MODELLING ELECTRICITY DEMAND IN TURKEY FOR 1998-2011

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İPEK SAYIN

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Approval of the Graduate School of Social Sciences

Prof. Dr. Meliha Altunışık
Director

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

Prof. Dr. Erdal Özmen
Head of Department

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

Assist. Prof. Dr Esma Gaygısız
Supervisor

Examining Committee Members

Assist. Prof. Dr Esma Gaygısız	(METU,ECON)	
Prof. Dr. Erdal Özmen	(METU, ECON)	
Dr. Pınar Erdem	(TBMM)	

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Name, Last name : İPEK, SAYIN

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ABSTRACT

MODELING ELECTRICITY DEMAND IN TURKEY
FOR 1998-2011

Sayın, İpek
M.S., Department of Economics
Supervisor: Assist. Prof. Dr Esma Gaygısız

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This thesis estimates the quarterly electricity demand of Turkey. First of all proper seasonal time series model are found for the variables: electricity demand, temperature, gross domestic product and electricity price. After the right seasonal time series model are found Hylleberg, Engle, Granger and Yoo (1990) test is applied to each variable. The results of the test show that seasonal unit roots exist for the electricity price even it cannot be seen at the graph. The other variables have no seasonal unit roots when the proper seasonal time series model is chosen. Later, the cointegration is tested by looking at the vector autoregressive model. As the cointegration is seen vector error correction model is found. There is long-run equilibrium when the price is the dependent variable and independent variable is gross domestic product. Temperature is taken as exogenous variable and demand is not statistically significant.

Keywords: Seasonal Unit Root Test, Electricity Demand, Cointegration, Vector Error Correction Model

ÖZ

TÜRKİYE'DEKİ ELEKTRİK TALEBİNİ MODELLENMESİ:
1998-2011

Sayın, İpek
Yüksek Lisans, İktisat Bölümü
Tez Yöneticisi: Doç. Dr Esma Gaygısız

Ocak 2013, 83 sayfa

Bu tez Türkiye'nin çeyrek bazlı elektrik talebini tahmin etmektedir. İlk olarak değişkenler için uygun zaman serisi modeli bulunmuştur: elektrik talebi, gayri safi yurt içi hasıla ve elektrik fiyatı. Uygun zaman serisi modeli bulunduktan sonra Hylleberg, Engle, Granger ve Yoo (1990) testi değişkenlere uygulanmıştır. Sonuçlar elektrik fiyatı için mevsimsel birim kökün olduğunu göstermektedir, her ne kadar grafikden görülmesede. Uygun zaman serisi modeli seçildiği zaman, diğer değişkenlerde mevsimsel birim kök yoktur. Sonra koentegrasyon vektör otoregresif modele bakılarak bulunmuştur. Koentegrasyon olduğu için vektör hata düzeltme modeli bulunmuştur. Uzun dönem dengesi fiyat bağımlı değişken ve gayri safi yurt içi hasıla bağımsız değişken iken vardır. Sıcaklık dışsal değişken olarak alınırken, talep istatistiksel olarak anlamsızdır.

Anahtar Kelimeler: Mevsimsel Birim Kök, Elektrik Talebi, Coentegrasyon, Vektör Hata Düzeltme Modeli

To My Family

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ANN	Artificial neural networks
BMP	Balancing Power Market
BOT	Build-Operate-Transfer
BO	Build-Operate
DAM	Day-Ahead Market
EUAS	Electricity Generation Company
GDP	Gross Domestic Product
HEGY	Hylleberg, Engle, Granger and Yoo
IEA	International Energy Agency
MENR	Ministry of Energy and Natural Resources
NDC	National Dispatch Center
TEDAS	Turkish Electricity Distribution Company
TEI	Turkish Electricity Institution
TEIAS	Turkish Electricity Transmission Corporation
TETAS	Turkish Electricity Trade and Contracting Corporation
TOR	Transfer of Operating Rights
VAR	Vector Autoregression
VECM	Vector Error Correction Model

CHAPTER 1

INTRODUCTION

One of the critical issues for the countries is providing energy supply security considering economic growth under the restriction of crises and running out of primary resources coming up from climate change, technological progress and pollution. Turkey as a developing country faces these problems too, in March 2012 disagreement between Turkey and Iran about Iranian oil price reduction is a good example of the necessity of energy supply security. Under the projection which was made by Turkish Electricity Transmission Company (TEIAS,2011), under the assumption of high demand, peak demand can not be covered in 2020. Electricity has its unique property compared to other commodities in the market as it can not be stored and it needs to be consumed whenever it is produced. Therefore conditions for the electricity market is very important. If we look at the examples in the world, over the past two decades a number of countries decided to liberalize their power market. Nord Pool which was established in 2002 ,including Nordic countires is an good example of the liberalization of electric power. Turkey has also introduced a reform program of her energy market involves privatization and liberalization. In 2001, Electricity Market Law No. 4628 was enacted and set up the regulatory framework to provide electicity in a high quality with the cost efficiency to the consumers and electicity demand forecasting became important in order to balance the market and get the equilibrium price. A number of early Turkish electricity demand studies were taken on by governmental institutions by using different models. When these forecasts are examined, there is a general tendency to over forecast the demand. According to Keleş (2005),the models did not perform well and forecasted demand more based on technical problems and bad assumptions, resulting with excess capacity, wrong investments like Build-Operate-Transfer (BOT), Build-Operate (BO) and Transfer of Operating Rights (TOR) projects. Turkish government attempted to solve these problems with short term solutions such as installation of natural gas plants which ended up increasing Turkey's dependecy on natural gas, made the market uncompetitive and vulnerable to the price volatility.

Long term electricity demand forecasting are made from 5 years to 25 years and important in terms of goverment spending , tariff planning, generation and transmission. Economic variables such as prices, GDP are important. Medium term forecasts including temperature and social variables that are from few weeks to years can be used for scheduling maintenance and diversity interchanges. Short term forecasts are also important because under free market conditions prices are set hourly.

Various methods have been used to forecast electricity demand such as artificial neural networks (ANN) and neural fuzzy logics in terms of first studies. Following these first studies, end-use method and disaggregation and time series models such as AutoRegressive Integrated Moving Average and Error Correction models (ECM) , smoothing methods, decomposition, and hybrid approaches can be given as an example. The offical use of mathematical modelling (Erdogdu,2011) in energy planning and national policy making by the Ministry of Energy and National Resources (MENR) was realized only after 1984. Before 1984, forecasts were based on various bes-fit curves developed by the State Planning Organization (SPO) and MENR. In 1984, Model for Analysis of Energy Demand and Wien Automatic System Planning were recommended by the World Bank. Since 1984 projections are prepared by MENR under growth targets set by SPO.

This study aims to model electricity demand bu using quarterly data while taking into consideration the seasonal effects on the series. Under the restriction of supply conditions the demand analysis should be done efficiently. The aim of the paper is to suggest the right model for the electricity demand and find out the relationship between GDP, price and temperature.

Chapter 2 analyses the history of the electricity market. Before starting this analysis, it also gives information about the energy resources.

Chapter 3 talks about the literature review and the technics in order to find the right model and estimation tools. VECM is explained in details as a cointegration method.

In chapter 4, the variables are analyzed and the cointegration is done. Finally, chapter 5 concludes the study.

CHAPTER 2

ENERGY SECTOR in TURKEY

In the coming decades, considering the supply of primary energy resources and increasing energy demand needs of countries, the energy sector will face challenges. At the same time supplies of primary resources such as oil and natural gas are expected to decline and as they are under the control of specific countries Iran, Russia (gas) and Middle East (oil) any political conflict causes several problems to countries (OECD, 1999). Even though the reserves for the coal are enough for the next 100 years, gas and oil have reserves for only 45 and 60 years respectively (Linyit Sektör Raporu, 2010). This is why countries like United Kingdom and France build off-shore wind farms and try to increase the production coming from renewable resources.

According to the key energy statistics prepared by the International Energy Agency while the supply of the primary resources has increased to 12.267 Mtoe from 6.115 Mtoe in 2008 since 1973, world total final consumption has increased to 8.428 Mtoe from 4.676 Mtoe. (IEA, 2010)

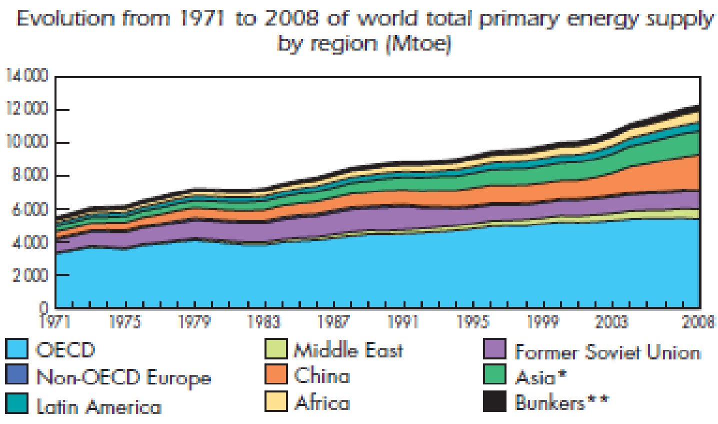


Figure 1.1 World Primary energy supply by Region (Mtoe)

Source: IEA, 2010

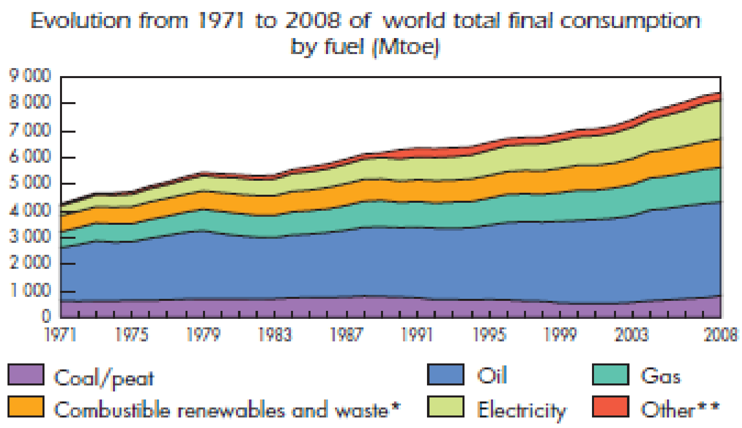


Figure 1.2 Total final consumption (Mtoe)

Source: IEA, 2010

2.1 Turkey's Primary Energy Resources:

After mentioning the supply and demand of primary energy resources, the distribution of the resources to produce electricity should be discussed. In the year 2008, the world electricity production was 20.181 TWh and 41% of which obtained from coal, 21.3% from natural gas and 15.9% from hydroelectric resources. When compared to the world statistics, it is seen that with the percentage of 49.47, Turkey is dependent on natural gas. As the share of the natural gas is more than two times the world average, the share of the coal is below the world average.

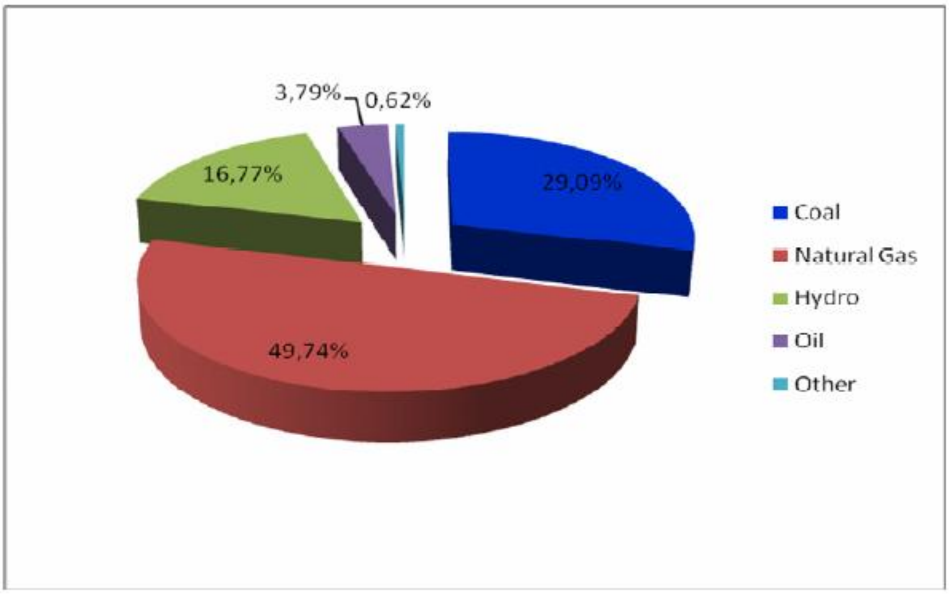


Figure 1.1 Distribution of Energy Resources to produce Electricity

Source: IEA,2010

In Turkey, coal and hydraulic resources are the main primary energy resources which are followed by the oil, natural gas and geothermal resources. The total lignite reserves which are concentrated in Kangal, Orhaneli, Tufanbeyli, Soma, Tunçbilek, Seyitömer, Çan, Muğla, Beypazarı, Afşin-Elbistan and Karapınar reached 11.5 billion tons. 70% of lignite reserves are classified as low calorific value lignite (below 2000 kCal/kg) and only 6% of the reserves are mentioned as better quality lignite (over 3000 kCal/kg) (EUAS,2010).

Hydraulic potential that has been approximated about 130 billion kWh for a year with a normal hydrological conditions become dense in 11 basins and Fırat-Dicle is the biggest basin in Turkey composes 45% of the total potential.

2.2 Supply and Demand

Turkey's total primary energy supply (TPES) was 99 million tons of oil equivalents (Mtoe) in 2008. From 1990 to 2008, total primary energy supply increased by 87% while the economy doubled. In line with the economic crises, energy supplied decreased by 1.5% from 2007 to 2008. 72% of TPES is dependent on imports of mostly oil, natural gas and coal. (IEA Turkey, 2009)Since 2000, the increase in

TPES mainly comes from two sources: natural gas up by 18 Mtoe and coal up by close to 7 Mtoe. While the use of biomass (firewood) declines as the economy develops, the other primary energy resources nearly remained the same. From 2000 to 2009 gas-fired generation grew by 48 TWh while the coal-fired grew by 17 TWh and hydropower increased by 5 TWh. Oil-fired generation has been sloping downward since its peak in 2002.

In Turkey between the years 1990 and 2008, the primary energy demand increased by the average rate of 4.3%. Compared to other OECD countries, Turkey has had the highest rate of energy demand increase in the last 10 years. Likewise, since 2000, Turkey has been the second largest economy after China for having the highest rate of increase in electricity and natural gas demand. Projections made by the Ministry of Energy and Natural Resources (MENR) show that this trend is going to be followed in the medium term.

In 2008, total primary energy consumption of Turkey was actualized as 106.3 million TEP, while production was at 29.2 million TEP (tons of equivalent petroleum). When you take into account the total energy supply natural gas comes first (32%), followed up by oil (29, 9%), coal (29, 5%), and renewable energy sources including hydraulic (8, 6%). Based on the reference scenario that was used by MENR, primary energy consumption is expected to increase by 4% annually by 2020. (MENR, 2010)

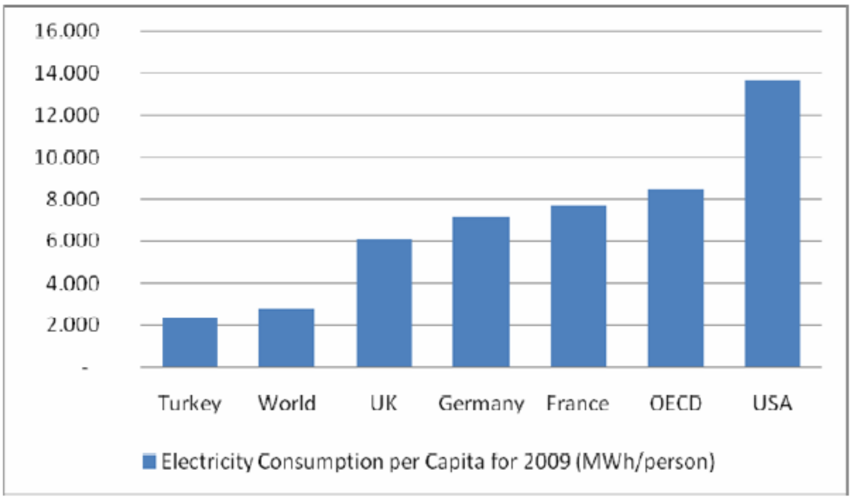


Figure 1.4 Electricity Consumption per Capita for 2009 (MWh/person)

Source: OECD, 2009

At the end of 2010, Electrical Energy Installed Power of Turkey was realized as 49524.1 MW with an increase of 4762,9 MW corresponding to 11% compared to the previous year. An increase of 2939.4 MW was ensured at thermal power plants, while 1277.9 MW in hydraulic power plants and 545.6 MW at geothermal and wind power plants (TEIAS, 2010).

