FLEXIBILITY MODELLING OF NATURAL GAS CONTRACTS:
İSTANBUL CASE

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ABSTRACT

FLEXIBILITY MODELLING OF NATURAL GAS CONTRACTS:
İSTANBUL CASE

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Natural gas is one of the main energy source in the world and plays an important role in energy demand. The liberalization process in the natural gas market has shifted the focus on the Local Distribution Companies (LDCs) which make the procurement and transportation decisions. The decisions such as the pipeline sales, Liquefied Natural Gas (LNG) sales, other sources of natural gas procurement, transportation and storage opportunities provide the LDCs an opportunity to trade the natural gas in a least-costs manner. It also makes the portfolio selection more complex for LDCs. The LDCs will consider other factors such as supply reliability, price uncertainty, demand uncertainty and other uncertain costs in a liberalized natural gas market.

This study aims to develop an algorithm based on all contractual and technical real-world constraints for a gas import/wholesale company in the concept of flexibility. The methodology is applied to portfolio of contracts to produce the optimal amount of purchases and rates for the long term natural gas agreements, spot natural gas purchases, natural gas storage use levels and LNG purchases based on a real life case under various commitments such as Monthly Contract Quantity (MCQ) and Annual Contract Quantity (ACQ). Multivariate Adaptive Regression Splines (MARS) is applied to the natural gas supply to determine the pattern of the future demand by including factors like heating degree days (HDD), cooling degree days (CDD) and previous gas supply realizations. The output of the proposed methodology enables LDCs to develop criteria on producing the optimal future natural gas purchases depending on different oil scenarios proposed by World Energy Outlook (WEO) report, World Bank (WB) oil price forecasts and a stochastic oil price model (ARIMA) based on historical development of oil prices. A real life case study is applied to İstanbul which is a highly industrialized and populated metropolitan in Turkey. The data sets considering the natural gas demand were taken from İGDAŞ. The long term gas purchase price curves for different Take-or-Pay (ToP) rates are derived to guide the LDCs on their willingness to pay for long term natural gas contracts. LDCs assumed to act as a main supplier in this thesis.

Keywords: Natural Gas, Consumption Forecast, Multivariate Adaptive Regression Splines (MARS), Optimal Contract Decision, ARIMA Oil Price Modelling

ÖZ

ESNEKLİK KAVRAMI ALTINDA DOĞAL GAZ KONTRAT ŞARTLARININ MODELLENMESI: İSTANBUL ÖRNEĞİ

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Doğal gaz, dünyadaki temel enerji kaynaklarından biridir ve doğal gaz enerji talebinin karşılanmasında önemli bir rol oynamaktadır. Doğal gaz piyasasındaki liberalleşme süreci doğal gaz dağıtım şirketlerini daha önemli bir hale getirmiştir. Öyle ki, doğal gaz dağıtım şirketleri liberal piyasalarda tedarik ve depolama seçimlerini yapmak zorundadır. Bu durum doğalgaz dağıtım şirketlerini portföy seçimlerinin daha karmaşık hale getirmektedir. Doğal gaz dağıtım şirketleri portföy seçimlerini yaparken fiyat riski, doğal gaz talep belirsizliği ve diğer maliyetleri göz önünde bulundurmak zorundadır.

Bu çalışma, esneklik kavramı altında bir doğal gaz ithalat-toptan satış şirketi için tüm sözleşme, teknik ve gerçek dünya kısıtlarına dayalı bir algoritma geliştirmeyi amaçlamaktadır. Geliştirilen metot uzun vadeli doğal gaz alım kontratları, spot doğal gaz alımı, sıvılaştırılmış doğal gaz alımı ve depolama opsiyonlarını içeren bir portföye, aylık ve yıllık doğalgaz kısıtları göz önüne alınarak uygulanmıştır. Doğal gaz talep kısmında ise Isıtma Gün-Derecesi (HDD), soğutma gün derecesi (CDD) ve bir periyot öncesi doğalgaz tüketimi göz önüne alınarak, Çok Değişkenli Uyarlanabilir Regresyon Eğrileri (MARS) programı yardımıyla geçmiş verilerden yola çıkarak, gelecek doğal gaz tüketim tahminleri yapılmıştır. Talep tahminleri doğrultusunda hareket edecek bir şirketin doğal gaz boru hatları, depo kapasite miktarı kısıtları ve Dünya Bankası, Dünya Enerji Ajansı raporu ve geçmiş veriye bağlı stokastik (ARIMA) petrol fiyatları tahminleri doğrultusunda değişken doğal gaz fiyatları senaryoları altında kurulan model vasıtasıyla ticari olarak en uygun farklı kontrat alım miktarları belirlenmiştir.

Kurulan model endüstriyel ve gelişmiş bir şehir olan İstanbul'a uygulanmıştır. İGDAŞ'tan temin edilen İstanbul şehrinin 2010-2015 yılları arasındaki aylık doğal gaz tüketim miktarları veri analizinde kullanılmıştır. İstanbul şehrindeki talep ve arz kısıtları ile hareket edecek doğalgaz dağıtım şirketinin farklı ToP oranları için uzun vadeli alım kontrat eğrileri belirlenmiştir. Bununla birlikte bu çalışmada, doğal gaz dağıtım şirketinin bir doğal gaz ana tedarikçisi gibi hareket ettiği varsayımından hareket edilerek, yasal kısıtlamalara tabi tutulmamıştır.

Anahtar Kelimeler: Doğal Gaz, Tüketim Tahmini, Çok Değişkenli Uyarlanabilir Regresyon Eğrileri (MARS), Optimal Doğalgaz Kontrat Seçimleri, ARIMA Petrol Fiyat Modeli

To Hilal YAZICI

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LIST OF ABBREVIATIONS

σ^2	Variance
ε	Error
B	Set of Basis Functions
E	Expectation
r	Correlation Coefficient
R^2	Coefficient of Determination
R^2_{adj}	Adjusted Coefficient of Determination
M_{max}	Maximum Number of BF
RMSE	Root Mean Squared Error
AAE	Average Absoulte Error
ACER	Acency for the Cooperation of Energy Regulator
ANN	Artificial Neural Network
ARIMA	Autoregressive Integrated Moving Average
Bcm	billion cubic meter
BF	Basis Function
BOTAŞ	Petroleum Pipeline Corporation
CDD	Cooling Degree Days
cmy	cubic meters per year
DM	Data Mining
DSO	Distribution System Operator
EC	European Commission
FERC	US Federal Energy Regulation Commission
GA	Genetic Algorithm
HDD	Heating Degree Day
LDC	Local Distribution Company
İGDAŞ	İstanbul Gas Distribution Industry and Trade Incorporated Company
LOF	Lack-of-Fit
LSE	Least Squares Estimation
LTF	Linear Transfer Function
MARS	Multivariate Adaptive Regression Spline

MSE	Mean Squared Error
NG	Natural Gas
RSS	Residual Sum of Square
TANAP	Trans Anatolian Pipeline
TAP	Trans Adriatic Pipeline
Tcm	trillion cubic meter
TSO	Transmission System Operator

CHAPTER 1

INTRODUCTION

Natural is one of the main energy source in the world. The use of the natural gas in different areas from the heating purpose to electricity production makes it more significant and strategic energy source. According to the WEO [7] report, total demand for natural gas will be expected to increase to 5.2 Tcm (Trillon cubic meters) levels till 2040. Moreover, it is predicted that the European natural gas demand will have an increasing trend in the long run. Because of that reason, the efficient use of this energy source is vital. Alternative natural gas resources such as the shale gas will be considered as an important source of meeting the natural gas demand of the world. The shale gas production in the world has an escalating trend. In 2013, the shale gas production was 610 Bcm (Billion cubic meters) and the total shale production will be estimated to reach to a level of 974 Bcm in 2040 ([7]) with almost %40 enhancement. Moreover, LNG production and the international trade through continentals will be an alternative source of natural gas demand that the total volume of LNG trade will reach to the 600 Bcm level in 2040 ([7]). The liberalization process considering the natural gas market changed its nature in which the natural gas is traded in a market and its price is determined in the market rather than with long term contracts that the price of the natural gas depends on the change of oil or other products.

Considering the case of Turkey which is highly dependent on the external sources, the natural gas sector is an important strategic energy segment and the natural gas sector has been under government control because of the problems that the Turkish government deals with it like the uncertainty in Turkey's energy security and insufficient natural gas supply sources to meet the natural gas demand in the long run. These uncertainties lead Turkish government to long term natural gas agreements with guaranteed delivery or Take-or-Pay(ToP) contracts. ToP provisions or ToP contract is "an agreement between a purchaser and a seller that requires the purchaser either pay for take delivery of a pre-specified quantity of a commodity or service at specific time and pre-determined price or pay the same quantity without taking delivery" ([31]). ToP contracts ensure the natural gas supply. On the other hand, Turkish government mostly faces with problems regarding with the issue of the daily contract quantities in which Turkey paid the penalties to suppliers because of the Take-or-Pay (ToP) natural gas agreements. As a result of long term natural gas agreements with ToP, Turkey has to pay the cost of unpurchased gas.

Turkish natural gas market is in the early stages of liberalization. There are new regulations concerning the functioning of natural gas market such as; permission to third party access to transmission network of BOTAŞ and gas transfer over the network, removing of import barriers for LNG import, third party access to LNG terminals, storage facilities and participation of private suppliers in the natural gas supply. These regulations would be indicated as the first stages of the liberalization process of Turkish natural gas market ([40]). The ultimate goal is diminishing BOTAŞ's market share as much as possible to create a competitive environment in which the companies would bring cheaper gas into the market and the participation of private suppliers would mitigate BOTAŞ's commercial risks and challenges. The main purpose of those reforms is to reduce the "Turkish government's share in natural gas market, increase the security of natural gas supply" and utilize from Turkey's geopolitical advantages in natural gas trading ([40]). In the current set up of the Turkish wholesale natural gas sector, the overwhelming majority of the natural gas contracts are based on the long term natural gas agreements with Take-or-Pay (ToP) obligations ([18]).

1.1 Aim of the Study

Natural gas markets change their structures in terms of their price determination methods. Considering the United States of America (U.S.) and European natural gas markets, the price of the natural gas is determined in the market rather than the long term oil based contracts. For Turkish natural gas market, most of the natural gas agreements depend on ToP provisions with oil or oil based product. However, it is expected to have a market based price determination mechanism. The liberalization process in the natural gas market creates new risks for the LDCs like price and demand risk. To be more precise, LDCs determine their natural gas purchase amounts considering the natural gas prices, other costs such as transportation and storage costs and their target consumers. Because of that reason, LDCs need a decision support system for their natural gas purchase agreements in order to maximize their utility.

The aim of this thesis is to determine the flexibility of a natural gas contract in terms of its components affecting the demand and supply in the market. Flexibility is the "ability of a system to react to unexpected changes in order to limit the losses" (Doege,[13]). In this context, we assume that LDCs switch the natural gas sources depending on their costs. The analyses consist of two parts: natural gas demand and natural gas supply. MARS is proposed by including relevant and significant explanatory variables to determine natural gas demand. After forecasting of natural gas demand, Mixed Integer Linear Programming (MILP) is applied to natural gas market by including all constraints and possible natural gas sources. These include: (i) different Pipeline Natural Gas (PNG) agreements, (ii) spot natural gas purchases, (iii) natural gas storage constraints (iv) LNG purchases and (v) LDCs transmission constraints. The proposed model is applied to İstanbul wholesale natural gas market data and its possible gas supply sources. Based on real life data for İstanbul, a forecast of 10 years natural gas demand is performed to determine the long term natural gas price curves considering different ToP levels for long term natural gas contracts. LDCs are assumed to act as natural gas supplier in Turkish natural gas market. The breakeven points in the model emphasize an upper price limit of long term natural gas contracts for LDCs. The illustration of future prices is significant because it will affect the negotiation of long term natural gas contract prices. As a result, LDCs will be able to determine its future natural gas purchase sources and quantities for different ToP levels which maximize their profit margin level.

The main contribution of this paper is the determination of long term natural gas contract price curves for different ToP levels for the first time in existing literature. The model that we propose illustrates willingness to pay of LDCs for the long term natural gas contracts, including their physical and contractual restrictions. The application of the model to İstanbul natural gas market under different ToP levels is also among the original contributions of the thesis.

1.2 Literature Survey

In relation to natural gas market, there are several articles regarding the issues of the natural gas demand, natural gas supply and the market equilibrium condition for both the supplier and consumer of natural gas. Gabriel et al. [22] explains the North American natural gas industry which is deregulated and there is an opportunity for the third party marketers to purchase the natural gas and sell it to the customers. The authors analyse the market by using a linear complementary equilibrium model that includes the producers, peak-gas operators, third party marketers and storage facilities. Bopp et al. [8] relates with local natural gas distribution companies which should manage the natural gas purchases under the uncertainty in demand and price. The authors use a stochastic optimization model in order to solve this uncertainty. Moreover, Holtz et al. [29] mentions the model for the European gas supply which is a two stage game of natural gas export to Europe and the wholesale trade within the European markets. The article concentrates on four market scenarios as including the Cournot competition, perfect competition and the perfect competition in the European gas supply market and Cournot competition considering the wholesale trade. Street et al. [44] illustrates the integration of the electricity and natural gas sectors and the creation of a flexible natural gas market for industrial users in which it might be applied for the case of Turkey because of the similarities considering the natural gas sector for both of the countries.

Considering the natural gas demand part, Lui and Lin [34] mention the time series analysis for residential natural gas demand analysis. The authors clearly illustrate that monthly analysis is more reliable than the quarterly analysis and price of the natural gas has a very important impact on the consumption growth of the natural gas. Moreover, whereas Soldo [43] illustrates different natural gas forecasting models. Suykens et al. [45] concentrates on the Belgium natural gas consumption by using neural networks, Sánchez-Úbeda et al. [41] mentions about forecasting method on flexible medium term (1-3 years) natural gas consumption. Rui et al. [39] uses genetic algorithm for estimating natural gas demand of China and Vondráček et al. [48] utilizes nonlinear regression model for demand forecasting purpose. Moreover, Artificial Neural Network (ANN) applied considering the natural gas consumption in Aydinalp-

Koksal and Ugursal [4],Kızılaslan and Karlık [33],Tonkovic et al. [46].

For Turkish natural gas demand forecast, Demirel et al. [11] uses neural networks and multivariate time series analysis for forecasting natural gas consumption in İstanbul. Moreover, ANN method has been applied for the case of Ankara by Gorucu [24]. In addition, Gümrah et al. [23] utilized from the multivariate regression analysis for Ankara. Besides that, Autoregressive Integrated Moving Average (ARIMA) model is used for daily natural gas demand forecasting by Akpinar and Yumusak [3]. Considering the flexibility concept; we refer to studies of Doege et al. [14] and Doege [13] which are taken as a guide of the natural gas supply part of the thesis.

