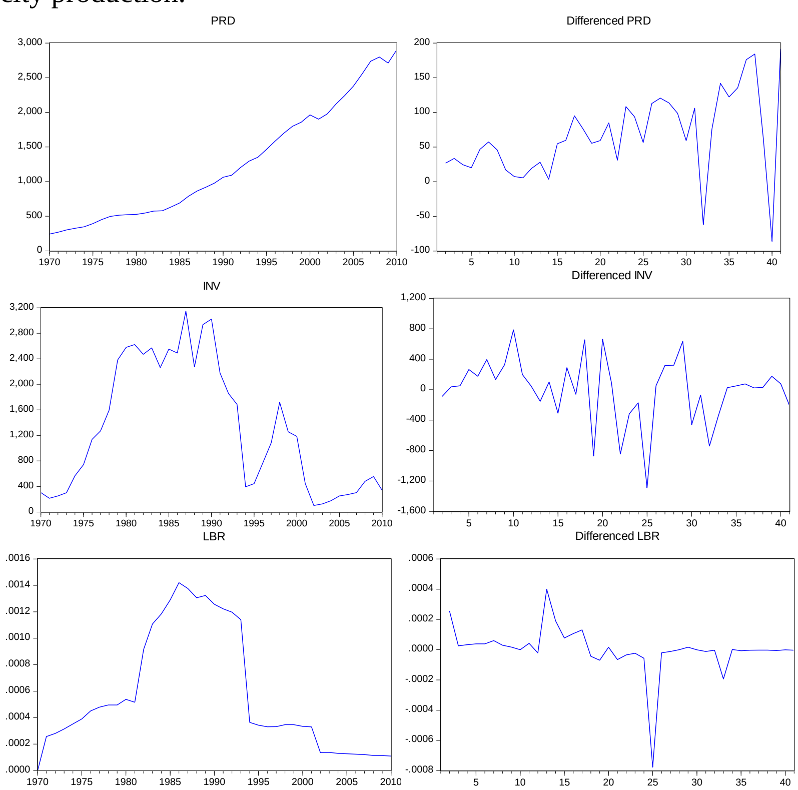
Table 3.4: The summary of estimated models for electricity demand

Variable	Substituted Coefficients
Total electricity consumption (kwh)	$\widehat{DCONS}_t = 56.45906$
Electricity power and distribution losses (kwh)	$\widehat{DLOS} = 10.24809 + 0.121646\varepsilon_{t-1} + 0.929248\varepsilon_{t-2}$
Gross domestic product (GDP) (kwh)	$\widehat{DLNGDP} = 0.075944$
Urbanization rate	$\widehat{DURB} = 0.008176 + 0.837607DURB_{t-1}$

Annual average electricity prices (cent/kwh)	$\widehat{PRICE} = 3.0962 + 0.857384PRICE_{t-1}$
Industry value added (cent)	$\widehat{DIND} = 55.67247 + 1.5537DIND_{t-1} - 0.669322DIND_{t-1} + 0.121646\varepsilon_{t-1} + 0.929248\varepsilon_{t-2}$

3.1.2. Electricity Supply

For supply side of electricity market, additional to mean adjusted annual electricity prices, electricity losses and GDP, investments, labor force in electricity sector and gross profit in electricity market, labor supply, investments amount and profitability are taken into account as they are directly related to electricity production. In this case, electricity supply is determined through electricity production.



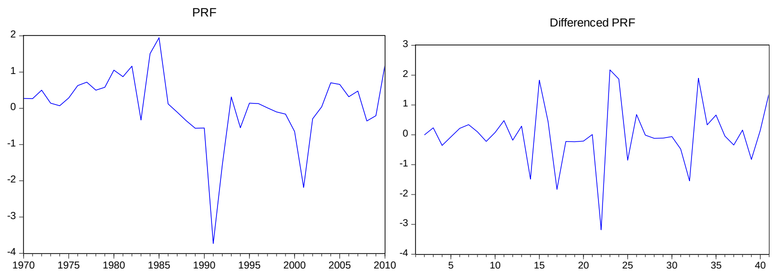


Figure 3.3: Time series plots of original and first differenced electricity supply variables

In Figure 3.3, time series plots for electricity supply and its components are displayed. It can be seen that annual electricity production per capita (PRD) variable has trend that it increases over time. Moreover, investments per capita (INV), labor supply (LBR) and gross profit rate in electricity sector (PRF) are not stable and fluctuates over time. On the other hand, in the first differenced data sets trend seems to be disasppeared.

As we observe a significant trend in electricity production variable and other variables are not stable, unit root test is employed to the original (level) and the differenced data sets.

Table 3.5: Unit root test results for electricity production and its components

		ADF Statistics	Lag			ADF Statistics	Lag
PRD	Intercept	-2.9375	0	DPRD	Intercept	-4.4317[a]	0
PRD	Intercept and Trend	-1.0989	0	DPRD	Intercept and Trend	-5.5316[a]	0
INV	Intercept	-1.3486	0	DINV	Intercept	-5.9551[a]	0
INV	Intercept and Trend	-1.8269	0	DINV	Intercept and Trend	-6.1856[a]	0
LBR	Intercept	-1.2138	0	DLBR	Intercept	-5.2357[a]	0
LBR	Intercept and Trend	-1.7834	0	DLBR	Intercept and Trend	-5.3721[a]	0
PRF	Intercept	-3.6331[a]	0	DPRF	Intercept	-6.5430[a]	1
PRF	Intercept and Trend	-3.6250[b]	0	DPRF	Intercept and Trend	-5.372[a]	0

Based on ADF test results displayed in Table 3.5, annual electricity production per capita, investments per capita in electricity sector and labor supply in electricity sector are stationary at first level. On the other hand, gross profit in electricity sector is found to be I(0). Each variable is modeled with respect to the orders which are firstly selected based on the correlagram plots, and then selecting the one yielding the smallest AIC, SIC values and required residual analysis which are displayed in appendix 1. The summary of the time series models based on the data set is shown in Table 3.7.

Table 3.6: Estimation results for electricity production and its components

Variable	Model	Parameters of	t-stat	p-value	AIC	SIC
Annual electricity	White noise	C=66.49909	7.144983	0.0000	11.01299	11.05522

production per capita						
Investments per capita	White noise	C= 0.902860	7.142545	0.0000	14.96124	15.00346
Labor supply in electricity sector	White noise	C= 0.0000027	2.709471	0.0094	-14.65045	-14.60823
Gross profit	AR(2)	C=-0.083748	1.818685	0.0218	2.695081	2.823047
		AR(1)= 0.479290	2.796494	0.0082		
		AR(2)= -0.02672	-2.155886	0.0155		

Table 3.7: The summary of estimated models and its components for supply

Variable	Model
Total electricity production (kwh)	$\widehat{DPRD} = 66.49909$
Labor supply in electricity sector	$\widehat{DLBR} = 0.0000027$
Investments (cents)	$\widehat{DINV} = 0.902860$
Gross profit (cent)	$\widehat{PRF} = -0.083748 + 0.479290DPRF_{t-1} - 0.02672DPRF_{t-2}$

3.2. Linear Regression Models

In this thesis both ordinary least squares (OLS) and generalized method of moments (GMM) methods are used in order to estimate electricity consumption and production with considering main macroeconomic and sectoral indicators effect.

3.2.2. Multiple Linear Regression Modeling for Electricity Market

In this section, multiple linear regression models are constructed through ordinary least squares estimation for determining annual electricity consumption and production in Turkey. For electricity consumption estimation, variables such as; GDP, industry value added, electricity transmission and distribution losses, mean adjusted annual average electricity prices, and urbanization ratio are used. For electricity production; GDP, investments and labor force in electricity sector, mean adjusted annual average electricity prices, gross profit and a dummy variable for the period from 1970 to 2002 are used to distinguish the impact of pre and post privatization.

3.2.2.1. Annual Electricity Consumption

Annual electricity consumption in Turkey for the period 1970-2010 is estimated with OLS and results are displayed in Table 3.8. It can be seen that all coefficients are significant and coefficient values are meaningful as well as they are compatible with economic theory. Moreover, according to F-statistics overall model is found to be significant.

Table 3.8: Multiple linear regression results for annual electricity consumption

Dependent Variable: CONS
Method: Least Squares
Sample: 1970 2010
Included observations: 41

Variable	Coefficient	Std. Error	t-Statistic	Prob.
LNGDP	76.48577	44.56952	1.716100	0.0950
IND	0.366734	0.048295	7.593603	0.0000
LOSS	1.575410	0.244121	6.453400	0.0000
PRC	-30.73171	6.961963	-4.414231	0.0001
URB	1533.674	314.1060	4.882664	0.0000
C	-1221.709	481.6008	-2.536766	0.0158

R-squared	0.994560	Mean dependent var	1085.255
Adjusted R-squared	0.993783	S.D. dependent var	686.6566
S.E. of regression	54.14214	Akaike info criterion	10.95556
Sum squared resid	102598.0	Schwarz criterion	11.20633
Log likelihood	-218.5890	Hannan-Quinn criter.	11.04688
F-statistic	1279.763	Durbin-Watson stat	1.429346
Prob(F-statistic)	0.000000		

Therefore, under the light of estimation results, least squares estimation for annual electricity consumption is expressed in Equation 3.1.

$$\widehat{CONS} = -1221.709 + 76.48577GDP + 0.366734IND + 1.575410LOS - 30.73171PRC + 1533.674URB \quad (3.1)$$

However, it should be noticed that high R^2 and low DW statistic values question the validity of the models. Normality checks done to the residuals indicate that residuals are normally distributed and as Q-statistics insignificant they have no autocorrelation pattern.

3.2.2.2. Annual Electricity Production

In OLS estimation of annual electricity production, explanatory variables are selected as; GDP, investments, labor supply, gross profit in electricity sector, and mean adjusted annual average electricity prices. Moreover, dummy variable for the period 1970 to 2002 added to model since until this year electricity sector dominated by government. However, privatization period has started since 2002. In Table 3.9, all variables are found to be significant within 10% significance level and overall model is acceptable in accordance with F-statistics.

Table 3.9: OLS estimation result for annual electricity production

Dependent Variable: PRD
Method: Least Squares
Sample: 1970 2010
Included observations: 41

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	-3156.100	744.8323	-4.237329	0.0002
PRF	-2.602245	1.290100	-2.017087	0.0683
PRC	-18.04755	14.78767	-1.220445	0.2309
LOSS	3.466131	0.313134	11.06917	0.0000
LBR	211873.0	68582.39	3.089321	0.0041
INV	-0.083408	0.030648	-2.721488	0.0103
LNGDP	325.9295	62.85631	5.185311	0.0000
DUMMY2002	-267.0844	82.88975	-3.222165	0.0029

R-squared	0.992424	Mean dependent var	1260.241
Adjusted R-squared	0.990817	S.D. dependent var	828.2678
S.E. of regression	79.37040	Akaike info criterion	11.75931
Sum squared resid	207888.8	Schwarz criterion	12.09366
Log likelihood	-233.0658	Hannan-Quinn criter.	11.88106
F-statistic	617.5665	Durbin-Watson stat	0.788560
Prob(F-statistic)	0.000000		

Therefore, with OLS estimation for annual electricity production, multiple linear regression model could be expressed in Equation 3.2:

$$\widehat{PRD} = -3156.1 + 325.9295LNGDP - 0.083408INV + 21873LBR$$
$$+3.4661LOS - 18.047PRC - 2.6022PRF - 267.0844D_{2002} \quad (3.2)$$

Dummy variable used for the period from 1970 to 2002 represents that before 2002, government intervention as a monopoly in electricity market caused 119.8998 kwh decrease in electricity production per capita in average.

However, it should be noticed that high R^2 and low DW statistic values question the validity of the models. Residual checks indicate that residuals are normally distributed and as Q-statistics insignificant they have no autocorrelation pattern.

3.2.2. Generalized Method of Moments Estimation

Generalized method of moments estimation technique is employed in this part in order to determine electricity consumption and production in Turkish electricity market.

3.2.2.1. Electricity Consumption

To obtain GMM estimation, first step is to determine moment conditions. In other words, orthogonality conditions should be specified as instrumental variables. Instrument variables are specified as: logarithm of GDP, industry value added, electricity transmission and distribution losses, mean adjusted annual average electricity prices, urbanization rate, value of electricity prices for previous period, value of electricity prices two years before and previous year's annual electricity consumption with respect to their contribution to significany of overall model which can be observed in Table 3.10. Moreover, a constant added to instruments list. By this assumption, orthogonality conditions could be written as:

$$\sum(CONS_t - \beta_1 - \beta_2 LNGDP_t - \beta_3 IND_t - \beta_4 LOS_t - \beta_5 PRC_t - \beta_6 URB_t) INS_t = 0 \tag{3.3}$$

Table 3.10: GMM estimation results for electricity consumption

Dependent Variable: CONS
Method: Generalized Method of Moments
Sample (adjusted): 1971 2010
Included observations: 40 after adjustments
Linear estimation with 1 weight update
Estimation weighting matrix: HAC (Bartlett kernel, Newey-West fixed
bandwidth = 4.0000)
Standard errors & covariance computed using estimation weighting matrix
Instrument specification: LNGDP IND LOSS PRC URB CONS(-1) PRC(-1)
Constant added to instrument list

Variable	Coefficient	Std. Error	t-Statistic	Prob.
LNGDP	46.91922	26.05941	1.800471	0.0807
IND	0.414291	0.032040	12.93047	0.0000
LOSS	1.891962	0.348530	5.428411	0.0000
PRC	-21.61498	8.213574	-2.631617	0.0127
URB	1176.738	298.5022	3.942143	0.0004

C	-781.2448	355.6580	-2.196618	0.0350

R-squared	0.993809	Mean dependent var	1106.919
Adjusted R-squared	0.992899	S.D. dependent var	681.0663
S.E. of regression	57.39255	Sum squared resid	111992.8
Durbin-Watson stat	1.321501	J-statistic	0.000000
Instrument rank	8		

For computing correct J-statistics, the value in the Table 3.10 should be multiplied by the number of observations but since it is equal to zero, result would be the same. Furthermore, it can be observed that all coefficients and overall model is statistically significant and R^2 is saliently high which implies changes in dependent variable are highly explained by changes in independent variables. In addition, sign of coefficients is meaningful since it is expected that GDP, electricity transmission and distribution losses and urbanization ratio are positively related to annual electricity consumption. Conversely, industry value added, and mean adjusted annual average electricity prices have negative effects on electricity consumption.

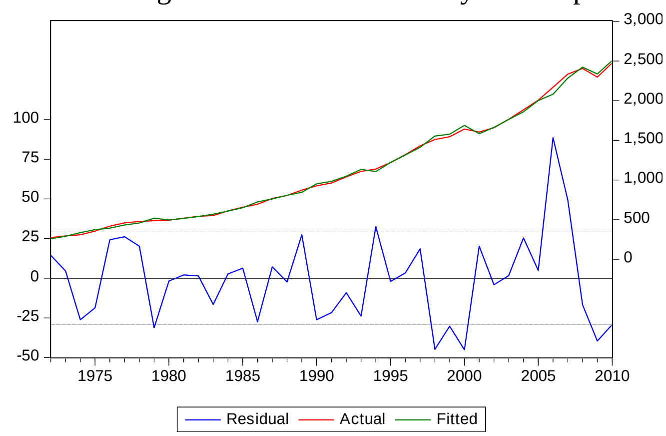


Figure 3.4: Diagnostic graphs of GMM model for the electricity consumption

It can be seen from Figure 4.4 that actual and fitted values are very close to each other and residuals lay within acceptable range except the residual belong to year 2008. Therefore, GMM model for annual electricity consumption can be expressed as:

$$\widehat{CONS} = -781.2445 + 46.91922LNGDP + 0.414291IND + 1.891962LOS - 21.61498PRC + 1176.738URB \tag{3.4}$$

3.2.2.2. Electricity Production

For GMM estimation of annual electricity production for the period from 1970 to 2010, instrumental variables are chosen as first lags of gross profit, mean adjusted annual average electricity prices, electricity transmission and distribution losses, labor supply, investments in electricity sector, and GDP. By those variables orthogonality conditions could be expressed in Equation 3.5 in which INS_t expresses instrumental variables.

$$\sum(PRD_t - \beta_1 - \beta_2 PRF_t - \beta_3 PRC_t - \beta_4 LOS_t - \beta_5 LBR_t - \beta_6 INV_t - \beta_7 LNGDP_t) INS_t = 0 \quad (3.5)$$

Table 3.12: GMM estimation results for annual electricity production

Dependent Variable: PRD
Method: Generalized Method of Moments
Sample (adjusted): 1971 2010
Included observations: 40 after adjustments
Linear estimation with 1 weight update
Estimation weighting matrix: HAC (Bartlett kernel, Newey-West fixed bandwidth = 4.0000)
Standard errors & covariance computed using estimation weighting matrix
Instrument specification: INV LBR LNGDP LOSS PRC PRF PRD(-1) PRC(-1)
Constant added to instrument list

Variable	Coefficient	Std. Error	t-Statistic	Prob.
INV	-0.130052	0.021546	-6.036041	0.0000
LBR	335416.4	60098.65	5.581096	0.0000
LNGDP	485.9655	71.39434	6.806779	0.0000
LOSS	3.048041	0.383775	7.942268	0.0000
PRC	-46.38854	11.71784	-3.958797	0.0004
PRF	14.58392	6.385470	2.283922	0.0289
C	-5195.891	818.3796	-6.348998	0.0000

R-squared	0.991052	Mean dependent var	1285.669
Adjusted R-squared	0.989425	S.D. dependent var	822.4535
S.E. of regression	84.57541	Sum squared resid	236049.0
Durbin-Watson stat	0.869057	J-statistic	7.174880
Instrument rank	9	Prob(J-statistic)	0.027669

GMM estimation results for electricity production are displayed in Table 3.12 by constructing weighting matrix through HAC method. It can be claimed that the model is statistically significant with high R^2 value, significant variables and meaningful coefficients.

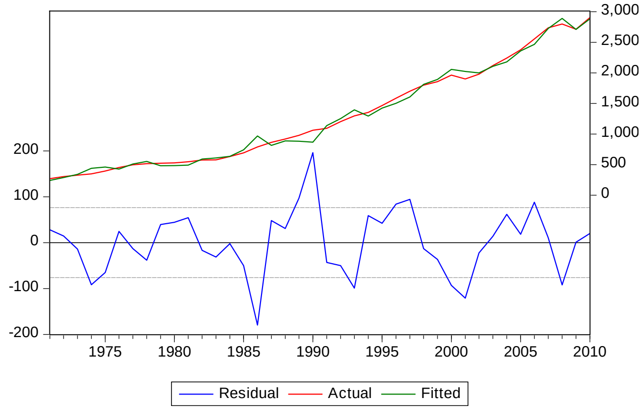


Figure 3.5: Diagnostic graphs of GMM model for electricity production

From Figure 3.6, it could be extracted that actual and fitted values are close for GMM model. Even though residuals are fluctuating, since overall model is significant with reasonable coefficients, model is acceptable. Therefore, GMM model for annual electricity production could be constructed as:

$$\widehat{PRD} = -5195.891 + 14.58392 - 46.38854PRC + 3.04804LOS + 335416.4LBR - 0.130052INV + 485.9655LNGDP \quad (3.6)$$

3.3. Multivariate Time Series Analysis: ARDL Approach

By determining long term cointegrating relationship, models for electricity demand and supply are constructed by using ARDL approach. Implementing cointegration procedure requires that all variables should be at the same order of integration. However, even one of the variables used in model has different order of integration, cointegration is inapplicable and autoregressive distributed lags (ARDL) approach should be preferred to determine the association between variables as it provides flexibility in determining cointegrating relationships. In contrast to OLS and GMM, GDP is taken its original form, as log-transformation does not lead to meaningful results in ARDL.