Table 1.1 Breakdown of Installed Power and Production

BREAKDOWN OF INSTALLED POWER AND PRODUCTION OF ELECTRICAL ENERGY IN TURKEY BY PRODUCERS

INSTITUTIONS	2010	
	INSTALLED POWER (MW)	PRODUCTION (GWh)
EÜAŞ	20.368,8	79.258,3
EÜAŞ AFFILIATIONS	3.834,0	16.274,1
MOBILE	262,7	0,0
OTOP	3.143,1	12.447,4
BO+BOT+IPP+TOOR	21.915,5	103.227,9
TOTAL (TURKEY)	**49.524,1**	**211.207,7**

Source: EUAS, 2010

Table 1.2 Breakdown of Electrical Energy

BREAKDOWN OF ELECTRICAL ENERGY PRODUCED IN TURKEY BY PRIMARY ENERGY RESOURCES 2009-2010					
	2009		2010		Increase
	GWh	%	GWh	%	%
Coal	55.685,1	26,5%	55.046,4	26,1%	-1,1%
liquid Fuels	4.803,5	2,3%	2.180,0	1,0%	-54,6%
Natural Gas	96.094,7	45,7%	98.143,7	46,5%	2,1%
Renewable + Waste	340,1	0,2%	457,5	0,2%	34,5%
Hydraulic	35.958,4	17,1%	51.795,5	24,5%	44%
Geo + Wind	1.931,1	0,9%	3.584,6	1,7%	85,6%
TOTAL	**194.812,9**	**100,0%**	**211.207,7**	**100,0%**	**8,4%**

Source: EUAS,2010

2.3 Electricity in Turkey:

2.3.1 History of Electricity:

The very first attempt to produce electricity in Turkey was during the beginning of the 20th century in 1902. In Mersin-Tarsus, electricity was first generated and distributed to the village by connecting a 2 kW dynamo to a watermill. As the technical knowledge was limited during that time, the Ottoman Empire decided to get foreign investment to supply electricity generation. In order to ease the process, the ‘Privileges for Public Wealth’ law was put into force 1910. With the help of this privilege given by law, Hungarian Ganz Partnership set up the Ottoman Electricity Stock Company. In 1913, the first electricity power plant with the capacity of 13.4MW was constructed in Silahtarağa, Istanbul and it was followed by other power plants in Anatolia. (Dolun, 2002 and TEI, 1972)

The Ottoman Electricity Company was bought by the government in 1938. The installed electricity capacity was 33 MW with production around 50 million kW in 1923, the first year of the Turkish Republic establishment. The new Republic was also aware of the lack of technical knowledge therefore approved the new privileged contracts with the foreign countries, but this time only for a temporary period. These contracts were being indexed to gold prices which came with several drawbacks. As the prices were very high electricity intensive factories started to build their own power generation facilities. (Dolun, 2002 and TEI, 1972)

The aim of the foreign companies at that time in the market was maximizing profits so they were involuntary to invest in rural areas which would result in the slowing down of electricity generation and electrification. As a consequence, the government took a step and Etibank was established in 1935 to operate in electricity and mining sectors. Following Etibank, the Electric Power Resources and Survey Administration was formed to find out the possible electricity generation opportunities from hydro and other fuels. Starting from 1938 to 1944, the Turkish government bought the private electricity companies and made them public by giving them to municipalities. In 1948, the first power plant was built in Zonguldak named as Çatalağzı. Northwest Anatolia Interconnected System was formed in 1956 and Sarıyar plant was integrated to the system. Starting in 1952 through 1956 more companies were added to the system such as Northwest Electricity Turkish, Çukurova Electricity and Kepez Power Plant Trading. More steps were taken to overcome the drawbacks: in 1957 the Energy and Natural Resources department which was in control of coordinating the electricity generation and distribution of electricity companies was established. In 1963, the Ministry of Energy and Natural Resources was built to manage energy policies of Turkey. (Dolun, 2002 and TEI, 1972). Following the period of the first and second development plans in 1970, Turkish Electricity Institution (TEI) was established which was a monopoly in the generation, transmission and distribution of electricity with the Law 1312 (TETAS, 2010). In 1982, the Law 2705 was put into force and TEI became the fully vertically integrated state owned monopoly. With the fifth (1985-1989) and sixth (1990-1994) five year development plan the privatization of TEI was foreseen. In 1993, Law 513 was introduced in order to privatize TEI and it was divided into two state owned enterprises; the “Turkish Electricity Distribution

Co. (TEDAS) and the "Turkish Electricity Generation and Transmission Co. (TEAŞ) but their relationship was kept with the MENR. (Dolun, 2002). Private companies that get necessary permissions from the Ministry would be able to have contracts to generate, transmit and distribute electricity. Build-Own-Operate (BO), Build-Operate-Transfer (BOT), Transfer of Operating Rights (TOR) and auto producer model were established during these years.

In 2001, Electricity Market Law No. 4628 was presented to regulate the electricity market with the foundation of the Energy Market Regulatory Authority (EMRA). The purpose of the law: In 2001, Electricity Market Law No. 4628 was presented to regulate the electricity market with the foundation of the Energy Market Regulatory Authority (EMRA). The purpose of the law:

"…ensuring the development of a financially sound and transparent electricity market operating in a competitive environment under provisions of a civil law and the delivery of sufficient, good quality, low cost and environment-friendly electricity to consumers and to ensure the autonomous regulation and supervision of this market."

Moreover, TEDAS was restructured and divided into three for different purposes: generation, transmission and trading Turkish Electricity Generation Co. (EUAS), Turkish Electricity Transmission Co. (TEIAS), and Turkish Electricity Trading Co. (TETAS). With this new structure TETAS was the new holder of the agreements that was made by BO, BOT and TOR and long term agreements with the treasury and in charge of wholesale agreements. EUAS took over the public power plants. TEIAS was in charge for transmission and the balancing power operation between parties, that encompassed both the physical and financial aspects of the transmission operation (Dolun, 2002)

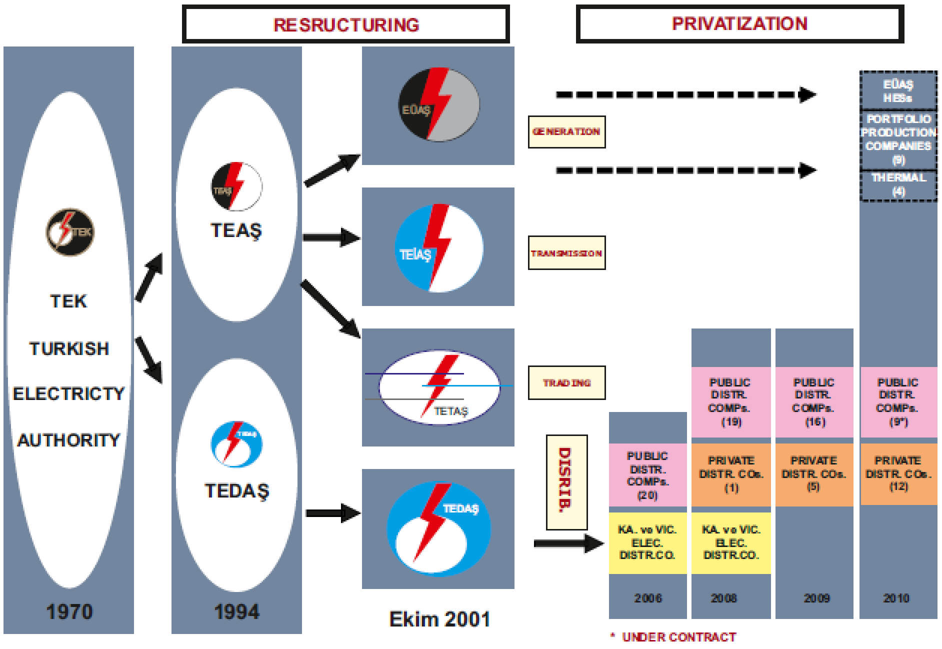


Figure 1.5 History of Electricity Market

Source: TETAS,2010

2.3.2 Electricity Market Structure:

The electrical energy sector constitutes about 2.5% of Turkey's total economy. Its compound annual growth rate is 4.7% between 2005 and 2009 and private sector investments totaled 3 Billion USD. It is estimated to increase by 6.3-7% until 2018.

Electricity energy sector, being indispensable for economic growth and human development constitutes approximately 2.5% of Turkish economy. It is expected to increase by 6.3% to 7% between 2009 and 2018 (Deloitte, 2010). The compound annual growth rate was 4.7% between 2005 and 2009 and to meet this energy demand investment made by the private sector was 3 billion USD.

The task of electricity generation is handled by public sector, EUAS and partner private companies. The main types of partnerships are Build Own Operate (BO), Build Operate Transfer (BOT), Generation Companies with Transfer of Operation Rights (TOR) and Auto Producers. The rest of the supply comes from imports.

Generation: Electricity generation is done by both of the public, EUAS and private sectors. As seen in the figure the main electricity generators are EUAS and its partners BO, BOT and TOR projects conducted by private sector, autoproducers and private generation companies with generation licenses some part of the demand is supplied by imports (EUAS, 2010).

Table 1.3 Share of the producers

Share Of The Producers In Turkey Electricity Generation

KURULUŞLAR *Producers*	**ÜRETİM** / *Generation* **GWh**
EÜAŞ	95.532,42
Yap-İşlet (Yİ) *Build Own Operate (BO)*	45.218,14
Serbest Üretim Şirketleri + İşletme Hakkı Devri (İHD) *Generation Companies + Transfer of Operation Rights (TOR)*	44.433,70
Yap-İşlet-Devret (YİD) *Build Operate Transfer (BOT)*	13.576,02
Otoprodüktörler *Auto Producers*	12.447,45
Mobil / *Mobile*	0,0
TOPLAM / *TOTAL*	**211.207,73**

Source: EUAS, 2010

The total installed capacity of EUAS is 24.203 MW. The breakdown is 12.525 MW thermal and 11.678 MW hydro energy. EUAS's share of Turkey's total installed capacity, which is 49.524, is 48.8%. 95.532 GWh worth of electricity is produced by EUAS, which comprises 45.2% of the total production (EUAS, 2010).

Thermal plants generate 56.7% of EUAS's total electricity production and 43.3% is generated by hydraulic plants. Thermal plants main sources are 57.6% lignite, 38.8% natural gas, 3.5% hard coal and 0.1% liquid fuels.

EUAS's privatization starts with Reform of the Electricity Sector and Strategy Paper by the High Planning Council in 2009. 50 small hydroelectric plants and 21 power plants are auctioned to private companies and Privatization Administration handles the rest of the remaining plants' privatization. Main objectives of privatization are efficient capacity utilization, more electricity generation and increased competition.

BOT: Build-Operate-Transfer model was coined in 1984. Investment is predicted to be made by the private sector and the company to sell electricity to public companies at a predetermined contract rate. When the contract expires, Government takes over the plant from the company. This way it is intended for the private sector to take the burden of investment costs and profit from lower costs and premium rates. This method is an important part of privatization (Imre, 2001).

Build and Operate (BO): This model is in effect since 1997 by the law 4283. This way, private companies are allowed to build and operate power plants and sell their generated electricity to public companies under treasury guarantee. However hydraulic, nuclear, geothermal and renewable energy plants are not covered by this law.

Transfer of Operating Rights (TOR): It is the model where the government has the ownership of the plant and a private company operates it. The company profits by selling the electricity it creates.

Autoproducer and Autoproducer Groups: Autoproducers operating principles are regulated under Electricity Market Law in 2001. They generate electricity for their own or affiliates' needs. They are also allowed to sell their excess generated electricity to the market.

Private Generator Companies: Their operations are also defined under Electricity Market Law in 2001. They are allowed to build and operate electricity generation plants with a generation license. They mainly sell electricity via bilateral contracts on the market and beneficial for a strong, competitive and transparent industry.

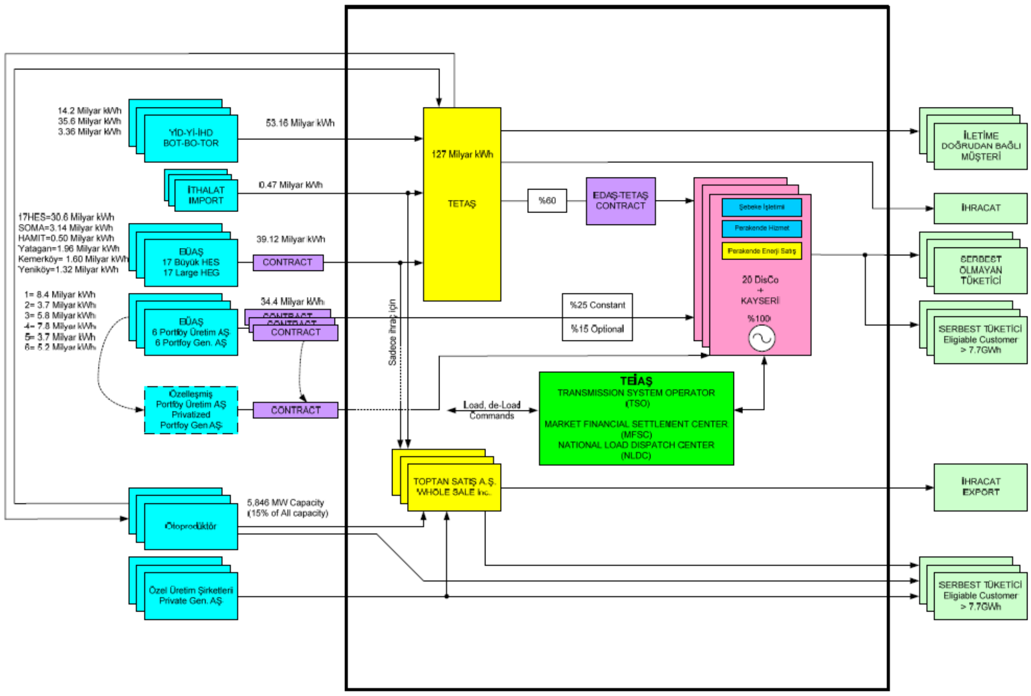


Figure 1.6 Structure of Electricity Market

Source: Starodubtsev, 2006

Transmission: TEİAS (Turkish Electricity Transmission Inc.) is founded after TEAŞ's being divided into three public companies in accordance with the vision provided by the government programme "Program for Economic Stability and Fighting Inflation" and Electricity Law in 2001. TEİAS has the possession of all the transmission facilities. TEİAS's main responsibilities are planning of the load dispatch, forecasting of the electricity demand by the counterparties (distribution companies, government agencies etc.), electricity generation capacity projections, investment planning according to new requirements for the transmission lines, operation and maintenance of existing infrastructure, R&D activities, planning of electricity transmission and utilization tariffs and preparation of contracts with all the companies that are connected to the grid.

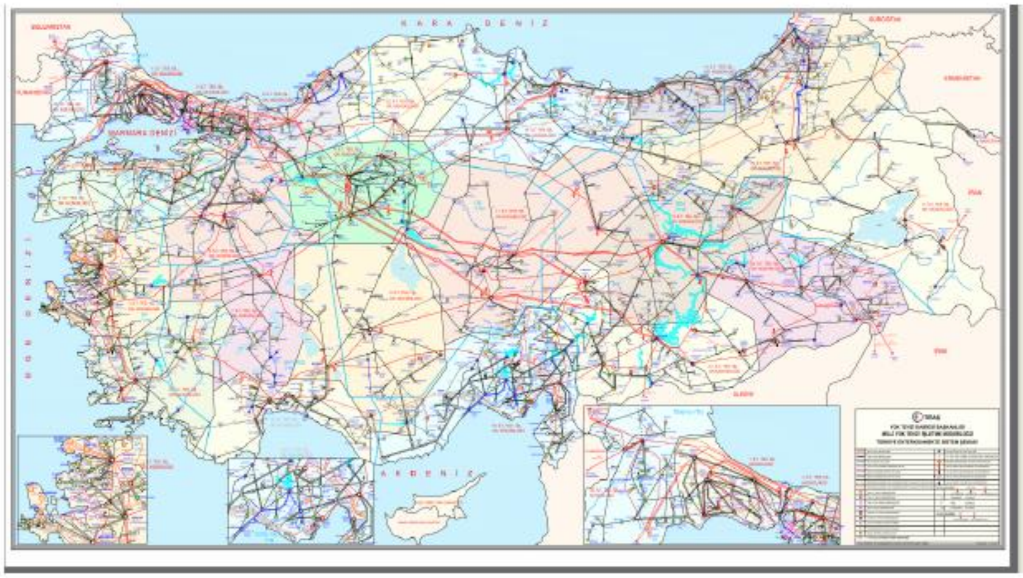


Figure 1.7 The Transmission Schema

Source: TEIAS, 2010

Distribution: Defined as in the Electricity Law 2001 “Distribution is the transport of electricity through 36 kV or lower lines. Distribution Companies are any legal entities engaged in electricity distribution in a certain geographical region”, Turkish Electricity Distribution Company has started its operations in 1994 with the aim of reaching maximum productivity and profitability in its services which mainly cover distribution and trading of electricity (TEDAS, 2010). TEDAS operates through a central organization having 14 units and 9 affiliated Electricity Distribution Companies. TEDAS in 2004 was put in the privatization programme for sector liberalization.

Accordinlgy, distribution regions are re-defined and Turkey is divided into 21 regions and 20 Electricity Distribution Companies started to operate in the market.

Trading: Trading is regulated with the Electricity Law 2001 aiming at establishing a stable, competitive and transparent market based on contracts between parties (Erdogdu, 2009). Afterwards, balancing and settlement system was introduced in order to create an exchange market where generation apart from bilateral contracts can be traded in November 2004. Yet, the implementation commenced in 2006 and some market players have been critical from the very beginning as it is profitable for private generation companies.