The expectation of the liberalization process will clearly indicate that the natural gas market will be based on the LDCs and these companies have to optimize their position in the natural gas market. In this study, it is assumed that LDCs act as main suppliers. In order to develop an optimization model for the LDCs, we concentrate on the study of Guldmann and Wang [26] which takes mixed integer linear program (MILP) in order to determine an optimal level of natural gas supply for the LDCs. The natural gas market will be divided into submarkets such as households, commercial users, industrial users and electricity generation. The natural gas requirements for the households and commercial sector have the highest seasonality. These customers are the core customers who have mostly no alternatives other than natural gas and should be supplied on an uninterruptible basis.

The main concern of LDCs is going to be achieving to the supply demand balance of natural gas. In this context, these companies decide how much natural gas should be taken from different sources, how much should be allocated between various customers and curtailing some of them if the demand for the natural gas exceeds the supply of the natural gas. Moreover, the ToP rates for the LDCs are one of the main factors for the natural gas market that for the long term PNG contracts the company must pay the amount of natural gas demanded in the contract even if the natural gas is not taken. In addition, the availability of the natural gas storage facility complicates the supply planning in which this variable also creates flexibility for the natural gas market.

This thesis is organized as follows: In Chapter 2, we give a brief overview of World, European and Turkish natural gas markets. Chapter 3 presents WEO and World Bank oil price forecast and the stochastic (ARIMA) oil price modelling and forecasting. Chapter 4 explains the natural gas demand by introducing MARS model and the natural gas market model by including the flexibility concept. Chapter 5 illustrates the implementation of the natural gas model to the İstanbul natural gas market. The conclusion of the thesis and remarks for future studies are stated in Chapter 6.

CHAPTER 2

NATURAL GAS MARKETS

In this part, an overview on natural gas markets and their components for the World, Europe and Turkey are presented in details.

2.1 World Natural Gas Markets

In this specific part, we illustrate the world natural gas market overview. The demand for natural gas has an increasing trend in the world. According to the BP statistical review of 2014 ([10]), the total world natural gas consumption grew 1.4% which is below the average growth rate of 2.6%. The OECD total natural gas consumption is %1.8 which is above the world average natural gas consumption. The Figure 2.1 shows the total natural gas consumption in the world.

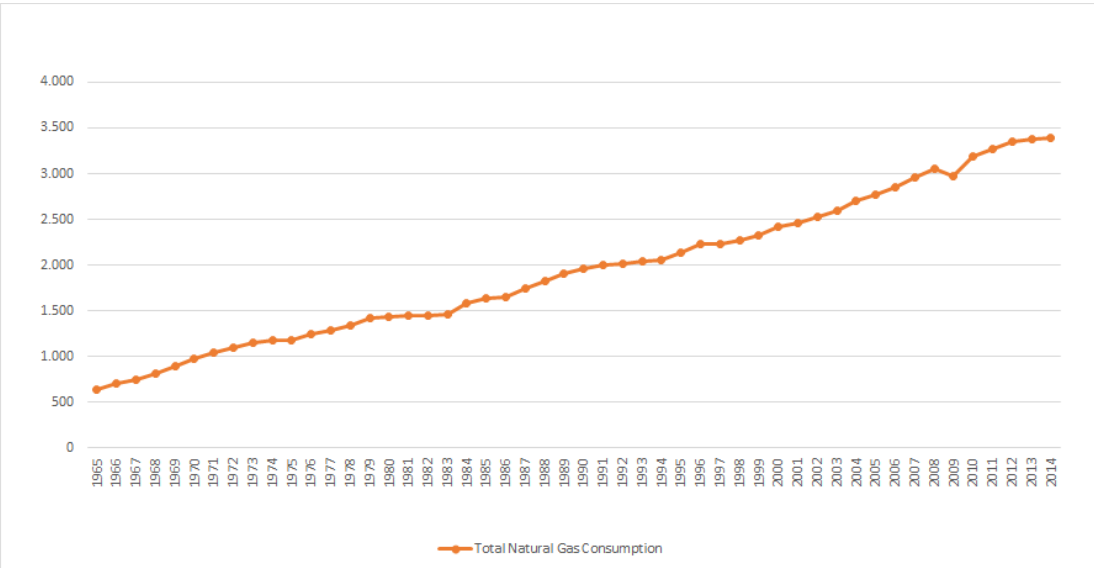

Figure 2.1: World Natural Gas Consumption (in Bcm) [10].

As it is seen in the Figure 2.1, the world natural gas demand has an increasing trend. In 1965, total world natural gas consumption was around 550 Bcm reached to the level of almost 3500 Bcm in 2014.

The Figure 2.2 illustrates the expected natural gas demand of the world up to 2040 in 3 different scenarios ([7]). According to Current and New policies scenarios, the natural gas demand in the world is expected to increase to the level of 5500 Bcm in 2040. On the other hand, the 450 scenario is illustrated a horizontal natural gas demand that will stay at the level of 4100 Bcm between the years 2015 to 2040. The shale gas production is considered as an important natural gas supply source. The developments in the shale gas technology will increase the shale gas share in the natural gas market. According to the WEO [6] report, the shale gas production will be 610 Bcm in 2025 and reach to the level of 954 Bcm in 2040.

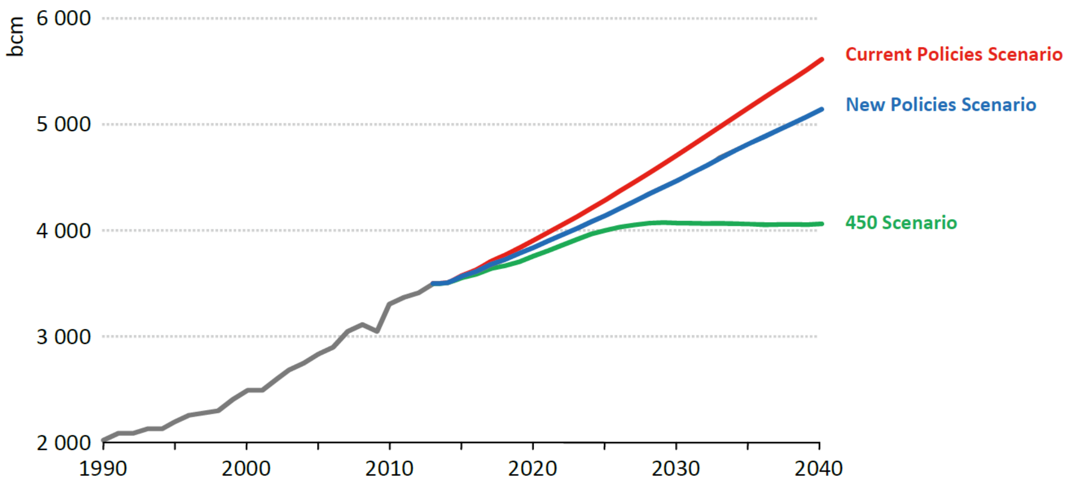

Figure 2.2: World Energy Outlook Report Natural Gas Demand by Scenairos [6].

The total natural gas consumption of the world in different regions is illustrated in the Figure 2.3. According to BP statistical review report([10]); the total Europe and Eurasia consumption appeared as 32% of the world total consumption which was followed by the North America (28%) and Asian and Pacific (19%) natural gas consumption in 2014. Although the world natural gas consumption growth was around 1.6%, Chinese natural gas consumption growth was 10.8%. It has been followed by the U.S. natural gas consumption growth rate (2.4%) which was above the total natural gas consumption growth level.

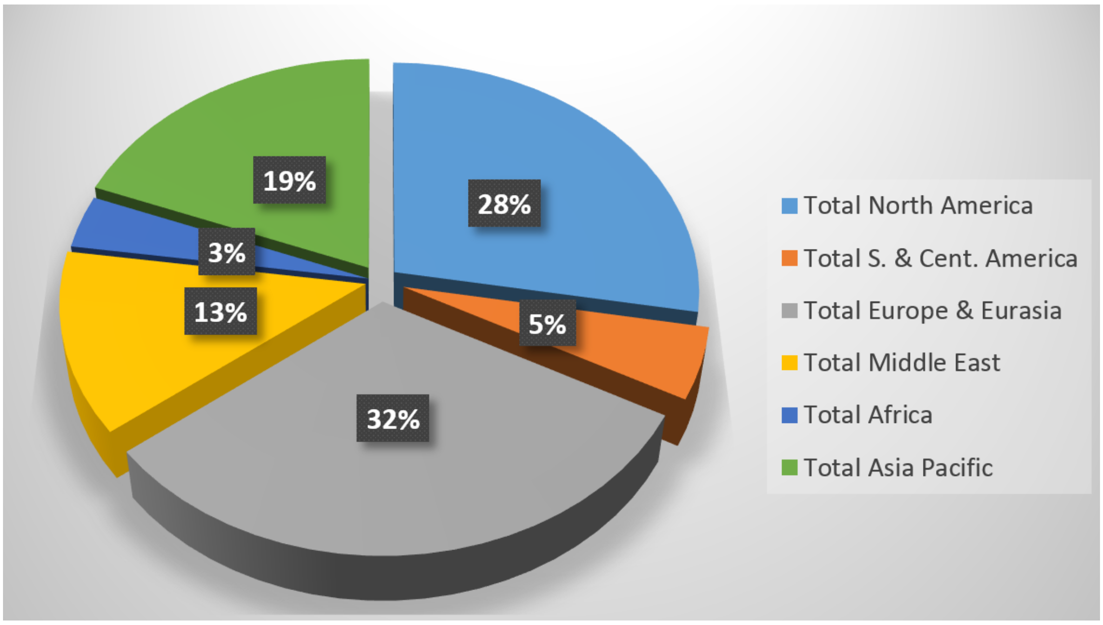

Figure 2.3: Regional Natural Gas Consumption (%) [10].

The Figure 2.4 indicates the world natural gas production by countries in 2014. As it is seen in the Figure 2.4, Russia was the main supplier. It produced almost 578.7 Bcm in 2013 and it has respectively been followed by the Norway (108.8 Bcm) and Turkmenistan (69.3 Bcm).

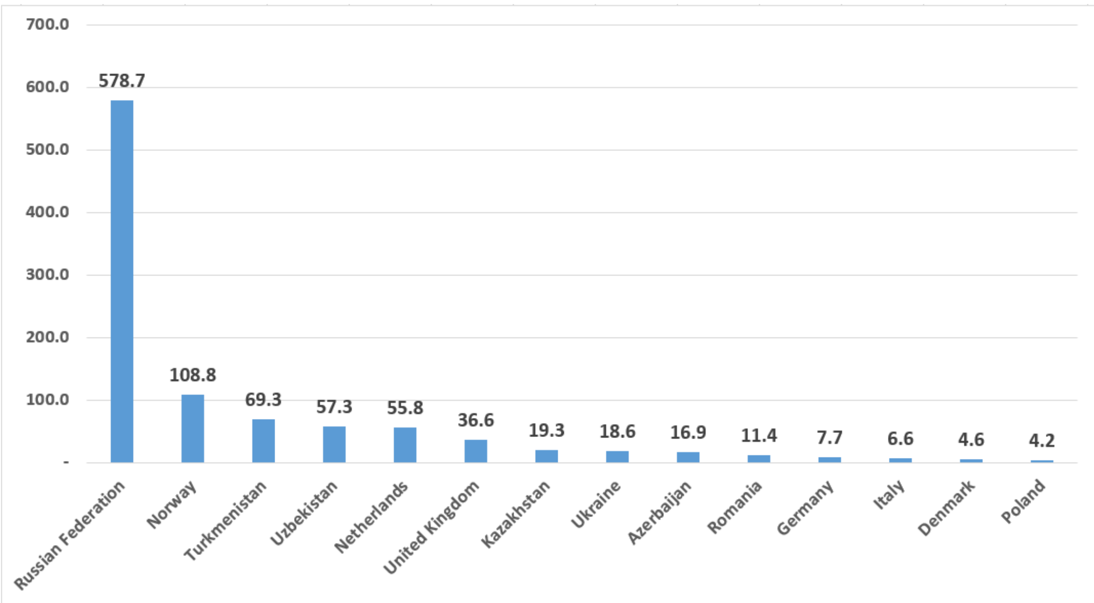

Figure 2.4: Natural Gas Production (Bcm) [10].

The Figure 2.5 illustrates the intercontinental natural gas trade forecasting as LNG and pipeline trade from 2012 to 2040. The intercontinental PNG trade constituted 57%

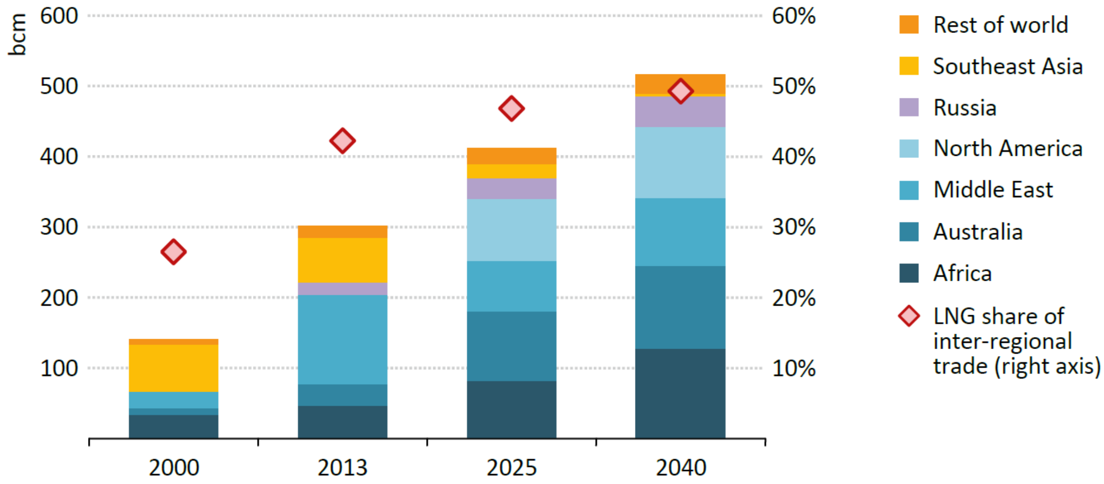

Figure 2.5: Natural Gas Trade by Pipeline and LNG [6].

of the total intercontinental trade and intercontinental LNG trade was 43% in 2012. The intercontinental LNG trade will be an important natural gas supply in future since it is estimated that almost 15% of the total natural gas trade will be in the form of LNG ([6]).

The Figure 2.6 displays the natural gas price changes between 2000 and 2016 for 3 different markets.