3.3.1. Electricity Consumption

As an initial step in cointegration analysis, level of stationarity should be analyzed by implementing the unit root test which is expressed in Table 3.2. As it is mentioned before, all variables are I(1) except mean adjusted annual average electricity prices, which is I(0). Therefore, ARDL procedure concerned in the cointegration analysis is implemented rather than Engle-Granger Method as it requires all variables are to be I(1).

Thereafter, appropriate lag length is determined for implementing ARDL procedure and it is selected as three in accordance with final prediction error and Akaike Information Criterion. With determining optimal lag length, bounds testing is employed in order to determine cointegrating relations between variables.

Table 3.13: Bounds-Testing procedure results for demand

Cointegration hypothesis	F-statistics
F(CON|GDP,IND,LOS,PRICE,URB)	3.1012**
F(GDP|CON,IND,LOS,PRICE,URB)	6.3478*
F(IND|CON,GDP,LOS,PRC,URB)	7.2093*
F(LOS|CON,GDP,IND,PRICE,URB)	1.8595
F(PRC|CON,GDP,IND,LOS,URB)	5.5008*
F(URB|CON,GDP,IND,LOS,PRC)	0.88845

* significance at 1%, ** at 2.5% levels with respect to Pesaran and Pesaran (1997) critical values.

Bounds Test results given in Table 3.13 indicate that there are four cointegated relations when dependent variables are selected as annual electricity consumption, GDP, industry value added and mean adjusted annual average electricity prices. Based on significancy with respect to Bounds-Test, cointegrated relations for annual electricity consumption can be expressed as follows:

$$DCON_t = \alpha + \sum_{i=1}^{3} \beta_{1,i}\, DCON_{t-i} + \sum_{i=1}^{3} \beta_{2,i}\, DGDP_{t-i} + \sum_{i=1}^{3} \beta_{3,i}\, DIND_{t-i} + \sum_{i=1}^{3} \beta_{4,i}\, DLOS_{t-i}$$

$$+ \textstyle\sum_{i=1}^{3} \beta_{5,i}\, DPRC_{t-i} + \sum_{i=1}^{3} \beta_{6,i}\, DURB_{t-i} + \delta_1 CON_{t-1} + \delta_2 GDP_{t-1} \qquad (3.7)$$

$$+\delta_3 IND_{t-1} + \delta_4 LOS_{t-1} + \delta_5 PRC_{t-1} + \delta_6 URB_{t-1} + \varepsilon_t$$

In Equation 3.7, α represents constant term, $\beta_{k,i}$ where k=1,2,3,4,5,6 represents short term effect of independent variables on electricity consumption and δ_ks express long term cointegration coefficients.

Table 3.14: Estimated ARDL model for CONS and ARDL(3,2,2,3,3,3)

(a) Estimated Long Run Coefficients			
Regressor	Coefficients	Standard Error	T-Ratio (Prob*1%,**5%)
GDP	0.0020823	0.1058E-3	19.6864*
IND	-0.50248	0.052200	-9.6260*
LOS	1.9291	0.059938	32.1848*
PRC	-0.17769	3.6958	-0.048078*
URB	1977.1	104.0641	18.9993*
Constant	-627.1865	37.8846	-16.5551
(b) Error Correction Representation for the ARDL Model			
ΔCON(-1)	1.1063	0.23387	4.7303*
ΔCON(-2)	0.63176	0.18166	3.4777*
ΔGDP	0.0027787	0.4203E-3	6.6117*
ΔGDP(-1)	-0.0017604	0.4911E-3	-3.5848*
ΔIND	-0.74040	0.14494	-5.1084*
ΔIND(-1)	0.42188	0.13797	3.0579*
ΔLOS	2.7343	0.44020	6.2116*
ΔLOS(-1)	-0.035601	0.46645	-0.076323(.940)
ΔLOS(-2)	-2.0454	0.49798	-4.1074*
ΔPRC	-21.6140	6.7027	-3.2247*
ΔPRC(-1)	-14.7163	6.7179	-2.1906**

ΔPRC(-2)	-19.7450	8.4128	-2.3470**
ΔURB	2992.8	1910.6	1.5664(.132)
ΔURB(-1)	141.2130	2060.3	0.068541(.946)
ΔURB(-2)	-5826.9	1823.4	-3.1957*
INTERCEPT	-1286.2	192.2404	-6.6905*
ECM(-1)	-2.0507	0.30552	-6.7122*

After implementing Bounds-Testing procedure to determine cointegrating relationships, short and long run coefficients and related Error Correction Models (ECM) have been estimated within ARDL method whose orders are selected with respect to Schwarz Information Criterion (SIC). In Table 3.14, part “a” expresses long term coefficients and part “b” represents short term coefficients and error correction term. Therefore, with respect to the estimation results and their significance, in the long run, annual electricity consumption can be expressed in a linear function of other independent variables as:

$$\widehat{CON} = -627.1865 + 0.0020823GDP - 0.50248IND + 1.9291LOS - 0.17769PRC + 1977.1URB \tag{3.8}$$

In Equation 3.15, GDP affects electricity consumption positively as increase in the national income in Turkey stimulates aggregate expenditure which includes consumption of electricity. Industry value added is found to be negatively related to electricity consumption. This is agreeable because still Turkey has been within the industrialization period and major part of increase in industry value added comes from increase in the efficiency of industrial sector through technological innovations. Thus, because of efficiency, electricity consumption decreases even though industrial production increases in Turkey. Moreover, it is found that electricity transmission and distribution losses are positively related to the annual electricity consumption, as unpaid consumption of a basic facility attracts especially low income consumers. In addition, in accordance with law of demand in Economics, electricity prices and consumption have an inverse relationship. Furthermore, positive association between urbanization and consumption is inevitable. Moreover, ECM term shows that the system came back to equilibrium in 6 months (1/ 2.05 years) in case of a shock caused by the independent variables.

Table 3.15: Estimated ARDL model for GDP and ARDL(3,3,3,3,3,3)

(a) Estimated Long Run Coefficients			
Regressor	Coefficients	Standard Error	T-Ratio (Prob*1%,**5%)
CONS	505.0663	36.2760	13.9229*
IND	230.6708	19.1247	12.0614*
LOS	-943.4381	79.1494	-11.9197*
PRC	-1192.3	2214.9	-0.53830 (.599)
URB	-961288.5	43640.3	-22.0276*
CC	308703.2	15975.1	19.3241*
(b) Error Correction Representation for the ARDL Model			
ΔGDP(-1)	0.22867	0.25461	0.89812 (.380)
ΔGDP(-2)	-0.23245	0.18601	-1.2496 (.227)
ΔCONS	219.0330	46.1705	4.7440 *
ΔCONS(-1)	-290.0416	107.2414	-2.7046 **
ΔCONS(-2)	-255.5565	77.2504	-2.9198 *
ΔIND	283.4724	11.1232	25.4848 *
ΔIND(-1)	-34.2725	67.7903	-0.50557 (.619)
ΔIND(-2)	92.7463	58.4180	1.5876 (.129)

ΔLOS	-878.1429	142.4284	-6.1655 *
ΔLOS(-1)	-55.1860	209.6804	-0.2631 (.795)
ΔLOS(-2)	471.9024	187.7296	2.5137 **
ΔPRC	7026.9	1910.7	3.6777*
ΔPRC(-1)	6323.9	2050.8	3.0837 *
ΔPRC(-2)	5758.6	2487.1	2.3154 **
ΔURB	-1509710	607881.6	-2.4836 **
ΔURB(-1)	336674.5	727510.7	0.46278 (.649)
ΔURB(-2)	1575900	543281.3	2.9007 *
INTERCEPT	363525.2	79983.1	4.5450 *
ECM(-1)	-1.1776	0.28493	-4.1329 *

In Table 3.15, estimation results are displayed when GDP is selected as dependent variable in linear form. Therefore, in the long run GDP can be modeled by other independent variables as:

$$\begin{aligned}\widehat{GDP} &= 308703.2 + 505.0663CONS + 230.6708IND - 943.4381LOS \\ &\quad -1192.3PRC - 961288.5URB \end{aligned} \tag{3.9}$$

From Equation 3.9, it can be said that there is a positive relationship between GDP and electricity consumption. The negative relationship between GDP and the mean adjusted annual average electricity prices implies that increase in the price of energy would decrease the capacity of energy usage and also the economic growth in Turkey. Moreover, increase in electricity losses stimulates decrease in GDP since it is included in informal economy. The urbanization has also a negative impact on the GDP. In Turkey increase in urbanization is uncontrolled and is mainly caused by migrations from rural to urban areas which cause decrease in the economic activity. Economic activity could decline by the decrease in the agricultural production in rural areas, increase in low skilled workers as well as expand in unemployment or marginal sectors. Thus, neither their participation to economy increase nor their consumption levels stabilize or decrease. Moreover, industry value added is positively related to GDP as industrial production directly leads to increase in GDP and so in national income. In addition, ECM term expresses that if this system is exposed to a shock, it requires almost one year returning back to equilibrium.

Table 3.16: Estimated ARDL model for IND and ARDL(0,3,0,2,0,3)

(a) Estimated Long Run Coefficients			
Regressor	Coefficients	Standard Error	T-Ratio (Prob*1%,**5%)
CONS	-1.1900	0.12562	-9.4732 *
GDP	0.0032532	0.1347E-3	24.1548 *
LOS	1.9023	0.27841	6.8327 *
PRC	-12.2859	5.8746	-2.0913 **
URB	3153.0	240.9749	13.0844 *
CC	-1046.4	81.3730	-12.8596 *
(b) Error Correction Representation for the ARDL Model			
ΔCONS	-0.53498	0.14107	-3.7924 *
ΔCONS(-1)	0.42978	0.088176	4.8741 *
ΔCONS(-2)	0.64173	0.15634	4.1047 *
ΔGDP	0.0032532	0.1347E-3	24.1548 *
ΔLOS	1.5983	0.41675	3.8352*
ΔLOS1	1.5374	0.36379	4.2261 *
ΔPRC	-12.2859	5.8746	-2.0913 *

ΔURB	5863.5	1669.2	3.5128 *
ΔURB(-1)	-340.9798	2078.6	-0.16405 (.871)
ΔURB(-2)	-5759.7	1762.4	-3.2682 *
INTERCEPT	-1046.4	81.3730	-12.8597 *
ECM(-1)	-1.000	0.000	NONE

ARDL model by taking industry value added as dependent variable could be expressed as:

$$\widehat{IND} = -1046.4 - 1.1900CONS + 0.0032532GDP + 1.9023LOS - 12.2859PRC + 3153URB \quad (3.10)$$

From Table 3.16, it can be seen that industry value added negatively related with consumption and positively related with GDP as reasons behind these explained before. Moreover, it is realized that electricity losses variable has a positive effect on industry value added which can be caused by the illegal consumption of electricity by small industrial producers. Moreover, increase in electricity prices cause decrease in industry value added because of the opportunity cost of using electricity for producers. In addition, there is a positive relationship between urbanization ratio and industry value added as increase in urban population leads to increase in labor supply in industrial sector which is mainly located in urban areas. In this model it is important to note that error correction term is not statistically significant since ECM term is not stationary. Thus, when a shock occurs for any independent variable, industry value added is affected from this shock but it does not come back to equilibrium after that shock.

Table 3.17: Estimated ARDL model for PRC and ARDL(1,0,0,0,0,0)

(a) Estimated Long Run Coefficients			
Regressor	**Coefficients**	**Standard Error**	**T-Ratio (Prob)**
CONS	-0.0027537	0.0093372	-0.29492 (.770)
GDP	-9812E-5	0.1859E-4	0.52772 (.601)
LOS	0.0036936	0.019044	0.19395 (.847)
IND	-0.0034684	0.0048692	-7.1231 (.482)
URB	8.8253	19.5885	0.45053 (.655)
CC	0.65583	6.7835	0.096680 (0.924)
(b) Error Correction Representation for the ARDL Model			
ΔCONS	-0.0010818	0.0036656	-0.29511 (.770)
ΔGDP	0.3854E-5	0.7367E-5	0.52319 (.605)
ΔLOS	0.0014510	0.0074314	0.19525 (.846)
ΔIND	-0.0013625	0.0019627	-0.69420 (0.493)
ΔURB	3.4668	7.9308	0.43714 (.665)
INTERCEPT	0.2576	2.6494	0.997242 (.923)
ECM(-1)	-0.39283	0.13768	-2.8533 (0.008)

Estimation results are displayed when dependent variable is chosen as mean adjusted annual average electricity prices in Table 3.17. Therefore, the linear model for this variable could be expressed as:

$$\widehat{PRC} = 0.65538 - 0.0027537CONS - 0{,}09812\mathrm{GDP} + 0.00366\mathrm{LOS} - 0.003\mathrm{IND} + 8.8253\mathrm{URB} \quad (3.11)$$

The change in the price with respect to the other variables are analyzed and presented in Equation 3.11. The effect of GDP and annual electricity consumption on annual average electricity prices is negative. In addition, electricity transmission and distribution losses positively affect electricity prices. Moreover, industry value added has a negative relationship with electricity prices and urbanization has positive effect on it. It should be noted that all coefficients are not statistically significant. Before the privatization, electricity prices are determined by the government agencies rather than the market equilibrium. This may cause the insignificancy in the model. Although the coefficients of the model are found to be insignificant, ECM term is significant and it represents that the system come back to equilibrium in three years when there exists a unexpected changes in the quantity of independent variables.

Even though none of the variables appears to be significant in the model Sari et al (2007), Renani (2007) and Budha (2012) explain the advantage of deducing the long term behavior by using ARDL approach.

In addition to ARDL models impulse-response function graphs and variance decomposition table have been extracted in order to understand the effect of a shock occur in each independent variable on annual electricity consumption. In general, impulse response functions represent if one-time shock occurs to endogenous variable, how it reacts to it under the VAR concept. Forecast error variance decomposition measures the contribution of each variable shock to the forecast error variance.

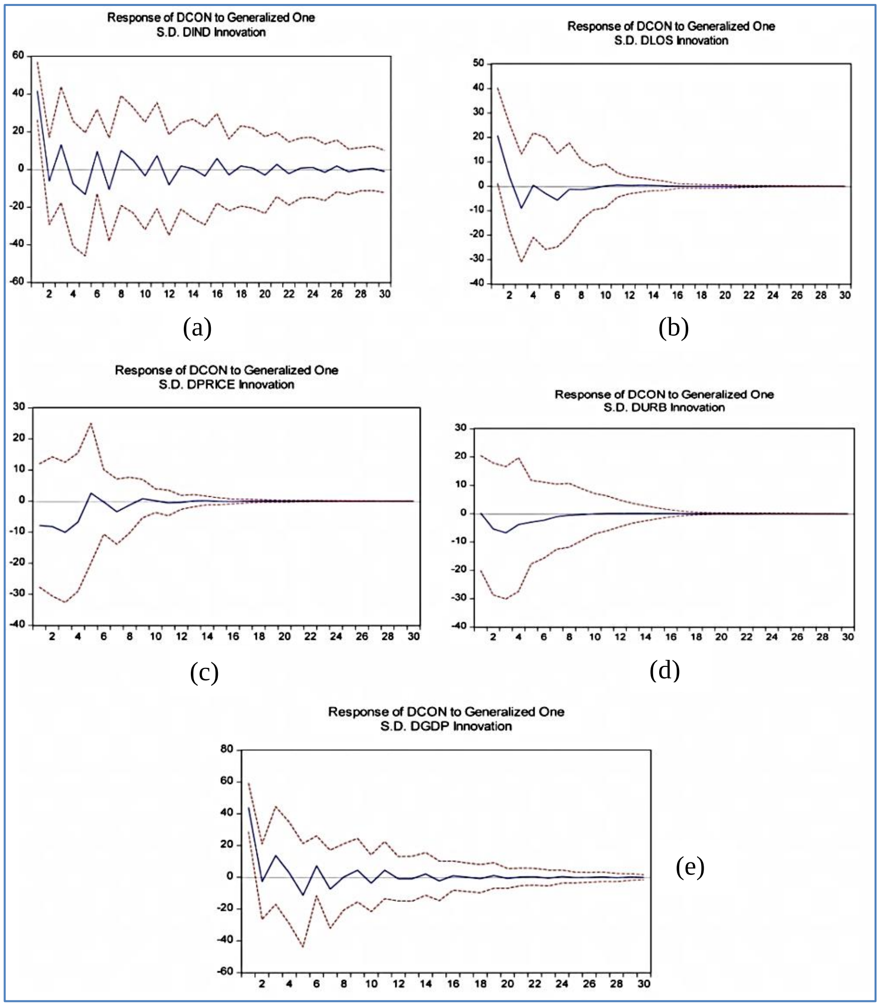


Figure 3.6: Impulse response graphs of electricity consumption to the other variables

In Figure 3.6, a-e impulse response graphs of annual electricity consumption with respect to (a) industry value added, (b) electricity transmission and distribution losses, (c) mean adjusted annual average electricity prices, (d) urbanization rate and (e) GDP. A random shock in industry value added causes the electricity consumption to respond with a sharp decrease and not to position back to the equilibrium even in 30 years. The impact of electricity transmission and distribution losses on the electricity consumption is a decrease for 3 years and thereafter that to increase reaching to the equilibrium approximately in 15 years. A shock on the annual average electricity prices causes the electricity consumption to decrease slightly for three years, then climbing up to the equilibrium approximately in 12 years. The urbanization rate does have also a long term impact on the electricity consumption to reach its equilibrium and responds first with a decrease for 3 years. The electricity consumption responses to a shock in GDP with a significant price decline which requires 30 years to come back to equilibrium.