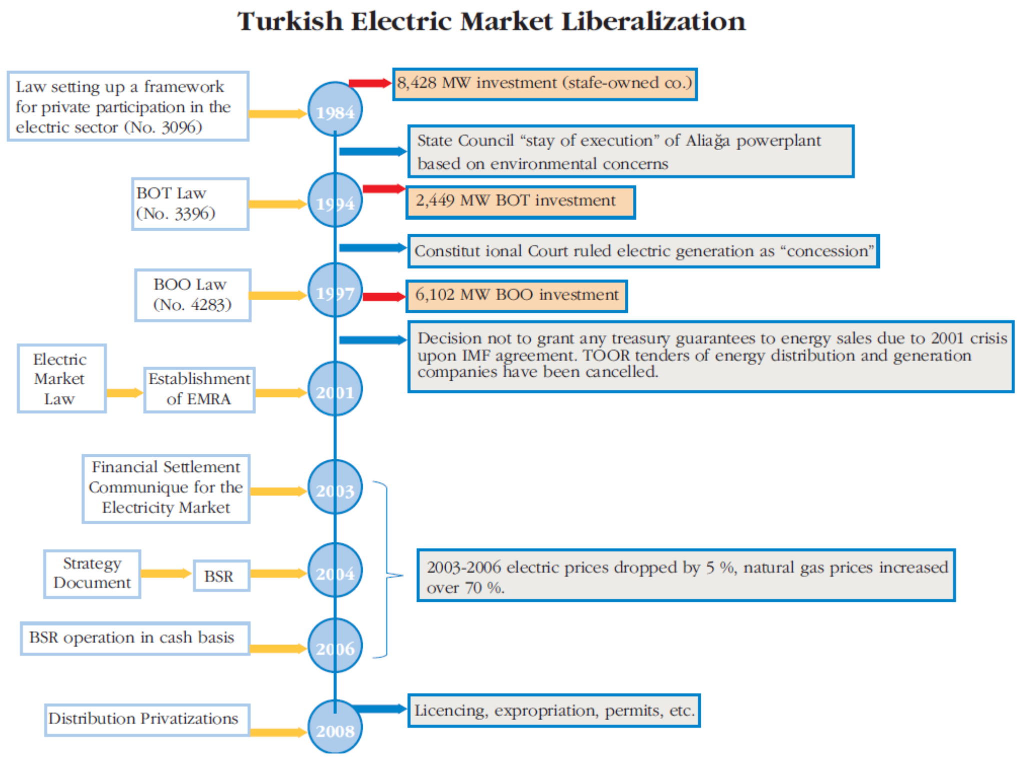


Figure 1.8 Market Liberalization

Source: TEDAS, 2009

In October 2011, the structure of the market brings along the need for effective electricity price risk management as the market becomes highly competitive. Therefore, base load electricity futures has been introduced at Turkish Derivatives Exchange (TurkDex) and started to be traded. Even though the market is not deep enough, the number of the contracts are increasing. The reference price for Base-Load Electricity contracts is the average of the day-ahead hourly prices of the maturity month obtained from the TEIAS.

In the day-ahead planning market and balancing power market

Private Generator Companies: They can sell the electricity they produce

- To wholesaler companies by bilateral agreements. Bilateral agreements are signed up between natural persons and legal entities for the buy and/or sale of electricity under civil law. Wholesale companies are legal entities that exercise activities such as wholesale, import, export, trade of electricity and/or capacity and the sale of the same to the eligible consumers. Eligible consumers can decide to choose among suppliers to whom they want to work.

- To retailer companies that are legal entities that carry on activities such as import of electricity and/or capacity and retail sale to consumers excluding the ones that are directly connected to the transmission system and provide retail sale services to consumers with bilateral agreements. Distribution companies are retail companies and have retail sales licenses.

- To Electricity Market Settlement Mechanism: The electricity that is generated by the companies can be sold to the balancing and settlement mechanism. As mentioned above it is a free market mechanism and was introduced in November, 2004. In August 2006, the real mechanism started its operations. The basic goal of this mechanism is have continuous and sufficient electricity supply with low cost and high quality. Under this new mechanism they provide the information of hourly electricity bids they are going to produce during the next month. Market Settlement Center named as National Load Dispatch Center (NLDC) as a unit under TEİAS gathers production information. NLDC is engaged to system balancing of electricity demand and supply by load shedding. The bids are sorted from the lowest to highest price and price is set at the point where supply is equal to the demand and all the generators sell at that price.
- To eligible consumers who have the rights to choose their suppliers.

EUAS: It is one of the market players which sell the electricity to TEDAS and TETAS with bilateral contracts. To produce electricity, EUAS gets the natural gas from BOTAS. If it produces more than the amount arranged to be sold by bilateral contracts it can sell it to the Market Settlement Center.

TETAS, Wholesaler and Retailer Companies: As the market players they act as the trading companies by buying and selling electricity. TEDAS can sell the electricity to the customers directly connected to grid, to TEDAS and also under necessary conditions it can engaged in export activities. Wholesalers can buy and sell the electricity under the conditions determined by their licenses. Retailer companies have being obliged to sell the electricity to eligible and non-eligible consumers- in order to increase the market efficiency the number of the non-eligible consumers is planned to be become zero to make it possible for them to select their distributors. The National Load Dispatch Center does not make any profit from buying and selling activities it is the pool system which can be thought as the manager that arranges demand and supply of the system to provide continuous electricity for the system.

Eligible and Non-eligible Consumers: Non-eligible consumers are not free to choose their distribution company. They have to buy the electricity from the retail sale companies or from a distribution company which provide electricity in their location. For example, households in Turkey are non-eligible. Unlike non-eligible consumers eligible consumers have the right to choose among their suppliers. In the UK, the new NETA/BETA (Erdogdu, 2009), for example, the country has a single-price market with bilateral contracts and non-eligible consumers are non-existent. There are conditions that are determined such as being connected to the grid directly or consumption limit to be an eligible customer in the present year or the year before. The limit is continuously being decreased in order to decree more customers eligible. The limit is decreased to 25.000kWh in 2012 from 30.000 kWh in 2011.

Import and Export: TETAS is the responsible unit for import and export. In 2010, 539.550,64 MWh energy was imported from Turkmenistan which was the 0, 6 % energy imported from other countries. TETAS exported 85.263.538, 43 MWh to Nakhchivan excluding Georgia.

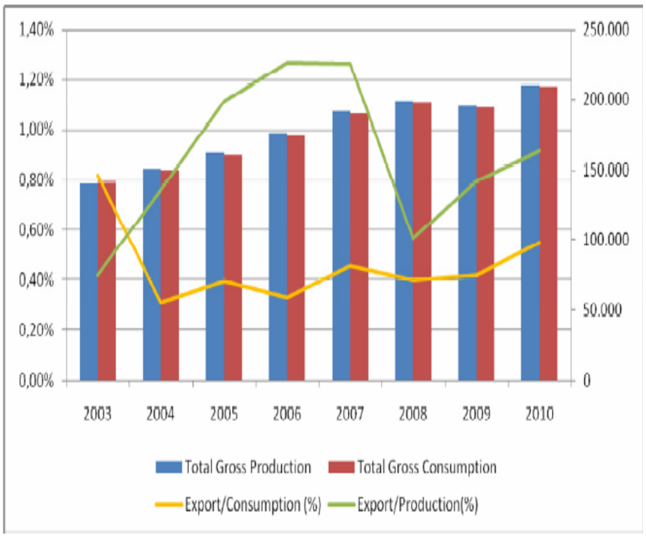


Figure 1.9 Development of Import, Export, Gross Production and Demand , GWh

Source: TEIAS, 2010

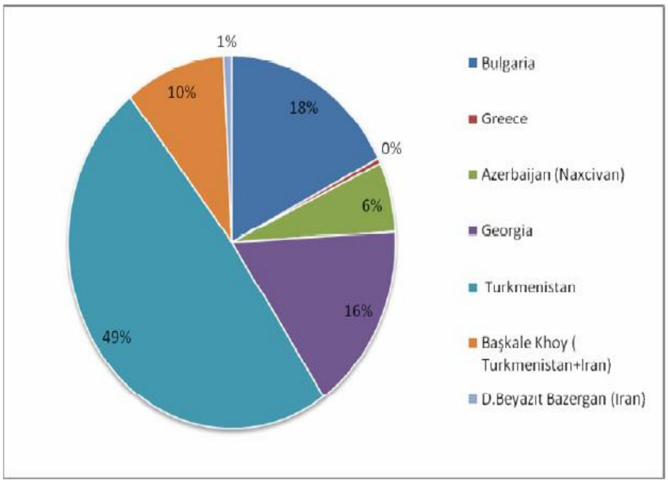


Figure 1.10 Distribution of Total Import since 2003

Source: TEIAS, 2010

Turkey wants to take place in the interconnected system covering the Eastern Europe (AEE, 2010). TEAS, applied to Union for Coordination of Transmission of Electricity (UCTE) (ENTSO-E since July 1, 2009) on March 21, 2000 which was built to organize Network of European Continent Synchronous Zone. The tests were completed in 2010 and it was one year trial for connection of Turkish Electricity System to European System. Turkish System has been connected to Bulgarian and

Greece systems by 400 kV transmission lines each. A sum of 753.21 GWh and 734.24 GWh energy have been supplied by Bulgaria and Greece respectively.

Electricity Prices: When we look at the market models we can see two types systems: single-price model and dual-price market model. The current system in Turkey is the single-price market with bilateral contracts and balancing market. The system has been criticized and the aim is to convert to the portfolio based self-dispatched dual-price model similar to Europe’s (Erdogdu,2009). Electricity prices are settled according to bilateral contracts, and retail tariffs are officially announced by TEDAS, TETAS and spot market players. With Electricity Market Balancing and Settlement Agreement market players had an opportunity to sell the electricity in the spot market. The pool system has been organized by National Dispatch Center (NDC). There are two types of prices that the players need to notify the NDC for the markets: Day-ahead and Balancing Power. Spot market gives an opportunity of buy and sales bids for single hours and block bids. Market price is set by suppliers as well as consumers. There are three periods defined for the day: day, peak and night. Day hours start from 06:00 and ends at 17:00, peak hours are between 17:00-22:00 and night hours are from 22:00 to 06:00.

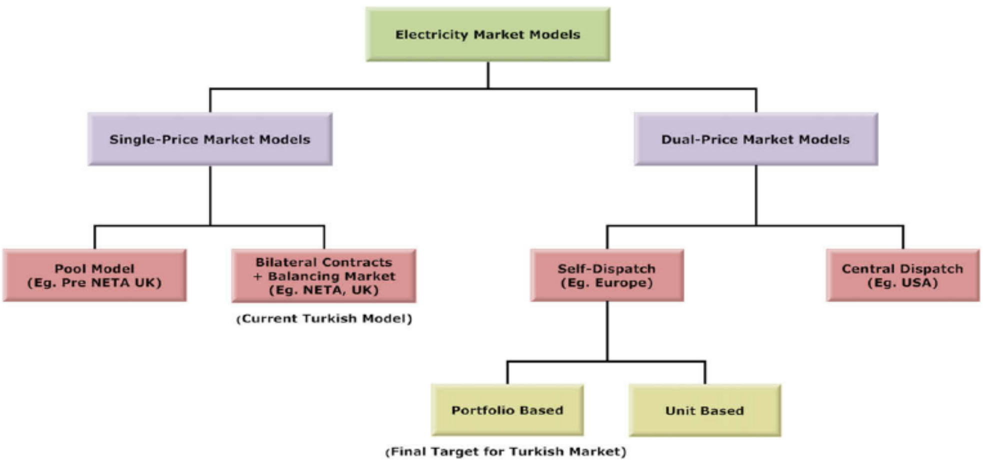


Figure 1.11 Electricity Market Models

Source: Erdogdu, 2009

In the wholesale market, when the day-ahead market is considered, the average price was 122 TL/MWh in 2010, and in the balancing power market the average price was 118 TL/MWh (AEE, 2010). In both markets, the highest price was 420 TL, on August 19, the time of annual peak. Depending on the weather conditions the price of the electricity rises. In winter time, it is because of heating purposes; and during summer, because of air-conditioning. In February 2012, Turkey had natural gas problem of importing from Azerbaijan and Iran, even some power plants faltered due to gas shortage. The price of electricity rose to 2000 TL/MWh during the peak hours. (National Dispatch Institute, Garanti Bank Report, 2012)

In Turkey many of the power plants work by natural gas so when there is rise in natural gas price it is directly reflected on electricity prices. In April, 2012 natural gas price rose by 18% while the electricity prices rose around 9%.

Distribution companies sell the electricity to non-eligible end users (October, 2012):
Household electricity prices ~ 20, 8 Kr/kWh

Industrial electricity prices ~ 18, 16 Kr/kWh

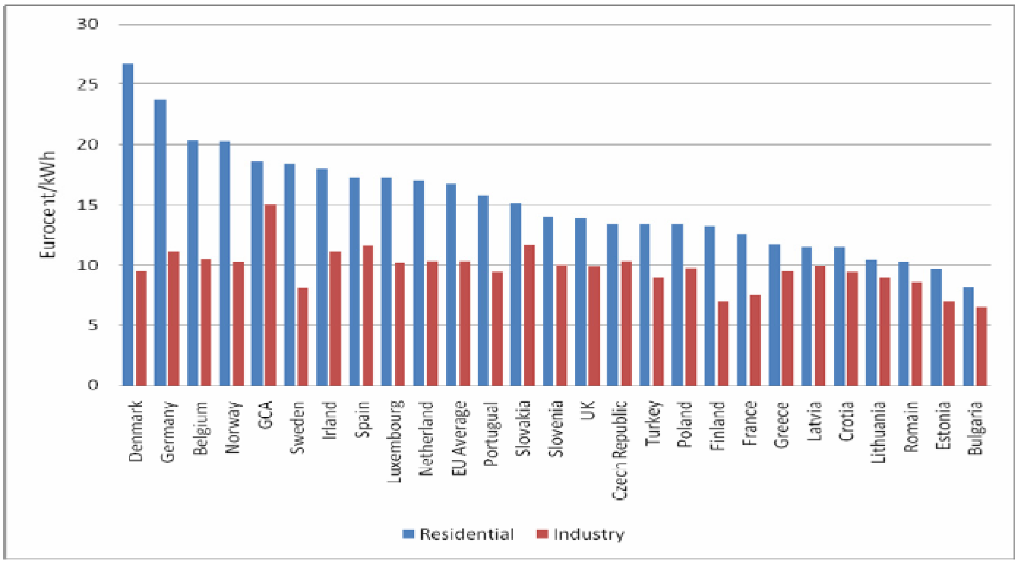


Figure 1.12 Residential and Industrial Prices (€c\kWh)

Source: AEE, 2010

According to the EU legislation, the consumers with annual electricity consumption between 500-2000 MWh are defined as industrial consumers. Even though the residential price in Turkey is lower than the EU, average the rise in the prices is higher. This situation is also similar for the industrial sector.

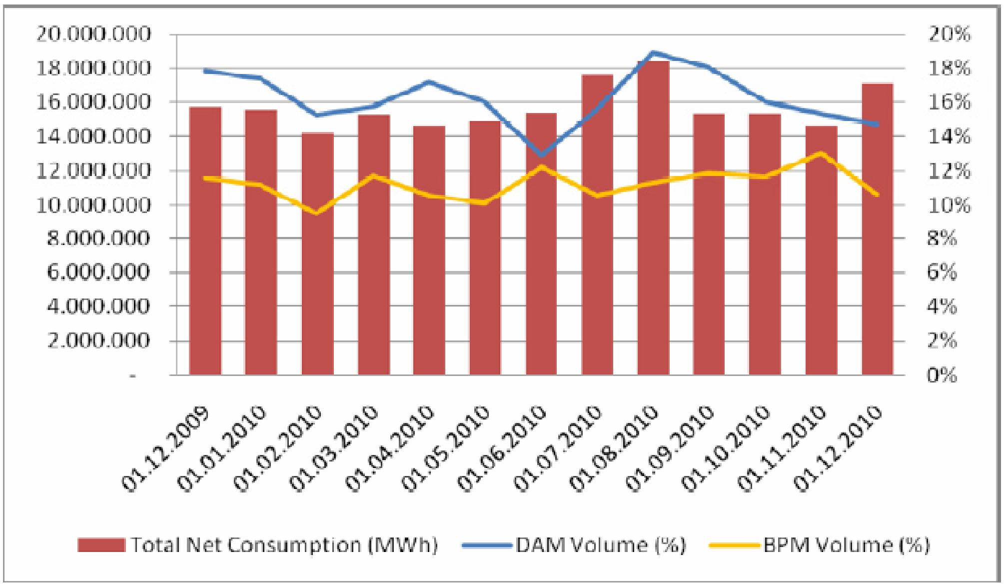


Figure 1.13 DAM and BPM Volumes (MWh)

Source: TEIAS, 2010

Theft and losses: Turkey has a big problem in the field of loss and theft. With the help of privatization, there can be a reduction of loss and theft rate. When the rate is high it reduces the efficiency of the market. This amount is charged from the customers and there is a big conflict on the topic who should be the one that is charged. In the figure 1.14 below it can be easily noticed this is a big problem in terms of efficiency and customer satisfaction. In April 2012, a trial was won by a customer and she got the right to get her money from the distributor that had been charged under the line of theft and losses in her bill. Besides, efficiency from another perceptive is rate of energy that has been lost. Parallel to the amount of consumption rates that has been increasing in Turkey the loss rate has been increasing, too. For example, in 2010 the average price calculated in the day-ahead market was 12, 16 kr/kWh and the cost of the loss and theft ratio was approximately 3 billion TL (AEE, 2010). The rate was highest at Dicle Electricity Distribution Co.

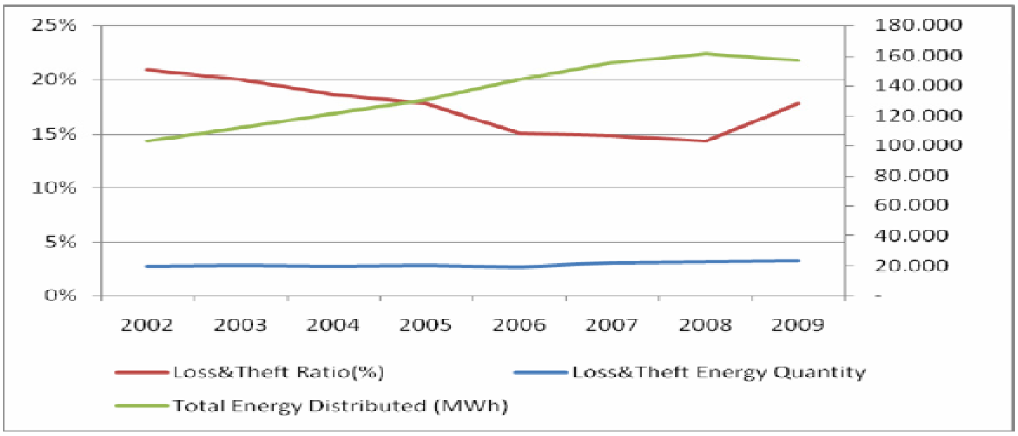


Figure 1.14 Loss and Theft Quantity (MWh) and Ration at Distribution Level Across Turkey

Source: TEDAS, 2010

CHAPTER 3

LITERATURE REVIEW

3.1 Literature Review

Analyzing and forecasting electricity demand is a significant challenge and a crucial need for countries. Many countries suffered supply shortages due to insufficient energy generation and increased demand due to growth in production and climate changes. So, many countries such as France and the UK build off-shore wind farms.