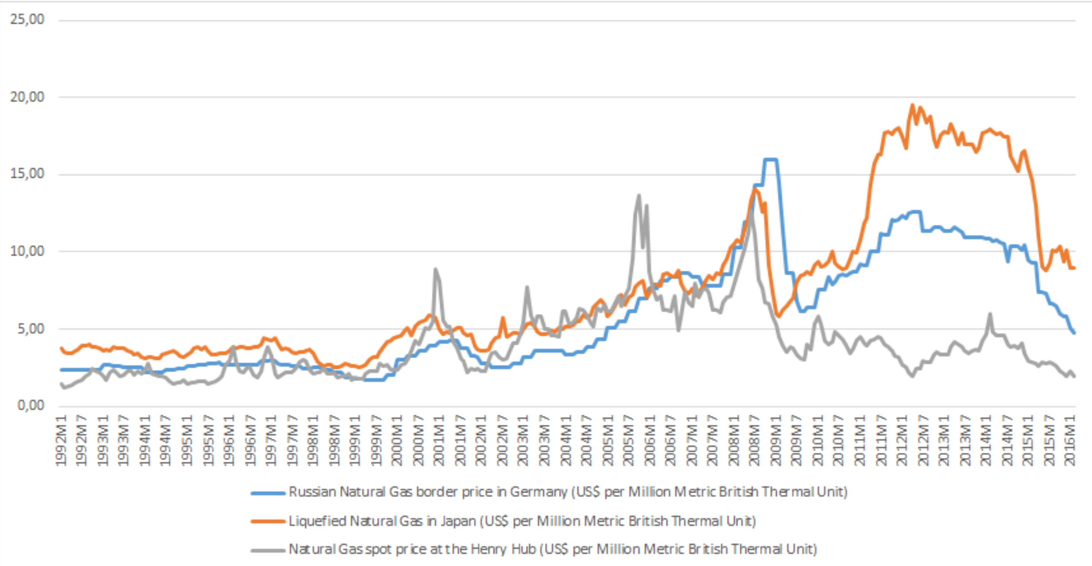

Figure 2.6: Natural Gas Prices in 3 Natural Gas Markets [30].

As it is seen in the Figure 2.6, the natural gas price between the years of 1992 to 2000 moved in the same direction and the price of natural gas was fluctuating around 3 to 5 USD. Between 2000 and 2007, both of the price curves had an increasing trend with high volatility. After 2009, the natural price curves were separated in terms of their prices. Fukushima nuclear disaster affected the LNG market. As a result, Japanese authorities increased the amount of LNG imports which also decreased the amount of LNG that was supplied to Europe. Because of that reason, the amount of natural gas import destined to Europe from Russia has increased. The main consumer of global LNG supply is Asian countries especially Japan, Korea and Taiwan since they do not have any other source of natural gas. Only the amount of natural gas which was not consumed by Asia was available for European Markets. As Rogers [38] illustrates;

"Europe will receive LNG volumes which are surplus to requirements from other markets."

The Russian pipeline natural gas import to Europe increased because of the high demands of natural gas in Asian markets. The Japanese government's attempts of bringing back the electricity generation by using nuclear power plants will be expected to decrease the amount of LNG demanded by Japan. Because of the high demand of LNG in the Asian natural gas market, as the reflection to the European natural gas markets, the natural gas price dramatically increased. As a result, the price of LNG reached to the level of 15 USD/MMBtu and Russian natural gas was around 10 USD/ MMBtu. After 2015, the natural gas prices in three different markets have a decreasing trend as a result of the lower oil prices, decrease in LNG demand and increase in the supply of alternative sources such as shale gas; especially in the U.S.

The Figure 2.7 indicates the general natural gas transportation network and suppliers

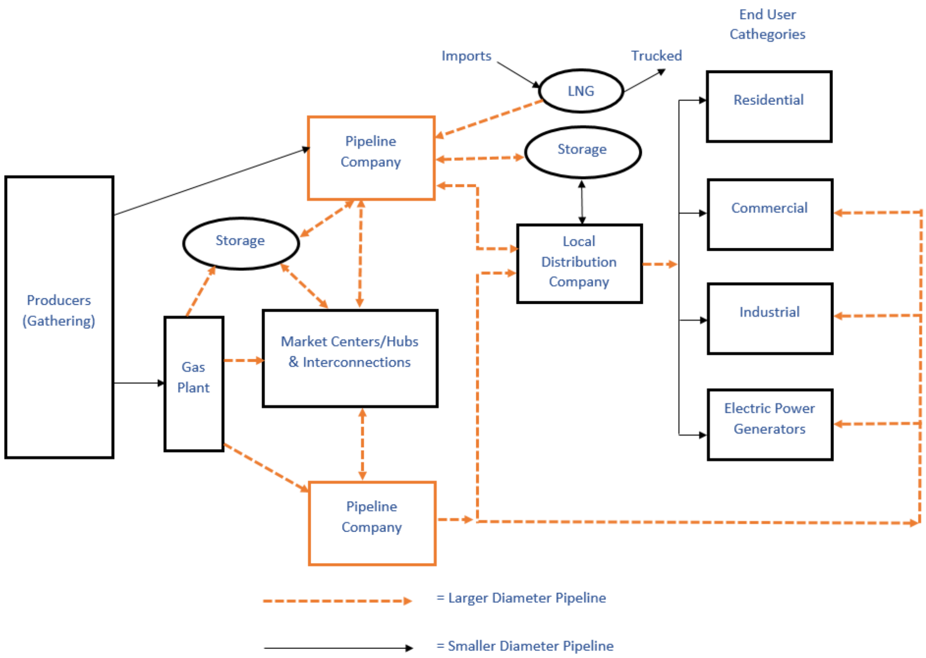

Figure 2.7: The General Natural Gas Transportation and Supply Network.

As it is seen in Figure 2.7, there are 3 main bodies considering the natural gas market. The first part is producers, that they have a chance to access to the gas plant, storage and pipeline companies. The storage is open to all producers, pipeline companies and the markets or hubs. The LDCs directly are supplied by pipeline companies or hubs. Moreover, LDCs have the right to access the natural gas storage. The end users buy the natural gas from a LDC of the region or directly from pipeline companies depending on the volume of the contracts.

2.2 European Natural Gas Market

The European natural gas market is one of the biggest natural gas market in the world that represents almost 32% of the total natural gas consumption. The demand for natural gas in Europe is presented in Figure 2.8. As it is seen in the Figure 2.8, Russia was the main consumer of natural gas in Europe and followed by Germany that consumed 70.9 Bcm. United Kingdom was the third biggest consumers in Europe that had the total natural gas consumption of 66.7 Bcm in the same year. Turkey's natural gas consumption was around 48.6 Bcm in 2014.

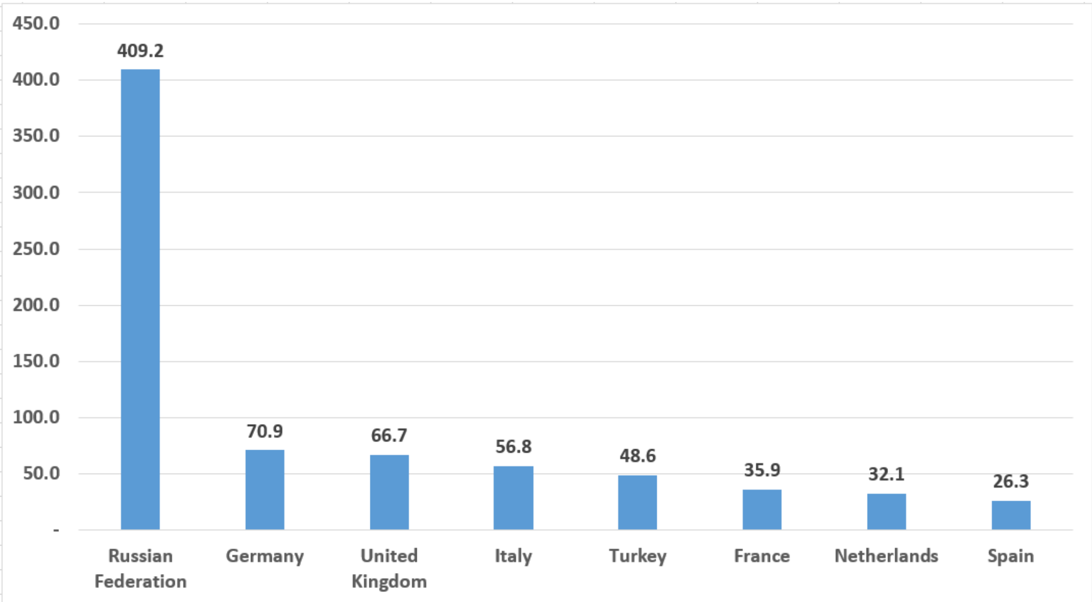

Figure 2.8: Natural Gas Consumption in Europe [10].

The Figure 2.9 shows the Europe natural gas import sources. The European main natural gas supplier is Russia [19]. The LNG supply of Europe has a decreasing trend since 2010 due to nuclear disaster in Japan. The North Africa natural gas supply and the southern corridor represent almost 20% of the European natural gas supply between the years 2010 to 2013.

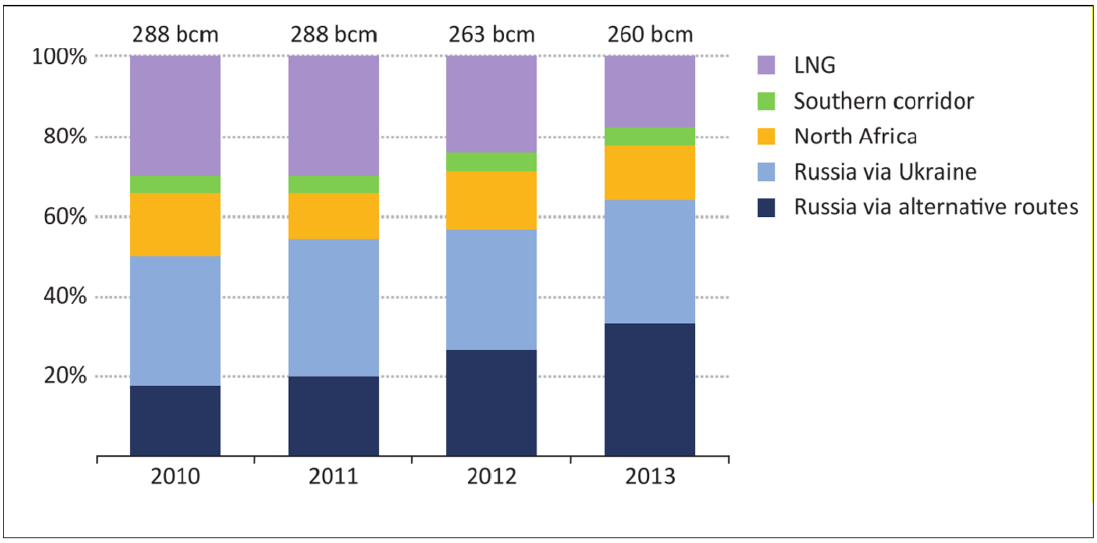

Figure 2.9: Europe Natural Gas Import By Source [6].

2.3 Natural Gas Price Determination Mechanisms

One of the main problems considering the natural gas trade is how to determine the price of the natural gas. According to the International Gas Union, there are three major price determination mechanisms covering the OECD and non-OECD countries. The first one is the oil or product index price determination process in which the natural gas price are linked to the oil or other fuel products such as other oil or refined products and coal. The second way of natural gas price determination is the gas-to-gas competition. In this method, the natural gas price is based on the Spot market price of the natural gas. In other words, the natural gas price depends on the natural gas demand and supply in the market. The last one is the Netback from final product at which the price of the natural gas is linked to the price of ammonia or other products. The mainstream after 2000 in Europe, is to determine the price of the natural gas via gas-to-gas competition rather than oil based pricing, specifically Hub based pricing. Most of the long term natural gas contracts are still based on oil index. However, the Hub concept will shift the long term oil based or other product based natural gas contracts to the gas-to-gas competition price determination. EON claimed that its long term contracts were responsible for its gas trading losing 1 billion Euro in 2011 ([38]). According to Rogers [38]; At the Offshore Northern Seas conference in 2010 Klaus Schafer indicated that;

”*Hubs are the reference point when the customers talk to us LTCs in their current form no longer reflect the market..... We have to re-engineer the LTCs to anticipate the future needs of the market price levels, indexation and review mechanism.*”

Hub based pricing reflects the real market values of the natural gas price rather than the oil based pricing of natural gas in which the price changes in oil affect the natural gas price within 6 months. The hub based pricing is assumed to be the vital step for liberalized natural gas market for Europe and also for Turkey which is considered as locating at the first stage of liberalization process.

A natural gas hub is the location (physical or virtual) of the gas transmission system where the transfer and trade of natural gas can take place under the framework of a regulatory system. There are 3 types of hubs which differ in terms of their maturity and trading volumes. The first one is Trading Hubs which defined in [28] as follows;

"*Trading Hubs which reached certain level of maturity and which are already being used for the financial risk management of gas portfolios. They are based on virtual trading points, have open and easy access to trade to a wide number and variety of participants, have good transparency and reporting and have proven reliable markets.*"

The second one is the Transit Hubs which are defined as; *"transit locations or physical points at which market participants can choose to trade gas. Their primary role is to facilitate the transit of large quantities of gas onward transportation"* ([28]).

Transition Hubs as being the last one among them are the virtual trading points but they do not reach to a mature level. These markets act as a balancing point but there is not any price determination process similar to the trading hubs.

Figure 2.10 illustrates the natural gas hubs locations in Europe like Central European Gas Hub (CEGH), Title Transfer Facility (TTF) in Netherlands, National Balancing Point (NBP) in the United Kingdom. Henry Hub (HH) is one of the natural gas market in the U.S. which the short-term gas and gas future contracts are traded similar to NYSE, APX-ENDEX (Amsterdam Power Exchange) and ICE (Intercontinental Exchange). In these markets, natural gas is traded as a commodity and its price is determined by the market.