Table 3.18: Generalized forecast error variance decomposition for electricity consumption data set

	Horizon	ΔCON	ΔGDP	ΔPRC	ΔLOS	ΔURB	ΔIND
	0	1.0000	0.6073	0.0600	0.0473	0.0519	0.5285
	1	0.8137	0.5213	0.0662	0.0644	0.0419	0.4503
Panel A	**2**	0.7509	0.5561	0.1226	0.0617	0.0377	0.4905
	3	0.7448	0.5526	0.1253	0.0613	0.0419	0.4874
	4	0.7349	0.5435	0.1226	0.0652	0.0427	0.4777
	5	0.7319	0.5411	0.1229	0.0650	0.0445	0.4758
	10	0.7226	0.5348	0.1214	0.6828	0.0465	0.4702
	20	0.7223	0.5343	0.1213	0.0684	0.0472	0.4697
	50	0.7223	0.5343	0.1213	0.0684	0.0472	0.4697
	0	0.6073	1.0000	0.0541	0.0022	0.0422	0.9473
	1	0.4490	0.8244	0.0506	0.0016	0.0342	0.7744
	2	0.4793	0.7925	0.1106	0.0114	0.0325	0.7363
	3	0.4885	0.7710	0.1176	0.0143	0.0326	0.7216
Panel B	**4**	0.4679	0.7439	0.1219	0.0392	0.0316	0.6917
	5	0.4658	0.7409	0.1134	0.0391	0.0333	0.6897
	10	0.4577	0.7280	0.115	0.0437	0.0355	0.6778
	20	0.4577	0.7276	0.1115	0.0438	0.0360	0.6774
	50	0.4577	0.7276	0.1115	0.0438	0.0360	0.6774
	0	0.0599	0.0541	1.0000	0.0092	0.0394	0.0740
	1	0.0572	0.0570	0.9488	0.0335	0.0376	0.0836
	2	0.0574	0.0527	0.9081	0.0690	0.0387	0.0770
	3	0.0612	0.0677	0.8825	0.0691	0.0449	0.0883
Panel C	**4**	0.0630	0.0806	0.8692	0.0671	0.0457	0.1049
	5	0.0632	0.0821	0.8618	0.0686	0.0456	0.1049
	10	0.0648	0.0819	0.8569	0.0690	0.0489	0.1044
	20	0.0650	0.0821	0.8564	0.0692	0.0472	0.1046
	50	0.0650	0.0821	0.8564	0.0692	0.0472	0.1046
	0	0.0473	0.0021	0.0092	1.0000	0.1649	0.0159
	1	0.0422	0.0344	0.0109	0.9092	0.1437	0.0044
	2	0.1485	0.1230	0.0131	0.8083	0.1268	0.1739
Panel D	**3**	0.1297	0.1267	0.0114	0.7706	0.1115	0.1611
	4	0.1556	0.1486	0.0202	0.7404	0.1071	0.1891
	5	0.1521	0.1470	0.0203	0.7381	0.1050	0.1848
	10	0.1535	0.1474	0.0210	0.7342	0.1045	0.1855
	20	0.1536	0.1475	0.0210	0.7341	0.1050	0.1855
	50	0.1536	0.1475	0.0210	0.7341	0.1050	0.1855
	0	0.0519	0.0422	0.0394	0.1649	1.0000	0.0311
	1	0.0990	0.1175	0.0198	0.0999	0.9214	0.0830
	2	0.1029	0.0869	0.0402	0.0779	0.8686	0.0567
	3	0.1305	0.0843	0.0488	0.0819	0.8337	0.0495
Panel E	**4**	0.1369	0.0817	0.0475	0.0855	0.8238	0.0461
	5	0.1542	0.0908	0.0446	0.0869	0.8161	0.0519
	10	0.1860	0.0958	0.0396	0.1042	0.8003	0.0559
	20	0.1860	0.0958	0.0396	0.1042	0.8003	0.0559
	50	0.1860	0.0958	0.0396	0.1042	0.8003	0.0559
	0	0.5285	0.9473	0.0739	0.0160	0.0311	1.0000
	1	0.3691	0.7669	0.0580	0.0138	0.0248	0.7862
	2	0.3975	0.7548	0.1003	0.0239	0.0229	0.7581
	3	0.4181	0.7309	0.1081	0.0265	0.0218	0.7359
Panel F	**4**	0.4028	0.7079	0.1039	0.0520	0.0209	0.7100
	5	0.4021	0.7067	0.1048	0.0517	0.0217	0.7088
	10	0.2963	0.6968	0.1034	0.0569	0.0224	0.6968
	20	0.3964	0.6967	0.1034	0.0568	0.0225	0.6993
	50	0.3964	0.6967	0.1034	0.0568	0.0225	0.6993

In Table 3.18, results of generalized variance decomposition analysis are reported. The orders of the VAR systems are determined through Akaike Information Criterion (AIC). Results are reported with first five years, then tenth, twentieth and fifth years until systems for each variable come back to equilibrium. The results show that 72% to 81% of the forecast error variance in consumption can be explained by its own shock while the impacts of GDP is around 50% and industry value added is around 47%. Annual average electricity prices explain about 12% of forecast variance error and urbanization ratio explains about 4% of forecast variance error on the electricity consumption. Other panels, B to F, also express forecast variance errors for GDP, annual electricity price, electricity transmission and distribution losses, urbanization ratio and industry value added as dependent variables, respectively.

3.3.2. Electricity Production

In this section, the cointegrated behavior between annual electricity production in Turkey and macroeconomic or sectoral indicators such as GDP, investments in electricity sector, electricity transmission and distribution losses, labor supply and gross profit in electricity sector, and mean adjusted annual average electricity prices are examined for the period from 1970 to 2010. At first stage unit root tests are employed in order to determine the level of integration of variables used in model. Unit root test results, displayed in Table 3.5, indicates that except gross profit and annual average electricity prices all other variables are I(1) but they are I(0). This situation makes impossible to implement cointegration method as it requires all variables to be at the same order of integration. Therefore, ARDL procedure is employed for estimating the cointegrated relationship between annual electricity production and other selected explanatory variables.

Table 3.19: Bounds-Testing procedure results for electricity supply

Cointegration hypothesis	F-statistics
F(PRD|GDP,INV,LOS,PRC,LBR,PRF)	3.5164*
F(GDP|PRD,INV,LOS,PRC,LBR,PRF)	3.8908**
F(INV|GDP,PRD,LOS,PRC,LBR,PRF)	6.0427*
F(LOS|GDP,PRD,INV,PRC,LBR,PRF)	2.7166***
F(PRC|GDP,PRD,INV,LOS,LBR,PRF)	1.1212
F(LBR|GDP,PRD,INV,LOS,PRC,PRF)	7.4945*
F(PRF|GDP,PRD,INV,LOS,PRC,LBR)	5.8336*

*Represents significance at 1%, ** at 2.5%, *** at 5% and **** at 10%. The critical values from Pesaran and Pesaran (1997) are 2.141-3.250, 2.476-3.646, 2.823-4.069 and 3.267-4.540 for 10%, 5%, 2.5%, and 1% significance level, respectively.

ARDL Bounds-Testing procedure results are displayed in Table 3.19 by selecting each variable in the system as dependent variable one by one. F-statistics have been computed by selecting appropriate lag length as three and results shows that there are 6 cointegrating relationship. In other words, a cointegrating relationship exists when dependent variables are selected as annual electricity production, GDP, investments and labor supply in electricity sector, electricity transmission and distribution losses, and gross profit in electricity production sector. Therefore, by these test results model for electricity production is expressed in Equation 3.12. All models for other dependent variables could be expressed in the same manner.

$$DPRD_t = \alpha + \sum_{i=1}^{3} \beta_{1,i}\, DPRD_{t-i} + \sum_{i=1}^{3} \beta_{2,i}\, DGDP_{t-i} + \sum_{i=1}^{3} \beta_{3,i}\, DPRF_{t-i} + \sum_{i=1}^{3} \beta_{4,i}\, DINV_{t-i} \quad \sum_{i=1}^{3} \beta_{5,i}\, DLOS_{t-i} + \sum_{i=1}^{3} \beta_{6,i}\, DPRC_{t-i} \tag{3.12}$$

$$+\sum_{i=1}^{3}\beta_{6,i}\,DLBR_{t-i}+\delta_1 PRD_{t-1}+\delta_2 GDP_{t-1}+\ \delta_3 INV_{t-1}$$
$$+\delta_4 LOS_{t-1}+\ \delta_5 PRC_{t-1}+\delta_6 PRF_{t-1}+\delta_7 LBR_{t-1}+\varepsilon_t$$

Table 3.20: Estimated ARDL model for PRD and ARDL(1,3,1,3,0,3,0)

	(a) Estimated Long Run Coefficients		
Regressor	Coefficients	Standard Error	T-Ratio (Prob*1%,**5%)
GDP	0.7032E-3	0.2334E-3	3.0126*
INV	-0.041482	0.025196	-1.6464
LOS	5.1507	0.53929	9.5509*
PRC	-67.5671	29.3704	-2.3005**
LBR	384860.9	90121.2	4.2705*
PRF	109.1725	41.8693	2.6075**
CC	237.672	71.8615	3.3073*
	(b) Error Correction Representation for the Selected ARDL Model		
ΔGDP	0.5950E-3	0.8261E-4	7.2029*
ΔGDP(-1)	0.9125E-4	0.5705E-4	1.5997
ΔGDP(-2)	0.3444E-3	0.9481E-4	3.6324*
ΔINV	-0.050102	0.011531	-4.3449*
ΔLOS	2.3596	0.42162	5.5964*)
ΔLOS(-1)	0.48336	0.35605	1.3576
ΔLOS(-2)	-2.5396	0.44971	-5.6472*
ΔPRC	-22.0022	7.3127	-3.0088*
ΔLBR	38674	29438.7	1.3137
ΔLBR(-1)	-43189.5	28680.1	-1.5059
ΔLBR(-2)	-113582.4	26867.3	-4.2275*
ΔPRF	35.5503	5.6801	6.2587*
INTERCEPT	77.3925	21.8812	3.5369*
ECM(-1)	-0.32563	0.12161	-2.6776**

In Table 3.20 long run coefficients and error correction model are estimated for annual electricity production which is taken as dependent variable. Optimal lag length for ARDL model is selected through Schwarz Information Criterion and model for long run electricity production is estimated in Equation 3.13.

$$\widehat{PRD}=237.672+0.7032GDP-0.041482INV+5.1507LOS-67.5671PRC+384860.9LBR+\ 109.1725 \tag{3.13}$$

Equation 3.13 indicates that there is a positive relationship between electricity production and GDP which is reasonable that if economy stimulates with increase in GDP, electricity production will increase accordingly. Secondly, results reflect that there is a positive relation between electricity transmission and distribution losses, and electricity production. It is also meaningful that as losses increases more electricity should be produced in order to meet increased electricity demand. Thirdly, electricity production and gross profit moves at the same direction. In accordance with economic theory, if profitability increases production will increase too. In addition, there is a negative relationship between electricity production and independent variables; investments in electricity sector and annual average electricity prices exist for the annual data containing the period from 1970 to 2010 but the coefficient for investments in electricity sector is not found to be statistically significant. ECM term is significant and it represents that the system come back to equilibrium in three years when there exists an unexpected changes in the quantity of explanatory variables.

Table 3.21: Estimated ARDL model for GDP and ARDL(0,0,0,0,3,0,3)

	(a) Estimated Long Run Coefficients		
Regressor	Coefficients	Standard Error	T-Ratio (Prob*1%,**5%)
PRD	739.4082	28.8995	25.5855*
INV	53.2018	12.2385	4.3471*
LOS	-2441.2	192.1447	-12.7052*
PRC	-47556.9	14005.8	-3.3955*
LBR	-9.02E+07	3.07E+07	-2.9365*)
PRF	33926.5	10191.7	3.3288*
CC	-27124.9	27833.0	-0.97456
	(b) Error Correction Representation for the Selected ARDL Model		
ΔPRD	739.4082	28.8995	25.5855*
ΔINV	53.2018	12.2385	4.3471*
ΔLOS	-2441.2	192.1447	-12.7052*
ΔPRC	923.4950	10901.2	0.084715
ΔPRC(-1)	40350.6	9909.2	4.0720*
ΔPRC(-2)	31616.4	10023.0	3.1544*
ΔLBR	-9.02E+07	3.07E+07	-2.9365*
ΔPRF	4619.9	7185.7	0.64293
ΔPRF(-1)	-26576.6	7585.7	-3.5035*
ΔPRF(-2)	-21881.9	6750.8	-3.2414*
INTERCEPT	-27124.9	27833.0	-0.97456
ECM(-1)	-1.0000	0.00	NONE

In Table 3.21, estimation results for the relation between GDP and other independent variables are expressed and under the light of estimation results, model for GDP is expressed in Equation 3.14. There is a positive relationship between GDP and annual electricity production. Moreover, it can be said that investments in electricity sector and increase in gross profit stimulate GDP. In addition, there is a negative relationship between GDP and electricity transmission and distribution losses. Increase in losses lead to increase proportion of informal economy which affects formal GDP negatively. Also it is found that mean adjusted annual average electricity prices and labor force in electricity sector affect GDP negatively. In this case; error correction term is not statistically significant in the short term which means under the situation of a shock occurs in independent variables; dependent variable could not come back to equilibrium again as it is valid for some economic variables. Therefore, ECM model for GDP for the supply side of electricity market can be expressed as:

$$\widehat{GDP} = -27124.9 + 7394082PRD + 532018INV - 2441.2LOS$$
$$-47556.9PRC90200000LBR + 33926.5PRF \quad (3.14)$$

Table 3.22: Estimated ARDL model for INV and ARDL(3,3,1,3,1,3,1)

	(a) Estimated Long Run Coefficients		
Regressor	Coefficients	Standard Error	T-Ratio (Prob*1%,**5%)
GDP	0.0043446	0.0043122	1.0075

PRD	-6.6787	3.7838	-1.7651**
LOS	33.8986	16.3256	2.0764**
PRC	-249.3923	281.9289	-088459
LBR	3585345	891619.5	4.0212*
PRF	774.4979	352.2121	2.1990**)
CC	1505.2	844.3751	1.7826**
(b) ***Error Correction Representation for the Selected ARDL Model***			
ΔINV(-1)	0.16997	0.18882	0.90016
ΔINV(-2)	0.48957	0.20155	2.4290**
ΔGDP	0.0059868	0.0014745	4.0602*
ΔGDP(-1)	0.0016574	0.9025E-3	1.8365**
ΔGDP(-2)	0.0025157	0.0015835	1.5887
ΔPRD	-10.1093	2.0125	-5.0232*
ΔLOS	25.3575	7.5628	3.3529*
ΔINV(-1)	0.16997	0.18882	0.90016
ΔLOS(-1)	8.6339	4.3065	2.0049**
ΔLOS(-2)	-28.5626	7.7775	-3.6724*
ΔPRC	-339.5007	119.8321	-2.8331**
ΔLBR(-1)	-443323.3	406985.6	-1.0893
ΔLBR(-2)	-1723116	380972.0	-4.5229*
ΔPRF	475.3558	96.6420	4.9187*
INTERCEPT	726.3401	319.3265	2.2746**
ECM(-1)	-0.48255	0.15065	-3.2031*

In Table 3.22, coefficients are estimated in ARDL model when dependent variable is selected as amount of investments in electricity sector. As it is expressed before, there is a positive relationship between investments and GDP. Moreover, price has an inverse relation with investments because of the expectations about decrease in prices under competitive market environment. However, this coefficient is not found to be significant. In addition, labor supply and gross profit has a positive relationship with investments as it is expected through profitability and efficiency. The relationship between electricity production and investment is negative due to the time delay until generation of electricity, during construction period of new power plant projects. Moreover, as it is expected error correction term has a negative sign and statistically significant which indicates that if one of the independent variables is exposed to a random shock, system will come back to equilibrium approximately in 2.5 years. Hence, model for investments in electricity sector is expressed in Equation 3.15.

$$\widehat{INV} = 1505.2 - 6.6787PRD + 0.0043446GDP + 33.8986LOS - 249.3923PRC + 3585345LBR + 774.4979PRF \quad (3.15)$$

Table 3.23: Estimated ARDL model for LOS and ARDL (3,0,2,3,1,3,1)

Regressor	Coefficients	Standard Error	T-Ratio (Prob*1%,**5%)
(a) Estimated Long Run Coefficients			
GDP	-0.2061E-3	0.2460E-4	-8.3762*
PRD	0.21426	0.010086	21.2427*

INV	0.014203	0.0055564	2.5562**
PRC	8.9504	3.8562	2.3211**
LBR	-74271.7	11655.3	-6.3723*
PRF	-13.3933	3.4106	-3.9270*
CC	-36.5560	8.1748	-4.4718*
	(b) ***Error Correction Representation for the Selected ARDL Model***		
ΔLOS(-1)	0.11112	0.088976	1.2489
ΔLOS(-2)	0.91422	0.10706	8.5394*
ΔGDP	-0.1363E-3	0.2864E-4	-4.7598*
ΔPRD	0.25535	0.028612	8.9244*
ΔPRD(-1)	-0.063927	0.023894	-2.6754**
ΔINV	0.014423	0.0038644	3.7323*
ΔINV(-1)	-0.0041388	0.0039002	-1.0612
ΔINV(-2)	-0.013069	0.0039782	-3.2852*
ΔPRC	10.6172	2.4552	4.3244*
ΔLBR	-18948.1	9994.8	-1.8958**
ΔLBR(-1)	16770.6	8156.8	2.0560**)
ΔLBR(-2)	40497.9	9416.2	4.3009*
ΔPRF	-12.2934	2.1284	-5.7759*
INTERCEPT	-24.1837	5.9416	-4.0702*
ECM(-1)	0.66155	0.084305	-7.8472*

Estimated short and long run coefficients are displayed in Table 3.23 when dependent variable is selected as electricity transmission and distribution losses. In Equation 3.16, model for electricity transmission and distribution losses is displayed for the supply side of electricity sector.

$$\widehat{LOS} = -36.5560 + 0.21426PRD - 0.0002061GDP + 0.014203INV + 8.9804PRC - 74271.7LBR - 13.3933PRF \qquad (3.16)$$

From Equation 3.16 it can be seen that GDP and gross profit are negatively related to electricity losses. Conversely, the effects of investments and annual total production on electricity losses are positive. The relationship between electricity losses and prices are positive as increase in prices makes electricity less affordable so illegal consumption increase. There is a negative relationship between labor supply in electricity sector and electricity losses that may be due to the lack of supervision caused by decrease in the labor force in electricity sector. In addition, error correction term indicates that if a random shock occurs, dependent variable could return back to equilibrium approximately in 1 year and 6 months.