The UK invested 52 billion dollars to the world's biggest off-shore wind farm with 367MW capacity which can provide energy to 320,000 houses on Feb 9, 2012. It is projected that UK's energy capacity will reach 18 GW until 2020.

Market demand and supply determine the electricity prices. So, if demand is underestimated the prices can rise sharply and it would damage the service quality even causing blackouts. If overestimated, it means the capacity is not efficiently utilized.

There are many criteria that affect the electricity demand such as climate conditions, growth and production levels as mentioned above but also GDP, population and developments in technology can alter it. Data frequency is an important factor that affects the demand model. It could be short, medium or long term. But non-stationary short term variables can be co-integrated.

Oil crises of 70s and sustainability concerns in the 80s gave people enough incentives to put effort in energy demand research. Different estimation methods are conceived but mainly experience and research suggest that demand is mostly dependent on price and income. So analyzing the economic situation and energy prices became the primary pieces of the demand puzzle. Long-run income elasticity is generally found to be a unit or a small fraction higher and price elasticity is quite small. (Bentzen and Engsted, 1993)

In most cases, two different types of modeling have been used in the studies: Reduced form: A double-log linear model and energy demand is the response variable to the linear combination of energy price and real income.

1) Kouris (1981), Drollas (1984), Stewart (1991) and Dahl and Sterner (1991) used reduced form models in their studies.
2) Structural form: A disaggregated where energy demand is split into categories (i.e. lightning, heat and power) All those categories have different demand dynamics and the aggregate electricity demand is indirectly related to energy price and real income. Pindyck (1979) studies structural form problems in detail. Although it has more explanatory power it is difficult to fit a complex model.

Wolfram (1971) coined the irreversibility and price decomposition model and it is later developed by Traill et al. (1978). Former model assumes the response to price changes will be asymmetric in favor of positive changes in terms of magnitude. Later, three way price decomposition is developed by Dargay (1992) and Gatley (1992) as an improvement to the model which eliminates price effects on the demand when price changes are out of historic boundaries. Dargay and Gately (1995), Haas and Schipper (1998) used the model in their studies.

The prominent problem in reduced form models is the assumption of constant elasticity for the whole period. Considering the cycles in the economy, the assumption is dubious. The model should be devised such that as new data emerges the parameters evolve with the new information over the long run. An additional issue for model construction is the stationary data assumption. For the most cases, stationary data for time series prove difficult to work with.

Engle and Granger's (1987) method "co-integration and error correction" is used to analyze the time series data before the estimation process. Their study includes consideration of several tests (i.e. Dickey-Fuller). Johansen Maximum Likelihood Model (Johansen, 1988) and Autoregressive Lag Model (ARDL) are also considered for further improvement.

Policy makers consult to econometric models for energy demand to comprehend the past and to make predictions for the future; so that investments can be made efficiently into areas such as research and utilization of new technologies, gathering of necessary natural resources and increasing the output capacity. (McVeigh and Mortue, 1999) So, modeling the energy demand is utmost necessary.

Mainly due to lack of technical and technological developments, energy demand modeling studies are limited before 1970 and most models are constructed by government bodies like State Planning Organization (SPO), State Institute of Statistics (SIS) and Ministry of Energy and Natural Resources (MENR). These institutions use their own models constructed independent of each other's studies. Mathematical models were unlikely before 1984, as SPO uses simple best-fit curves (Ediger and Tatlıdil, 2002). However, MENR had different models for demand estimation and forecasting. "Balance" models are non-linear equilibrium models which demand and available resources and technologies are correlated. "Impact" models that seek for relationships between demand and its interaction with environment were part of the Energy and Power Evaluation Program (ENPEP). Those two models were used to fit long-run supply-demand forecasts between 1981-1985. MENR used a simulation model Model for Analysis of Energy Demand, Wien Automatic System Planning III developed by International Atomic Energy Agency and Energy Flow Optimization Model 12 C Mark developed by a commission of the European Union from 1984 (Ediger and Tatlıdil, 2002).

Meanwhile, SPO had constructed models that involves segmentation of sectoral demand into consumer categories, and sub-categories using regression. SIS sought for a relationship between demographics, economic indicators and energy demand.

Both institutions found evidence about the correlation between GDP and energy demand. (Ediger, Tatlıdil, 2002)

All the considered models had the objective of optimized energy planning for sustainable economic growth. Yet, their common problem is the overestimation of demand. As a result, Keleş (2005) claims the policy decisions based on these models caused an inflated energy generation capacity most of which is idle, increased dependence on primary energy resources, lack of liberalization and privatization in the energy market and as a consequence, higher electricity prices.

Turkish energy modeling studies:

There was a proliferation of energy industry modeling studies during the 2000s. A prominent portion of studies were based on statistical causality (i.e. Granger Causality) between consumption and economic indicators (i.e. GDP). To name some of them Karagol (2005), Soytas and Sari (2007), Jobert and Karanfil (2007), Lise and Montfort (2007), Karanfil (2008), Erdal et al.(2008) and Erbaykal (2008). They incorporated methods such as Vector Autoregression (VAR), Simple Granger Causality, Pair-wise Granger Causality, Instantaneous Causality, Vector Error Correction Models (VECM), Bonds Testing Co-integration, Johansen Co-integration, Implulse Response and Error Variance Decomposition. Their main objective was to find evidence for the causality between consumption and economic variables and their relationship.

There are also studies that focus on the relationship between energy, price and activity; and the direction and magnitude of this relationship. Studies of Bakirtas et al. (2000), Erdogdu (2007), and Halicioglu (2007) use methods like Auto Regressive Moving Average, Partial Adjustment Model, and Bonds Testing Co-integration and Engle-Granger two-step procedure, mainly to estimate price and income elasticities for the gross and residential electricity demands in Turkey.

Elasticities found by studies vary. Bakirtas et al. (2000) found the long run total elasticity 3.1 and price elasticity about zero. Erdogdu's (2007) method estimates long run income and price elasticity for total demand as 0.41 and -0.30 respectively. Halicioglu (2007) claims these values are 0.70 for income and -0.52 for price elasticities in the long run for the residential demand.

There are also studies for forecasting future energy demand. Some of the prominent studies are Ediger and Tatlidil (2002), Ceylan and Ozturk (2004), Ozturk et al. (2005), Akay and Atak (2006), Ediger and Akar (2007), Hamzacebi (2007) and Erdogdu (2007). They use methods like Auto Regressive Integrated Moving Average (ARIMA), Genetic Algorithm Approach, Univariate Cycle Analysis, Grey Prediction with Rolling Mechanism, and Artificial Neural Networks.

To give further details, the studies that worked on total Turkish Electricity demand and forecasting are Bakirtas (2000), Erdogdu (2007) Ozturk and Ceylan (2004) Kavaklioglu (2009), Hamzacebi (2007) and Akay and Atak (2006).

Bakirtas (2000) sought for the relationship between aggregate electricity consumption per capita, income per capita and electricity price using annual data and cointegration method. The data considers the timeframe between 1962 and 1996. Even though government intervention and a non-liberal market pollute the analysis, it is found that income per capita is a significant covariate. Short term elasticity is 0.7 and long term elasticity is 3.1. Forecast is also conducted for years from 1997 to 2000 using ARMA model.

Erdogdu's (2007) study uses Partial Adjustment Model to find a significant relationship between net electricity consumption per capita, real GDP per capita and the price. Quarterly data is used within the timeframe 1984-2004. Short run price elasticity is -0.04 and long run is -0.30. Interpolation is used in order to modify the data to quarterly periods. This is due to concerns for artificial data generation and biased estimators, therefore making elasticity estimates suspicious. A simple univariate ARIMA model is used for the period 1923-2004. A yearly 3.3% increase in total Turkish electricity demand is estimated until 2014. The final consumption in 2014 is forecasted to be 160 TWh.

Genetic Algorithm method is used in the study of Ozturk and Ceylan (????). Annual data from 1980 to 2003 is considered and relevant candidate variables are chosen as population, imports, exports and GDP to estimate aggregate electricity consumption. Prices are not included in the model. The forecasted electricity demand is between 462 and 500 TWh in 2020.

Kavaklioglu (2009) uses artificial neural networks using the annual data between 1975 and 2006. Population, GDP, imports and exports are taken as covariates to explain aggregate electricity consumption. One issue with the model is their relationship is not clearly defined. Prices are also not included in the model.

Hamzacebi's (2007) demand forecast is below 500 TWh in 2020 using artificial neural network model and annual data between 1970 and 2004. Akay and Atak's (2006) forecast for aggregate and industrial electricity consumption is below 266 TWh in 2015 using Grey Prediction.

Studies of Bakirtas et al. (2000), Erdogdu (2007), Hamzacebi (2007) and Akay and Atak (2006) only consider past electricity consumption to forecast future demand. They all ignore interaction between demand, income and price. Even though Ozturk and Ceylan (2004) and Kavaklioglu et al. [9] include economic variables in their models, the identification is not clear for the forecast.

3.2 Technics to Estimate Electricity Demand:

Moving Average Processes:

A moving average process model is simply a linear combination of white noise processes at which y_t depends on the current and previous values of a white noise disturbance term. Let u_t (t = 1, 2, 3,..) be a white noise process with $E(u_t) = 0$ and $Var(u_t) = \sigma^2$

$$y_t = \mu + u_t + \theta_1 u_{t-1} + \theta_2 u_{t-2} + \cdots + \theta_q u_{t-q}$$

is a qth order moving average mode, denoted MA(q) which can be also written as

$$y_t = \mu + \sum_{i=1}^{q} \theta_i u_{t-i} + u_t$$

and if the lag operator expression is used

$$y_t = \mu + \sum_{i=1}^{q} \theta_i L^i u_t + u_t$$

or

$$y_t = \mu + \theta(L) u_t$$

where $\theta(L) = 1 + \theta_1 L + \theta_2 L^2 + \ldots \theta_q L^q$

MA(q) process can be summarized:

(1) $E(y_t) = \mu$

(2) $var(y_t) = \gamma_0 = (1 + \theta_1^2 + \theta_2^2 + \ldots.. + \theta_q^2)\sigma^2$

(3) covariance $\gamma_s = 0$ for s > q and for s= 1,2… q

$\gamma_s = (\theta_s + \theta_{s+1}\theta_1 + \theta_{s+2}\theta_2 + \ldots\ldots.\theta_q \theta_{q-s})\sigma^2$

MA process has constant mean, constant variance and autocovariances which may be non-zero to lag q and will always be zero thereafter.

Autoregressive processes:

An autoregressive model is where the current values of y depend only on the values in the previous periods and an error term. (p is the order) and AR(p)

$y_t = \mu + \phi_1 y_{t-1} + \phi_2 y_{t-2} \ldots\ldots + \phi_p y_{t-p} + u_t$; u_t is a white noise disturbance term.

$$y_t = \mu + \sum_{i=1}^{p} \phi y_{t-i} + u_t$$

Or by using lag operator

$$y_t = \mu + \sum_{i=1}^{p} \phi L^i y_t + u_t$$

$$\phi(L) y_t = \mu + u_t$$

Where

$$\phi(L) = (1 - \phi_1 L - \phi_2 L^2 - \ldots\ldots. - \phi_p L^p)$$

Setting μ to zero for a zero mean AR (*p*) process, y_t given by $\varphi(L)y_t = u_t$ it would be stated that the process is stationary if it is possible to write $y_t = \phi(L)^{-1} u_t$; with $\phi(L)^{-1}$ converging to zero. When the lag length is increased, the autocorrelations will decline.

Autocorrelation function and correlogram:

$E\,(y_{t1}-\mu)\,(y_{t2}-\mu) = \gamma_{t2-t1}\ \forall\ t_1, t_2$

function used for autocovariance which is talked at the type of the stationarity.

The autocovariances determine how *y* is related to its previous values, and for a stationary series they depend only on the difference between t_1 and t_2, so that the covariance between y_t and y_{t-1} is the same as the covariance between y_{t-10} and y_{t-11}, etc. The moment

$E(y_t - E(y_t))(y_{t-s} - E(y_{t-s})) = y_s$, $s = 0, 1, 2, \ldots$

is known as the autocovariance function. When $s = 0$, the autocovariance at lag zero is obtained, which is the variance of y.

The more useful way of using the autocorrelations is the normalised form which is obtained by dividing the autocorrelations to the variance

$$\tau_s = \frac{\gamma_s}{\gamma_0} \quad , s = 0, 1, 2, \ldots$$

The standard property of correlation coefficients is obtained for τ_s and the values lie between ±1. For $s = 0$, the autocorrelation at lag zero is obtained that is 1. The autocorrelation function (acf) or correlogram is acquired when τ_s is plotted against $s = 0, 1, 2, \ldots,$

The partial correlation function:

The partial autocorrelation function, or pacf (denoted τ_{kk}), measures the correlation between an observation k periods ago and the current observation, after controlling for observations at intermediate lags (i.e. all lags$<k$) -- i.e. the correlation between y_t and y_{t-k}, after removing the effects of y_{t-k+1}, y_{t-k+2}, . . . , y_{t-1}. For example, the pacf for lag 3 would measure the correlation between y_t and y_{t-3} after controlling for the effects of y_{t-1} and y_{t-2}.

At lag 1, the autocorrelation and partial autocorrelation coefficients are equal, $\tau_{11} = \tau_1$

At lag 2, $\tau_{22} = (\tau_2 - \tau_1^2) / (1 - \tau_1^2)$, τ_1 and τ_2 are the autocorrelation coefficients at lags 1 and 2.

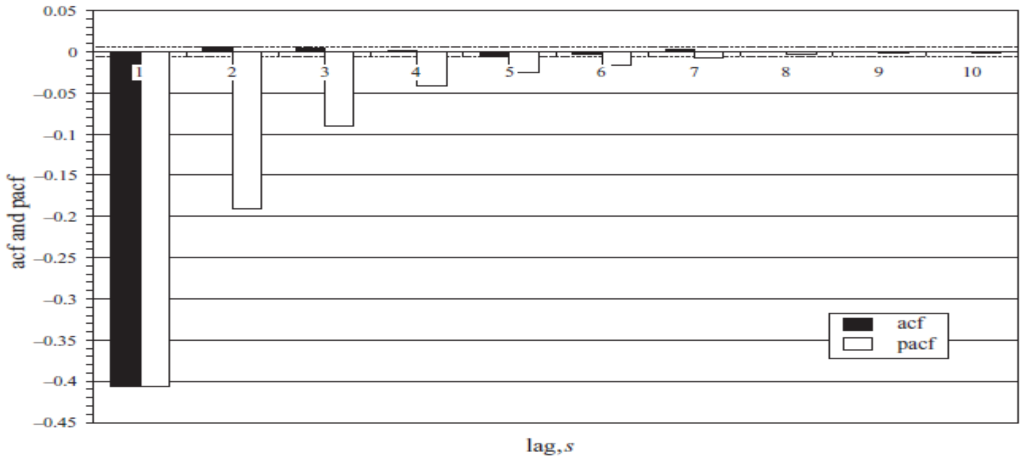


Figure 3.1 ACF and PACF of MA1 process

Source: Brook, 2008

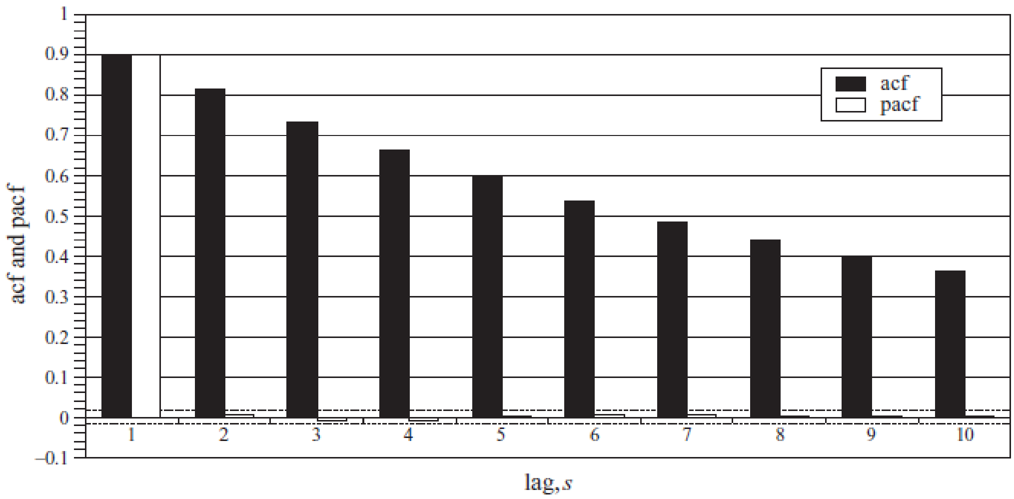


Figure 3.2 ACF and PACF of AR1 process

Source: Brooks, 2008

ARMA process:

By combining the AR(p) and MA(q) models, an ARMA(p, q) model is obtained.

$$y_t = \mu + \phi_1 y_{t-1} + \phi_2 y_{t-2} \ldots\ldots + \phi_p y_{t-p} + \theta_1 u_{t-1} + \theta_2 u_{t-2} + \ldots\ldots + \theta_q u_{t-q} + u_t$$

with $E(u_t) = 0$; $E(u_t^2)=\sigma^2$; $E(u_t u_s) = 0$, $t \neq s$

An autoregressive process has:

- a geometrically decaying acf
- a number of non-zero points of pacf=AR order

A moving average process has:

- a geometrically decaying pacf
- a number of non-zero points of acf=MA order

A combination autoregressive moving average process has:

- a number of non-zero points of acf=MA order
- a number of non-zero points of pacf=AR order

the mean of an ARMA series is given by

$$E(y_t) = \frac{\mu}{1 - \phi_1 - \phi_2 - - - - - \phi_p}$$

ARMA models: the Box- Jenkins approach:

Box and Jenkins (1976) approach is the first to estimate an ARMA model in a systematic manner that involves three steps:

1) Identification

Graphical procedures are used (acf and pacf are plotted) to determine the order of the model to get dynamic features.