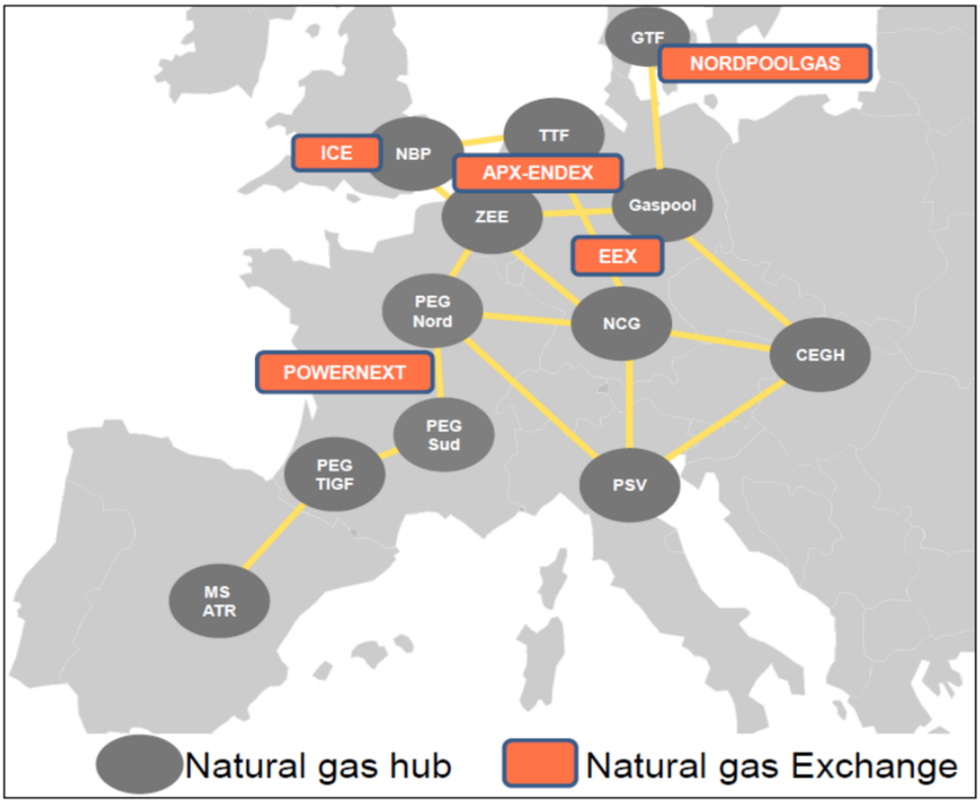

Figure 2.10: The Location of the European Natural Gas Hubs [28].

The Table 2.1 displays the percentage of hub based pricing in 3 different part of Europe. The North West European natural gas pricing based on the hubs and the percentage of hub based pricing decreases as moving towards the South East Europe. Europe is moving from oil-index natural gas price formation to hub-index natural gas price formation process. The natural gas markets in the Western Europe and the U.S. might be considered as the "liberalized" market in the sense that the developments and deregulations in the natural gas markets and the determination of the natural gas prices by hubs can clearly be taken as the manifestations of liberalization process. On the other hand, the Asian countries rely on the oil-index natural gas contracts rather than the Hub based pricing.

The Figure 2.11 illustrates World and Asian and Pacific natural gas price formation mechanism. As it is seen in Figure 2.11, the world price determination was mostly based on the market which had an increasing trend between the years of 2005 to 2010. 63% of natural gas price determined by the natural gas market. On the other hand, when we examine the Asian natural gas price determination mechanism, it can be observed that market based pricing fluctuates around 50% to 53% levels.

Table 2.1: The European Wholesale Pricing (%) [28].

REGION (approximate % of total european demand)	Oil Price Escalation (OPE = oil-linked pricing in long term contracts)	Gas on Gas Competition Price (GOG = hub price)	Regulated Cost of Service Price (RCS)	Regulated Social Price (RSP)
NORTH WEST EUROPE (50%)	20	80		
CENTRAL EUROPE (10%)	35	50		15
MEDITERRANEAN EUROPE (30%)	85	15		
SOUTH EAST EUROPE (10%)	41		47	12

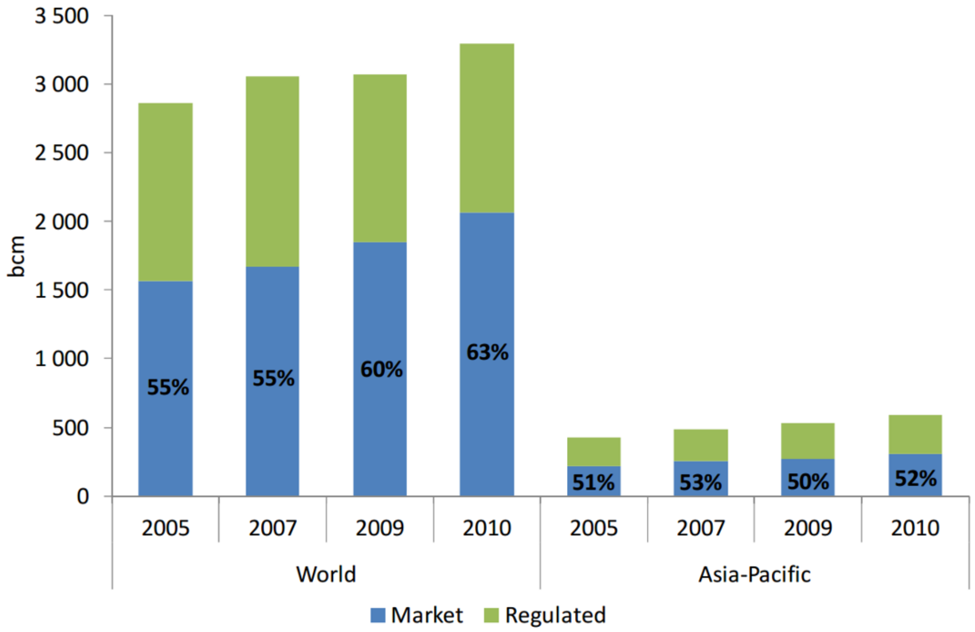

Figure 2.11: Price Formation World, Asia and Pacific [15].

The Figure 2.12 illustrates the price formation mechanism in world and Asia-Pacific markets in terms of oil index or gas-to-gas competition. As it is seen in Figure 2.12, the price formation mechanism in the world mostly depended on the oil index pricing rather than gas-to gas competition mechanism. However, the decreasing trend in the oil index pricing made obvious that the oil index pricing which was around 75% in 2005 felt to the level of 65% in 2010. On the other hand, the oil indexation pricing fluctuated around 88% to 95% between the years of 2005 to 2010 considering the Asian-Pacific market. Figure 2.13 illustrates the natural gas price determination mechanism in a detailed form. As it is seen in Figure 2.13, the North American natural gas markets determined the natural gas price through the mechanisms of gas to gas competition. Moreover, the European natural gas determination process had a decreasing trend in the oil index based natural gas price determination that the oil based pricing was at the

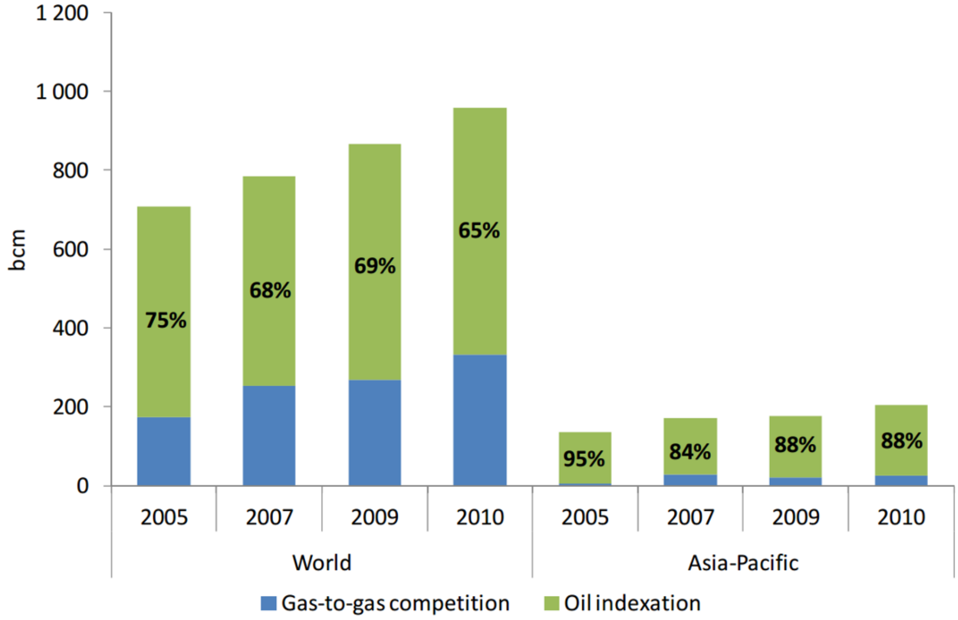

Figure 2.12: Price Formation of Natural Gas Trade [15].

level of 94% of the natural gas contract in 2005 to decreased to the level of 67% in 2010.

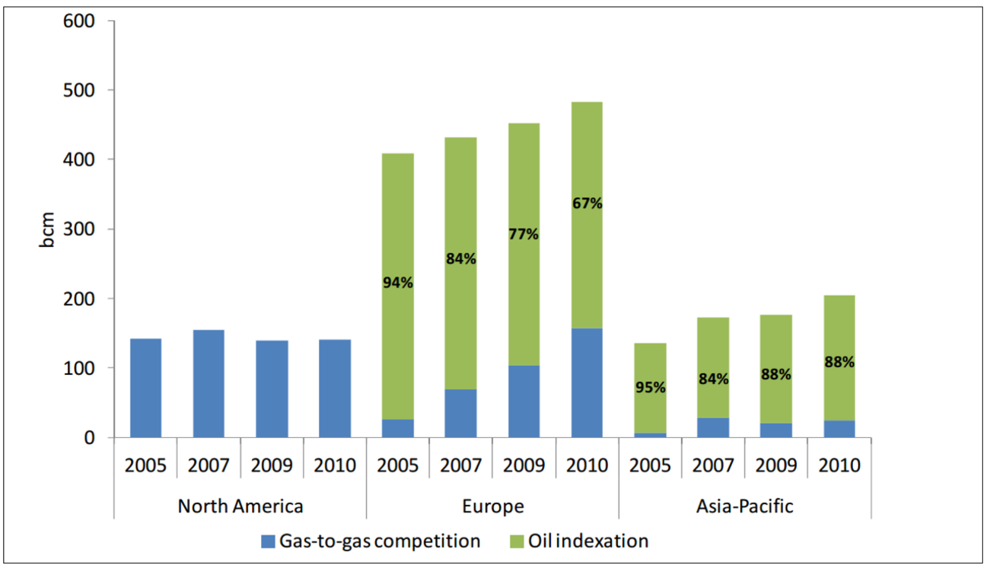

Figure 2.13: Market Based Gas Trade North America, Europe and Asia/Pasific [15].

Figure 2.14 clearly indicates that the Asian natural gas contracts mostly depend on oil index pricing rather than Hub index pricing.

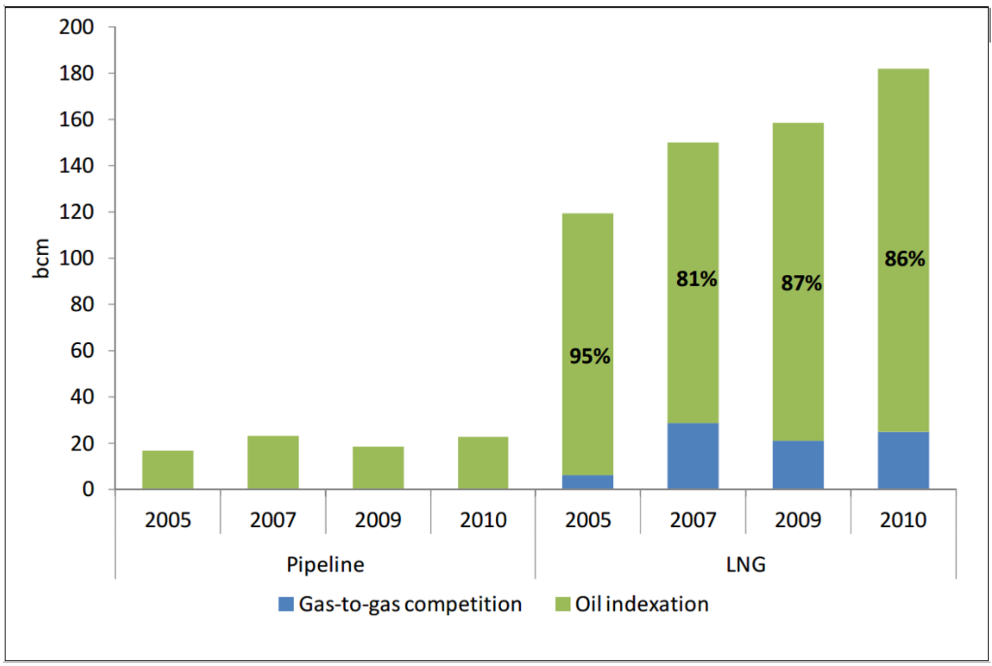

Figure 2.14: Asia and Pacific pricing mechanisms for natural gas trade as pipeline and LNG [15].

The Hub based pricing of the natural gas is a "real time" reflection of the natural gas price. Because of that reason, the uncertainties in demand and supply will have an immediate effect on the price of the natural gas. This creates price risk for the market players. In other words, as it is mentioned by Rogers [38];

"Because hub pricing reflects supply and demand conditions in close to "real time" it will inevitably be more unpredictable and at certain times volatile and this is why price risk management skills become important for market players"

On the other hand, oil index price formation of natural gas has an early warning system in which the oil price changes affect the natural gas price 6 to 9 months later. So, the market players or other demanders of natural gas will expect the increasing or decreasing trend of natural gas price because of the lags in the determination of the natural gas price.

2.4 Turkish Natural Gas Market

Turkey owns a significant natural gas market in which the demand for the natural gas has an increasing trend throughout the years 1988 to 2014 (1986 the First natural gas purchase agreement between BOTAŞ and Soyugas (USSR)). BOTAŞ is a monopolistic Turkish natural gas company which is responsible for trading and transportation of the natural gas in Turkey. Moreover, the company is responsible for the long term natural gas agreements with foreign countries. According to Figure 2.15, the demand for natural gas is 48.6 Bcm for 2014 and this demand has an expanding trend for Turkey since 1986. The natural gas sector is a significant strategic energy segment for Turkey.

The main concern for Turkish government is the energy security. As it is mentioned in Rzayeva [40], there are 2 main issues for the natural gas market in Turkey. The first one is the "ensuring Turkey's energy security" and the second one is "meeting demand in the long run and making sure that no periodic supply shortages occur during the next periods".