Table 3.24: Estimated ARDL model for LBR and ARDL(1,1,0,3,1,0,1)

(a) Estimated Long Run Coefficients			
Regressor	Coefficients	Standard Error	T-Ratio (Prob*1%,**5%)
GDP	-0.7728E-9	0.1406E-8	-0.54878
PRD	0.6331E-6	0.1019E-5	0.62146

INV	0.4701E-6	0.1394E-6	3.3731*
PRC	-0.5021E-4	0.1385-3	-0.36250
LOS	-0.2658E-5	0.3821E-5	-0.69568
PRF	0.3037E-3	0.1990E-3	1.5261
CC	-0.7887E-5	0.3052	-0.025841
(b) ***Error Correction Representation for the Selected ARDL Model***			
ΔGDP	0.2655E-9	0.5600E-9	0.47401
ΔPRD	0.2180E-6	0.3856E-6	0.56525
ΔINV	0.7252E-7	0.5259E-7	1.3789
ΔINV(-1)	-0.1036E-6	0.5986E-7	-1.7316**
ΔINV(-2)	-0.1503E-6	0.5476E-7	-2.7453**
ΔPRC	0.9814E-4	0.3802E-4	2.5811**
ΔLOS	-0.9150E-6	0.1482E-5	-0.61749
ΔPRF	-0.2687E-4	0.2563E-4	-1.0482
ΔPRF(-1)	-0.1136E-3	0.2806E-4	-4.0500*
ΔPRF(-2)	-0.6045E-4	0.2299E-4	-4.0500*
ΔPRF(-2)	-0.6045E-4	0.2299E-4	-2.6295**
INTERCEPT	-0.2715E-5	0.1053E-3	-0.025785
ECM(-1)	-0.34425	0.11579	-2.9731*

Long run coefficients and error correction model are expressed for the model whose dependent variable is selected as labor force in electricity sector in Table 3.24. Even though coefficients are not found to be statistically significant as Bounds-Testing procedure claims that there exists a cointegration relationship in the long run so that model can be expressed in a linear form as:

$$\widehat{LBR} = -0.0000078 + 0.000000633PRD - 0.00000000077GDP + 0.000000471INV - 0.0000502PRC - 0.0000026LOS + 0.0003037PRF \quad (3.17)$$

Table 3.25: Estimated ARDL model for PRF and ARDL(1,0,2,3,2,3,3)

(a) ***Estimated Long Run Coefficients***			
Regressor	Coefficients	Standard Error	T-Ratio (Prob*1%,**5%)
GDP	-0.7719E-5	0.3126E-5	-2.4698**
PRD	0.0089951	0.0026818	3.3541*
INV	0.7169E-3	0.3439E-3	2.0850**
PRC	0.83868	0.16371	5.1230*
LOS	-0.046198	0.10813	-4.2723*
LBR	-4398.5	848.2747	-5.1852*
CC	-2.2156	0.45328	-4.8878*
(b) ***Error Correction Representation for the Selected ARDL Model***			
ΔGDP	-0.5963E-5	0.2273E-5	-2.6228(**
ΔPRD	0.015369	0.0021057	7.2991*
ΔPRD(-1)	-0.0046459	0.0013986	-3.3219*
ΔINV	0.0010394	0.2122E-3	4.8981*
ΔINV(-1)	0.2637E-3	0.2448E-3	-1.0773
ΔINV(-2)	-0.0011130	0.2100E-3	-5.3007*
ΔPRC	0.88819	0.12217	7.2701*
ΔPRC(-1)	-0.21642	0.12966	-1.6691
ΔLOS	-0.048463	0.0091102	-5.3187*
ΔLOS(-1)	0.0024918	0.0057685	0.43197
ΔLOS(-2)	0.056101	0.0080238	6.9919*
ΔLBR	-1924.4	618.7793	-3.1100*
ΔLBR(-1)	1415.6	553.4143	2.5579**
ΔLBR(-2)	2921.4	510.6164	5.7214*
INTERCEPT	-1.7114	0.35365	-4.8393*
ECM(-1)	-0.77245	0.098601	-7.8341*

In Table 3.25, ARDL model estimated for gross profit in electricity sector. With long run coefficients and error correction model estimated, linear model for gross profit in electricity sector could be expressed in Equation 3.18.

$$\widehat{PRF} = -2.2156 + 0.0089951PRD - 0.00007719GDP + 0.0007169INV + 0.83868PRC - 4398.5LBR - 0.046198LOS \tag{3.18}$$

In addition to analytical models expressed, impulse response graphs and variance decompositions are analyzed in order to determine the effect of random shock on annual electricity production. Figure 3.7 a-f contains the impulse response graphs of annual electricity production with respect to (a)GDP, (b) labor force in electricity sector, (c) gross profit in electricity sector, (d) investments in electricity sector, (e) electricity transmission and distribution losses and (f) annual average electricity prices. A random shock in GDP causes the electricity production to respond with a sharp decrease and not to position back to the equilibrium even in 15 years. The impact of labor supply in electricity sector on the electricity production is a decrease for 3 years and thereafter that to increase reaching to the equilibrium approximately in 18 years. A shock on the gross profit in electricity sector causes the electricity production to rapid increase at the moment of shock, and then slightly decreases up to the equilibrium approximately in 14 years. The investments in electricity sector do have also a long term impact on the electricity production to reach its equilibrium approximately in 15 years. The electricity production responses to a shock in electricity losses with a significant price decline which requires 15 years for equilibrium. The impact of annual electricity prices on the electricity production is a decrease for 3 years and thereafter that to increase reaching to the equilibrium approximately in 12 years.

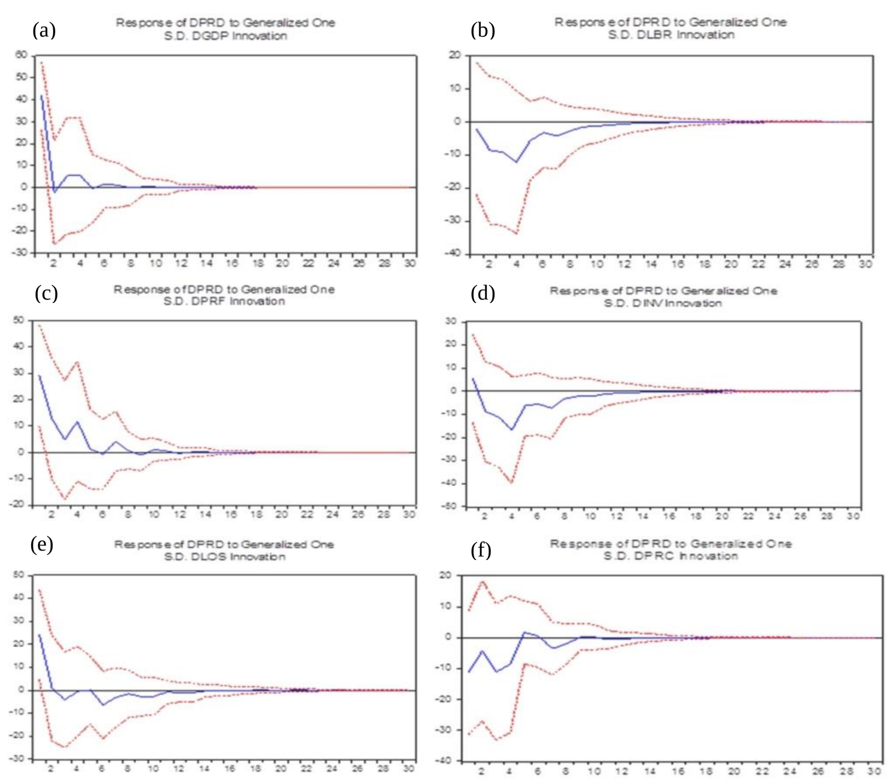


Figure 3.7: Impulse response graphs of electricity production to the other variables

In Table 3.26, results of generalized variance decomposition analysis are reported. The orders of the VAR systems are determined through Akaike Information Criterion (AIC). Results are reported with first five years, then tenth, twentieth and fifth years until systems for each variable come back to equilibrium. The results show that 53% to 83% of the forecast error variance in production can be explained by its own shock while the impacts of GDP is around 30% and gross profit is around 15%. Annual average electricity prices explain about 5% of forecast variance error and investments explain about 10% of forecast variance error on the electricity consumption. Electricity losses and labor force in electricity sector has small effect on explaining forecast variance error by explaining 7% and 1% parts. Forecast error variance for production is represented in Panel C. Other panels, A to G except C also express forecast variance errors for GDP, gross profit, investments, annual average electricity prices , electricity losses and labor supply in electricity sector as independent variables, respectively.

Table 3.26: Generalized Forecast Error Variance Decomposition

	Horizon	**ΔGDP**	**ΔPRF**	**ΔPRD**	**ΔINV**	**ΔPRC**	**ΔLOS**	**ΔLBR**
	0	1.0000	0.32747	0.54054	0.10224	0.001874	0.019356	0.005083
	1	0.75848	0.26121	0.39872	0.080689	0.022783	0.032696	0.005064
	2	0.71885	0.24768	0.38492	0.077548	0.028736	0.054073	0.007925
	3	0.65554	0.24857	0.34902	0.066837	0.032807	0.13881	0.006983
Panel A	**4**	0.60534	0.23596	0.31913	0.11958	0.030784	0.12815	0.008208
	5	0.58348	0.23796	0.31188	0.13152	0.029928	0.12939	0.010088
	10	0.53781	0.22858	0.30411	0.12389	0.040327	0.14769	0.019105
	20	0.50114	0.21931	0.32356	0.11811	0.038361	0.14358	0.022129
	50	0.41964	0.19841	0.36682	0.10878	0.032965	0.13193	0.030310
	Horizon	**ΔGDP**	**ΔPRF**	**ΔPRD**	**ΔINV**	**ΔPRC**	**ΔLOS**	**ΔLBR**
	0	0.32747	1.0000	0.27496	0.38752	0.077588	0.073083	0.013381
	1	0.24864	0.87609	0.25816	0.39514	0.10180	0.050243	0.082129
	2	0.20104	0.83131	0.25014	0.31806	0.10885	0.071722	0.057229
	3	0.20548	0.80572	0.24876	0.29060	0.098866	0.11002	0.053418
Panel B	**4**	0.19444	0.75206	0.24436	0.27392	0.11588	0.12425	0.050197
	5	0.18319	0.71082	0.23991	0.27444	0.12122	0.13351	0.050708
	10	0.17379	0.64996	0.23547	0.25932	0.11333	0.13599	0.054622
	20	0.17753	0.59121	0.27200	0.23739	0.10425	0.13277	0.054374
	50	0.15479	0.48093	0.33241	0.19982	0.082948	0.12248	0.056204
	Horizon	**ΔGDP**	**ΔPRF**	**ΔPRD**	**ΔINV**	**ΔPRC**	**ΔLOS**	**ΔLBR**
	0	0.54054	0.27496	1.00000	0.412E-4	0.573E-5	0.036492	0.372E-4
	1	0.41460	0.22491	0.83800	0.041123	0.636E-4	0.038501	0.363E-4
	2	0.36973	0.21647	0.80177	0.035676	0.039751	0.052627	0.004116
	3	0.36873	0.18039	0.68497	0.058719	0.073824	0.094443	0.020648
Panel C	**4**	0.30118	0.14708	0.62571	0.14578	0.059695	0.078995	0.019397

	Horizon	ΔGDP	ΔPRF	ΔPRD	ΔINV	ΔPRC	ΔLOS	ΔLBR
	5	0.29702	0.15281	0.61056	0.15235	0.059216	0.079629	0.019541
	10	0.26032	0.12529	0.53460	0.13150	0.054816	0.099214	0.025468
	20	0.23042	0.12445	0.53816	0.11885	0.046070	0.094414	0.034673
	50	0.17097	0.11855	0.53952	0.099649	0.032036	0.090934	0.045631
	Horizon	**ΔGDP**	**ΔPRF**	**ΔPRD**	**ΔINV**	**ΔPRC**	**ΔLOS**	**ΔLBR**
	0	0.10224	0.38752	0.412E-5	1.0000	0.10474	0.02763	0.11603
	1	0.12000	0.30800	0.886E-4	0.80750	0.16746	0.08667	0.11182
	2	0.12133	0.30206	0.767E-4	0.69175	0.16048	0.17437	0.12085
	3	0.13291	0.27424	0.736E-4	0.57196	0.13981	0.13923	0.10009
Panel D	**4**	0.12568	0.27954	0.02068	0.54335	0.13433	0.13478	0.09452
	5	0.13872	0.29644	0.04689	0.52294	0.13002	0.12870	0.90050
	10	0.14330	0.27514	0.13360	0.45463	0.11430	0.12732	0.08644
	20	0.14615	0.24167	0.18714	0.38412	0.09831	0.12357	0.07996
	50	0.12685	0.20053	0.29935	0.28536	0.07979	0.11142	0.07423
	Horizon	**ΔGDP**	**ΔPRF**	**ΔPRD**	**ΔINV**	**ΔPRC**	**ΔLOS**	**ΔLBR**
	0	0.00187	0.07758	0.573E-5	0.10474	1.00000	0.03915	0.27740
	1	0.11722	0.05815	0.02145	0.07074	0.66745	0.04675	0.22838
	2	0.10293	0.06621	0.02692	0.06062	0.67426	0.05556	0.20225
Panel E	**3**	0.15330	0.05888	0.09959	0.08647	0.55479	0.05589	0.20390
	4	0.14411	0.07018	0.09317	0.07439	0.51966	0.09680	0.20074
	5	0.13651	0.08151	0.12861	0.07439	0.49198	0.09922	0.18467
	10	0.12071	0.10241	0.19235	0.07889	0.38583	0.09048	0.15903
	20	0.11026	0.10483	0.31149	0.07691	0.26699	0.09123	0.12413

Table 4.27 (Continued)

	Horizon	ΔGDP	ΔPRF	ΔPRD	ΔINV	ΔPRC	ΔLOS	ΔLBR
Panel E	**50**	0.09810	0.10720	0.41629	0.07409	0.14878	0.08908	0.09681
	Horizon	**ΔGDP**	**ΔPRF**	**ΔPRD**	**ΔINV**	**ΔPRC**	**ΔLOS**	**ΔLBR**
	0	0.01936	0.07308	0.03649	0.00276	0.03915	1.00000	0.00116
	1	0.02537	0.07027	0.03850	0.01304	0.03741	0.97044	0.00517
	2	0.02102	0.06466	0.03430	0.01144	0.03039	0.93896	0.00916
	3	0.02996	0.05785	0.04806	0.03964	0.08211	0.83838	0.66307
Panel F	**4**	0.02797	0.07320	0.04960	0.06881	0.07795	0.80935	0.07361
	5	0.03002	0.07139	0.05859	0.08867	0.08380	0.77709	0.08372
	10	0.07024	0.06030	0.10101	0.13959	0.09267	0.63476	0.08135
	20	0.07709	0.05983	0.11261	0.14301	0.09296	0.62420	0.07858
	50	0.07726	0.06031	0.11719	0.14232	0.09211	0.60844	0.07841
	Horizon	**ΔGDP**	**ΔPRF**	**ΔPRD**	**ΔINV**	**ΔPRC**	**ΔLOS**	**ΔLBR**
	0	0.00508	0.01338	0.372E-4	0.11603	0.27740	0.001165	1.0000
	1	0.00455	0.01323	0.500E-4	0.10273	0.31208	0.001417	0.88453
	2	0.00377	0.04995	0.01338	0.11586	0.26014	0.12765	0.72571
	3	0.01301	0.14245	0.04756	0.35547	0.16237	0.078492	0.41822
Panel G	**4**	0.03039	0.13779	0.06964	0.34022	0.16534	0.076766	0.39887
	5	0.03127	0.13464	0.06855	0.32859	0.17809	0.089019	0.38564
	10	0.04281	0.14319	0.10235	0.28146	0.15462	0.10403	0.31874
	20	0.06779	0.13631	0.15708	0.25449	0.13775	0.11870	0.27659
	50	0.07145	0.13079	0.23830	0.21534	0.11113	0.10432	0.23138

CHAPTER 4

Partial Equilibrium Analysis and Comparison of Models

To find equilibrium prices in electricity energy sector, partial equilibrium analysis are employed in this chapter. In microeconomic theory, under the condition of ceteris paribus, partial equilibrium prices are determined through equalizing quantity supplied and quantity demanded. Therefore, to find equilibrium prices of demand and supply, raw equations are extracted for the given values of all variables except the price. Hence, electricity consumption model transformed to a raw model with one unknown parameter is as follows:

$$CON_t = \gamma_t + \varphi_t PRC_t \tag{4.1}$$

Here, φ_t represent the partial coefficient estimated for electricity prices by different estimation techniques implemented in this thesis and γ_t is a constant for demand equation which is estimated through:

$$\widehat{\gamma_t} = \widehat{\alpha_t} + \widehat{\beta_{1,t}} GDP_t + \widehat{\beta_{2,t}} IND_t + \widehat{\beta_{3,t}} LOS_t + \widehat{\beta_{4,t}} URB_t \tag{4.2}$$

This equation is calculated for models based on different estimation techniques as OLS, ARDL and GMM implemented to original and first differenced data. Same procedure is implemented for electricity supply and raw models are acquired like expressed as:

$$PRD_t = \delta_t + \tau_t PRC_t \tag{4.3}$$

where τ_t represent the partial coefficient of electricity prices acquired from different estimation techniques and. δ_t is a constant for supply equation calculated as follows:

$$\widehat{\delta_t} = \widehat{\alpha_t} + \widehat{\beta_{1,t}} GDP_t + \widehat{\beta_{2,t}} INV_t + \widehat{\beta_{3,t}} LOS_t + \widehat{\beta_{4,t}} PRF_t + \hat{\beta}_{5,t} LBR_t \tag{4.4}$$

Thereafter, equilibrium prices are obtained by equalizing Equation 4.1 to Equation 4.3. Table 4.1 illustrates computed equilibrium prices in terms of cent/kwh.

Table 4.1: Equilibrium prices estimated for four different econometric models

Years	GMMeq	OLSeq	ARDLeq	Price
1970	7.326446	0.048099	2.767395	1.363636
1971	4.801743	0.060858	4.245877	1.333333
1972	1.502044	0.073225	4.714275	1.714286
1973	1.494967	0.086249	4.220244	1.857143
1974	5.068625	0.100041	4.034668	2.785714
1975	7.436649	0.106988	4.356143	2.857143
1976	7.478564	0.102344	5.001444	2.8125
1977	8.919491	0.108996	5.400025	3.444444
1978	8.285586	0.104526	4.790099	4.083333
1979	6.600548	0.088568	4.909428	3.315789
1980	4.139907	0.083071	5.706593	4.368421
1981	1.987879	0.067025	5.168875	4.463636
1982	6.299501	0.087885	7.95809	4.540373
1983	6.144964	0.090489	5.987778	3.879464
1984	8.898095	0.096387	9.219439	4.232877
1985	9.326713	0.091104	10.0292	5.664093
1986	10.98908	0.108948	9.315691	5.748879
1987	7.186579	0.083503	7.969828	4.616822
1988	10.44713	0.101078	8.162215	3.576355
1989	7.314943	0.076841	7.086939	4.100896
1990	7.990961	0.069349	6.478555	6.344709
1991	10.18368	0.0965	2.218648	6.476632
1992	13.89707	0.113172	6.694844	7.302135

1993	16.7045	0.123001	10.02994	8.445527
1994	11.0085	0.116273	6.229243	3.649006
1995	12.96111	0.12409	8.613517	3.43913
1996	13.13264	0.134399	9.397332	3.364734
1997	13.00256	0.146499	10.85863	3.202898
1998	9.211207	0.119383	12.62481	3.363951
1999	13.66612	0.151396	12.14177	3.948225
2000	16.14412	0.175946	11.95275	4.063704
2001	18.64021	0.204074	8.863952	4.12858
2002	20.38399	0.202228	10.64939	0.388649
2003	20.48995	0.188846	10.64497	0.408314
2004	18.76999	0.15795	10.40352	0.439098
2005	16.7499	0.137504	10.20419	0.465083
2006	15.0895	0.124866	9.685043	0.445768
2007	12.46875	0.102667	10.4012	0.413365
2008	9.158737	0.081427	8.523886	0.399958
2009	15.22993	0.135673	8.688961	0.447508
2010	13.41564	0.108855	11.39592	0.000452

Estimated equilibrium prices are found to be different from actual prices and the deviations between actual and estimated prices are represented in Table 4.2. This variation implies that practically electricity prices are not determined directly from partial equilibrium. In other words, electricity prices are not formed at the point of equilibrium. Since in Turkey for many years electricity sector is under control of the government, prices have been determined by the government intervention. Moreover, variant taxes collected from electricity market, either subsidies or consumption taxes, may have an effect on electricity prices which are not taken into account in this study due to lack of data.