2) Estimation

Estimation of the parameters by using Least Square method or another one such as Maximum Likelihood depending on the model.

3) Diagnostic checking

Checking whether the model specified and estimated is adequate. Box and Jenkins suggest two methods: overfitting and residual diagnostics. Fitting a larger model is involved than that required to capture the dynamics of the data as identified in stage 1. Residual diagnostics checks the residuals for evidence of linear dependence. The acf, pacf or Ljung-Box tests can be used.

Before talking about ARIMA, it is useful to explain orders of integration:
If a non-stationary series, y_t must be differenced d times to be stationary, then it is said to be integrated of order d that is shown as $y_t \sim I(d)$ and then $\Delta^d y_t \sim I(0)$.
A process with no unit roots is obtained by taking the difference operator Δ, d times.

The autoregressive integrated moving-average model, ARIMA

The autoregressive integrated moving-average model, or ARIMA (p,d,q)

$$\Delta^d y_t = \mu + \gamma_1 \Delta^d y_{t-1} + \gamma_2 \Delta^d y_{t-2} + \ldots\ldots.. + \gamma_p \Delta^d y_{t-p} + \varepsilon_t - \theta_1 \varepsilon_{t-1} - \ldots\ldots \theta_q \varepsilon_{t-q},$$

where

$$\Delta y_t = y_t - y_{t-1} = (1-L)\, y_t$$

Seasonal Autoregressive Integrated Moving Average Model, SARIMA

The natural variability of many variables such as at physics, economics, biology tends to have seasonal fluctuations. Because of this it is suitable to introduce ARMA process with seasonal lags. The pure seasonal ARMA model; ARMA (p, q) $_s$ has the form:

$\Phi_P(B^s)x_t = \Theta_Q(B^s)w_t$ with the operators

$\Phi_p(B^s) = 1 - \Phi_1 B^s - \Phi_2 B^{2s} - .....\Phi_p B^{Ps}$ and

$\Theta_Q(B^s) = 1 + \Theta_1 B^s + \Theta_2 B^{2s} + ...\Theta_Q B^{Qs}$

are the seasonal autoregressive operator and the seasonal moving average operator of orders P and Q, respectively with seasonal period s.

A process x_t is said to be ARIMA(p,d,q) if

$\Delta^d x_t = (1-B)^d x_t$ is ARMA(p,q). The general form of the model is

$$\phi(B)(1-B)^d x_t = \theta(B) x_t$$

If E($\Delta^d x_t$)= μ , the model can be written as

$$\phi(B)(1-B)^d x_t = \delta + \phi(B) w_t$$

where $\delta = \mu(1-\phi_{1-}\text{.......}\phi_p)$

The multiplicative seasonal autoregressive integrated moving average model or SARIMA is given by

$$\Phi_p(B^s)\phi(B)\Delta_s^D \Delta^d x_t = \delta + \Theta_Q(B^s)\theta(B) w_t$$

Where w_t is the usual Gaussian white noise process. The general model can be shown as ARIMA (p,d,q) x $(P,D,Q)_s$. The ordinary autoregressive and moving average components are represented by polynomials $\phi(B)$ and $\theta(B)$ of orders p and q, respectively. The seasonal autoregressive and moving average components are represented by $\Phi_P(B^s) and \Theta_Q(B^s)$ of orders P and Q. The ordinary difference component is $\Delta^{d\,=}$ $(1-B)^d$ whereas the seasonal one is $\Delta_s^D = (1-B)^D$

Stationarity:

Most of the series contain seasonal components, **Hylleberg et al(1990)** in order to deal with this situation improved a new technique to test seasonal unit roots at different frequencies. He mentions that it can be talked by using three time series model for seasonality.

1) Purely deterministic seasonal process
2) Stationary seasonal process
3) Integrated seasonal process

The aim of his paper is to determine the class of seasonal process in univariate models that cause the seasonality. In the literature, Dickey, Hazsa, and Fuller (1984) propose the test for zero-frequency unit-root case. The problem of the test is it does not allow testing unit roots at different frequencies. The same problems can be seen at tests which are proposed by Bhargava (1987).

In Hylleberg paper, for quarterly data, the polynomial $(1 - B^4)$ can be expressed as

$$
\begin{aligned}
(1 - B^4) &= (1 - B)(l + B)(l - iB)(l + iB) \\
&= (1 - B)(l + B)(l + B^2)
\end{aligned}
$$

The unit roots are 1,-1, i, and –i. The root 1 stands for zero frequency, -1 is for ½ cycle per quarter or 2 cycles per year. The root i stands for ¼ cycle per quarter or 1 cycle per year. The last root –i is for the annual cycle. The root 1 indicates no seasonal unit root in the series.

The hypothesis that the roots of φ(B) lie on the unit circle against the alternative that they lie outside the unit circle is tested. The equation is restructured. A stationary seasonal process can be generated by a potentially infinite autoregression

$$\varphi(B)\, x_t = \varepsilon_t \qquad (3.2.1)$$

ε_t i.i.d., with all of the roots lying outside the unit circle but where some are complex pairs with seasonal periodicities.

In order to test seasonal unit roots for quarterly data the polynomial φ(B) is expanded about the roots +1, -1, i and –i as θ_k k=1,..4.

$$
\begin{aligned}
&\varphi(B) = \lambda_1 B(1+B)(1+B^2) + \lambda_2(-B)(1-B)(1+B^2) \\
&+\lambda_3(-iB)(1-B)(1+B)(1-iB) \\
&+\lambda_4(iB)(1-B)(1+B)(1+iB) \\
&+\varphi^*(B)(1-B^4)
\end{aligned} \qquad (3.2.2)
$$

λ_3 and λ_4 must be complex conjugates since the polynomial is real. If the substitution $\pi_1 = -\lambda_1, \pi_2 = -\lambda_2, 2\lambda_3 = -\pi_3 + i\pi_4$ and $2\lambda_4 = -\pi_3 - i\pi_4$ is done,

$$\begin{aligned}\varphi(B) &= -\pi_1 B(1+B+B^2+B^3) - \pi_2(-B)(1-B+B^2-B^3) \\ &-(\pi_4 - \pi_3 B)(-B)(1-B^2) + \varphi^*(B)(1-B^4).\end{aligned} \tag{3.2.3}$$

Testing the seasonal unit roots:

φ (B) $x_t = \varepsilon_t$

φ (B) is replaced by the equation (3.2.3)

$$\varphi^*(B) y_{4t} = \pi_1 y_{1t-1} + \pi_2 y_{2t-1} + \pi_3 y_{3t-2} + \pi_4 y_{3t-1} + \varepsilon_t \tag{3.2.4}$$

where

$$\begin{aligned} y_{1t} &= (1+B+B^2+B^3)x_t = S(B)x_t \\ y_{2t} &= -(1-B+B^2-B^3)x_t \\ y_{3t} &= -(1-B^2)x_t \\ y_{4t} &= (1+B^4)x_t = \Delta_4 x_t \end{aligned} \tag{3.2.5}$$

Equation 3.2.4 can be estimated by OLS. For the root 1, the π_1=0 is tested while π_2=0 is tested for the root -1. π_3 and π_4 are jointly tested for the complex root λ_3. There will be no unit root if π_2 and either π_3 or π_4 are different from zero. The alternative of these tests is stationarity which is; $\pi_1 < 0$ and $\pi_2 < 0$ and $\pi_3 = \pi_4$ are not both equal to zero. If π's values are not negative numbers the series have unit root and they are not stationary. The critical values for the unit roots are given for the sample size 48, 100, 136 and 200 at Hylleberg (1990). Constant, trend and seasonal dummy can be added to HEGY test but critical values change.

The application of HEGY test to quarterly data has been extended to monthly data by Bealieu and Miron (1993). Monte Carlo simulations are used to compute critical values. HEGY test is superior compared to other unit root tests as it allows getting roots at any seasonal frequency without being dependent on the other unit roots.

Vector Autoregressive Models:

Vector autoregressive (VAR) models that are suggested as an alternative to large-scale simultaneous equations structural models become popular by Sims (1980).

$$y_t = \mu + \Gamma_1 y_{t-1+} .... + \Gamma_p y_{t-p+} + \varepsilon_t$$

where ε_t is a vector of nonautocorrelated disturbances with zero means and contemporary covariance matrix $E\left[\varepsilon_t \varepsilon_t^{'}\right] = \Omega$. This equation system is VAR. This equation can be written also in the form of

$$\Gamma(L) y_t = \mu + \varepsilon_t$$

Where $\Gamma(L)$ is a matrix of polynomials in the lag operator. The individual equations are where $\Gamma(L_i)_{lm}$ indicates the (l,m) element of Γ_j is

$$y_{mt=\mu_m} + \sum_{j=1}^{p} (\Gamma_j)_{m1} y_{1,t-j} + \sum_{j=1}^{p} (\Gamma_j)_{m2} y_{2,t-j} ...... + \sum_{j=1}^{p} (\Gamma_j)_{mM} y_{M,t-j} + \varepsilon_{mt}$$

The VAR model can be used to test the causality of lagged values of for example x_t have explanatory power in a regression of variable y_t on lagged values of y_t and x_t that is defined by Granger (1969) and Sims (1972). F test is used to test the restrictions.

VAR model have some advantages that can be listed as: You do not need to specify your variable as endogenous or exogenous at the beginning. It allows the value of a variable to depend on more than just its own lags by offering a rich structure.

Besides its advantages, the estimation of the optimal lag for VAR is difficult. There are many parameters to be estimated and for small sample size this causes the problem of degrees of freedom. It should be noted that the components of the model have to be stationary.

Vector Error Correction Models and Johansen Approach:

In order to apply Johansen test, first of all the VAR is formulated

$$y_t = \Gamma_1 y_{t-1} + \Gamma_2 y_{t-2} + ... + \Gamma_p y_{t-p} + \varepsilon_t$$

The optimal lag p is determined in advance. Let, z_t denote the vector of M(p-1) variables,

$$z_t = \left[\Delta y_{t-1}, \Delta y_{t-2} ..... \Delta y_{t-p+1} \right]$$

z_t contains the lags 1 to p-1 of the first difference of all M variables. Then, two T x M matrices of least squares residuals is obtained

D= the residuals in the regressions of Δy_t on z_t

E= the residuals in the regressions of y_{t-p} on z_t

The M squared canonical correlations between the columns in D and those in E. Linear combinations of the columns D is denoted by d_1^* and e_1^* denoted the linear combinations of E. Two linear combinations are picked up to maximize the correlation between them. The first canonical variates are this pair of variables and their correlation which is denoted by r_1^* is the first canonical correlation. A second pair of variables d_2^*, e_2^* is searched to maximize the correlation under the restriction that the second variable in each pair be orthogonal to the first. The squared canonical correlations are the ordered characteristic roots of the matrix

$$R^{*} = R_{DD}^{-1/2} R_{DE} R_{EE}^{-1} R_{ED} R_{DD}^{-1/2}$$

R_{DE} is the cross correlation matrix between D and E. The null hypothesis that are r or fewer cointegrating vectors is tested by the statistic:

$$Tracetest = -T \sum_{i=r+1}^{M} \ln\left[1-(r_i^{*})^2\right]$$

The statistic is referred to the χ^2 distribution with M-r dof, if the correlations based on the actual disturbances are seen instead of the estimated.

CHAPTER 4

ELECTRICITY DEMAND IN TURKEY: 1998-2011

In order to model electricity demand in Turkey for quarterly data the variables that are covered in this study are: electricity consumption, electricity price, gross domestic product and temperature as most of the electricity demand studies covers that are worked on for Turkey. VECM is used for cointegration as it does not restrict you to decide on the dependent variable. The disadvantage of the ECM has been tried to be eliminated as it does not take into consideration the mutual relationship. The temperature is used as external variables. Before applying the cointegration test the following procedure is applied to each variable.

1) Time series graph is drawn
2) The autocorrelation function (ACF) and the partial autocorrelation function (PACF) graphs are drawn
3) Proper seasonal time series model is obtained by looking at the graphs and AIC/Schwarz Criterian
4) The stationarity is analyzed under HEGY criteria, also ADF test

4.1 Some Univariate Time Series Properties of the Variables

The variables used in the VECM are domestic electricity consumption (mWh), $dem(t)$, real gross domestic product (GDP), $gdp(t)$ electricity price, $pri(t)$, the average temperature variable, $tem(t)$. All the variables are quarterly and the data samples are from 1998Q1 to 2011Q4. In the analysis of the quarterly time series, seasonal characterizations of the variables are needed. In this respect the series are analyzed to find out whether they display non-stationary stochastic seasonality by testing the existence of unit roots at the seasonal frequencies. The method developed by Hylleberg, Engle, Granger, and Yoo (1990) (the HEGY test) is applied to the quarterly data sets of the variables. A constant, trend and seasonal dummies are also added for quarterly data and series are tested against alternative that there exists no unit root in time series data. Critical values for the test statistics at %5 level are used.

Before talking about the HEGY test results first of all the graphs of each series are drawn by looking at the raw data and means by season. Later, by using ACF and PACF graphs with the help AIC/Schwarz Criterian the proper time series model is chosen for the series and stationarity tests are applied.

In order to check the efficiency of the model the following tests are applied: normality, serial correlation and ARCH effect. The Jarque-Bera test is used for normality while the ARCH test is chosen for the ARCH effect. Finally for the serial correlation analysis Breush-Goldfrey test is used. All three tests are important but the models are still accepted when the residuals have no serial correlation and ARCH effect at the same time.

Some Univariate Time Series Properties of the Electricity Consumption (mWh) in Turkey between 1998Q1 and 2011Q4

Data is obtained from National Load Dispatch Center, which is the unit under TEIAS and the transmission system operator. The center is in charge of control and organization of the system all the time. It also works on the forecasting of electricity demand. By controlling the system in case of breakdowns it can interfere and another producer can start to operate.

The plot of the electricity consumption series suggests that electricity consumption is seasonal.

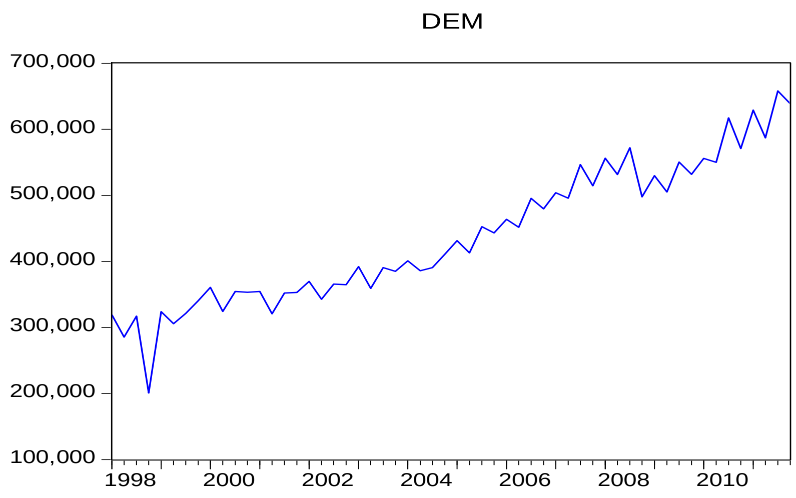


Figure 4.1 Electricity Consumption (MHW), 1998Q1-2011Q4

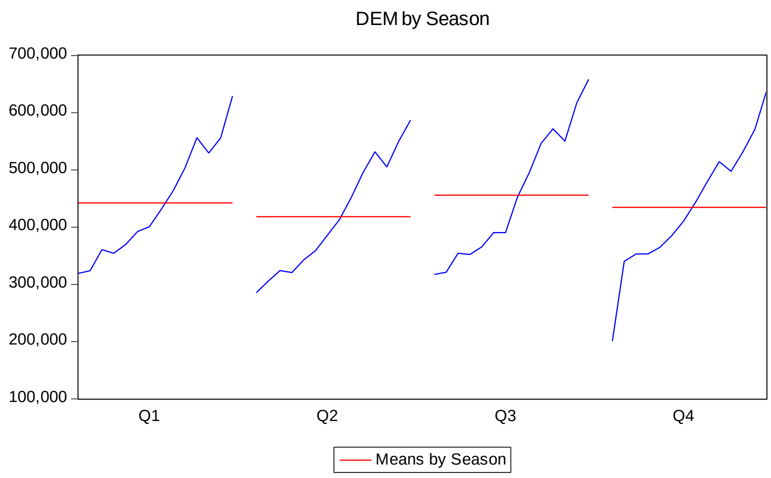


Figure 4.2 Means of Electricity Consumption (MHW), 1998Q1-2011Q4

Univariate Seasonal Model for the Quarterly Electricity Consumption, 1998Q1-2011Q4

As mentioned above the graphs of the electricity demand suggest seasonality and the proper model should be found. Here the investigation of stochastic seasonality is carried out for the quarterly electricity consumption, $dem(t)$. Let

$$d(t) = dem(t) - dem(t-1) - dem(t-4) + dem(t-5) \qquad (4.1.1)$$

Then the estimation of the regression equation

$$d(t) = \beta d(t-1) + \gamma u(t-1) + u(t) \qquad (4.1.2)$$

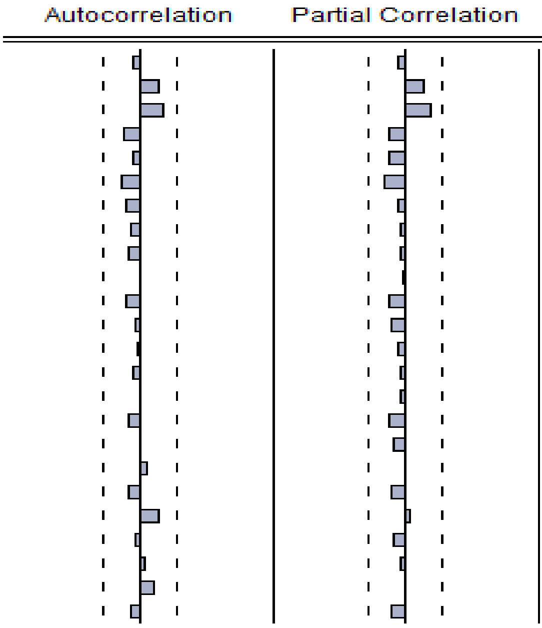
gives

$$\beta = 0.384, \gamma = -0.961$$

with the probability of 0.0086 and 0.0002. The parameters are statistically significant.