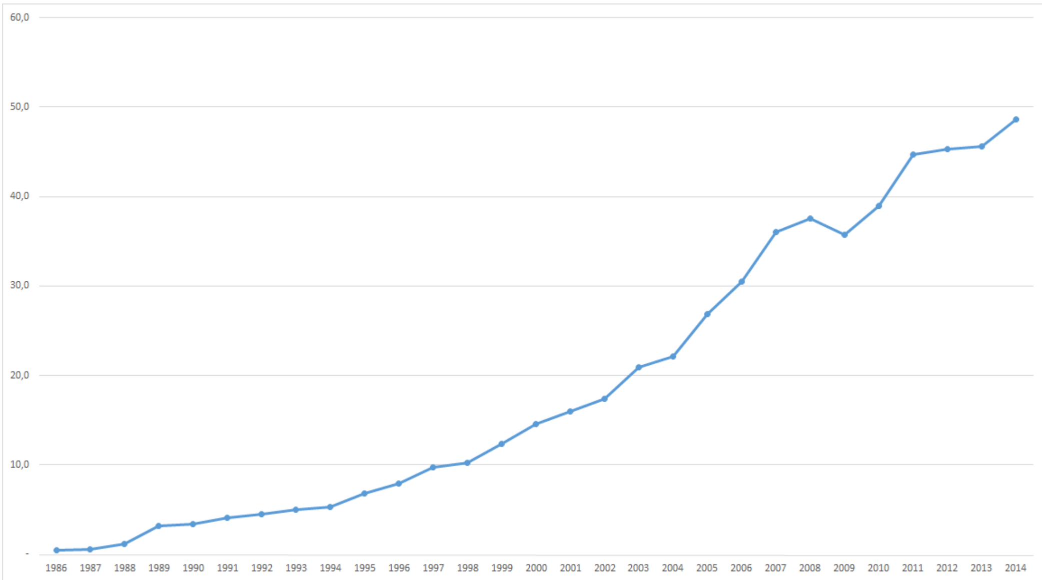

Figure 2.15: Turkey Natural Gas Consumption (in Bcm) [10].

The demand estimation for Turkey considering the Daily Contract Quantities (DCQ), Monthly Contract Quantities (MCQ) and Annual Contract Quantities for natural gas is vital in the sense that the Turkish government mostly faces with problem of daily contracting in which Turkey paid the penalties to suppliers because of the ToP contracts.

ToP provisions provide that a buyer must pay for specified quantities of energy (such as natural gas) from a seller, even if the buyer is unwilling or unable to take such quantities. Because BOTAŞ has monopolistic position in the Turkish natural gas market, the market has not become a liberalized market.

However, the growing demand of Turkey and its debt burden forced the Turkish Government to review the Turkish natural gas market and its structure. With the new regulations such as permission to third party access to transmission network of BOTAŞ, gas transfer over the network, removing import barriers for LNG import, third party access to LNG terminals, underground storage facilities and participation of private suppliers in the natural gas supply and the unbundling of BOTAŞ would be indicated as the first stages of the liberalization process of the Turkish natural gas market (PwC, 2012 [37]). Rzayeva [40] illustrates that the goal is to reduce BOTAŞ's market share as much as possible in order to create a competitive market for private suppliers. As private entrepreneurs more heavily participate into natural gas market, BOTAŞ will started to lose its monopolistic position which also decrease its commercial risks and challenges.

For the supply side of the natural gas market, the Shah Deniz Phase-2 which will be expected to be available from 2017 will increase the supply of the natural gas for Turkey. With new sources and alternative routes will increase the number of natural gas sources that will diversify the risk of supply shortages.

Table 2.2: Turkish Long Term Natural Gas Agreements [2].

Agreements	Volume BCMA (During The Plateau Period) (Billion m^3/year)	Date Of Signature	Status	End Date
Algeria (LNG)	4.4	1988	In operation	October 2024
Nigeria (LNG)	1.3	1995	In operation	October 2021
Iran	9.6	1996	In operation	July 2026
Russian Fed. (Black Sea)	16	1997	In operation	End of 2025
Russian Fed. (Westward)	4	1998	In operation	End of 2021
Turkmenistan	15.6	1999	-	
Azerbaijan(Phase-I)	6.6	2001	In operation	April 2021
Azerbaijan(Phase-II)	6	2011	2017/2018	2032/2033
Azerbaijan(BIL)	0.15	2011	In operation	2046

There are 7 operating natural gas supply sources for Turkey. These natural gas agreements are illustrated in Table 2.2. As it is seen in Table 2.2, [2] Russia is the main natural gas supplier of Turkey (20 Bcm). Iran (9.6 Bcm) and Azerbaijan (12.75 Bcm) are the secondary suppliers of Turkey's natural gas demand. In addition to pipeline natural gas, Turkey imports 5.7 Bcm of LNG from Algeria and Nigeria by long term natural gas contracts.

The Figure 2.16 shows distribution of natural gas import shares of Turkey in 2014. As it is seen in the figure, 85.22% of natural gas imports was carried out by Pipeline natural gas and the remaining amount (14.78%) was the LNG imports (Long Term LNG Contracts). Among those 96.57% was carried out by long term natural gas contracts and only 3.43% of the LNG imports were Spot market LNG imports ([18]).

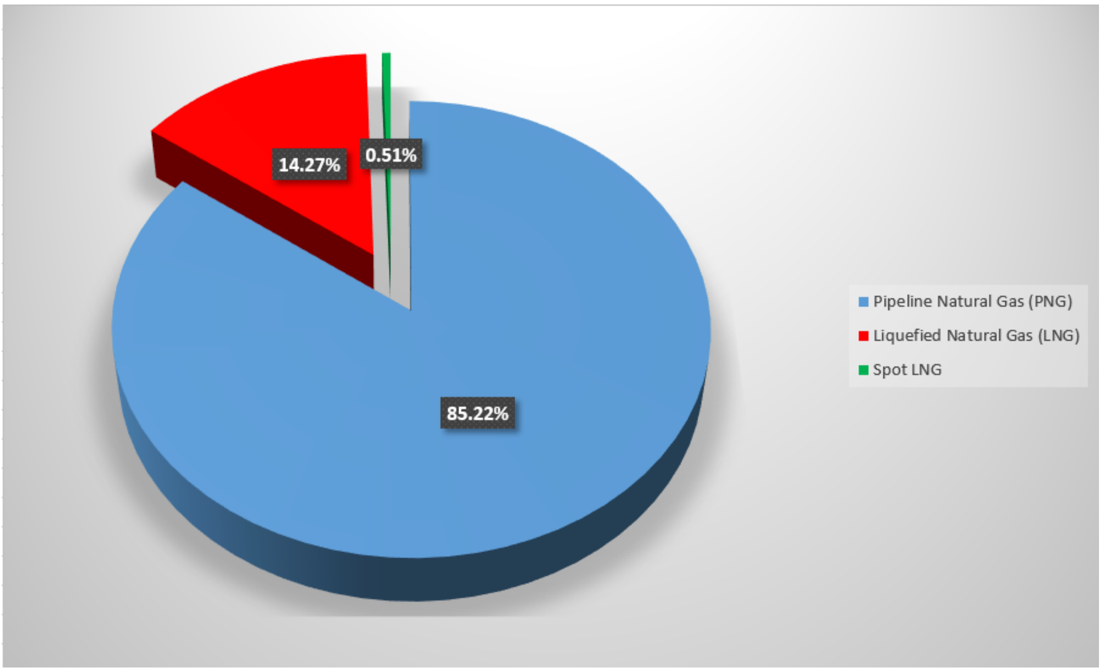

Figure 2.16: Distribution of Natural Gas Imports (Shares of Turkey, 2014) [18].

The Figure 2.17 indicates Turkey's natural gas consumption profile (2014). As it is seen in Figure 2.17, 19.10% of total natural gas consumed by households, 25.40% used for industry, 5.82% for commercial and 48.12% for electricity generation purposes.

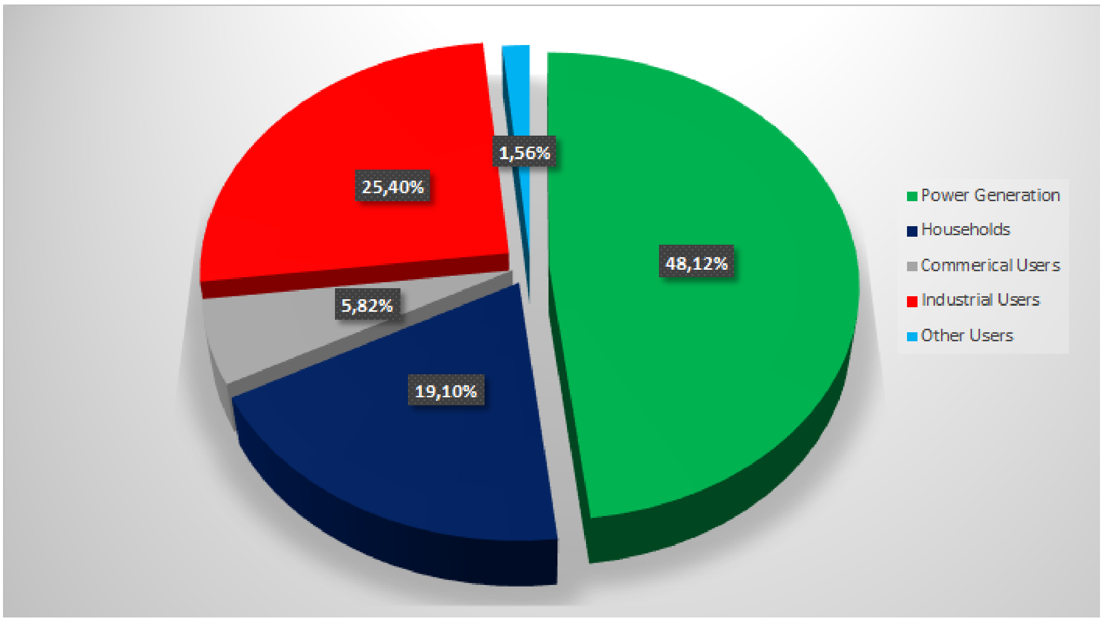

Figure 2.17: Turkey's Natural Gas Consumption Profile (2014) [18].

The main reason of the increase in the natural gas consumption in 2014 was the increase in the use of natural gas to produce electricity as a result of the drought in 2014 summer. Because of the drought, the dams operated in low levels and the demand of electricity was satisfied mostly by the electricity generators operating with natural gas. The natural gas dependency in electricity production in Turkey was 45.85% in 2013 ([17]) and reached to the level of 48.12% in 2014 ([18]) which can be considered as very high for Turkey. Because of the natural gas expenses that negatively affected the budget balance, the Turkish government aims to reduce the amount of imported natural gas in the long run. As a result, Turkish Government distributes its energy investments in different power sources such as nuclear power plants, renewable sources and new water dams that will be expected to decrease the share of natural gas in electricity production. Akkuyu nuclear power plant and other power plants projects will be considered as an alternative energy sources of decreasing natural gas dedependency in order to produce electricity in the long term.

CHAPTER 3

STOCHASTIC ESTIMATION OF OIL PRICES

3.1 The Oil Price Scenarios

Natural gas procurement costs and natural gas prices are highly correlated with the oil prices. Because of that reason, the knowledge on future oil prices are important for LDCs. As a result, we concentrated on six oil price forecasting scenarios which were World Energy Outlook ([7]) scenarios, the World Bank oil price forecast [49] that was published in January 2016 and ARIMA oil price forecasting scenario based on the past oil price movements.

First of all, we illustrate the WEO report oil price scenarios. There are 4 different oil price scenarios in WEO [7] report which are the Current policies scenario, New policies scenario, 450 policies scenario and Low oil price scenario. The Current policies scenario indicates the failure of continuation of the mid-2014 energy policies. In other words, in current policies scenario the governments;

"Fail to follow through on policy proposals that have yet to be backed-up by legislation or other bases for implementation and do not introduce any other policies that effect the energy sector" [6].

Correspondingly, the decline of the fossil fuel use is limited and demand increase will escalate the price. High demand in the current policies scenario leads the countries to the more expensive oil sources such as oil from non-OPEC countries in order to meet the oil demand.

The New policies scenario concentrate on the implementation of the relevant policy proposals. These policies include the targets and programs for supporting the renewable energy, energy efficiency, alternative fuels in order to decrease carbon emissions ([6]). The environmental policies will be expected to decrease the rate of participation of the high-cost oil supply. In other words, the non-OPEC oil supply will limit the oil price escalation. The main assumption in this scenario is the world will have a slower growth rate than it will expect.

The 450 policies scenario illustrates the aim of limiting the long-term average global temperature to two degrees Celsius which will be achieved by applying the new policies. In other words, the 450 scenario indicates that "there is less need to produce fossil fuels from resources higher up the supply cost curve"([6]). As a result of this policy, the fossil-fuel prices will be expected to be lower than the Current and New policies scenario.

Moreover, the Low-oil price scenario illustrates the oil prices lower than the 450 scenario as a result of the lower economic growth and increase in the supply of oil. The U.S. tight oil production has an important effect on the over-supply of the oil that decrease the oil prices and the price forecast will have a slightly increasing trend.

As it is seen in Figure 2.1 with the Current policies scenario the oil price is expected to exceed the level 120$ in 2025 and almost reach to 160$ in 2040. In the new policies scenario, the oil price will reach 115$ in 2025 and 130$ levels in 2040. In the Low Oil Price Scenario, the oil price is around $50-60 range until 2020s, that increase to the level of $85/bbl in 2040. The last scenario which is 450 Oil price scenario, the oil price will be at 100$ levels in 2025 and is expected to be lower than 100$ in 2040.

The Figure 3.2 illustrates the World Bank oil price scenario [49] which indicates that, the price of oil will decrease to the level of 40$ in 2015 and then the price will have an increasing trend, that the oil price is expected to reach the level of 80$ in 2025. The thesis model for oil price is based on the past oil price movements after the breaking point of the oil prices.

The price scenarios are vital in this study because we rely on the assumption that the change in the oil price have an impact on the Spot natural gas prices and on the transportation and storage costs in which the LDCs should reconsider on their natural gas supply sources and storage decisions.

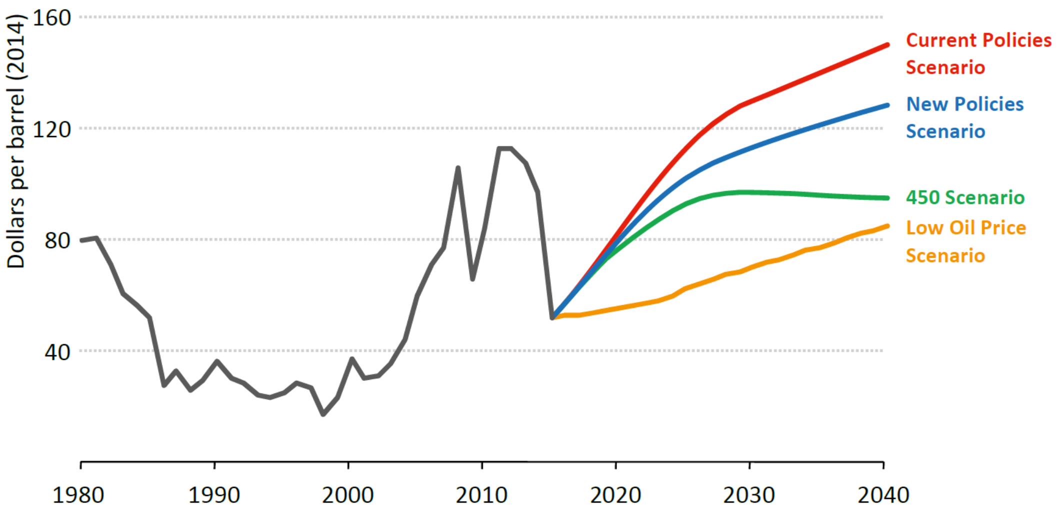

Figure 3.1: World Energy Outlook Oil Price Forecast Scenarios [7].