Table 4.2: Deviation between estimated and actual prices for the methods used

Years	ΔGMM	ΔOLS	ΔARDL	Price
1970	5.96281	-1.31554	1.403758	1.363636
1971	3.46841	-1.27248	2.912544	1.333333
1972	-0.21224	-1.64106	2.999989	1.714286
1973	-0.36218	-1.77089	2.363101	1.857143
1974	2.28291	-2.68567	1.248954	2.785714
1975	4.579506	-2.75016	1.499	2.857143
1976	4.666064	-2.71016	2.188944	2.8125
1977	5.475047	-3.33545	1.955581	3.444444
1978	4.202252	-3.97881	0.706765	4.083333
1979	3.284759	-3.22722	1.593639	3.315789
1980	-0.22851	-4.28535	1.338172	4.368421
1981	-2.47576	-4.39661	0.705239	4.463636
1982	1.759129	-4.45249	3.417717	4.540373
1983	2.2655	-3.78898	2.108314	3.879464
1984	4.665218	-4.13649	4.986562	4.232877
1985	3.662621	-5.57299	4.365107	5.664093
1986	5.240204	-5.63993	3.566812	5.748879
1987	2.569757	-4.53332	3.353005	4.616822

1988	6.870776	-3.47528	4.58586	3.576355
1989	3.214047	-4.02406	2.986043	4.100896
1990	1.646253	-6.27536	0.133846	6.344709
1991	3.707046	-6.38013	-4.25798	6.476632
1992	6.594936	-7.18896	-0.60729	7.302135
1993	8.258976	-8.32253	1.584415	8.445527
1994	7.359496	-3.53273	2.580238	3.649006
1995	9.521976	-3.31504	5.174387	3.43913
1996	9.767901	-3.23034	6.032598	3.364734
1997	9.799664	-3.0564	7.655731	3.202898
1998	5.847256	-3.24457	9.260859	3.363951
1999	9.717895	-3.79683	8.193549	3.948225
2000	12.08042	-3.88776	7.889048	4.063704
2001	14.51163	-3.92451	4.735372	4.12858
2002	19.99534	-0.18642	10.26074	0.388649
2003	20.08163	-0.21947	10.23665	0.408314
2004	18.33089	-0.28115	9.964424	0.439098
2005	16.28482	-0.32758	9.73911	0.465083
2006	14.64374	-0.3209	9.239275	0.445768
2007	12.05538	-0.3107	9.987833	0.413365
2008	8.758779	-0.31853	8.123928	0.399958
2009	14.78242	-0.31183	8.241454	0.447508
2010	13.41519	0.108404	11.39547	0.000452

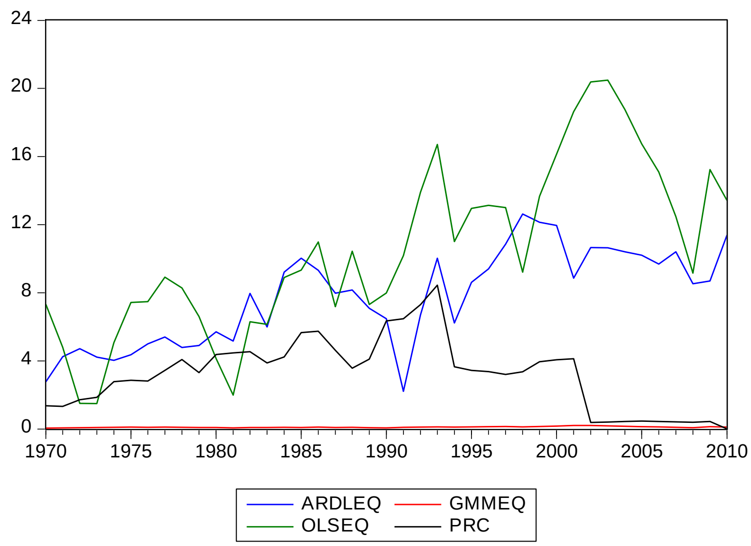


Figure 4.1: Equilibrium prices for proposed methods

In Figure 4.1, prices computed by using different estimation techniques and actual prices are represented. Red, green, blue and black lines represent computed prices through GMM, OLS, ARDL techniques and actual prices respectively.

Table 4.3: Descriptive statistics for the estimated equilibrium prices

	PRC	**OLSEQ**	**GMMEQ**	**ARDLEQ**

Mean	3.216989	10.48655	0.111715	7.749886
Median	3.439130	9.326713	0.104526	8.162215
Maximum	8.445527	20.48995	0.204074	12.62481
Minimum	0.000452	1.494967	0.048099	2.218648
Std. Dev.	2.080975	4.995841	0.036495	2.782857
Skewness	0.263848	0.209826	0.887854	-0.139957
Kurtosis	2.667562	2.363832	3.460918	1.906096
Jarque-Bera	0.664504	0.992228	5.749542	2.178085
Probability	0.717307	0.608892	0.056429	0.336539
c.o.v.	1.545904	2.099055	3.061104	2.784866

Equilibrium prices extracted from ordinary OLS, ARDL and actual prices are normally distributed with respect to Jarque Bera Test results within 1% significance level and Equilibrium prices extracted from GMM is normally distributed within 10% significance level which are displayed in Table 4.3. In addition, after actual prices, the lowest c.o.v value belongs to prices extracted from OLS technique. Therefore, variability is lower for OLS prices and actual prices. For selecting the most appropriate model, there are various tools to be used. In this thesis, comparisons are done by the mean squared error, mean absolute error and Theil inequality coefficient.

In statistics mean squared error (MSE) of an estimator could be accepted as a risk function which measures the average of squares of the errors. Errors in this calculation are equal to the difference between actual and estimated values. Therefore, MSE could be accepted as a risk function which reflects the most accurate estimation (Lehmann and George, 1988). Moreover, in statistics mean absolute error is another quantity used to compare the closeness of estimated values to actual values. (Hyndman and Koehler, 2005). In addition, Theil inequality coefficients (Thiel's U), provides a measure of how well a time series of estimated values compares to a corresponding time series of observed values. (Leuthold, 1975).

Mean squared error and mean absolute error statistics depend on scale of the dependent variable. Therefore, these are useful in the comparison of different measures of the same series. On the other hand, the Theil inequality is scale invariant. It always lies between zero and one where zero indicates a perfect fit. In Figure 4.2, the differences of actual prices from estimated prices are expressed for different prices resulted from each estimation method.

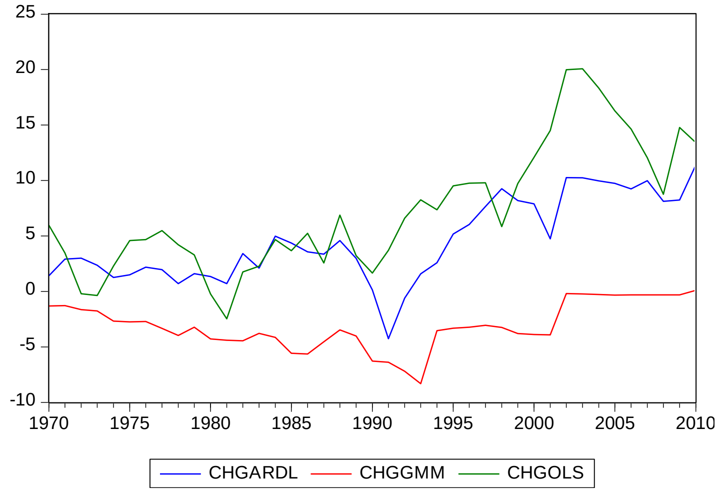


Figure 4.2: Deviation between estimated and actual prices for all models

Table 4.4: Statistical measurement methods results for all models

	GMM	**ARDL**	**OLS**
MSE	13.8966	34.0700	84.98027
MAE	3.11056	4.77022	7.429496
TIC	0.255547	0.256043	0.352342

Statistical models could be compared by using these coefficients as a measure of how they explain the given set of observations. The model with smallest MSE and MAE has the lowest variability. Moreover, the closest value to zero in TIC reflects better fit of model. In Table 4.4, measurement results for all models are displayed showing the most efficient price estimation is achieved by GMM.

CHAPTER 5

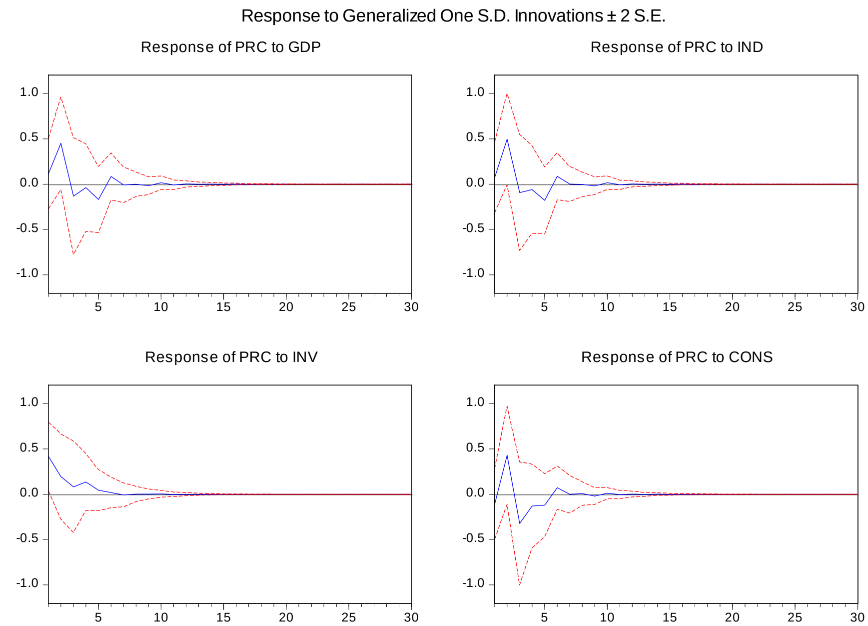
Risk Assessment of Electricity Pricing

Access to reliable electricity services is necessary for economic growth and sustainable development of a country. Therefore, it is important to known the risk factors in electricity sector in order to maintain equilibrium between supply and demand for maintaining sustainability in electricity energy sector. In this thesis, key risk factors are considered for Turkish electricity market which is summarized in Table 1.1. Therefore, data set are selected as each of them represents the related risk factor Turkish electricity market is exposed to.

Market risk can be specified as the main risk factor in electricity market including electricity price risk. Thus, market risk is represented through annual average electricity prices variable. Moreover, financial risks containing market failures and macroeconomic instability represented through; GDP, industry value added and urbanization ratio as they are important macroeconomic indicators affecting electricity production and consumption. Additionally, operational risks and strategic risks are displayed through the effect of variables such as; electricity transmission and distribution losses, investments for electricity sector, gross profit and labor force in electricity market. Figure 5.1 expresses impulse response graphs of annual average electricity prices with respect to GDP, industry value added, investments for electricity sector, annual electricity consumption, labor force in electricity sector, electricity transmission and distribution losses, annual electricity production, gross profit in electricity sector and urbanization ratio respectively. A random shock in GDP will be resulted in a sharp increase in prices for 5 years and then it started to decrease and return back to equilibrium within 13 years. A random shock in industry value added causes the electricity prices to respond with a sharp increase and not to position back to equilibrium even in 14 years. The impact of investments for electricity sector on electricity prices is a decrease of prices reaching to equilibrium in 10 years. A shock in annual electricity consumption causes the fluctuations in electricity prices then returning back to equilibrium within 13 years. Labor force in electricity sector have also long term impact on electricity prices to reach its equilibrium and responds first with a sharp decrease for 3 years. Electricity prices responses to a shock in electricity transmission and distribution losses with significant fluctuations which requires 17 years to come back equilibrium. A random shock in electricity production causes fluctuations in prices continuing for approximately 17 years then returning back to equilibrium. A shock on gross profit causes also fluctuations in prices and it returns back to equilibrium within 18 years. Urbanization ratio do have also long term impact on electricity prices to reach its equilibrium approximately in 20 years.

For reducing these risk factors which are depend on poor governance, institutional weaknesses, macroeconomic instability and lack of technical and managerial capacity requires understanding of impact of these risk factors.

Figure 5.1, indicates that, Turkish electricity market is vulnerable to macroeconomic and sectoral shocks and it should be transformed to more sturdy and competitive market in order to reduce these vulnerabilities. Impacts of these risk factors can be weakened with improving infrastructure and technical capacity of electricity sector, reducing foreign dependency of electricity market by encouraging investors to domestic renewable energy sources, increasing government subsidy especially for large scale power plant projects, and increasing supervision in electricity market with the enactment of new laws. Moreover, government should conduct up-to-date studies to analyze Turkish electricity market and should constitute both short and long term developments plans for electricity market.



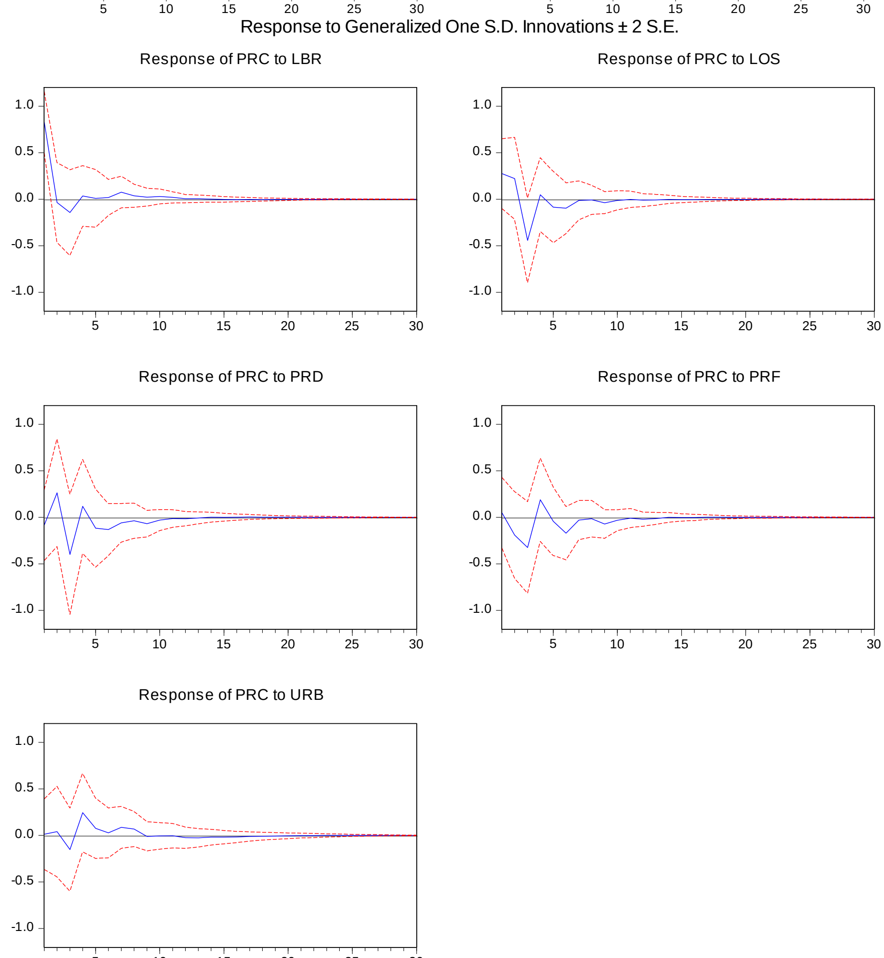


Figure 5.1: Impulse response graphs of electricity prices to the other variables

CHAPTER 6

Conclusion and Comments

Electricity is one of the main energy resources in the world and in Turkey. Therefore, it is important to understand the price behavior of electricity market for policy makers.

This study integrates different econometric methods to estimate the annual electricity supply and demand by using main macroeconomic and sectoral indicators. The aim of this study is to determine the effects of these variables on electricity consumption and production. The annual electricity demand and supply are estimated for Turkish electricity market for the period 1970-2010. The data set received from TEIAS and other sources is analyzed through various methods such as OLS, GMM and ARDL for comparison. The steps followed in analysis are as follows:

Firstly, electricity consumption, electricity production, main macroeconomic indicators such as; GDP, industry value added and urbanization ratio are independently modeled by using properties of time series analysis as well as the sectoral indicators such as; annual average electricity prices, gross profit and labor supply in electricity sector, electricity transmission and distribution losses, and investments in electricity sector.

Secondly, generalized method of moments estimation technique is used in order to determine the impact of both macroeconomic and sectoral variables on electricity demand and supply separately. With this method, electricity supply and demand are estimated as multivariate models.

Thirdly, ARDL method is used for estimating annual electricity demand and supply in Turkey for the same period. Moreover, impulse-response functions and error variance decomposition tables are extracted to detect effect of shocks on the systems.

Lastly, partial equilibrium analyses are employed by equalizing electricity demand equations to supply equations. Then, under ceteris paribus condition given the values of variables, the equilibrium prices are calculated and compared with actual prices. Comparative analyses are performed by using MSE, MAE and TIC values. This illustrates that generalized method of moments technique is reasonable for estimating annual electricity prices.

For the demand side of electricity market it is found that, annual electricity consumption is positively related to GDP. When national income increases, aggregate expenditure will increase which includes also electricity consumption. Industrial value added is found to be negatively related to electricity consumption because Turkey has been in an industrialization period so mainly increase in industrial output comes from increased efficiency which may stimulate a decrease in the usage of electricity in industry. Moreover, electricity transmission and distribution losses have positive effect on electricity consumption since unpaid consumption of a basic facility attracts low income consumers that this leads to an increase in electricity consumption. Urbanization rate also has positive impact on electricity consumption. Through urbanization, consumption of electricity increases by the development of industry, housing and transportation facilities. For the demand side, most importantly, it is found that annual average electricity prices have an inverse relationship with electricity consumption because of the law of demand explained in microeconomics.

On the other hand, for the supply side of electricity market, results indicate that, annual electricity production is positively related to GDP. Increase in GDP leads to increase in aggregate expenditure which is resulted in the decrease of inventories. For the elimination of the decreased inventories, aggregate production should increase which comprises electricity production as well. Moreover, an inverse relationship between electricity losses and electricity production is observed as increase in losses will stimulate more electricity production in order to prevent deficit in supply. In addition, gross profit is positively related to electricity production because increase in profitability leads to increase in production. Investment is found to be negatively related to electricity production. The long construction period of power plant projects creates a production gap since it takes a long time to start electricity generation. Labor supply in electricity sector is found to be positively related to electricity production. Most importantly, in the supply side of electricity market, price found to be negatively related to electricity production based on ARDL procedure results. If there is an excess production of electricity in order to prevent supply deficit, prices can decrease. On the other hand, from GMM estimation the relationship between electricity production and annual average electricity prices are found to be positive which is more prevalent result in economic theory.

For more sensitive modeling, it is needed to use reliable and qualified data as an input in analysis. In addition, adding the price and consumption data of natural gas into econometric models could be more effective in constructing partial equilibrium models for electricity prices. However, this data could not be acquired due to confidentiality.

This thesis reveals the effect of main macroeconomic and sectoral indicators on annual electricity supply and demand. It also considers the fragility of electricity market to local shocks in electricity sector or more comprehensive macroeconomic shocks which affects economic stability. With this manner, this study is a beneficial input for risk management strategy development for the electricity market in Turkey. It also shows that since Turkey has still been in liberalization period, annual average electricity prices are not determined with respect to market equilibrium directly. Even though, the most suitable estimation method is selected as GMM to observe overall effect of variables used in this thesis on electricity market.