Before choosing the model different ACF and PACF graphs are analyzed and smallest AIC is chosen in order to decide on the AR and MA process order. SARIMA (1, 1, 1) is chosen as the proper time series model for the quarterly electricity consumption series.

The ACF and PACF for the electricity consumption indicate the non-stationarity of the stochastic process for the quarterly series of the electricity consumption when the proper time series model is used.



	AC	PAC	Q-Stat	Prob
1	-0.065	-0.065	0.2244	
2	0.135	0.132	1.2188	
3	0.180	0.200	3.0077	0.083
4	-0.139	-0.139	4.0953	0.129
5	-0.052	-0.134	4.2522	0.235
6	-0.147	-0.168	5.5317	0.237
7	-0.104	-0.052	6.1857	0.289
8	-0.080	-0.028	6.5826	0.361
9	-0.092	-0.043	7.1203	0.416
10	0.000	-0.010	7.1203	0.524
11	-0.103	-0.122	7.8250	0.552
12	-0.049	-0.110	7.9889	0.630
13	-0.018	-0.064	8.0128	0.712
14	-0.058	-0.049	8.2586	0.765
15	0.008	-0.025	8.2631	0.826
16	-0.084	-0.133	8.7992	0.844
17	-0.002	-0.088	8.7994	0.888
18	0.053	-0.000	9.0291	0.912
19	-0.090	-0.114	9.7018	0.916
20	0.133	0.037	11.240	0.884
21	-0.039	-0.091	11.379	0.910
22	0.032	-0.046	11.476	0.933
23	0.102	-0.001	12.487	0.926
24	-0.076	-0.099	13.067	0.931

Figure 4.3 ACF and PACF Graphs for Electricity Consumption, 1998Q1- 2011Q4

Properties of the Residuals of the SARIMA(1,1,1) Model for the Quarterly Electricity Consumption for the period 1998Q1-2011Q4

Here the residuals of the SARIMA (1,1,1) model for the quarterly series are analyzed. The normality of residuals, the ARCH (autoregressive conditional heteroscedasticity) effect in residuals and the autocorrelation among residuals are investigated.

Efficiency Tests:

1) **Normality : not normally distributed**

H_o = Residuals are normally distributed

H_1 = Residuals are not normally distributed

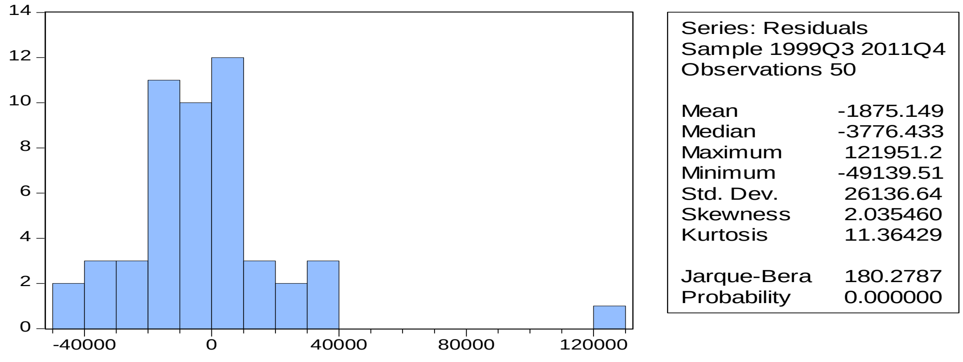


Figure 4.4 Normality of the residuals of the SARIMA(1,1,1) model for Electricity Consumption, 1998Q1-2011Q4

The assumption of the normality of the residuals does not hold with the Jarque-Bera test statistic value of 180.27.

2) Arch effect : no arch effect

H_o = There is no ARCH effect

H_1 = ARCH effect

The test statistic show no ARCH effect with the probability 0.630 for the F statistics of the value 0.234.

3) Serial correlation: no serial correlation

H_o = no serial correlation

H_1 = there is serial correlation

LM test statistics strongly indicate that there is no serial correlation in the residuals with F statistics equal to 0.590 and the probability is 0.558.

Even the normality assumption is not satisfied still we can accept the model as the residuals do not have serial correlation and ARCH effect problem.

Some Univariate Time Series Properties of the Real Gross Domestic Product (GDP) in Turkey between 1998Q1 and 2011Q4

GDP data is obtained from the Central Bank of the Republic of Turkey. The base year is 1998 and it is calculated by expenditure base.

The plot of the GDP series suggests that GDP is seasonal.

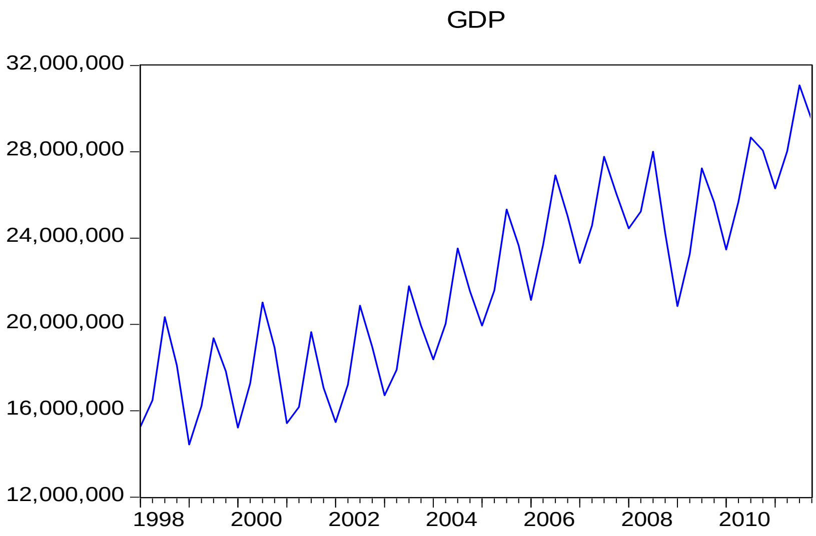


Figure 4.5 Quarterly GDP, 1998Q1-2011Q4

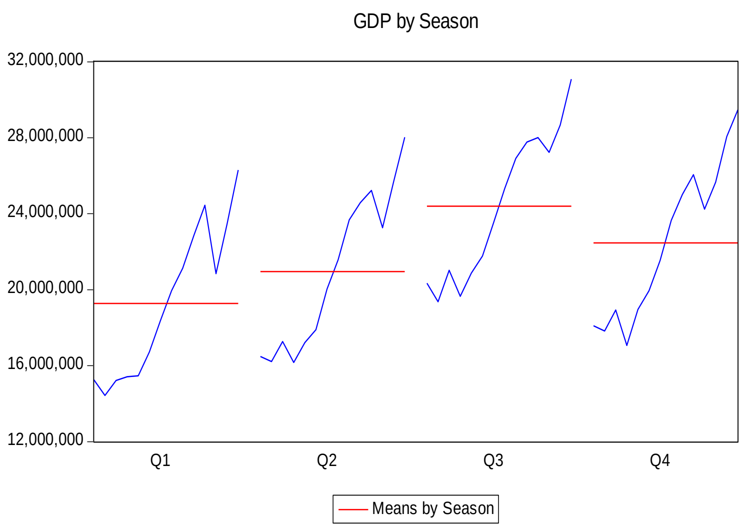


Figure 4.6 Means of GDP, 1998Q1-2011Q4

Univariate Seasonal Model for the Quarterly Real GDP, 1998Q1-2011Q4

As mentioned above the graphs of GDP suggest seasonality and the proper model should be found. Here the investigation of stochastic seasonality is carried out for the quarterly GDP, $gdp(t)$. Let

$$g(t) = gdp(t) - gdp(t-1) - gdp(t-4) + gdp(t-5) \quad (4.1.3)$$

Then the estimation of the regression equation

$$g(t) = \beta g(t-4) + \gamma u(t-4) + u(t) \quad (4.1.4)$$

gives

β is -0.100 , γ is -0.926

with the probability of 0.0053 and 0.0005. The parameters are statistically significant.

Before choosing the model different ACF and PACF graphs are analyzed and smallest AIC is chosen in order to decide on the AR and MA process order. SARIMA (4,1,4) is chosen as the proper time series model for the quarterly GDP series.

The ACF and the PACF for the GDP indicate the non-stationarity of the stochastic process for the quarterly series of the GDP when the proper time series model is used.

Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob
		1	0.170	0.170	1.4394	
		2	0.104	0.077	1.9917	
		3	-0.162	-0.198	3.3650	0.067
		4	-0.059	-0.010	3.5523	0.169
		5	-0.059	-0.010	3.7439	0.290
		6	0.133	0.129	4.7318	0.316
		7	-0.033	-0.089	4.7948	0.441
		8	-0.192	-0.239	6.9765	0.323
		9	-0.035	0.107	7.0489	0.424
		10	-0.166	-0.151	8.7737	0.362
		11	-0.050	-0.078	8.9357	0.443
		12	0.009	0.040	8.9416	0.538
		13	-0.099	-0.186	9.6121	0.566
		14	-0.047	0.042	9.7654	0.637
		15	-0.062	-0.100	10.042	0.691
		16	-0.042	-0.088	10.172	0.750
		17	-0.040	0.015	10.296	0.801
		18	-0.006	-0.164	10.299	0.851
		19	-0.074	-0.044	10.746	0.869
		20	-0.077	-0.120	11.251	0.883

Figure 4.7 ACF and PACF graphs for GDP, 1998Q1-2011Q4

Properties of the Residuals of the SARIMA(4,1,4) Model for the Quarterly Real GDP for the period 1998Q1-2011Q4

Here the residuals of the SARIMA (4,1,4) model for the quarterly series are analyzed. The normality of residuals, the ARCH (autoregressive conditional heteroscedasticity) effect in residuals and the autocorrelation among residuals are investigated.

Efficiency Tests:

1) **Normality : not normally distributed**

   H_o = Residual normally distributed

   H_1 = Residual is not normally distributed

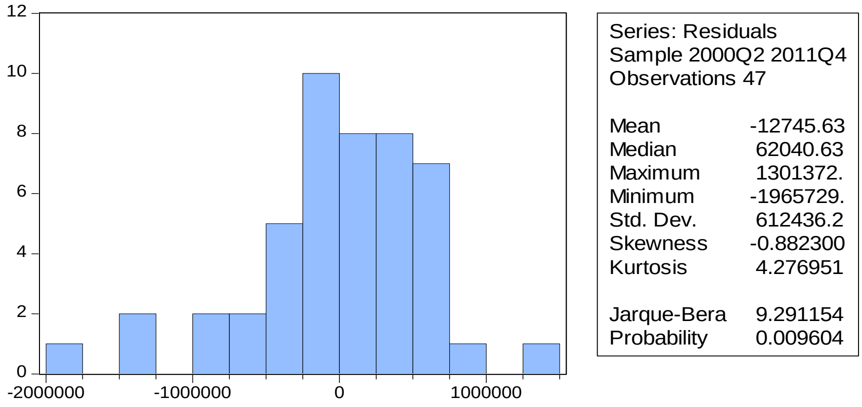


Figure 4.8: Normality of the residuals of the SARIMA(4,1,4) for GDP, 1998Q1-2011Q4

The assumption of the normality of the residuals does not hold with the Jarque-Bera test statistic value of 9.29.

2) Arch effect : no arch effect

H_o = There is no ARCH effect

H_1 = ARCH effect

F-statistic is 3.942 and the probability is 0.553

LM test statistics strongly indicate that there is no serial correlation in the residuals with F statistics equal to 3.942 and the probability is 0.553.

3) Serial correlation: no serial correlation

H_o = no serial correlation

H_1 = there is serial correlation

The test statistic show no ARCH effect with the probability 0.469 for the F statistics of the value 0.770.

Even the normality assumption is not satisfied still we can accept the model as the residuals do not have serial correlation and ARCH effect problem.

Some Univariate Time Series Properties of the Electricity Price in Turkey between 1998Q1 and 2011Q4

Electricity Price (Kr) : Data is obtained from TUİK.

The plot of the electricity consumption series does not suggest that electricity price is seasonal.

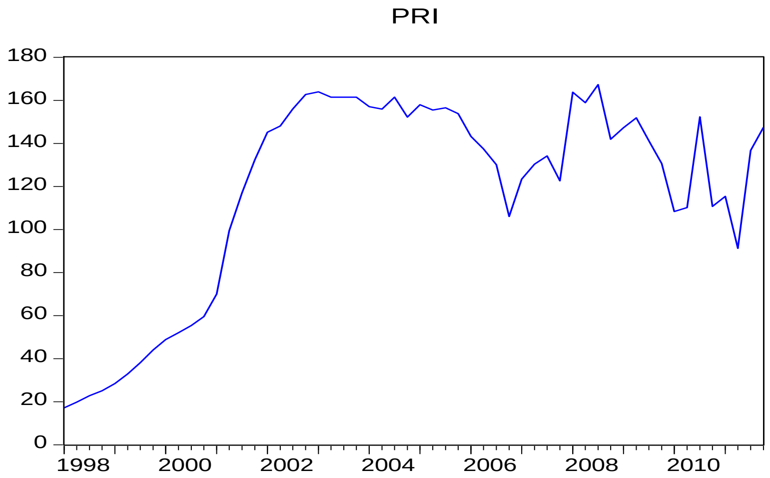


Figure 4.9 Quarterly Electricity Price, 1998Q1-2011Q4

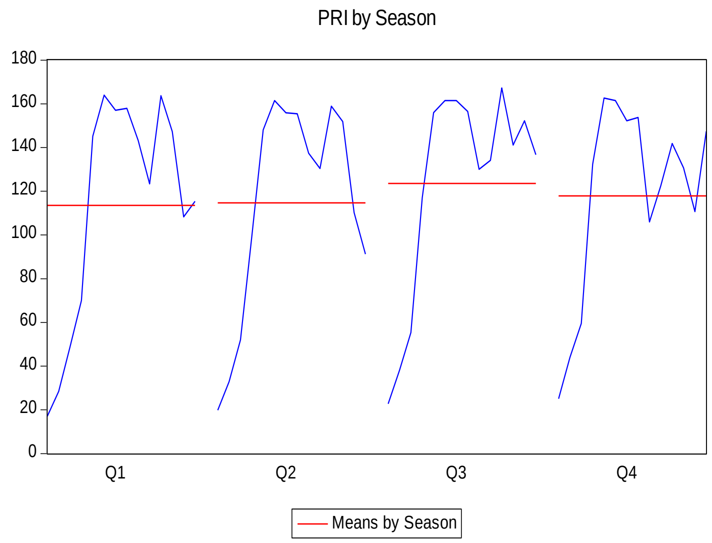


Figure 4.10 Means of Electricity Price, 1998Q1-2011Q4

Univariate Seasonal Model for the Quarterly Electricity Price, 1998Q1-2011Q4

Here the investigation of stochastic seasonality is carried out for the quarterly electricity price, $pri(t)$ .The estimation of the regression equation

$$\text{pri (t)= } \beta \text{ pri(t-1)+ } \gamma \text{ u(t-1) +u(t)} \qquad (4.1.5)$$

gives

β is 0.923 , γ is -0.158

with the probability of 0.0004 and 0.0028. The parameters are statistically significant.

Before choosing the model different ACF and PACF graphs are analyzed and smallest AIC is chosen in order to decide on the AR and MA process order. ARMA (1, 1) is chosen as the proper time series model for the quarterly electricity price series.

The ACF and the PACF for the electricity price indicate the non-stationarity of the stochastic process for the quarterly series of the electricity price when the proper time series model is used.

Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob
		1	-0.046	-0.046	0.1230	
		2	0.148	0.146	1.4186	
		3	-0.141	-0.132	2.6202	0.106
		4	-0.074	-0.109	2.9611	0.228
		5	-0.099	-0.068	3.5723	0.312
		6	0.011	0.015	3.5807	0.466
		7	0.075	0.081	3.9517	0.556
		8	-0.133	-0.171	5.1248	0.528
		9	-0.028	-0.081	5.1785	0.638
		10	-0.190	-0.147	7.6923	0.464
		11	0.073	0.062	8.0764	0.526
		12	-0.228	-0.228	11.874	0.294
		13	0.181	0.074	14.320	0.216
		14	-0.076	-0.055	14.766	0.254
		15	0.233	0.181	19.013	0.123
		16	-0.040	-0.051	19.144	0.160
		17	-0.032	-0.121	19.231	0.203
		18	-0.092	-0.110	19.954	0.222
		19	-0.063	0.007	20.298	0.259
		20	-0.008	-0.082	20.304	0.316
		21	0.034	0.029	20.413	0.370
		22	0.041	-0.117	20.575	0.423
		23	-0.084	-0.004	21.261	0.443
		24	-0.068	-0.166	21.724	0.476

Figure 4.11 ACF and PACF Graphs of Electricity Price, 1998Q1-2011Q4

Properties of the Residuals of the ARMA(1,1) Model for the Quarterly Electricity Price for the period 1998Q1-2011Q4

Here the residuals of the ARMA (1,1) model for the quarterly series are analyzed. The normality of residuals, the ARCH (autoregressive conditional heteroscedasticity) effect in residuals and the autocorrelation among residuals are investigated.