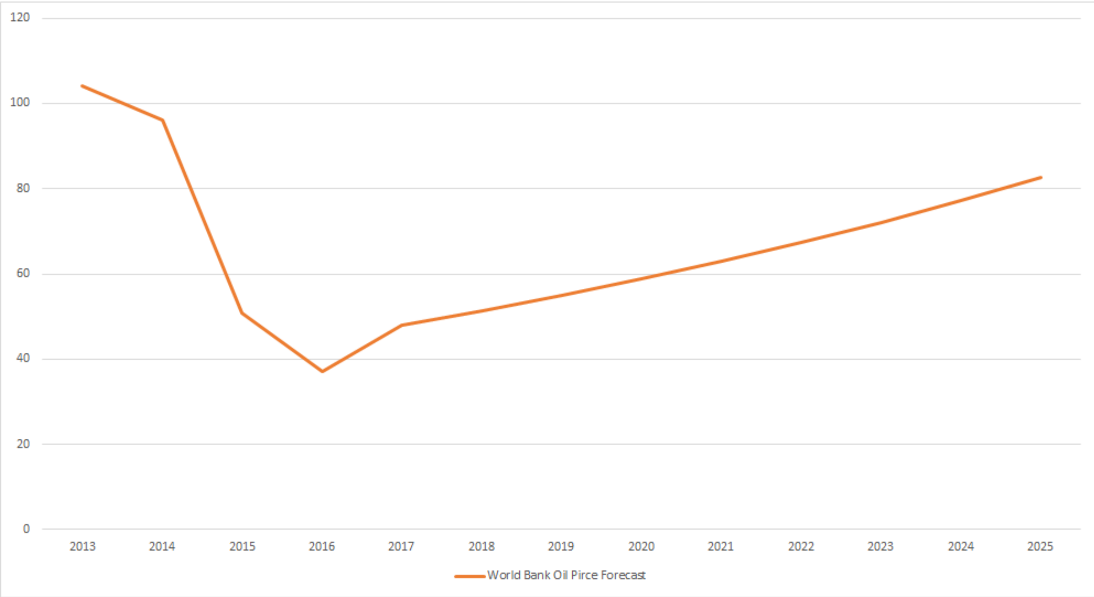

Figure 3.2: World Bank Oil Price Forecast in US Dollar per barrel [49]

3.2 Time Series Modelling

The oil price movements are correlated with the costs and spot prices of natural gas for LDCs. As a result, the oil price scenarios are significant for LDCs supply model and their procurement costs such as transportation and storage costs. In order to determine the oil price future movements taken from the U.S. Energy Information Administration ([16]) and we use time series analysis for forecasting. By using the past monthly oil price movements, we forecast the next 10 years' oil prices. A time series is defined as "a set of observations on the values that a variable takes at different times" [25].

Let stochastic process be;

$$\{y(r,t) : r \in \boldsymbol{R}, t \in \boldsymbol{T}\} \tag{3.1}$$

The aim is to develop mathematical models for the given time series data. Moreover, the given time series data should be stationary. By illustrating stationary, we concentrate on weakly stationary process. The process is weakly stationary if its mean and variance are constant over time and its covariance between two time periods depends on lag of the two time periods ([25]) given as:

$$\begin{aligned} E[y_t] &= \mu \\ E[(y_t - \mu)(y_{t-j} - \mu)] &= \gamma_j, \forall t, j \in \boldsymbol{T} \\ Var[y_t] &= E(y_t - \mu)^2 = \sigma^2 \end{aligned} \tag{3.2}$$

White noise process has the following properties;

$$\begin{aligned} E[\varepsilon_t] &= 0 \\ E[\varepsilon_t^2] &= \sigma^2 \\ E[\varepsilon_t \varepsilon_r] &= 0 \;\; for \;\; t \neq r \end{aligned} \tag{3.3}$$

There are several methods to determine whether the series is stationary or not. Dickey-Fuller Test with GLS Detrending (DF-GLS) and Augmented Dickey Fuller test ([12]) are conducted by "augmenting the preceding three equations by adding the lagged values of the dependent variable of ΔY_t" ([25]) where $\Delta Y_t = (Y_t - Y_{t-1})$.

3.2.1 ARIMA (p,d,q) Process

The autoregressive process of the order p is illustrated in Equation 3.4. AR process could be defined as the estimation of the dependent variable with its lagged values. ϕ_r is the parameter for the lagged value of order r and ε_t denotes random white noise error term. If $\mid \phi_r \mid > 1$, then the process grows without bound. In addition, if $\mid \phi_r \mid = 1$, it has a unit root. To ensure the covariance-stationary the coefficient should be $\mid \phi_r \mid < 1$ ([36]).

$$y_t = \sum_{r=1}^{p} \phi_r y_{t-r} + \varepsilon_t \tag{3.4}$$

The moving average (MA) process is the linear equation of random errors illustrated in Equation 3.5. The θ_s indicates constant with θ_0 = 1 and the ε_{t-s} is the sequence of independent random variables, denoted as white noise error term ([36]). The MA model is conceptually a linear modelling of the current and past white noise error terms.

$$y_t = \sum_{s=0}^{q} \theta_s \varepsilon_{t-s}; \theta_0 = 1 \tag{3.5}$$

The ARMA(p,q) process is shown as ([36]):

$$y_t - \sum_{r=1}^{p} \phi_r y_{t-r} = \sum_{s=0}^{q} \theta_s \varepsilon_{t-s}. \tag{3.6}$$

Considering the AR(p), MA(q) and ARMA(p,q), these processes should be stationary with constant mean, variance and time independent covariance. On the other hand, many time series are non-stationary and autoregressive integrated moving average (ARIMA(p,d,q)) is appropriate especially, when data has trend. Here, "p" represents the number of autoregressive terms, "d" indicates the order of integration and "q" illustrates the number of moving average terms.

The ARIMA(p,d,q) process consists of 4 main steps (Box-Jenkins) which are([9]);

(i) Identification
(ii) Estimation
(iii) Diagnostic test
(iv) Forecast

Considering the identification part, autocorrelation (ACF) and partial autocorrelation (PACF) functions are analyzed in order to determine the orders of ARIMA.

For the Estimation part of the ARIMA process, "p", "d" and "q" values are identified and parameters of AR and MA processes are estimated. If the time series process

(y_t) is not stationary, by taking first or second difference of the series; the stationary can be achieved.

Based on the recent development in oil prices, the mentioned oil price scenarios may not be realistic. For this purpose, a time series model is fitted to the historical observation of the oil prices and a stochastic model is presented as the third alternative in oil price development in the future. The monthly data of the spot Brent oil price data set taken from the U.S. Energy Information Administration website ([16]) and is plotted in Figure 3.3 to see the behaviour of the prices.

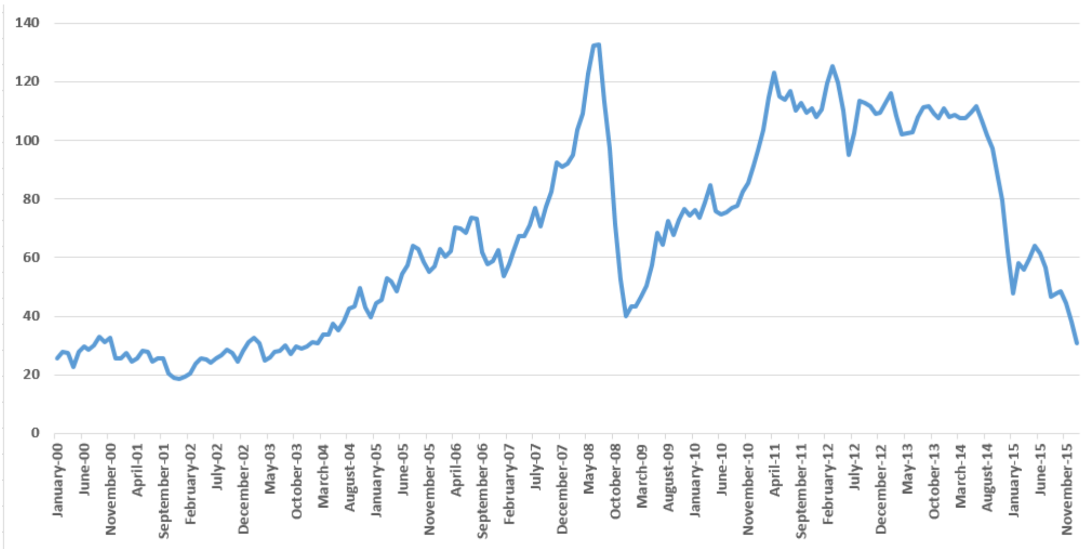

Figure 3.3: Brent Oil Prices between the years 2000-2016 US Dollars per barrel

As it is seen in Figure 3.3 the oil prices are highly volatile and it has certain structural breaks due to many crises such as financial crisis in 2008 or Arab Spring in 2011.

As a result, before concentrating on the ARIMA modelling, the Bai-Perron structural break test conducted by using Eviews. The result of the Bai-Perron structural break test ([5]) are shown in Figure 3.4 and the Eviews results are indicated in Table 3.1.

In the price history of oil, we see that there are many structural breaks due to different reasons (Figure(3.3)). A model fit on data within the whole time domain has not come up with a plausible model. Additionally, the sharp decrease in the oil prices in last years disturbs the fitted models. For this reason, based on the leads of structural tests and the recent behavior in prices, the time series model is applied to the data by the year of 2011.

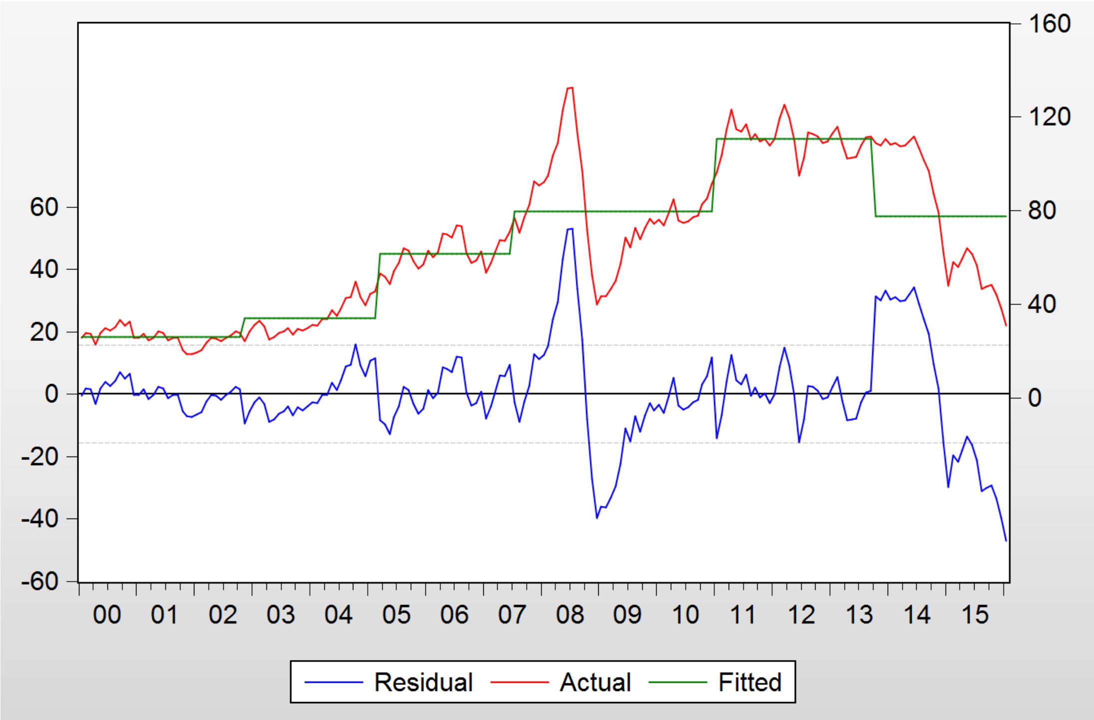

Figure 3.4: Bai-Perron Structural Break Test Results

Table 3.1: Bai-Perron Structural Break Test

Dependent Variable: OIL
Method: Least Squares with Breaks
Date: 03/25/16 Time: 20:46
Sample: 2000M01 2016M01
Included observations: 193
Break type: Bai-Perron tests of 1 to M globally determined breaks
Break selection: Unweighted max-F (UDmax), Trimming 0.15, Max. breaks 5, Sig. level 0.05
Breaks: 2002M11, 2005M03, 2007M07, 2011M01, 2013M10
HAC standard errors & covariance (Prewhitening with lags from AIC maxlags, Quadratic-Spectral kernel, Andrews bandwidth)
Allow heterogeneous error distributions across breaks

Variable	Coefficien...	Std. Error	t-Statistic	Prob.
	2000M01 - 2002M10 -- 34 obs			
C	25.95765	1.681718	15.43519	0.0000
	2002M11 - 2005M02 -- 28 obs			
C	33.85750	6.302741	5.371869	0.0000
	2005M03 - 2007M06 -- 28 obs			
C	61.56536	3.667984	16.78452	0.0000
	2007M07 - 2010M12 -- 42 obs			
C	79.63643	6.204063	12.83617	0.0000
	2011M01 - 2013M09 -- 33 obs			
C	110.6367	1.114961	99.22916	0.0000
	2013M10 - 2016M01 -- 28 obs			
C	77.67321	72.91896	1.065199	0.2882

R-squared	0.779944	Mean dependent var	65.93259
Adjusted R-squared	0.774060	S.D. dependent var	32.82670
S.E. of regression	15.60356	Akaike info criterion	8.363470
Sum squared resid	45529.10	Schwarz criterion	8.464901
Log likelihood	-801.0749	Hannan-Quinn criter.	8.404546
F-statistic	132.5567	Durbin-Watson stat	0.191329
Prob(F-statistic)	0.000000		

Firstly, we determine whether the series is stationary or not. In order to determine the stationarity of the series we use Augmented Dickey Fuller test (ADF). ADF Unit root test indicates that the series is not stationary as shown in Table 3.2. The differenced set becomes stationary (p-value < 0.01) which is justified by ADF test (Table 3.3). Moreover, we apply Dickey-Fuller Test with GLS Detrending (DF-GLS) which has the best overall performance considering small-size samples. Similar to ADF tests, the differenced set becomes stationary in DF-GLS tests that are illustrated in Table 3.4 and 3.5 respectively.