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APPENDIX 1

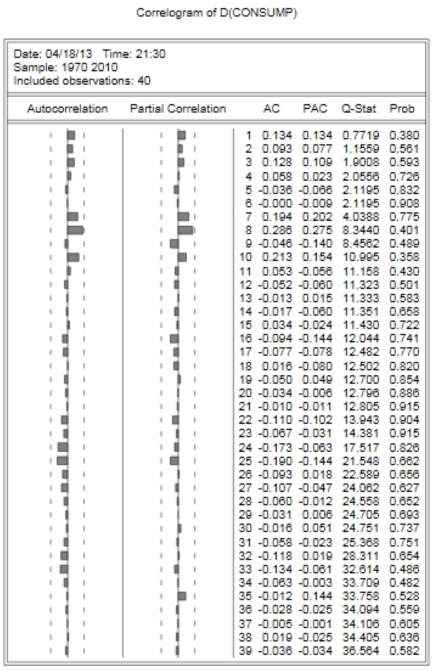
Time Series Correlograms and Diagnostic Checks

Table A.1.1: Time series model for electricity consumption per capita

Dependent Variable: DCONS
Method: Least Squares
Sample (adjusted): 1971 2010
Included observations: 40 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	56.45906	8.439097	6.690178	0.0000

R-squared	0.000000	Mean dependent var	56.45906
Adjusted R-squared	0.000000	S.D. dependent var	53.37354
S.E. of regression	53.37354	Akaike info criterion	10.81719
Sum squared resid	111100.7	Schwarz criterion	10.85941
Log likelihood	-215.3438	Hannan-Quinn criter.	10.83246
Durbin-Watson stat	1.587062		



Correlogram of D(CONSUMP)

Date: 04/18/13 Time: 21:30
Sample: 1970 2010
Included observations: 40

	AC	PAC	Q-Stat	Prob
1	0.134	0.134	0.7719	0.380
2	0.093	0.077	1.1559	0.561
3	0.128	0.109	1.9008	0.593
4	0.058	0.023	2.0556	0.726
5	-0.036	-0.066	2.1195	0.832
6	-0.000	-0.009	2.1195	0.908
7	0.194	0.202	4.0388	0.775
8	0.286	0.275	8.3440	0.401
9	-0.046	-0.140	8.4562	0.489
10	0.213	0.154	10.995	0.358
11	0.053	-0.056	11.158	0.430
12	-0.052	-0.060	11.323	0.501
13	-0.013	0.015	11.333	0.583
14	-0.017	-0.060	11.351	0.658
15	0.034	-0.024	11.430	0.722
16	-0.094	-0.144	12.044	0.741
17	-0.077	-0.078	12.482	0.770
18	0.016	-0.080	12.502	0.820
19	-0.050	0.049	12.700	0.854
20	-0.034	-0.006	12.796	0.886
21	-0.010	-0.011	12.805	0.915
22	-0.110	-0.102	13.943	0.904
23	-0.067	-0.031	14.381	0.915
24	-0.173	-0.063	17.517	0.826
25	-0.190	-0.144	21.548	0.662
26	-0.093	0.018	22.589	0.656
27	-0.107	-0.047	24.062	0.627
28	-0.060	-0.012	24.558	0.652
29	-0.031	0.006	24.705	0.693
30	-0.016	0.051	24.751	0.737
31	-0.058	-0.023	25.368	0.751
32	-0.118	0.019	28.311	0.654
33	-0.134	-0.061	32.614	0.486
34	-0.063	-0.003	33.709	0.482
35	-0.012	0.144	33.758	0.528
36	-0.028	-0.025	34.094	0.559
37	-0.005	-0.001	34.106	0.605
38	0.019	-0.025	34.405	0.636
39	-0.036	-0.034	36.564	0.582

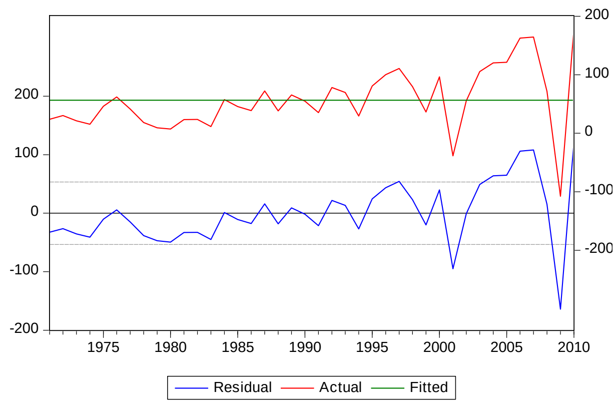


Figure A.1.1: Diagnostic graphs for annual electricity consumption per capita

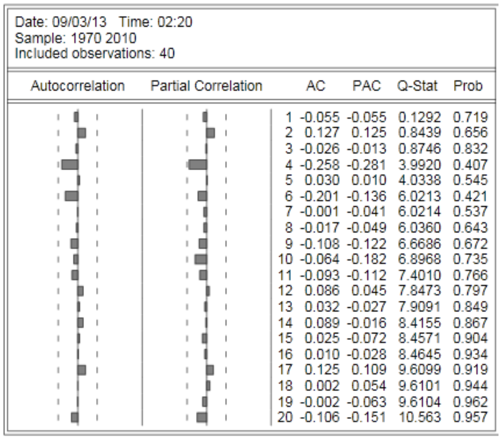
Table A.1.2: Time series model for logarithm of GDP per capita

Dependent Variable: DLNGDP
Method: Least Squares
Sample (adjusted): 1971 2010
Included observations: 40 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	0.075944	0.026460	2.870158	0.0066

R-squared	0.000000	Mean dependent var	0.075944
Adjusted R-squared	0.000000	S.D. dependent var	0.167347
S.E. of regression	0.167347	Akaike info criterion	-0.712815
Sum squared resid	1.092193	Schwarz criterion	-0.670593
Log likelihood	15.25630	Hannan-Quinn criter.	-0.697549
Durbin-Watson stat	2.082939		

Correlogram of DLNGDP


Date: 09/03/13 Time: 02:20
Sample: 1970 2010
Included observations: 40

Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob
		1	-0.055	-0.055	0.1292	0.719
		2	0.127	0.125	0.8439	0.656
		3	-0.026	-0.013	0.8746	0.832
		4	-0.258	-0.281	3.9920	0.407
		5	0.030	0.010	4.0338	0.545
		6	-0.201	-0.136	6.0213	0.421
		7	-0.001	-0.041	6.0214	0.537
		8	-0.017	-0.049	6.0360	0.643
		9	-0.108	-0.122	6.6686	0.672
		10	-0.064	-0.182	6.8968	0.735
		11	-0.093	-0.112	7.4010	0.766
		12	0.086	0.045	7.8473	0.797
		13	0.032	-0.027	7.9091	0.849
		14	0.089	-0.016	8.4155	0.867
		15	0.025	-0.072	8.4571	0.904
		16	0.010	-0.028	8.4645	0.934
		17	0.125	0.109	9.6099	0.919
		18	0.002	0.054	9.6101	0.944
		19	-0.002	-0.063	9.6104	0.962
		20	-0.106	-0.151	10.563	0.957

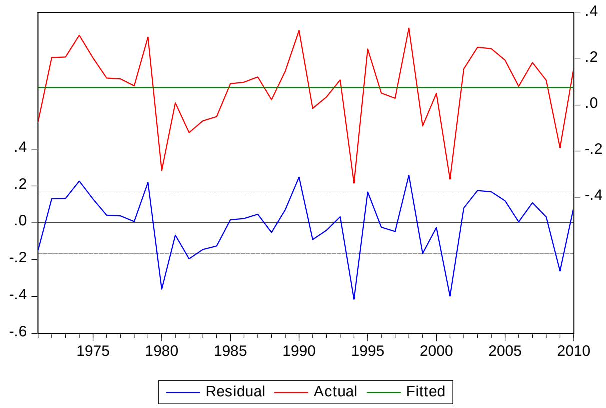


Figure A.1.2: Diagnostic graphs for logarithm of GDP per capita

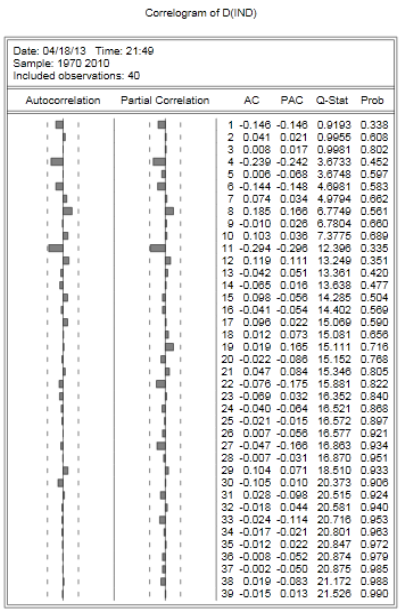
Table A.1.3: Time series model for industry value added per capita

Dependent Variable: DIND
Method: Least Squares
Sample (adjusted): 1973 2010
Included observations: 38 after adjustments
Convergence achieved after 17 iterations
MA Backcast: 1971 1972

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	55.67247	32.27659	1.724856	0.0939
AR(1)	-0.803666	0.173924	-4.620801	0.0001
AR(2)	-0.669322	0.214747	-3.116786	0.0038
MA(1)	0.618413	0.100414	6.158658	0.0000
MA(2)	0.892038	0.068396	13.04222	0.0000

R-squared	0.129824	Mean dependent var	58.89851
Adjusted R-squared	0.024348	S.D. dependent var	197.5660
S.E. of regression	195.1460	Akaike info criterion	13.50745
Sum squared resid	1256704.	Schwarz criterion	13.72292
Log likelihood	-251.6416	Hannan-Quinn criter.	13.58412
F-statistic	1.230842	Durbin-Watson stat	1.927341
Prob(F-statistic)	0.316764		

Inverted AR Roots	-.40+.71i	-.40-.71i
Inverted MA Roots	-.31+.89i	-.31-.89i



Correlogram of D(IND)

Date: 04/18/13 Time: 21:49
Sample: 1970 2010
Included observations: 40

	AC	PAC	Q-Stat	Prob
1	-0.146	-0.146	0.9193	0.338
2	0.041	0.021	0.9955	0.608
3	0.008	0.017	0.9981	0.802
4	-0.239	-0.242	3.6733	0.452
5	0.006	-0.068	3.6748	0.597
6	-0.144	-0.148	4.6981	0.583
7	0.074	0.034	4.9794	0.662
8	0.185	0.166	6.7749	0.561
9	-0.010	0.026	6.7804	0.660
10	0.103	0.036	7.3775	0.689
11	-0.294	-0.296	12.396	0.335
12	0.119	0.111	13.249	0.351
13	-0.042	0.051	13.361	0.420
14	-0.065	0.016	13.638	0.477
15	0.098	-0.056	14.285	0.504
16	-0.041	-0.054	14.402	0.569
17	0.096	0.022	15.069	0.590
18	0.012	0.073	15.081	0.656
19	0.019	0.165	15.111	0.716
20	-0.022	-0.086	15.152	0.768
21	0.047	0.084	15.346	0.805
22	-0.076	-0.175	15.881	0.822
23	-0.069	0.032	16.352	0.840
24	-0.040	-0.064	16.521	0.868
25	-0.021	-0.015	16.572	0.897
26	0.007	-0.056	16.577	0.921
27	-0.047	-0.166	16.863	0.934
28	-0.007	-0.031	16.870	0.951
29	0.104	0.071	18.510	0.933
30	-0.105	0.010	20.373	0.906
31	0.028	-0.098	20.515	0.924
32	-0.018	0.044	20.581	0.940
33	-0.024	-0.114	20.716	0.953
34	-0.017	-0.021	20.801	0.963
35	-0.012	0.022	20.847	0.972
36	-0.008	-0.052	20.874	0.979
37	-0.002	-0.050	20.875	0.985
38	0.019	-0.083	21.172	0.988
39	-0.015	0.013	21.526	0.990

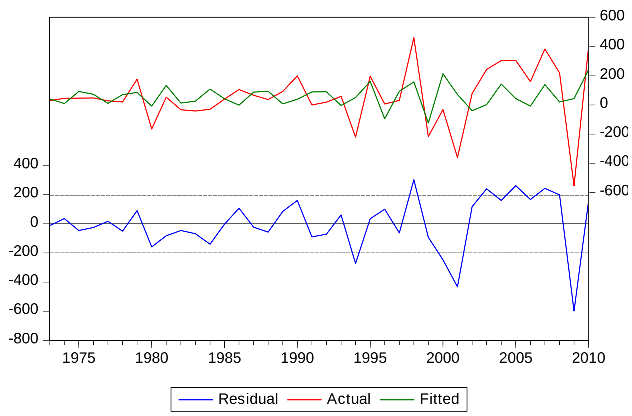


Figure A.1.3: Diagnostic graphs for industry value added per capita

Table A.1.4: ARMA roots for time series model of industry value added per capita

Inverse Roots of AR/MA Polynomial(s)
Specification: DIND AR(1) MA(1) AR(2) MA(2) C
Sample: 1970 2010
Included observations: 38

AR Root(s)	Modulus	Cycle
-0.401833 ± 0.712637i	0.818121	3.014640

No root lies outside the unit circle.
ARMA model is stationary.

MA Root(s)	Modulus	Cycle
-0.309206 ± 0.892429i	0.944478	3.299422

No root lies outside the unit circle.
ARMA model is invertible.

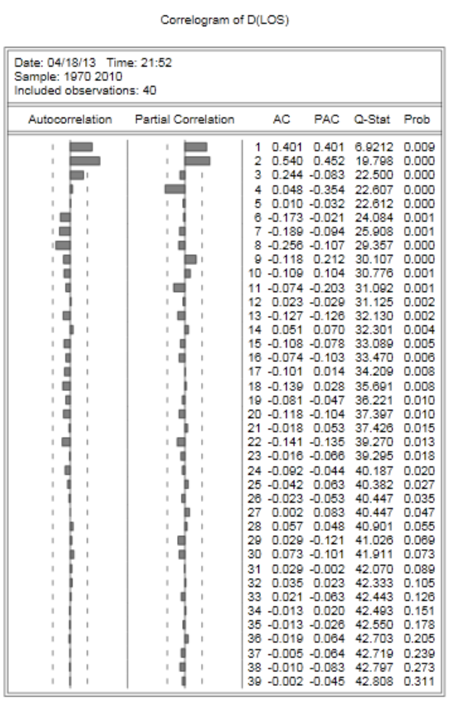
Table A.1.5: Time series model for electricity transmission and distribution losses per capita

Dependent Variable: DLOS
Method: Least Squares
Sample (adjusted): 1971 2010
Included observations: 40 after adjustments
Convergence achieved after 11 iterations
MA Backcast: 1969 1970

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	10.24809	3.011334	3.403174	0.0016
MA(1)	0.121646	0.068066	1.787166	0.0821
MA(2)	0.929248	0.047692	19.48438	0.0000

R-squared	0.471939	Mean dependent var	9.774055
Adjusted R-squared	0.443395	S.D. dependent var	12.43317
S.E. of regression	9.275889	Akaike info criterion	7.364752
Sum squared resid	3183.559	Schwarz criterion	7.491418
Log likelihood	-144.2950	Hannan-Quinn criter.	7.410551
F-statistic	16.53381	Durbin-Watson stat	1.695728
Prob(F-statistic)	0.000007		

Inverted MA Roots	-.06+.96i	-.06-.96i


Correlogram of D(LOS)

Date: 04/18/13 Time: 21:52
Sample: 1970 2010
Included observations: 40

	AC	PAC	Q-Stat	Prob
1	0.401	0.401	6.9212	0.009
2	0.540	0.452	19.798	0.000
3	0.244	-0.083	22.500	0.000
4	0.048	-0.354	22.607	0.000
5	0.010	-0.032	22.612	0.000
6	-0.173	-0.021	24.084	0.001
7	-0.189	-0.094	25.908	0.001
8	-0.256	-0.107	29.357	0.000
9	-0.118	0.212	30.107	0.000
10	-0.109	0.104	30.776	0.001
11	-0.074	-0.203	31.092	0.001
12	0.023	-0.029	31.125	0.002
13	-0.127	-0.126	32.130	0.002
14	0.051	0.070	32.301	0.004
15	-0.108	-0.078	33.089	0.005
16	-0.074	-0.103	33.470	0.006
17	-0.101	0.014	34.209	0.008
18	-0.139	0.028	35.691	0.008
19	-0.081	-0.047	36.221	0.010
20	-0.118	-0.104	37.397	0.010
21	-0.018	0.053	37.426	0.015
22	-0.141	-0.135	39.270	0.013
23	-0.016	-0.066	39.295	0.018
24	-0.092	-0.044	40.187	0.020
25	-0.042	0.063	40.382	0.027
26	-0.023	-0.053	40.447	0.035
27	0.002	0.083	40.447	0.047
28	0.057	0.048	40.901	0.055
29	0.029	-0.121	41.026	0.069
30	0.073	-0.101	41.911	0.073
31	0.029	-0.002	42.070	0.089
32	0.035	0.023	42.333	0.105
33	0.021	-0.063	42.443	0.126
34	-0.013	0.020	42.493	0.151
35	-0.013	-0.026	42.550	0.178
36	-0.019	0.064	42.703	0.205
37	-0.005	-0.064	42.719	0.239
38	-0.010	-0.083	42.797	0.273
39	-0.002	-0.045	42.808	0.311

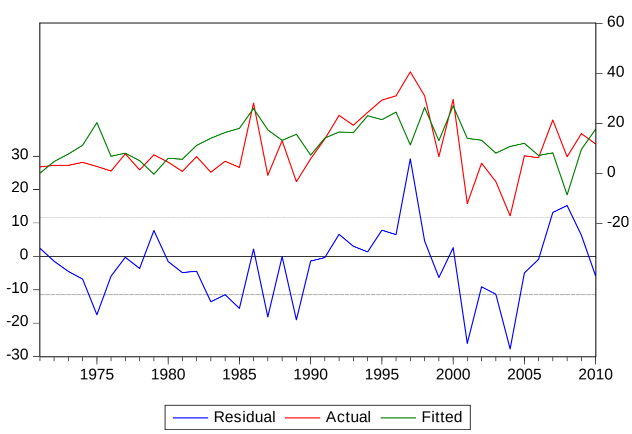


Figure A.1.4: Diagnostic graphs for electricity transmission and distribution losses per capita

Table A.1.6: ARMA roots for electricity transmission and distribution losses model

Inverse Roots of AR/MA Polynomial(s)
Specification: DLOS MA(1) MA(2) C
Sample: 1970 2010
Included observations: 40

MA Root(s)	Modulus	Cycle
-0.060823 ± 0.962054i	0.963975	3.845433

No root lies outside the unit circle.
ARMA model is invertible.