Efficiency Tests:

1) Normality: normally distributed

H_o = Residual normally distributed

H_a = Residual is not normally distributed

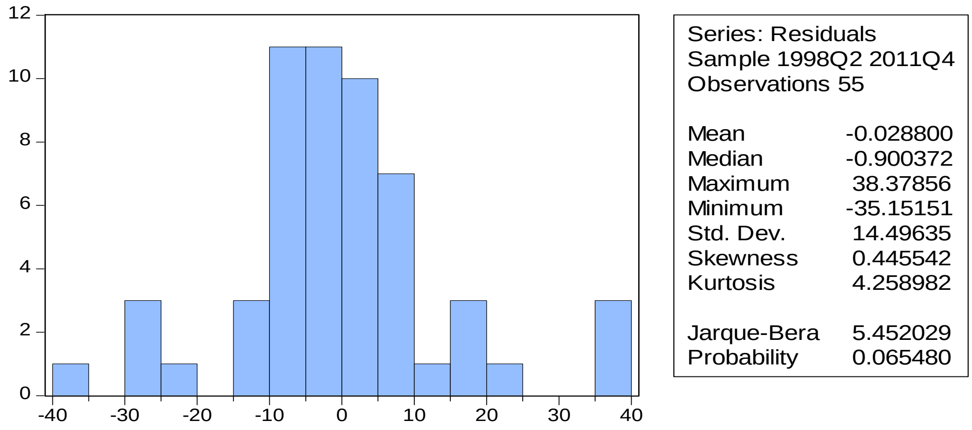


Figure 4.12 Normality of the residuals of the ARMA(1,1) model for Electricity Price , 1998Q1-2011Q4

The assumption of the normality of the residuals holds with the Jarque-Bera test statistic value of 5.45.

2) Arch effect : no arch effect

H_o = There is no ARCH effect

H_1 = ARCH effect

The test statistic show no ARCH effect with the probability 0.084 for the F statistics of the value 3.08.

3) Serial correlation: no serial correlation

H_o = no serial correlation

H_1 = there is serial correlation

F-statistic is 0.907 and the probability is 0.410. LM test statistics strongly indicate that there is no serial correlation in the residuals with F statistics equal to 0.907 and the probability is 0.410

We accept the model as the residuals do not have serial correlation, ARCH effect problem and are normally distributed.

Some Univariate Time Series Properties of the Temperature in Turkey between 1998Q1 and 2011Q4

Temperature (^oC): The temperature data is obtained from Turkish State Meteorology Institute for 81 cities. The weighted average of the temperature is calculated by using the area of the cities that is in the year book of Turkey.

The plot of the temperature series suggests that temperature is seasonal.

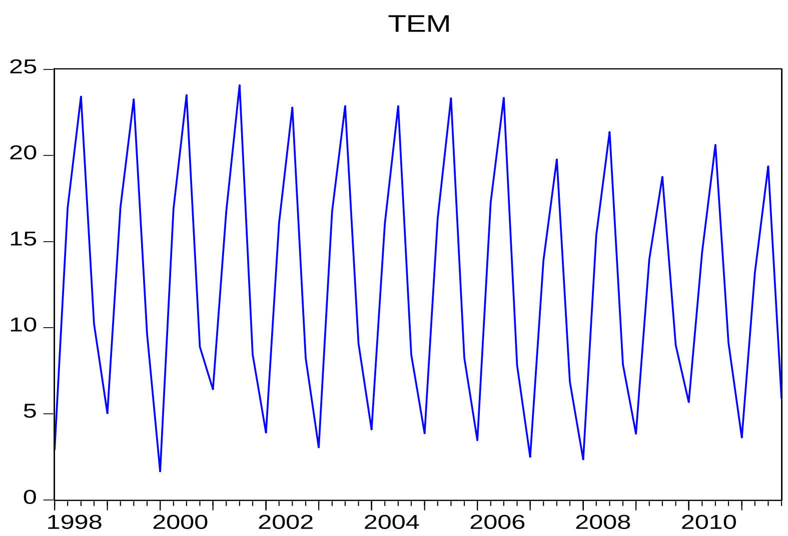


Figure 4.13 Temperature (^oC), 1998Q1-2011Q4

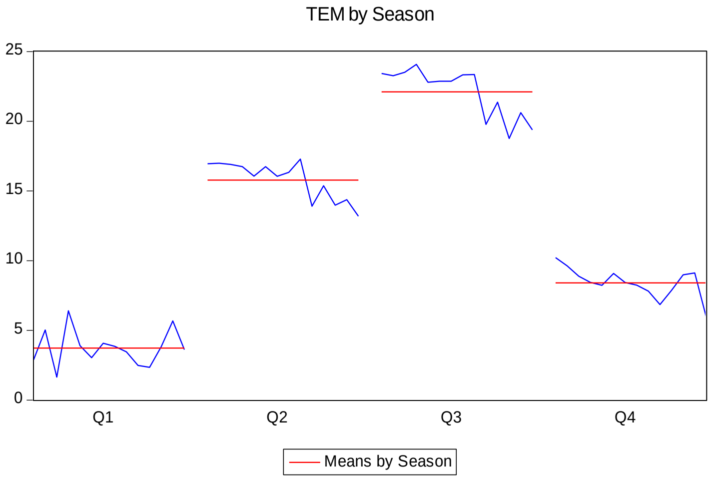


Figure 4.14 Means of Temperature (^{o}C), 1998Q1-2011Q4

Univariate Seasonal Model for the Quarterly Temperature, 1998Q1-2011Q4

As mentioned above the graphs of the temperature suggests seasonality and the proper model should be found. Here the investigation of stochastic seasonality is carried out for the quarterly temperature, $tem(t)$. Let

$$t(t)=tem(t)- tem(t-1)- tem(t-4)+ tem(t-5) \qquad (4.6.6)$$

Then the estimation of the regression equation

$$t(t)= \beta_1 t(t-1)+ \beta_2 t(t-4)+ \gamma_1 u(t-1)+ \gamma_2 u(t-4)+u(t) \qquad (4.6.7)$$

gives

β_1, β_2 are 0.162 -0.548 and γ_1, γ_2 are -0.853 and -0.082.

with the probability 0.0032, 0.0001, 0.0003 and 0.0052. The parameters are statistically significant.

Before choosing the model different ACF and PACF graphs are analyzed and smallest AIC is chosen in order to decide on the AR and MA process order. SARIMA, AR(1), MA(4) and MA(1) and MA(4) is chosen as the proper time series model for the quarterly temperature series.

The autocorrelation function (ACF) and the partial autocorrelation function (PACF) for the temperature indicate the non-stationarity of the stochastic process for the quarterly series of the temperature when the proper model is chosen.

Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob
		1	-0.038	-0.038	0.0741	
		2	-0.010	-0.011	0.0788	
		3	0.040	0.039	0.1620	
		4	0.018	0.021	0.1797	
		5	-0.066	-0.064	0.4166	0.519
		6	-0.110	-0.117	1.0997	0.577
		7	0.004	-0.008	1.1008	0.777
		8	-0.271	-0.274	5.4478	0.244
		9	0.044	0.033	5.5629	0.351
		10	-0.190	-0.218	7.8017	0.253
		11	-0.104	-0.129	8.4928	0.291
		12	-0.056	-0.115	8.7013	0.368
		13	-0.142	-0.237	10.061	0.346
		14	0.079	-0.027	10.492	0.398
		15	0.021	-0.060	10.522	0.484
		16	0.002	-0.190	10.523	0.570
		17	0.137	0.094	11.954	0.531
		18	0.218	0.042	15.741	0.329
		19	0.035	-0.031	15.844	0.392
		20	0.067	0.040	16.231	0.437

Figure 4.15 ACF and PACF graphs of Temperature (^{o}C), 1998Q1-2011Q4

Properties of the Residuals of the SARIMA Model for the Quarterly Temperature for the period 1998Q1-2011Q4

Here the residuals of the SARIMA model for the quarterly series are analyzed. The normality of residuals, the ARCH (autoregressive conditional heteroscedasticity) effect in residuals and the autocorrelation among residuals are investigated.

Efficiency Tests:

1) **Normality : normally distributed**

H_o = Residual normally distributed

H_1 = Residual is not normally distributed

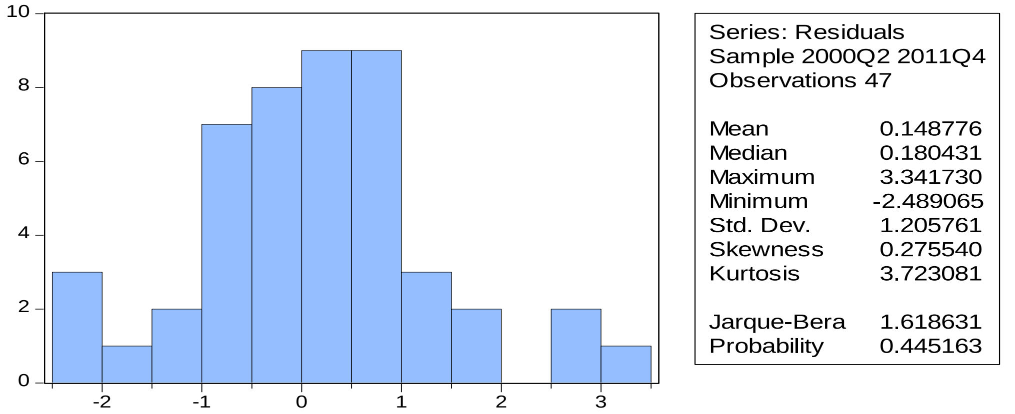


Figure 4.16 Normality of the residuals of the SARIMA model for Temperature , 1998Q1-2011Q4

The assumption of the normality of the residuals holds with the Jarque-Bera test statistic value of 1.6186.

2) **Arch effect : no arch effect**

H_o = There is no ARCH effect

H_1 = ARCH effect

F-statistic is 1.448 and the probability is 0.235. The test statistic show no ARCH effect with the probability 0.235 for the F statistics of the value 1.448.

3) **Serial correlation: no serial correlation**

H_o = no serial correlation

H_1 = there is serial correlation

F-statistic is 0.023 and the probability is 0.976. LM test statistics strongly indicate that there is no serial correlation in the residuals with F statistics equal to 0.023 and the probability is 0.976.

We accept the model as the residuals do not have serial correlation, ARCH effect problem and are normally distributed.

Stationarity Tests:

Augmented Dickey Fuller:

First of all, the unit roots are analyzed under Augmented Dickey Fuller test. Table 4.1 shows the results under the hypothesis testing

H_o = series has unit root

H_1 =series has no unit root

Table 4.1 ADF results for the series

	Electricity consumption	GDP	Price	Temperature
t statistics	0.261	0.023	-2.118	-0.638
probability	0.971	0.956	0.238	0.851
t statistics I (1)	-3.594	-3.288	-8.561	-5.771
probability	0.0092	0.02	0.001	0.001

When the test results are analyzed all series have unit roots but they become stationary when the first difference is taken. So the quarterly electricity consumption, GDP, electricity price and temperature are I (1) between periods 1998Q1 and 2011Q4.

HEGY Test Results:

The null and alternative hypotheses for the HEGY test are as follows:

H_o = series has unit root

H_1 = series has no unit root

Zero cycles per year, one cycle per year $(\pi / 2)$ and two cycles per year (π). π and $\pi / 2$ are needed to be different from zero which means the rejection of hypothesis in order not to have seasonal unit roots in the series. Also different terms are added such as Intercept(I), Seasonal Dummies(SD) and Trend (TR).

Table 4.2 HEGY test results

			Frequency		
		lag orders	zero	π	π/2
Electricity Demand	-	1,2,4	-3,064	-4,809	7,979
	p values		0,01	0,011	0,01
	I	1,2,4	-3,152	-4,837	8,172
			0,032	0,01	0,01
	I,SD	1,2,4	-2,937	-4,97	9,241
			0,067	0,01	0,01
	I,TR	1,2,4	-3,183	-4,698	7,797
			0,1	0,01	0,01
	I,SD,TR	1,2,4	-2,958	-4,811	8,744
			0,1	0,01	0,014
GDP	-	4	-3,998	-3,003	16,787
	p values		0,01	0,01	0,01
	I	4	-3,919	-2,979	16,416
			0,01	0,01	0,01
	I,SD	2,4	-2,996	-2,681	15,57
			0,062	0,1	0,01
	I,TR	4	-3,973	-3,023	16,418
			0,02	0,01	0,01
	I,SD,TR	2,4	-3,001	-2,704	15,342
			0,1	0,1	0,01
Price	-	2,4	0,207	-2,468	10,728
	p values		0,1	0,021	0,01
	I	2,4	-2,605	-2,425	9,093
			0,1	0,019	0,01
	I,SD	2,4	-2,416	-2,726	7,555
			0,1	0,094	0,028
	I,TR	2,4	-1,576	-2,242	8,571
			0,1	0,025	0,01
	I,SD,TR	2,4	-1,504	-2,557	7,001
			0,1	0,1	0,04

Table 4.2 (cont'd)

			Frequency		
		lag orders	zero	π	π/2
Industry Production Index	-	1,3,4	0,859	-2,711	4,296
	p values		0,1	0,01	0,021
	I	1,3,4	-1,269	-2,554	4,311
			0,1	0,014	0,017
	I,SD	2,3,4	-1,121	-3,666	4,135
			0,1	0,013	0,1
	I,TR	1,3,4	-2,747	-2,798	5,036
			0,1	0,01	0,01
	I,SD,TR	2,3,4	-2,996	-4,144	4,318
			0,1	0,01	0,1
Temperature	-	2,3	-2,221	-5,821	10,542
	p values		0,03	0,01	0,01
	I	2,3	-2,279	-5,687	9,042
			0,1	0,01	0,01
	I,SD	3	-1,748	-5,327	28,479
			0,1	0,01	0,01
	I,TR	2,3	-2,367	-5,583	8,026
			0,1	0,01	0,01
	I,SD,TR	3	-1,84	-5,152	26,889
			0,1	0,01	0,01

Table 4.3 HEGY table values

	0.05		
	zero	π	π/2
no intercept	-1.95	-1.95	3.26
I	-2.96	-1.95	3.04
I,SD	-3.08	-3.04	6.6
I,TR	-3.56	-1.91	2.95
I,SD,TR	-3.71	-3.08	6.55

When the table values are examined, it is seen that there are no seasonal unit roots for the quarterly series of the electricity consumption, 1998Q1-2011Q4. For GDP series there are no seasonal unit roots for I, I&TR and when no intercept is added.

When the values are compared to table values it is seen that the seasonal unit roots exist at the model where seasonal dummies are added for the quarterly series of the electricity price however when we look at the graph of the price the seasonality cannot be detected. When the table values are examined for the temperature, it is seen that there are no seasonal unit roots for the quarterly series 1998Q1-2011Q4.

4.2 Johansen Cointegration and VECM:

First of all optimal lag selection is done for the variables demand, GDP, price and temperature by using the unrestricted VAR model. After analyzing the AIC and Schwarz results the optimal lag of 4 should be chosen. However, when the lag is taken as 4 even there exists cointegration, VECM cannot be found. Therefore, the lag of order 5 is chosen and error correction mechanism can be found.

Table 4.4 AIC and Schwarz values for the VAR Model

lag of orders	**1**	**2**	**3**	**4**	**5**
Akaike	68.025	65.098	65.442	63.921	64.136
Schwarz	68.755	66.424	67.375	66.473	67.318

After selecting the lag of orders first of all cointegration is tested by using Johansen technique because VECM can be run when there is cointegration.

By using model and cointegration test: trace and max-eigen statistics the number of cointegrating equations is found at the level 0.05

H_o = none cointegrating equation

H_1 = there is at least 1 cointegration

Table 4.5 Trace and Max Eigen values for the cointegrating test for the quarterly data

hypothesized number of cointegrating		**Trace**				**Max-Eigen**		
equations	**Eigenvalue**	**Statistic**	**Critical V.**	**Prob.**	**Eigenvalue**	**Statistic**	**Critical V.**	**Prob.**
None *	0.5644	71.1372	47.8561	0.0001	0.5644	42.3895	27.5843	0.0003
At most 1	0.3129	28.7476	29.7971	0.0657	0.3129	19.1455	21.1316	0.0927
At most 2	0.1546	9.6021	15.4947	0.3126	0.1546	8.5703	14.2646	0.3236
At most 3	0.0200	1.0317	3.8415	0.3098	0.0200	1.0317	3.8415	0.3098

As the first trace value is bigger than the critical value, the hypothesis is rejected. As the second trace value is smaller than trace value we fail to reject the hypothesis so there is at least 1 cointegrating equation. The same result is obtained when the max-eigen statistic is checked.

After checking the cointegration, we can continue with the error correction mechanism and short run and long run equilibrium. Temperature is taken as exogenous variable. The model below is estimated and later the coefficients are checked if they are statistically significant. In order to have long run equilibrium c_1 should be negative and significant: the value of c_1 is -0.0710 but the probability is 0.3831 therefore it is not statistically significant. So there is no long run equilibrium. Only c_2 is statistically significant. Therefore, there is also no short run equilibrium. If the short run equilibrium can be checked, the Wald statistic is used and the hypothesis is tested as above by using χ^2 statistics.