Table 3.2: ADF Test for Oil Prices

Null Hypothesis: OIL has a unit root
Exogenous: Constant
Lag Length: 1 (Automatic - based on SIC, maxlag=10)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		0.081502	0.9617
Test critical values:	1% level	-3.546099	
	5% level	-2.911730	
	10% level	-2.593551	

*MacKinnon (1996) one-sided p-values.

Augmented Dickey-Fuller Test Equation
Dependent Variable: D(OIL)
Method: Least Squares
Date: 04/05/16 Time: 00:30
Sample (adjusted): 2011M03 2016M01
Included observations: 59 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
OIL(-1)	0.002739	0.033608	0.081502	0.9353
D(OIL(-1))	0.311271	0.132960	2.341083	0.0228
C	-1.193500	3.381508	-0.352949	0.7255

R-squared	0.100555	Mean dependent var	-1.237627
Adjusted R-squared	0.068432	S.D. dependent var	6.186911
S.E. of regression	5.971467	Akaike info criterion	6.461372
Sum squared resid	1996.872	Schwarz criterion	6.567009
Log likelihood	-187.6105	Hannan-Quinn criter.	6.502608
F-statistic	3.130320	Durbin-Watson stat	1.904162
Prob(F-statistic)	0.051438		

Table 3.3: ADF Test for First Difference Oil Prices

Null Hypothesis: DIF_OIL has a unit root
Exogenous: Constant
Lag Length: 0 (Automatic - based on SIC, maxlag=10)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-5.492269	0.0000
Test critical values:	1% level	-3.546099	
	5% level	-2.911730	
	10% level	-2.593551	

*MacKinnon (1996) one-sided p-values.

Augmented Dickey-Fuller Test Equation
Dependent Variable: D(DIF_OIL)
Method: Least Squares
Date: 04/05/16 Time: 00:31
Sample (adjusted): 2011M03 2016M01
Included observations: 59 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
DIF_OIL(-1)	-0.685236	0.124764	-5.492269	0.0000
C	-0.925477	0.780484	-1.185773	0.2406

R-squared	0.346068	Mean dependent var	-0.245932
Adjusted R-squared	0.334595	S.D. dependent var	7.256388
S.E. of regression	5.919205	Akaike info criterion	6.427592
Sum squared resid	1997.108	Schwarz criterion	6.498017
Log likelihood	-187.6140	Hannan-Quinn criter.	6.455083
F-statistic	30.16502	Durbin-Watson stat	1.904246
Prob(F-statistic)	0.000001		

Table 3.4: DF-GLS Test for Oil Prices

Null Hypothesis: OIL_PRICE has a unit root
Exogenous: Constant
Lag Length: 1 (Automatic - based on SIC, maxlag=10)

		t-Statistic
Elliott-Rothenberg-Stock DF-GLS test statistic		-0.650886
Test critical values:	1% level	-2.603423
	5% level	-1.946253
	10% level	-1.613346

*MacKinnon (1996)

DF-GLS Test Equation on GLS Detrended Residuals
Dependent Variable: D(GLSRESID)
Method: Least Squares
Date: 05/04/16 Time: 18:37
Sample (adjusted): 2011M03 2016M03
Included observations: 61 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
GLSRESID(-1)	-0.019284	0.029627	-0.650886	0.5176
D(GLSRESID(-1))	0.353592	0.127540	2.772412	0.0074

R-squared	0.088303	Mean dependent var	-1.073934
Adjusted R-squared	0.072851	S.D. dependent var	6.162637
S.E. of regression	5.933915	Akaike info criterion	6.431483
Sum squared resid	2077.470	Schwarz criterion	6.500692
Log likelihood	-194.1602	Hannan-Quinn criter.	6.458607
Durbin-Watson stat	1.897625		

Table 3.5: DF-GLS Test for First Difference Oil Prices

Null Hypothesis: D(OIL_PRICE) has a unit root
Exogenous: Constant
Lag Length: 0 (Automatic - based on SIC, maxlag=10)

		t-Statistic
Elliott-Rothenberg-Stock DF-GLS test statistic		-4.137378
Test critical values:	1% level	-2.603423
	5% level	-1.946253
	10% level	-1.613346

*MacKinnon (1996)

DF-GLS Test Equation on GLS Detrended Residuals
Dependent Variable: D(GLSRESID)
Method: Least Squares
Date: 05/04/16 Time: 18:37
Sample (adjusted): 2011M03 2016M03
Included observations: 61 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
GLSRESID(-1)	-0.442923	0.107054	-4.137378	0.0001

R-squared	0.221965	Mean dependent var	-0.019180
Adjusted R-squared	0.221965	S.D. dependent var	7.252026
S.E. of regression	6.396743	Akaike info criterion	6.565713
Sum squared resid	2455.099	Schwarz criterion	6.600317
Log likelihood	-199.2542	Hannan-Quinn criter.	6.579274
Durbin-Watson stat	1.990988		

The ACF and PACF of the oil prices and differenced set are illustrated in Figure 3.5 and Figure 3.6 respectively. It can be seen that the strong trend in original data set yield high correlation in ACF plot in Figure 3.5 which diminishes in Figure 3.6. Moreover, the ACF and PACF results of the residuals shows that the residuals are white noise. (Table 3.7)

After that several ARIMA models are tested in order to choose the best fit one depending on the Akaike Information Criterion (AIC) (Table 3.7). Among other possible p,d and q values, ARIMA(1,1,1) with AIC of -480.34 is chosen as the best fitting model because it yields the lowest AIC. The AR(1) coefficient is -0.32667 (p-value = 0.08211) and MA(1) coefficient is found to be 0.67538 (p-value = $8.678.10^{-6}$) (Table 3.6).

Table 3.6: Coefficient Significance Test for AR(1) and MA(1)

	Coefficients	St. Error	Z	p-value
AR(1)	-0.32667	0.1879	-1.7386	0.08211*
MA(1)	0.67538	0.15185	4.4477	0.01**
	* significant in %10 level; ** in %1 level			

Table 3.7: Akakike Information Criterion (AIC) Results

Model	**AIC**
ARIMA(2,1,2)(1,0,1)[12] with drift	-473.65
ARIMA(0,1,0) with drift	-466.19
ARIMA(1,1,0)(1,0,0)[12] with drift	-471.86
ARIMA(0,1,1)(0,0,1)[12] with drift	-477.52
ARIMA(0,1,0)	-467.18
ARIMA(0,1,1)(1,0,1)[12] with drift	-471.69
ARIMA(0,1,1) with drift	-473.96
ARIMA(0,1,1)(0,0,2)[12] with drift	-475.55
ARIMA(0,1,1)(1,0,2)[12] with drift	-469.81
ARIMA(1,1,1)(0,0,1)[12] with drift	-478.77
ARIMA(1,1,0)(0,0,1)[12] with drift	-475.8
ARIMA(1,1,2)(0,0,1)[12] with drift	-476.78
ARIMA(0,1,0)(0,0,1)[12] with drift	-468.24
ARIMA(2,1,2)(0,0,1)[12] with drift	-477.46
ARIMA(1,1,1)	**-480.34**
ARIMA(1,1,1)(1,0,1)[12]	-473.21
ARIMA(1,1,1)(0,0,2)[12]	-478.35
ARIMA(1,1,1)(1,0,2)[12]	-472.06
ARIMA(0,1,1)(0,0,1)[12]	-479.07
ARIMA(2,1,1)(0,0,1)[12]	-475.22
ARIMA(1,1,0)(0,0,1)[12]	-477.22
ARIMA(1,1,2)(0,0,1)[12]	-478.34
ARIMA(0,1,0)(0,0,1)[12]	-469.46
ARIMA(2,1,2)(0,0,1)[12]	-478.62

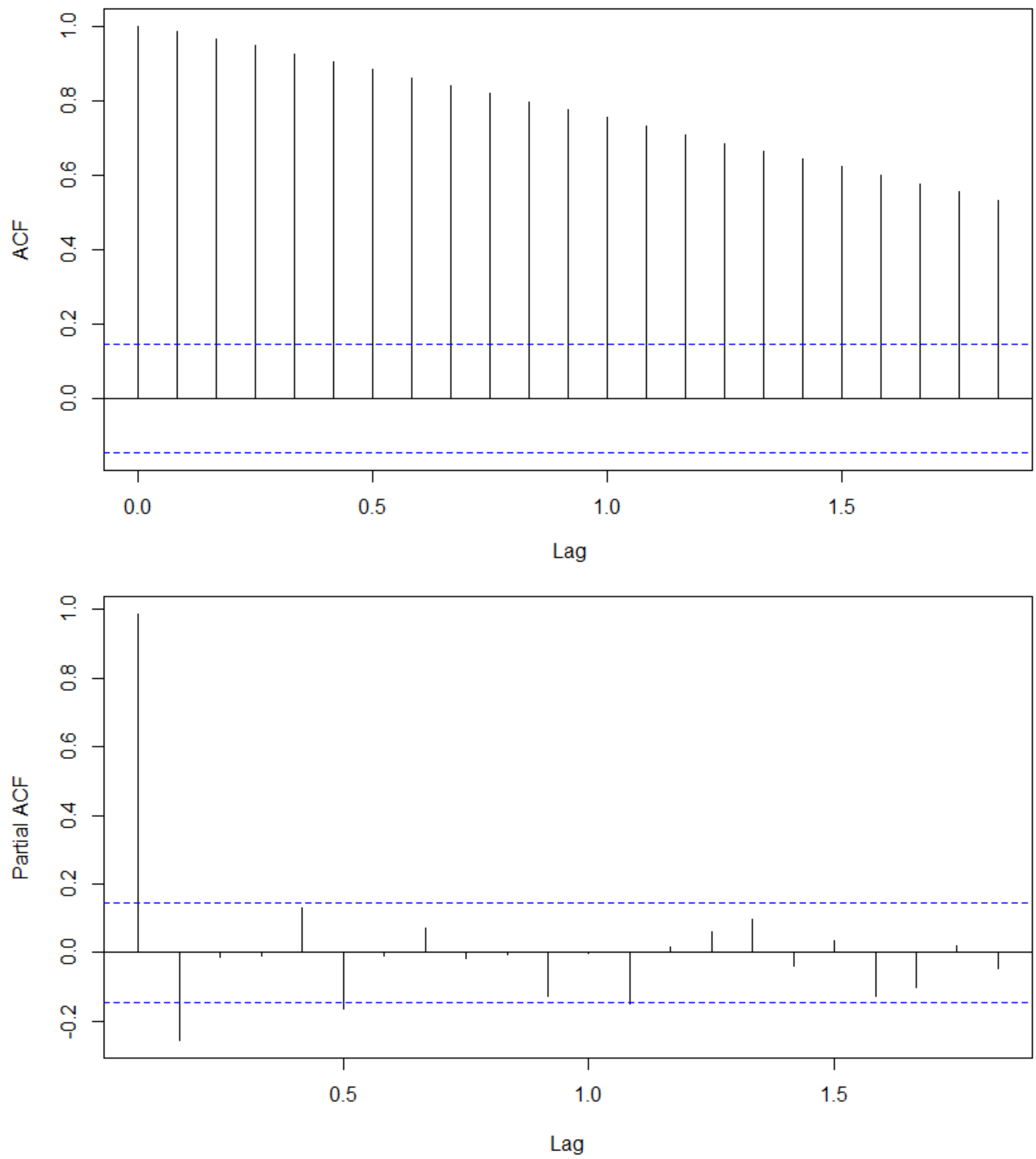

Figure 3.5: ACF and PACF of Oil Prices series.

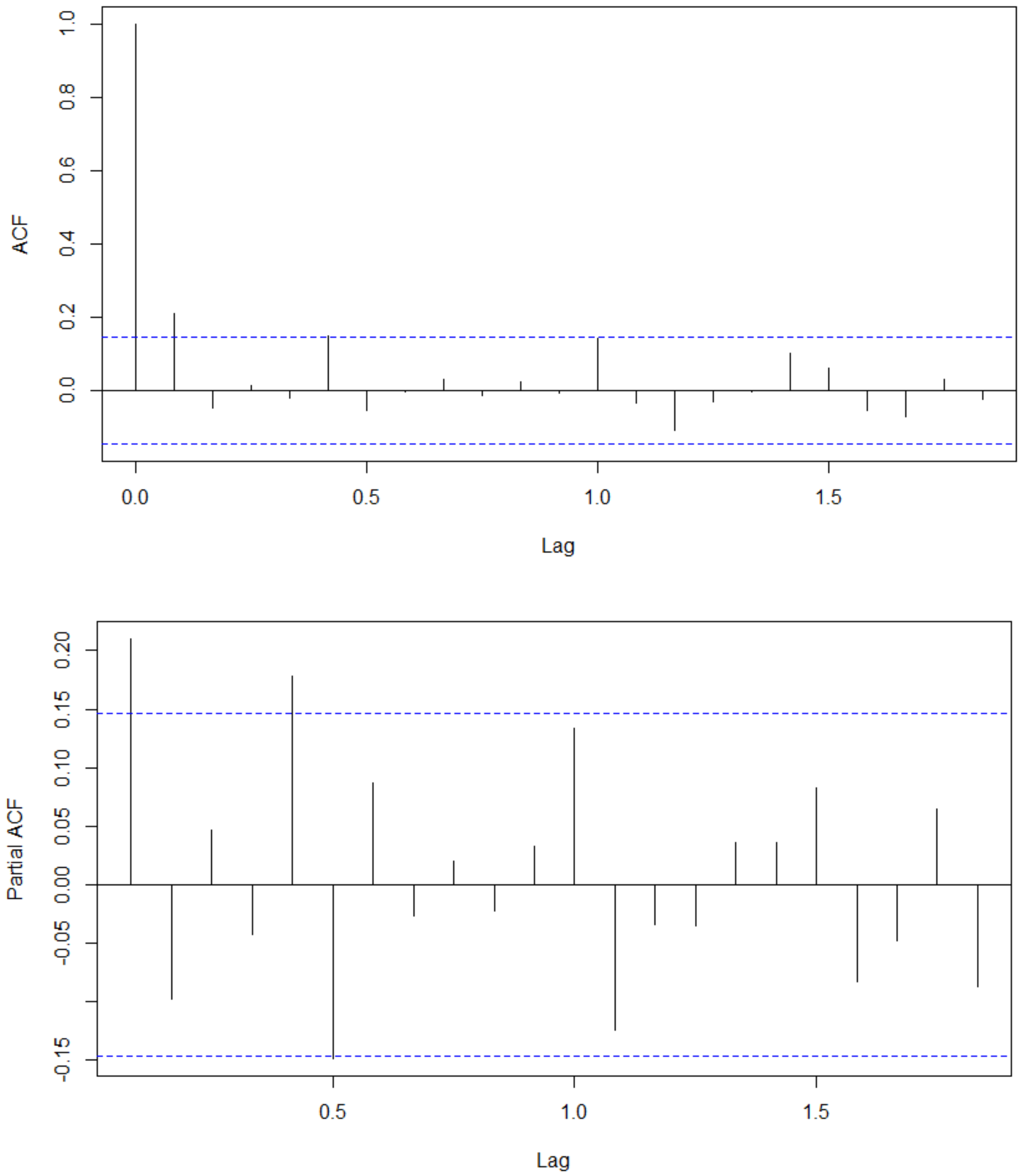

Figure 3.6: ACF and PACF of First Difference Oil Prices series.