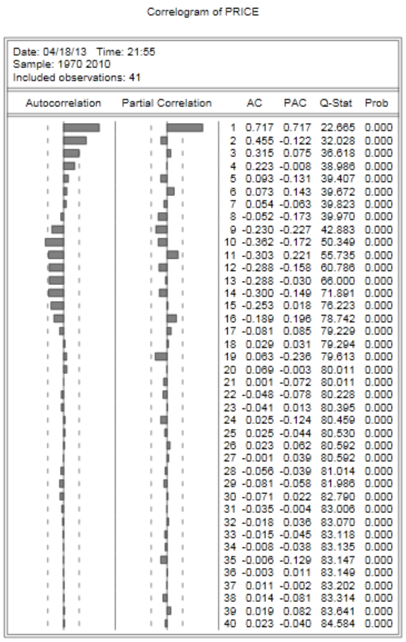
Table A.1.7: Time series model for annual average electricity prices

Dependent Variable: PRC
Method: Least Squares
Sample (adjusted): 1971 2010
Included observations: 40 after adjustments
Convergence achieved after 3 iterations

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	3.058442	0.903685	3.384441	0.0052
AR(1)	0.857384	0.090096	9.516360	0.0000

R-squared	0.704421	Mean dependent var	3.263323
Adjusted R-squared	0.696642	S.D. dependent var	2.085957
S.E. of regression	1.148902	Akaike info criterion	3.164196
Sum squared resid	50.15905	Schwarz criterion	3.248640
Log likelihood	-61.28393	Hannan-Quinn criter.	3.194729
F-statistic	90.56110	Durbin-Watson stat	1.910225
Prob(F-statistic)	0.000000		

Inverted AR Roots	.86



Correlogram of PRICE

Date: 04/18/13 Time: 21:55
Sample: 1970 2010
Included observations: 41

	AC	PAC	Q-Stat	Prob
1	0.717	0.717	22.665	0.000
2	0.455	-0.122	32.028	0.000
3	0.315	0.075	36.618	0.000
4	0.223	-0.008	38.986	0.000
5	0.093	-0.131	39.407	0.000
6	0.073	0.143	39.672	0.000
7	0.054	-0.063	39.823	0.000
8	-0.052	-0.173	39.970	0.000
9	-0.230	-0.227	42.883	0.000
10	-0.362	-0.172	50.349	0.000
11	-0.303	0.221	55.735	0.000
12	-0.288	-0.158	60.786	0.000
13	-0.288	-0.030	66.000	0.000
14	-0.300	-0.149	71.891	0.000
15	-0.253	0.018	76.223	0.000
16	-0.189	0.196	78.742	0.000
17	-0.081	0.085	79.229	0.000
18	0.029	0.031	79.294	0.000
19	0.063	-0.236	79.613	0.000
20	0.069	-0.003	80.011	0.000
21	0.001	-0.072	80.011	0.000
22	-0.048	-0.078	80.228	0.000
23	-0.041	0.013	80.395	0.000
24	0.025	-0.124	80.459	0.000
25	0.025	-0.044	80.530	0.000
26	0.023	0.062	80.592	0.000
27	-0.001	0.039	80.592	0.000
28	-0.056	-0.039	81.014	0.000
29	-0.081	-0.058	81.986	0.000
30	-0.071	0.022	82.790	0.000
31	-0.035	-0.004	83.006	0.000
32	-0.018	0.036	83.070	0.000
33	-0.015	-0.045	83.118	0.000
34	-0.008	-0.038	83.135	0.000
35	-0.006	-0.129	83.147	0.000
36	-0.003	0.011	83.149	0.000
37	0.011	-0.002	83.202	0.000
38	0.014	-0.081	83.314	0.000
39	0.019	0.082	83.641	0.000
40	0.023	-0.040	84.584	0.000

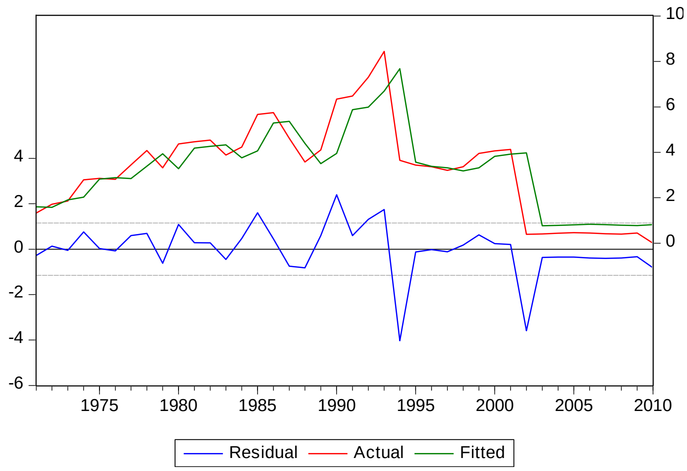


Figure A.1.5: Diagnostic graphs for mean adjusted annual average electricity prices

Table A.1.8: ARMA roots of time series model for annual average electricity prices

Inverse Roots of AR/MA Polynomial(s)
Specification: PRC AR(1) C
Sample: 1970 2010
Included observations: 40

AR Root(s)	Modulus	Cycle
0.857384	0.857384	

No root lies outside the unit circle.
ARMA model is stationary.

Table A.1.9: Time series model for urbanization rate
Dependent Variable: DURB
Method: Least Squares
Sample (adjusted): 1972 2010
Included observations: 39 after adjustments
Convergence achieved after 3 iterations

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	0.008176	0.002493	3.279158	0.0062
AR(1)	0.837607	0.089564	9.352078	0.0000

R-squared	0.702719	Mean dependent var	0.008098
Adjusted R-squared	0.694684	S.D. dependent var	0.004575
S.E. of regression	0.002528	Akaike info criterion	-9.072846
Sum squared resid	0.000236	Schwarz criterion	-8.987535
Log likelihood	178.9205	Hannan-Quinn criter.	-9.042237
F-statistic	87.46137	Durbin-Watson stat	1.852839
Prob(F-statistic)	0.000000		

Inverted AR Roots	.84

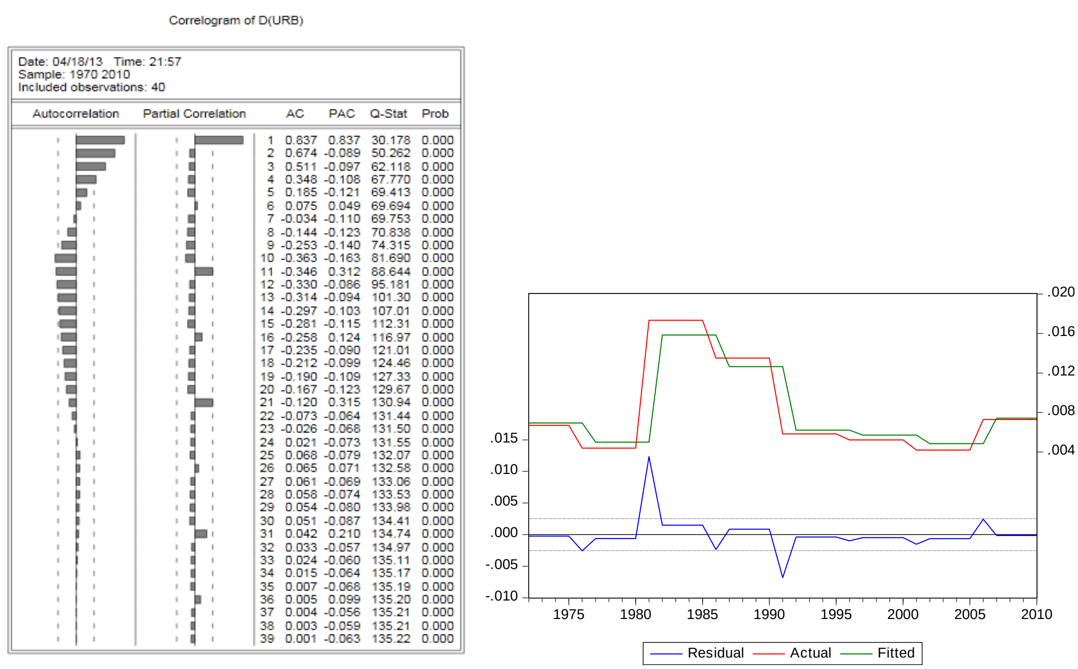


Figure A.1.6: Diagnostic graphs for urbanization ratio

Table A.1.10: ARMA roots for related time series model of urbanization rate

Inverse Roots of AR/MA Polynomial(s)
Specification: DURB AR(1) C
Sample: 1970 2010
Included observations: 39

AR Root(s)	Modulus	Cycle
0.837607	0.837607	

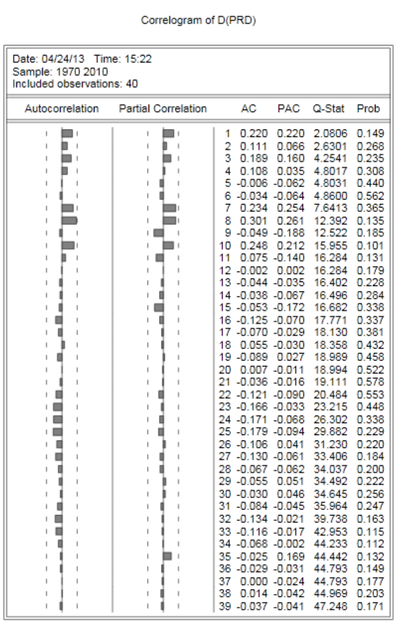
No root lies outside the unit circle.
ARMA model is stationary.

Table A.1.11: Time series model for electricity production per capita

Dependent Variable: DPRD
Method: Least Squares
Sample (adjusted): 1971 2010
Included observations: 40 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	66.49909	9.307101	7.144983	0.0000

R-squared	0.000000	Mean dependent var	66.49908
Adjusted R-squared	0.000000	S.D. dependent var	58.86328
S.E. of regression	58.86328	Akaike info criterion	11.01299
Sum squared resid	135130.5	Schwarz criterion	11.05522
Log likelihood	-219.2599	Hannan-Quinn criter.	11.02826
Durbin-Watson stat	1.432951		


Correlogram of D(PRD)

Date: 04/24/13   Time: 15:22
Sample: 1970 2010
Included observations: 40

	AC	PAC	Q-Stat	Prob
1	0.220	0.220	2.0806	0.149
2	0.111	0.066	2.6301	0.268
3	0.189	0.160	4.2541	0.235
4	0.108	0.035	4.8017	0.308
5	-0.006	-0.062	4.8031	0.440
6	-0.034	-0.064	4.8600	0.562
7	0.234	0.254	7.6413	0.365
8	0.301	0.261	12.392	0.135
9	-0.049	-0.188	12.522	0.185
10	0.248	0.212	15.955	0.101
11	0.075	-0.140	16.284	0.131
12	-0.002	0.002	16.284	0.179
13	-0.044	-0.035	16.402	0.228
14	-0.038	-0.067	16.496	0.284
15	-0.053	-0.172	16.682	0.338
16	-0.125	-0.070	17.771	0.337
17	-0.070	-0.029	18.130	0.381
18	0.055	-0.030	18.358	0.432
19	-0.089	0.027	18.989	0.458
20	0.007	-0.011	18.994	0.522
21	-0.036	-0.016	19.111	0.578
22	-0.121	-0.090	20.484	0.553
23	-0.166	-0.033	23.215	0.448
24	-0.171	-0.068	26.302	0.338
25	-0.179	-0.094	29.882	0.229
26	-0.106	0.041	31.230	0.220
27	-0.130	-0.061	33.406	0.184
28	-0.067	-0.062	34.037	0.200
29	-0.055	0.051	34.492	0.222
30	-0.030	0.046	34.645	0.256
31	-0.084	-0.045	35.964	0.247
32	-0.134	-0.021	39.738	0.163
33	-0.116	-0.017	42.953	0.115
34	-0.068	-0.002	44.233	0.112
35	-0.025	0.169	44.442	0.132
36	-0.029	-0.031	44.793	0.149
37	0.000	-0.024	44.793	0.177
38	0.014	-0.042	44.969	0.203
39	-0.037	-0.041	47.248	0.171

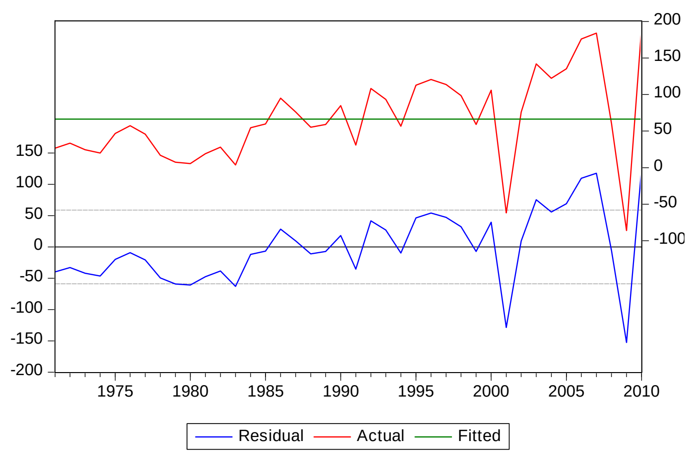


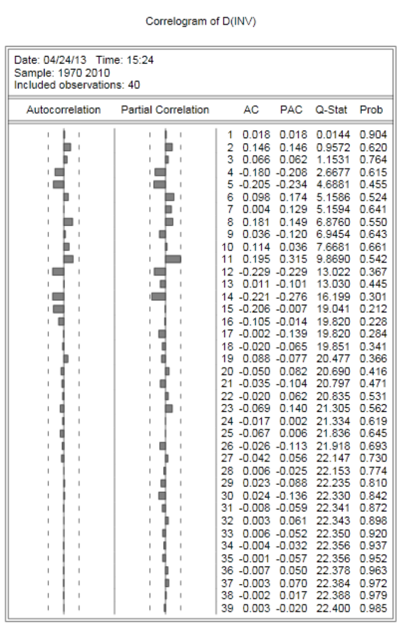
Figure A.1.7: Diagnostic graphs for electricity production per capi

Table A.1.12: Time series model for investments per capita in electricity sector

Dependent Variable: DINV
Method: Least Squares
Sample (adjusted): 1971 2010
Included observations: 40 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	0.902860	0.126405	7.142545	0.0000

R-squared	0.000000	Mean dependent var	0.902860
Adjusted R-squared	0.000000	S.D. dependent var	423.8330
S.E. of regression	423.8330	Akaike info criterion	14.96124
Sum squared resid	7005743.	Schwarz criterion	15.00346
Log likelihood	-298.2248	Hannan-Quinn criter.	14.97650
Durbin-Watson stat	1.955575		


Correlogram of D(INV)

Date: 04/24/13 Time: 15:24
Sample: 1970 2010
Included observations: 40

Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob
		1	0.018	0.018	0.0144	0.904
		2	0.146	0.146	0.9572	0.620
		3	0.066	0.062	1.1531	0.764
		4	-0.180	-0.208	2.6677	0.615
		5	-0.205	-0.234	4.6881	0.455
		6	0.098	0.174	5.1586	0.524
		7	0.004	0.129	5.1594	0.641
		8	0.181	0.149	6.8760	0.550
		9	0.036	-0.120	6.9454	0.643
		10	0.114	0.036	7.6681	0.661
		11	0.195	0.315	9.8690	0.542
		12	-0.229	-0.229	13.022	0.367
		13	0.011	-0.101	13.030	0.445
		14	-0.221	-0.276	16.199	0.301
		15	-0.206	-0.007	19.041	0.212
		16	-0.105	-0.014	19.820	0.228
		17	-0.002	-0.139	19.820	0.284
		18	-0.020	-0.065	19.851	0.341
		19	0.088	-0.077	20.477	0.366
		20	-0.050	0.082	20.690	0.416
		21	-0.035	-0.104	20.797	0.471
		22	-0.020	0.062	20.835	0.531
		23	-0.069	0.140	21.305	0.562
		24	-0.017	0.002	21.334	0.619
		25	-0.067	0.006	21.836	0.645
		26	-0.026	-0.113	21.918	0.693
		27	-0.042	0.056	22.147	0.730
		28	0.006	-0.025	22.153	0.774
		29	0.023	-0.088	22.235	0.810
		30	0.024	-0.136	22.330	0.842
		31	-0.008	-0.059	22.341	0.872
		32	0.003	0.061	22.343	0.898
		33	0.006	-0.052	22.350	0.920
		34	-0.004	-0.032	22.356	0.937
		35	-0.001	-0.057	22.356	0.952
		36	-0.007	0.050	22.378	0.963
		37	-0.003	0.070	22.384	0.972
		38	-0.002	0.017	22.388	0.979
		39	0.003	-0.020	22.400	0.985

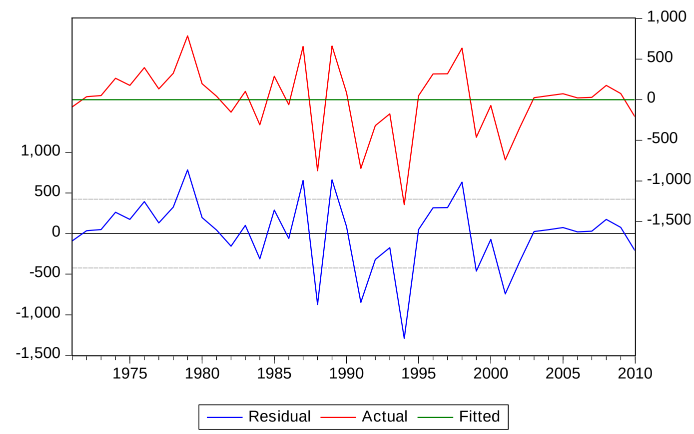


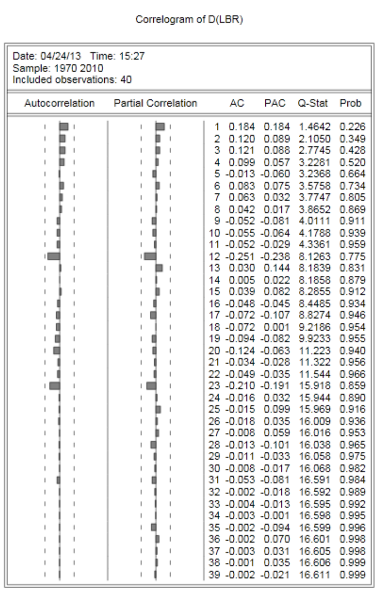
Figure A.1.8: Diagnostic graphs for investments per capita in electricity sector

Table A.1.13: Time series model for labor supply rate

Dependent Variable: DLBR
Method: Least Squares
Sample (adjusted): 1971 2010
Included observations: 40 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	2.72E-06	1.49E-08	2.709471	0.0094

R-squared	0.000000	Mean dependent var	2.72E-06
Adjusted R-squared	0.000000	S.D. dependent var	0.000157
S.E. of regression	0.000157	Akaike info criterion	-14.65045
Sum squared resid	9.67E-07	Schwarz criterion	-14.60823
Log likelihood	294.0091	Hannan-Quinn criter.	-14.63519
Durbin-Watson stat	1.562276		


Correlogram of D(LBR)

Date: 04/24/13 Time: 15:27
Sample: 1970 2010
Included observations: 40

	AC	PAC	Q-Stat	Prob
1	0.184	0.184	1.4642	0.226
2	0.120	0.089	2.1050	0.349
3	0.121	0.088	2.7745	0.428
4	0.099	0.057	3.2281	0.520
5	-0.013	-0.060	3.2368	0.664
6	0.083	0.075	3.5758	0.734
7	0.063	0.032	3.7747	0.805
8	0.042	0.017	3.8652	0.869
9	-0.052	-0.081	4.0111	0.911
10	-0.055	-0.064	4.1788	0.939
11	-0.052	-0.029	4.3361	0.959
12	-0.251	-0.238	8.1263	0.775
13	0.030	0.144	8.1839	0.831
14	0.005	0.022	8.1858	0.879
15	0.039	0.082	8.2855	0.912
16	-0.048	-0.045	8.4485	0.934
17	-0.072	-0.107	8.8274	0.946
18	-0.072	0.001	9.2186	0.954
19	-0.094	-0.082	9.9233	0.955
20	-0.124	-0.063	11.223	0.940
21	-0.034	-0.028	11.322	0.956
22	-0.049	-0.035	11.544	0.966
23	-0.210	-0.191	15.918	0.859
24	-0.016	0.032	15.944	0.890
25	-0.015	0.099	15.969	0.916
26	-0.018	0.035	16.009	0.936
27	-0.008	0.059	16.016	0.953
28	-0.013	-0.101	16.038	0.965
29	-0.011	-0.033	16.058	0.975
30	-0.008	-0.017	16.068	0.982
31	-0.053	-0.081	16.591	0.984
32	-0.002	-0.018	16.592	0.989
33	-0.004	-0.013	16.595	0.992
34	-0.003	-0.001	16.598	0.995
35	-0.002	-0.094	16.599	0.996
36	-0.002	0.070	16.601	0.998
37	-0.003	0.031	16.605	0.998
38	-0.001	0.035	16.606	0.999
39	-0.002	-0.021	16.611	0.999