$H_o = c_6=c_7=c_8=c_9 =0$ $\qquad$ $H_o = c_{10}=c_{11}=c_{12}=c_{13} =0$

$H_1 = c_6=c_7=c_8=c_9 \neq 0$ $\qquad$ $H_1 = c_{10}=c_{11}=c_{12}=c_{13} \neq 0$

$$\Delta(dem) = c_1(dem_{t-1} - 0.02963gdp_{t-1} + 857.1863pri_{t-1} + 100022.4186) +$$

$$c_2\Delta dem_{t-1} + c_3\Delta dem_{t-2} + c_4\Delta dem_{t-3} + c_5\Delta dem_{t-4} + \quad (4.2.1)$$

$$c_6\Delta gdp_{t-1} + c_7\Delta gdp_{t-2} + c_8\Delta gdp_{t-3} + c_9\Delta gdp_{t-4} +$$

$$c_{10}\Delta pri_{t-1} + c_{11}\Delta pri_{t-2} + c_{12}\Delta pri_{t-3} + c_{13}\Delta pri_{t-4} + c_{14} + c_{15}tem$$

Table 4.6 Coefficient results and t values

Dependent variable	**Demand Coefficient**	**Prob.**	**GDP Coefficient**	**Prob.**	**Price Coefficient**	**Prob.**
C(1)	-0.0710	0.3831	-0.2469	0.0194	-0.1518	0.0184
C(2)	-0.6456	0.0012	0.0220	0.8851	0.0936	0.5987
C(3)	-0.1252	0.545	-0.2333	0.0907	0.1783	0.3605
C(4)	-0.0216	0.9063	-0.3472	0.0203	0.0379	0.8262
C(5)	0.0068	0.9663	0.1298	0.45	0.1881	0.3204
C(6)	-0.2086	0.0904	-0.3292	0.0243	0.4874	0.0172
C(7)	0.0040	0.2658	5.7152	0.4629	-0.0002	0.1554
C(8)	0.0022	0.4887	13.8093	0.1224	-0.0001	0.5274
C(9)	-0.0009	0.7968	15.9030	0.0477	-0.0001	0.4619
C(10)	0.0059	0.1483	11.2274	0.1084	-0.0001	0.4322
C(11)	-0.0031	0.3521	1.3950	0.7854	-0.0001	0.512
C(12)	-54.3478	0.786	-12652.4700	0.1437	0.0000	0.7032
C(13)	90.0619	0.6804	-10394.1100	0.2676	0.0000	0.4239
C(14)	-586.0273	0.0047	-23819.4300	0.0066	0.0000	0.2546
C(15)	-141.5252	0.5053	-13160.6900	0.1504	0.0000	0.2235
C(16)	258.5022	0.2455	219.2547	0.9813	0.0000	0.5049
C(17)	30928.7700	0.0849	-1949219.0000	0.0129	22.9260	0.1472
C(18)	-1537.6740	0.2792	171646.3000	0.0069	-1.5714	0.214

$$\Delta(gdp) = c_1(gdp_{t-1} - 34.0361dem_{t-1} - 29175.2943pri_{t-1} - 3611113.1038) +$$

$$c_2\Delta gdp_{t-1} + c_3\Delta gdp_{t-2} + c_4\Delta gdp_{t-3} + c_5\Delta gdp_{t-4} + \quad (4.2.2)$$

$$c_6\Delta dem_{t-1} + c_7\Delta dem_{t-2} + c_8\Delta dem_{t-3} + c_9\Delta dem_{t-4} +$$

$$c_{10}\Delta pri_{t-1} + c_{11}\Delta pri_{t-2} + c_{12}\Delta pri_{t-3} + c_{13}\Delta pri_{t-4} + c_{14} + c_{15}tem$$

In order to have long run equilibrium c1 should be negative and significant: the value of c_1 is -0.1518 and the probability is 0.0184 therefore it is statistically significant and there is long run equilibrium but when the model is analyzed the long run impact of demand and price are negative and it is not logical the error correction model is not logical. The result that is expected to be seen is positive coefficients. There is also no short run equilibrium.

$$\begin{aligned}\Delta(pri) = {} & c_1(pri_{t-1} + 0.0011dem_{t-1} + 3.4275gdp_{t-1} + 107.9245) + \\ & c_2\Delta pri_{t-1} + c_3\Delta pri_{t-2} + c_4\Delta pri_{t-3} + c_5\Delta pri_{t-4} + \\ & c_6\Delta dem_{t-1} + c_7\Delta dem_{t-2} + c_8\Delta dem_{t-3} + c_9\Delta dem_{t-4} + \\ & c_{10}\Delta gdp_{t-1} + c_{11}\Delta gdp_{t-2} + c_{12}\Delta gdp_{t-3} + c_{13}\Delta gdp_{t-4} + c_{14} + c_{15}tem\end{aligned} \tag{4.2.3}$$

In order to have long run equilibrium c_1 should be negative and significant: the value of c_1 is -0.095 and the probability is 0.0281 therefore it is statistically significant and there is long run equilibrium. The problem with error correction model is sign of the demand. The t-statistics of the demand and GDP are 2.0044 and 2.3303 and table value is 2.021 therefore demand is not significant while GDP is statistically significant. What is seen in Turkey is that price is under the control. Even the demand increases the effect cannot be seen on price in terms of public service. There is also no short term equilibrium as the coefficients are not statistically significant.

Efficiency Tests:

1) **Normality : Residuals are not normally distributed**

   H_o = Residuals normally distributed

   H_a = Residuals are not normally distributed

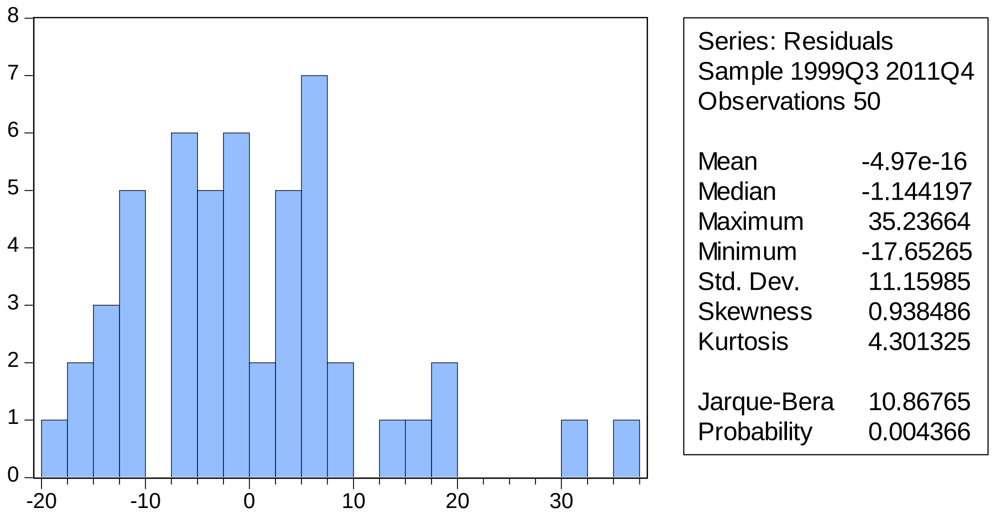


Figure 4.17 Normality of the model when pri is the dependent variable for the quarterly data, 1998Q1-2011Q4

The assumption of the normality of the residuals does not hold with the Jarque-Bera test statistic value of 10.8676.

2) **Arch effect : no arch effect**

H_o = There is no ARCH effect

H_a = ARCH effect

χ^2 -statistics is 0.1147 and the probability is 0.7298. The test statistic show no ARCH effect with the probability 0.7298.

3) **Serial correlation: no serial correlation**

H_o = no serial correlation

H_a = there is serial correlation

LM test statistics strongly indicate that there is no serial correlation in the residuals with χ^2 -statistics equal to 0.0939 and the probability is 0.8558.

We can accept the model as the residuals do not have serial correlation and ARCH effect problem even they are not normally distributed.

CHAPTER 5

CONCLUSION

When the recent developments are thought about supply and demand of the energy resources it is clear that in terms efficiency and restrictions, the electricity demand modeling should be done in the correct way. While doing this analysis, choosing the right variables that have effect on demand becomes important. When the quarterly data is used, seasonality becomes critical. So, first of all the right seasonal times series model has been chosen for the variables i.e. GDP, electricity demand, price and temperature. After finding the right model for the variables, for the cointegration process VECM is chosen. The aim of using Johansen cointegration is not to restrict the analysis by one linear cointegrating equation as in the Engle and Granger. However the problem is that, the sample size is not large enough therefore degrees of freedom becomes a problem while looking for the cointegration. So the model can work better with larger data set.

As the data is analyzed under the proper seasonal time series model and HEGY test has been applied which results in efficient modeling.

When the Day-Ahead market is taken into consideration it becomes obvious that short term modeling is necessary for the market players. As a future work, the modeling is going to be done for short term data. Also the demand is going to be calculated from the side of households and industries.

As a conclusion, while the market is becoming more liberalized, modeling the demand of electricity and forecasting become important and needed to be done efficiently.

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APPENDIX

Basic Concepts:

A time-series model describe the path of a variable y_t in term of contemporaneous (and perhaps lagged) factors x_t , disturbances ε_t, and its own past, y_{t-1} . . . For example,

$$y_t = \beta_1 + \beta_2\ x_t + \beta_3\ y_{t-1} + \varepsilon_t$$

The time series is a single occurrence of a random event. The sequence of observations $\{y_t\}_{t=-\infty}^{t=\infty}$ is a time-series process which is characterized by its time ordering and its systematic correlation between observations in the sequence.

One of the important concepts of the time series data is the stationarity as it has important effects on its behavior and properties.

A strictly stationary process is one where, for any $t_1, t_2........t_T$ ϵ Z, any kϵZ and T= 1, 2, 3 …..

Fy_{t1} , y_{t2}, . . . , y_{tT} (y_1, . . . , y_T) = Fy_{t1+k} , y_{t2+k}, . . . , y_{tT+k} (y_1, . . . , y_T)

where F denotes the joint distribution function of the set of random variables. A series is strictly stationary if the distribution of its values remains the same as time progresses, implying that the probability that y falls within a particular interval is the same now as at any time in the past or the future.

If a series satisfies the following 3 equations for $t = 1, 2, \ldots, \infty$, it is said to be weakly or covariance stationary

(1) $E(y_t) = \mu$

(2) $E(y_t-\mu)(y_t-\mu)= \sigma^2<\infty$

(3) $E(y_{t1}-\mu)(y_{t2}-\mu) = \gamma_{t2-t1} \ \forall \ t_1,t_2$

These equations mean that a stationary process should have a constant mean, a constant variance and a constant autocovariance structure, respectively.

When the series are non-stationary it affects the R-squared and t-statistics. A non-stationary series can be resulted in spurious regression. T-statistics are high and they do not follow asymptotic properties meaning that they do not follow t-distribution like F-statistics. Durbin-Watson statistic that is used to test autocorrelation is low at the same time. The model has autocorrelation when the Durbin-Watson statistic is low. In order to use this test for a model, there is an intercept term and no lagged dependent variable. Therefore it is clear that in dynamic models it is not applicable. Durbin’s H statistics is used for the dynamic ones. Lagrange Multiplier (LM) test is another statistics that can be used for autocorrelation.

Random Walk model:

Before talking about random walk process, a special type of stochastic process, a purely random or white noise, process should be mentioned. A stochastic process is purely random if it has zero mean, constant variance σ^2 and is serially uncorrelated. The random walk model (non-stationary stochastic process) can be distinguished as 2 types:

1) Random walk without drift (i.e. no constant or intercept term)

Suppose u_t is a white noise error term with mean 0 and variance σ^2. Then the series y_t is said to be random walk if

$$y_t = y_{t-1} + \varepsilon_t$$

2) Random with drift (i.e. constant term is present)

$$y_t = \mu + y_{t-1} + \varepsilon_t$$

White noise process has constant mean, variance and zero autocovariances, except at the lag zero. Except the single peak of 1 at s=0, each observation is uncorrelated with all other values in the series. Moreover, if y_t is distributed normally then

$\hat{\tau}_s \sim$ approx N (0, 1/T) where T is the sample size and $\hat{\tau}_s$ autocorrelation coefficient at lag s estimated from the sample

In order to build-up a non-rejection region for an estimated autocorrelation coefficient to find out if it is significantly different than zero the joint hypothesis that all coefficients are equal to zero at the same time can be tested by using Q statistics developed by Box and Pierce (1970).

$Q = T\sum_{k=1}^{m}\hat{\tau}_k^2$ where T =sample size, m=maximum length

Q-statistic is asymptotically distributed as a χ_m^2 under H_o= m=0. However, the Box-Pierce test has poor sample properties the statistic has been modified by Ljung-Box (1978)

$$Q^* = T(T+2)\sum_{k=1}^{m}\frac{\hat{\tau}_k^2}{T-k} \sim \chi_m^2$$

As the sample size increases the formula is inapplicable and the statistic is equal to Box-Pierce.

Stationarity:

Dickey and Fuller (1979) developed a method to test unit root.

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

Ho: ϕ = 1 (series has a unit root)

H_1: ϕ < 1 (series is stationary)

The equation 1 can be expressed also in the form of

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

Ho : ψ = 1 (series has a unit root)

H_1: ψ < 1 (series is stationary)

If the test statistic is more negative than the critical values , Ho is rejected. If there is autocorrelation in the dependent variable of Δy_t , the test is oversized and needs to be augmented by using p lags of Δy_t the statistic is known as Augmented Dickey-Fuller (ADF)

$$\Delta y_t = \psi y_{t-1} + \sum_{i=1}^{p} \alpha_i \Delta y_{t-i} + u_t$$

Philips-Perron test (PP):

They produce a similar test to ADF but an automatic correction is added to the DF procedure. One of the important criticisms both for PP and ADF tests is that their power is low when the process stationary with a root close to non-stationary boundary.

Kwiatkowski, Philips, Schmidt, Shin (KPSS) test:

This test which is developed in 1992 uses Ho: A series is trend stationary and the random walk equation has zero variance.

Model Selection tests :

The problem with the simple R^2 is that when you add a variable to the model it increases without taking into consideration if the variable is significant or not. For this reason forecasting the model becomes difficult as the model is overfitted. Adding variables to model may increase the variance of the forecast error despite the improved fit to the data. To overcome this problem with R^2 adjusted R^2 has been introduced.

$$\bar{R}^2 = 1 - \frac{n-1}{n-K}(1-R^2)$$

By using adjusted R^2, adding another variable causing the loss of degrees of freedom is penalized. Adjusted R^2 may fall when a variable is added if the sum of squares does not fall fast enough. The R^2 does not rise when a variable is added to the model unless the t ratio associated with the variable exceeds one in absolute value.

It is mentioned that R^2 penalizes adding a variable, and alternative fit measures are discussed below to choose the correct model as the sample size rises.

Akaike information criterion:

Suppose a normal regression model with k coefficients and denote the maximum likelihood estimator for the variance as

$$\hat{\sigma}^2 = \frac{SSE_k}{n}$$

Where SSE stands for the sum of squares under the model with k regression coefficients.

$$AIC = \log \hat{\sigma}_k^2 + \frac{n+2k}{n}$$

k : number of parameters in the model

Schwarz or Bayesian information criterion:

$$BIC = \log \hat{\sigma}_k^2 + \frac{k \log n}{n}$$

It cannot be said that the one has an advantage over it. The Schwarz has heavier penalty for degrees of freedom lost.

Some more measures are used for the models to evaluate ex post forecast, forecasts for which the independent variables do not themselves have to be forecasted.

The roots mean squared error and mean absolute error:

$$RMSE = \sqrt{\frac{1}{n^0}\sum (y_i - \hat{y}_i)^2}$$

and the mean absolute error

$$MAE = \frac{1}{n^0}\sum \left| y_i - \hat{y}_i \right|$$

n^0 is the number of periods being forecasted. These measures are backward looking and has the problem of scaling.

So scale free measurement known as Theil U Statistic is used.

$$U = \sqrt{\frac{(\frac{1}{n^0})\sum_i (y_{i-} \hat{y}_i)^2}{(\frac{1}{n^0})\sum_i (\hat{y}_i)^2}}$$

This measure has a relation with R^2 but it is not bounded by zero and one. Large values results in a poor forecasting performance. Another approach

$$U_\Delta = \sqrt{\frac{(1/n^0)\sum_i (\Delta y_i - \Delta \hat{y}_i)^2}{(1/n^0)\sum_i (\Delta y_i)^2}}$$

where $\Delta y_i = y_i - y_{i-1}$ and $\Delta \hat{y}_i = \hat{y}_i - y_{i-1}$, or, in percentage changes, $\Delta y_i = (y_i - y_{i-1}) / y_{i-1}$ and $\Delta \hat{y}_i = (\hat{y}_i - y_{i-1}) / y_{i-1}$. These measures reflect the model's ability to track turning points in the data.

Definition of Cointegration : (Engle and Granger, 1987)

Let w_t be a kx1 vector of variables, then the components of w_t are integrated of order (d,b) if:

1) All components of w_t are I(d)
2) There is at least one vector of coefficients α such that α 'w_t~ I(d-b)

Many economic variables are I (1); d=b=1. If a linear combination of variables is stationary they are defined as cointegrated.

Error Correction Models:

Engle and Granger have developed the technique cointegration and error correction method and the most common recommended test is known as Augmented Dickey Fuller (ADF). Since 1980 cointegration analysis become popular for studies of energy demand.

For example; consider two series y_t and x_t, that are both I(1). The error correction model or an equilibrium correction model of the series can be written as:

$$\Delta y_t = \beta_1 \Delta x_t + \beta_2 (y_{t-1} - \gamma x_{t-1}) + u_t$$

The error correction term is $y_{t-1} - \gamma x_{t-1}$. Provided that y_t and x_t are cointegrated with the coefficient γ, then $y_{t-1} - \gamma x_{t-1}$ is I (0). OLS can be used the model. It is also possible to add an intercept term both to the model and the cointegrating term. γ shows the long-run relationship between x and y, while β_1 stands for the short-term relationship. β_2 shows the speed of adjustment back to equilibrium. If the model is generalised for k variables;

$$y_t = \beta_1 + \beta_2 x_{2t} + \beta_3 x_{3t} + ...\beta_k x_{kt} + u_t$$

If the variables are cointegrated, u_t should be I(0). This can be tested by using DF and ADF on $\hat{u}_t$ by using the regression form

$$\Delta \hat{u}_t = \psi \hat{u}_{t-1} + v_t$$ with v_t an independent and identically distributed.

Engle-Granger have set new critical values as the test is now the residuals of the estimated model. The critical values become more negative as the cointegrating regression increases. It is possible to use Durbin Watson (DW) or Philips-Perron (PP) to test for non-stationarity of $\hat{u}_t$. If DW is applied to the residuals of the potentially cointegrating regression, the test is known as Cointeragrating Regression Durbin Watson (CRDW). The hypothesis testing is written as:

$$H_o = \hat{u}_t \sim I(1)$$
$$H_1 = \hat{u}_t \sim I(0)$$

The problem for the OLS regression when it is applied to many variables is that it only shows at most one cointegrating relation. However if there are multiple cointegrating relations this cannot be caught by OLS. For this problem Johansen's method is used.

TEZ FOTOKOPİSİ İZİN FORMU

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TEZİN ADI (İngilizce) : Modelling Electricity Demand in Turkey for 1988-2011

TEZİN TÜRÜ : Yüksek Lisans [x] Doktora [ ]

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