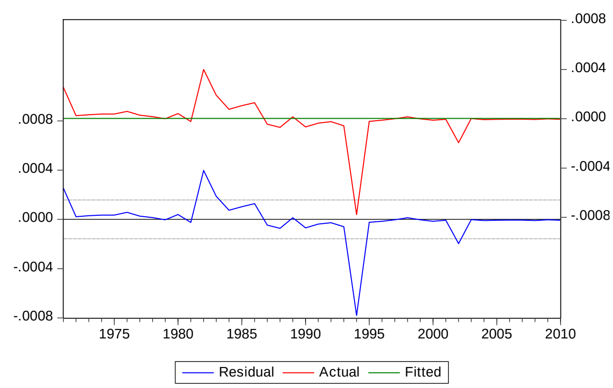


Figure A.1.9: Diagnostic graphs for labor supply rate in electricity sector

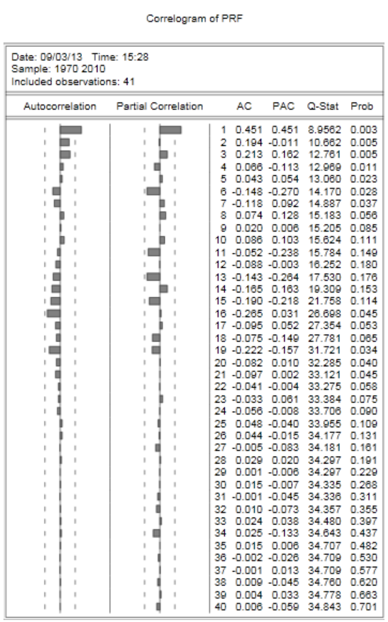
Table A.1.14: Time series model for gross profit in electricity sector

Dependent Variable: PRF
Method: Least Squares
Sample (adjusted): 1972 2010
Included observations: 39 after adjustments
Convergence achieved after 3 iterations

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	0.083748	0.046048	1.818685	0.0218
AR(1)	0.479290	0.171390	2.796494	0.0082
AR(2)	-0.026721	0.012394	-2.155886	0.0155

R-squared	0.210659	Mean dependent var	0.063342
Adjusted R-squared	0.166806	S.D. dependent var	0.983089
S.E. of regression	0.897359	Akaike info criterion	2.695081
Sum squared resid	28.98909	Schwarz criterion	2.823047
Log likelihood	-49.55408	Hannan-Quinn criter.	2.740994
F-statistic	4.803819	Durbin-Watson stat	1.936377
Prob(F-statistic)	0.014150		

Inverted AR Roots	.41	.06



Correlogram of PRF

Date: 09/03/13 Time: 15:28
Sample: 1970 2010
Included observations: 41

	AC	PAC	Q-Stat	Prob
1	0.451	0.451	8.9562	0.003
2	0.194	-0.011	10.662	0.005
3	0.213	0.162	12.761	0.005
4	0.066	-0.113	12.969	0.011
5	0.043	0.054	13.060	0.023
6	-0.148	-0.270	14.170	0.028
7	-0.118	0.092	14.887	0.037
8	0.074	0.128	15.183	0.056
9	0.020	0.006	15.205	0.085
10	0.086	0.103	15.624	0.111
11	-0.052	-0.238	15.784	0.149
12	-0.088	-0.003	16.252	0.180
13	-0.143	-0.264	17.530	0.176
14	-0.165	0.163	19.309	0.153
15	-0.190	-0.218	21.758	0.114
16	-0.265	0.031	26.698	0.045
17	-0.095	0.052	27.354	0.053
18	-0.075	-0.149	27.781	0.065
19	-0.222	-0.157	31.721	0.034
20	-0.082	0.010	32.285	0.040
21	-0.097	0.002	33.121	0.045
22	-0.041	-0.004	33.275	0.058
23	-0.033	0.061	33.384	0.075
24	-0.056	-0.008	33.706	0.090
25	0.048	-0.040	33.955	0.109
26	0.044	-0.015	34.177	0.131
27	-0.005	-0.083	34.181	0.161
28	0.029	0.020	34.297	0.191
29	0.001	-0.006	34.297	0.229
30	0.015	-0.007	34.335	0.268
31	-0.001	-0.045	34.336	0.311
32	0.010	-0.073	34.357	0.355
33	0.024	0.038	34.480	0.397
34	0.025	-0.133	34.643	0.437
35	0.015	0.006	34.707	0.482
36	-0.002	-0.026	34.709	0.530
37	-0.001	0.013	34.709	0.577
38	0.009	-0.045	34.760	0.620
39	0.004	0.033	34.778	0.663
40	0.006	-0.059	34.843	0.701

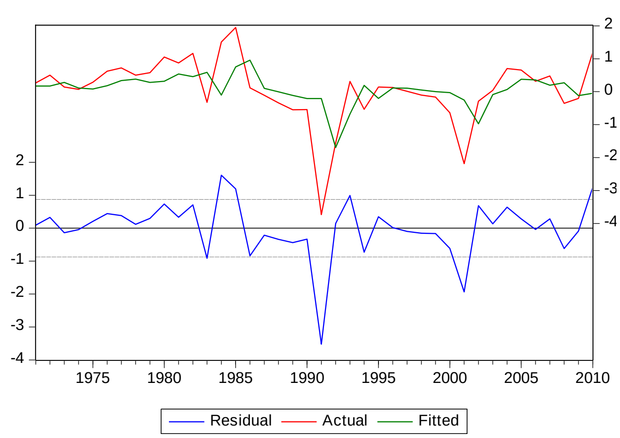


Figure A.1.10: Diagnostic graphs for gross profit in electricity sector

Table A.1.15: ARMA roots for time series model of gross profit

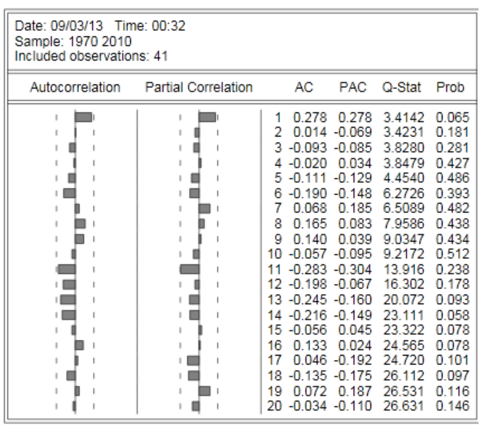
Inverse Roots of AR/MA Polynomial(s)
Specification: PRF AR(1) C
Sample: 1970 2010
Included observations: 40

AR Root(s)	Modulus	Cycle
0.467174	0.467174	

No root lies outside the unit circle.
ARMA model is stationary.

APPENDIX 2

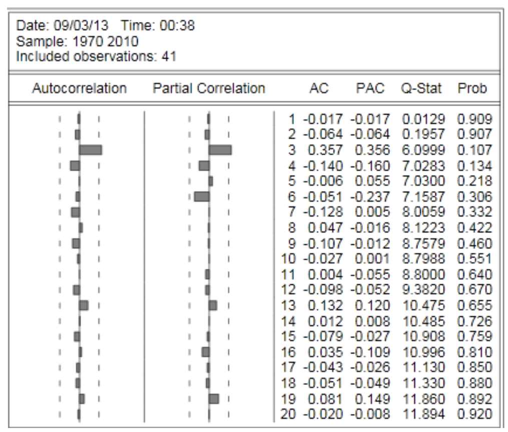
Diagnostic Checks for OLS and GMM Models



Correlogram of Residuals

Date: 09/03/13 Time: 00:32
Sample: 1970 2010
Included observations: 41

Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob
		1	0.278	0.278	3.4142	0.065
		2	0.014	-0.069	3.4231	0.181
		3	-0.093	-0.085	3.8280	0.281
		4	-0.020	0.034	3.8479	0.427
		5	-0.111	-0.129	4.4540	0.486
		6	-0.190	-0.148	6.2726	0.393
		7	0.068	0.185	6.5089	0.482
		8	0.165	0.083	7.9586	0.438
		9	0.140	0.039	9.0347	0.434
		10	-0.057	-0.095	9.2172	0.512
		11	-0.283	-0.304	13.916	0.238
		12	-0.198	-0.067	16.302	0.178
		13	-0.245	-0.160	20.072	0.093
		14	-0.216	-0.149	23.111	0.058
		15	-0.056	0.045	23.322	0.078
		16	0.133	0.024	24.565	0.078
		17	0.046	-0.192	24.720	0.101
		18	-0.135	-0.175	26.112	0.097
		19	0.072	0.187	26.531	0.116
		20	-0.034	-0.110	26.631	0.146



Correlogram of Residuals Squared

Date: 09/03/13 Time: 00:38
Sample: 1970 2010
Included observations: 41

Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob
		1	-0.017	-0.017	0.0129	0.909
		2	-0.064	-0.064	0.1957	0.907
		3	0.357	0.356	6.0999	0.107
		4	-0.140	-0.160	7.0283	0.134
		5	-0.006	0.055	7.0300	0.218
		6	-0.051	-0.237	7.1587	0.306
		7	-0.128	0.005	8.0059	0.332
		8	0.047	-0.016	8.1223	0.422
		9	-0.107	-0.012	8.7579	0.460
		10	-0.027	0.001	8.7988	0.551
		11	0.004	-0.055	8.8000	0.640
		12	-0.098	-0.052	9.3820	0.670
		13	0.132	0.120	10.475	0.655
		14	0.012	0.008	10.485	0.726
		15	-0.079	-0.027	10.908	0.759
		16	0.035	-0.109	10.996	0.810
		17	-0.043	-0.026	11.130	0.850
		18	-0.051	-0.049	11.330	0.880
		19	0.081	0.149	11.860	0.892
		20	-0.020	-0.008	11.894	0.920

Figure A.2.1: Diagnostic checks for OLS estimation for electricity consumption

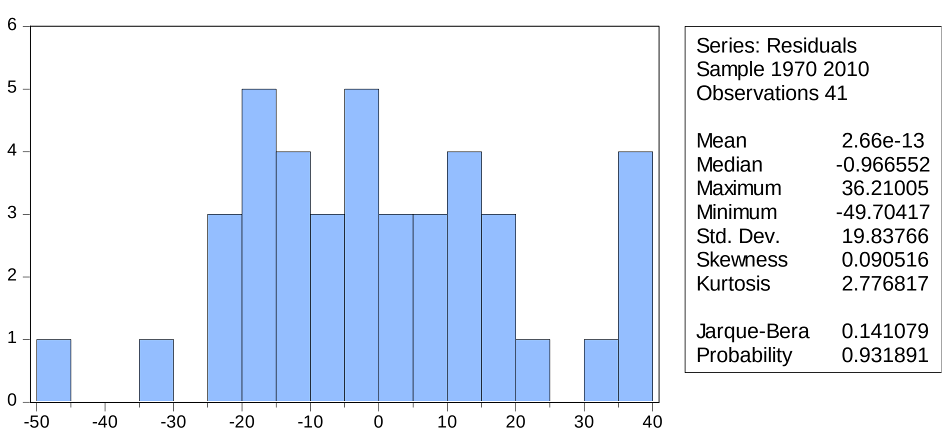
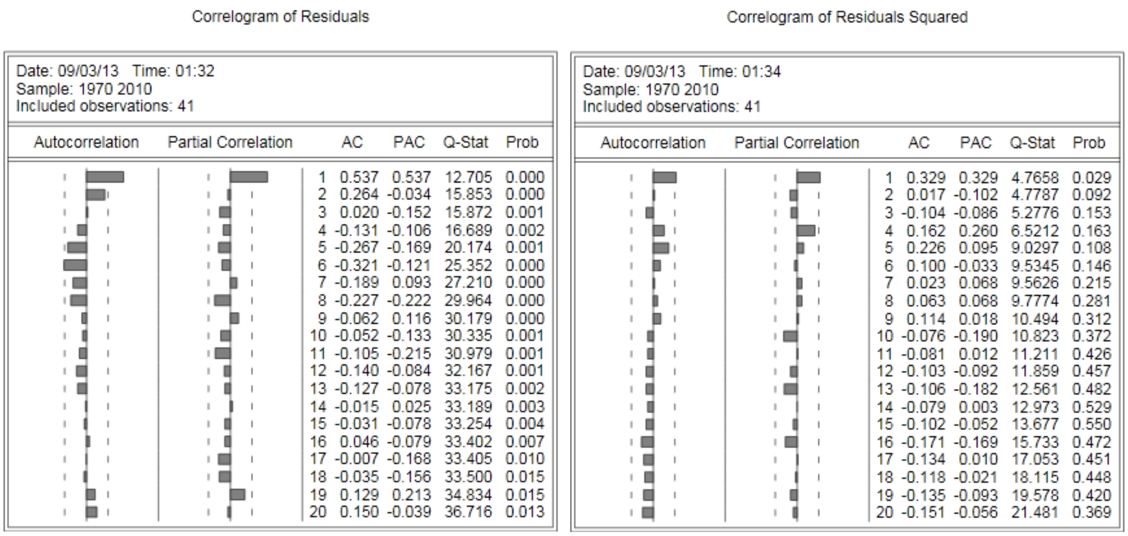


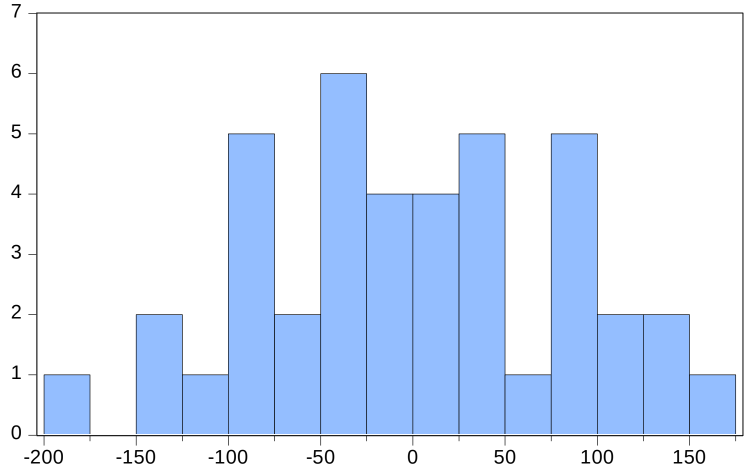
Figure A.2.2: Normality test of residuals for electricity consumption through OLS



	AC	PAC	Q-Stat	Prob
1	0.537	0.537	12.705	0.000
2	0.264	-0.034	15.853	0.000
3	0.020	-0.152	15.872	0.001
4	-0.131	-0.106	16.689	0.002
5	-0.267	-0.169	20.174	0.001
6	-0.321	-0.121	25.352	0.000
7	-0.189	0.093	27.210	0.000
8	-0.227	-0.222	29.964	0.000
9	-0.062	0.116	30.179	0.000
10	-0.052	-0.133	30.335	0.001
11	-0.105	-0.215	30.979	0.001
12	-0.140	-0.084	32.167	0.001
13	-0.127	-0.078	33.175	0.002
14	-0.015	0.025	33.189	0.003
15	-0.031	-0.078	33.254	0.004
16	0.046	-0.079	33.402	0.007
17	-0.007	-0.168	33.405	0.010
18	-0.035	-0.156	33.500	0.015
19	0.129	0.213	34.834	0.015
20	0.150	-0.039	36.716	0.013

	AC	PAC	Q-Stat	Prob
1	0.329	0.329	4.7658	0.029
2	0.017	-0.102	4.7787	0.092
3	-0.104	-0.086	5.2776	0.153
4	0.162	0.260	6.5212	0.163
5	0.226	0.095	9.0297	0.108
6	0.100	-0.033	9.5345	0.146
7	0.023	0.068	9.5626	0.215
8	0.063	0.068	9.7774	0.281
9	0.114	0.018	10.494	0.312
10	-0.076	-0.190	10.823	0.372
11	-0.081	0.012	11.211	0.426
12	-0.103	-0.092	11.859	0.457
13	-0.106	-0.182	12.561	0.482
14	-0.079	0.003	12.973	0.529
15	-0.102	-0.052	13.677	0.550
16	-0.171	-0.169	15.733	0.472
17	-0.134	0.010	17.053	0.451
18	-0.118	-0.021	18.115	0.448
19	-0.135	-0.093	19.578	0.420
20	-0.151	-0.056	21.481	0.369

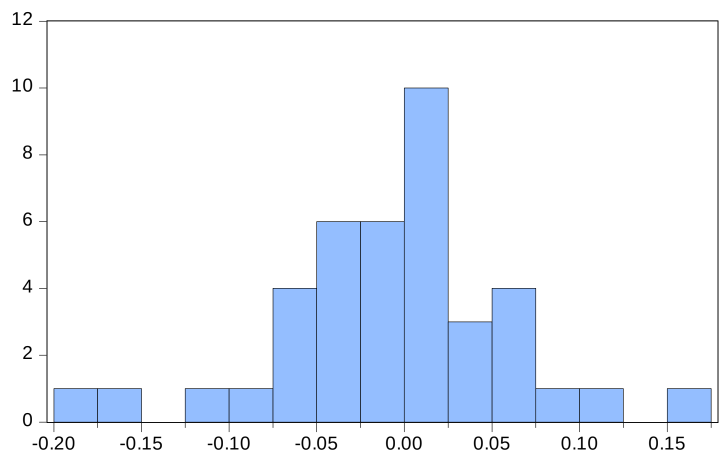
Figure A.2.3: Diagnostic checks for OLS estimation for electricity production



Series: Residuals
Sample 1970 2010
Observations 41

Mean	6.90e-13
Median	-2.228183
Maximum	174.1113
Minimum	-176.3716
Std. Dev.	82.65804
Skewness	-0.041561
Kurtosis	2.394549
Jarque-Bera	0.638028
Probability	0.726865

Figure A.2.4: Normality test of residuals for electricity production through OLS



Series: Residuals
Sample 1971 2010
Observations 40

Mean	-0.005223
Median	0.002315
Maximum	0.159820
Minimum	-0.191452
Std. Dev.	0.066800
Skewness	-0.424697
Kurtosis	4.306361
Jarque-Bera	4.046750
Probability	0.132208

Figure A.2.5: Normality test of residuals for electricity consumption through GMM

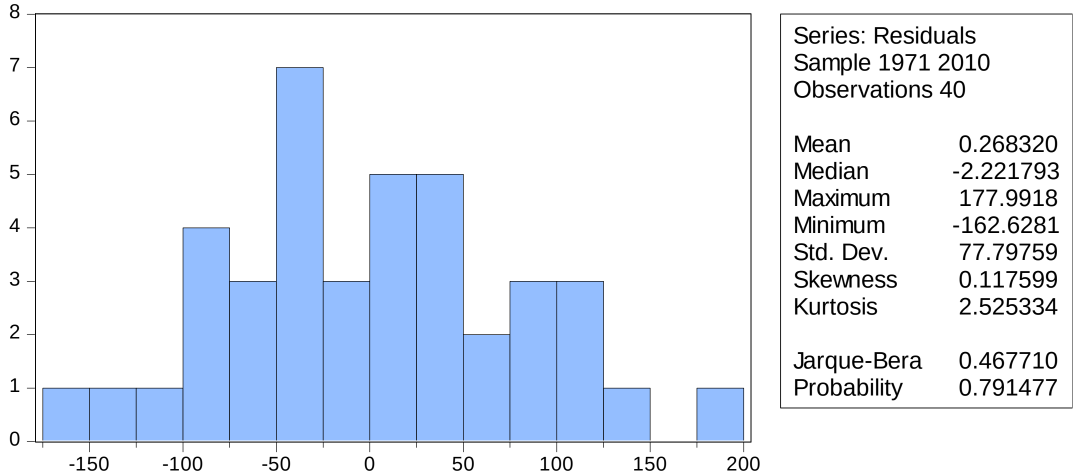


Figure A.2.6: Normality test of residuals for electricity production through GMM