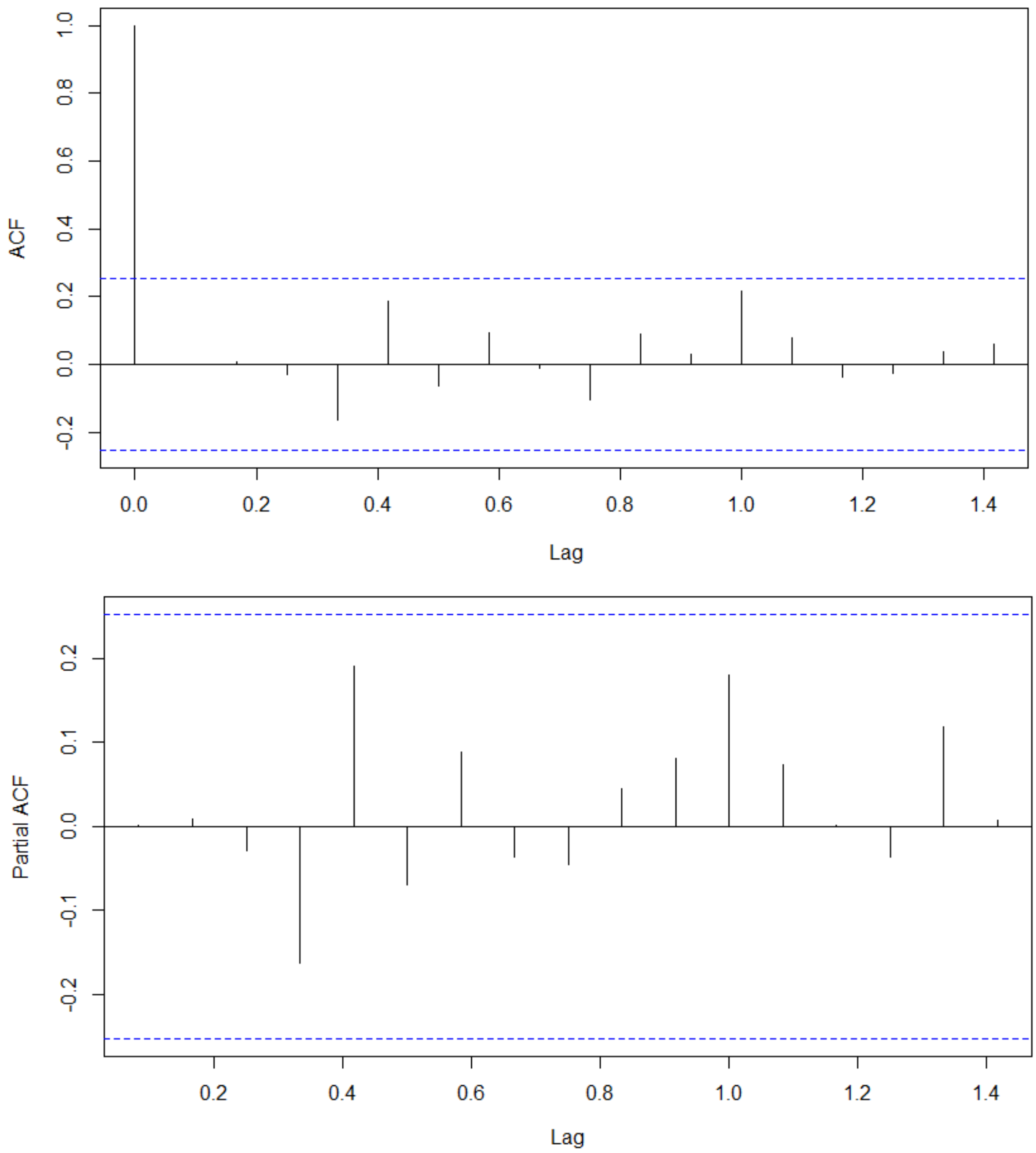

Figure 3.7: ACF and PACF of Residual of the Oil Prices.

In-sample forecasting from 2011 to 2016 is done to illustrate the efficiency of the estimation. The estimated model and log-transformed oil data set is given in Figure 3.8.

Figure 3.8 indicates the log oil prices between the years 2011 to 2016. The red line represents log-prices and the blue line is the forecasted values. We conclude that the model we propose fits well to the oil prices between the years 2011-2016.

As the final part, the estimated model is employed to predict monthly prices for the future 10 years. Additionally, the ACF and PACF of residuals indicate that the diagnostic

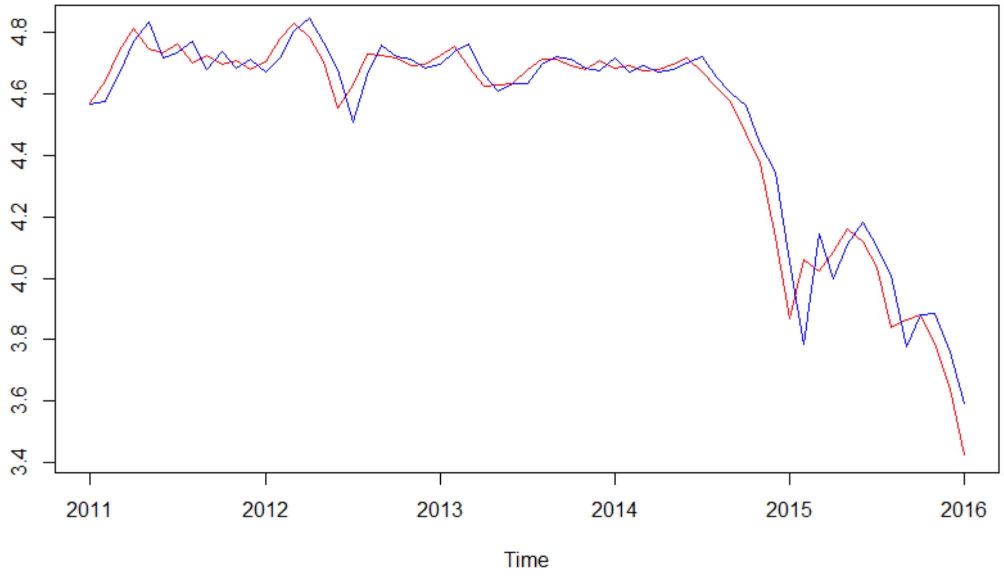

Figure 3.8: In-Sample Prediction of the Log-Transformed Oil Prices.

tests are justified for the white noise condition on random error.

The Figure 3.9 illustrates the Oil price forecast for the following ten years. Considering the Moving Average part, we added a white noise series in to the residual part of the model and forecast the oil price series.

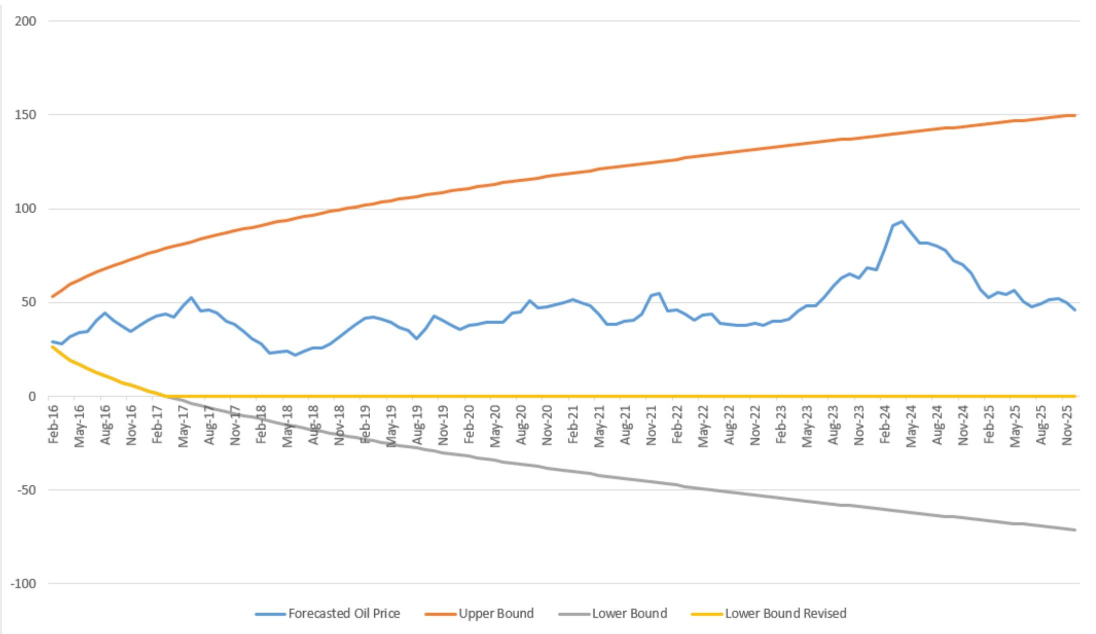

Figure 3.9: ARIMA (1,1,1) Oil Price Forecast.

As it is seen in the Figure 3.9, the oil price is expected to fluctuate around 30 to 50 $ for the following 7 years. After that, the oil price will increase to the levels of 100$ and fall to the 60$ levels. The bounds show the fluctuation area of the forecasted oil prices, but it is a fact that the oil prices will be always greater than zero. As a result, for the lower bound, we assume that the oil price range will be zero for the parts that are lower than zero that is illustrated as Lower bound revised.

CHAPTER 4

THE NATURAL GAS MARKET MODEL

We determine the optimal natural gas purchase amounts and long term natural gas price estimates under different ToP levels for the use of LDCs which is assumed to act as main supplier. To achieve this, we follow the flowchart given below:

(i) Estimate the natural gas demand using the amount of natural gas supplied to the customers and forecast the future pattern.
(ii) Estimate the natural gas supply for LDCs considering monthly supply capacities, the pipeline restrictions, storage constraints and possible natural gas price and cost scenarios depending on the WEO scenarios, World Bank oil price forecasts and the stochastic (ARIMA) oil price modelling.
(iii) Subject to some constraints and restrictions on LDCs find a natural gas source disregarding the price in order to meet the natural gas demand.
(iv) Determine the flexibility in willingness to pay for LDCs under different ToP levels.
(v) Apply the model to a real life data.

The methodology enables LDCs to set a buy and sell strategy depending on the outcomes of this thesis. The optimization problem set in the supply side of the natural gas market and a sophisticated regression model to estimate the demand yield a price equilibrium under different levels ToP which give also a flexibility in profit debates.

In order to determine the flexibility of natural gas contracts, using realization of the consumption and price in time, the data considered contains the observations obtained from a company in Turkish İGDAŞ between January 2010 and December 2015 for İstanbul city in Turkey. İstanbul is highly populated and industrialized city in Turkey [47]. Because of this reason, İstanbul is the best location to determine a better understanding of natural gas market in Turkey. The Figure 4.1 shows the natural gas consumption profile of İstanbul for different consumer groups.

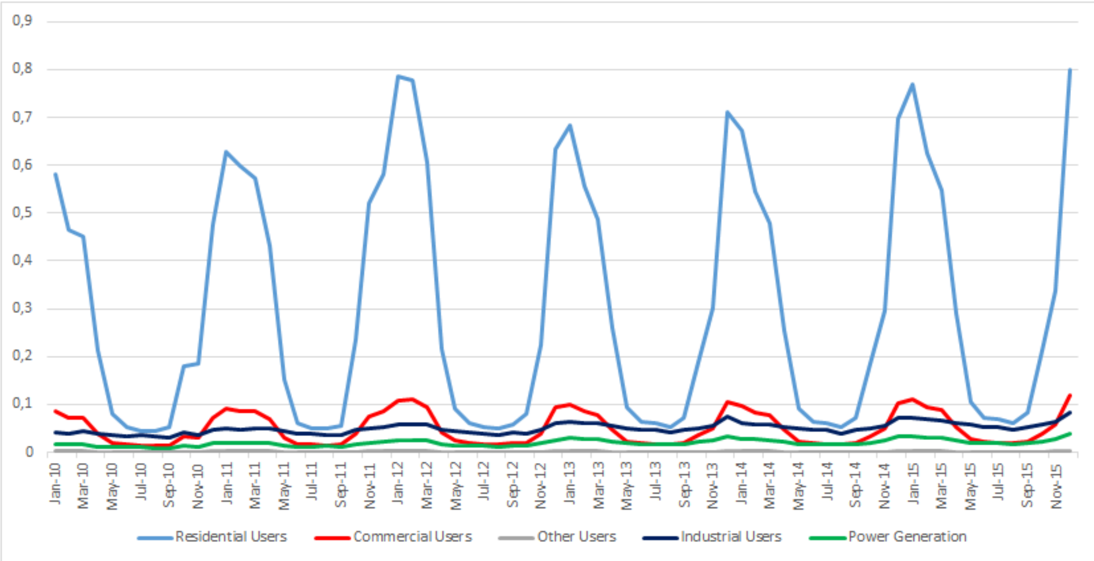

Figure 4.1: İstanbul Natural Gas Supplied to the Customers (Bcm).

As it is seen in Figure 4.1, the main consumer in İGDAŞ natural gas consumers' portfolio is the residential customers. Disregarding the effect of the cold weather in 2012 winter, the residential customer's natural gas supply curve has an increasing trend. In January 2010, the residential natural gas supply was 0.6 Bcm and in December 2015 it increased to the levels of 0.8 Bcm for İstanbul. On the other hand, in summer times the residential natural gas supply decreased to the levels below 0.1 bcm. The graph clearly illustrates the seasonal effect for residential consumption of the natural gas. Moreover, considering the moving patterns of the industrial, commercial, electricity generation and other customers such as mosques, churches and embassies, industrial and commercial natural gas supply has an increasing trend that, the industrial natural gas supply was 0.04 Bcm in 2010 and exceeded the level of 0.08 Bcm in 2015. Besides, the commercial natural gas supply was 0.08 Bcm in 2010 and in 2015 it reached to the level of 0.12 Bcm. In addition to the Commercial and Industrial consumption, the natural gas consumption in order to generate electricity was around 0.02 Bcm and increased to the levels of 0.04 Bcm. Furthermore, the other users natural gas consumption was around 0.001 to 0.003 Bcm between the years 2010 to 2015. The natural gas supply data is mostly consisting of the residential consumers and the natural gas use for electricity generation is very low in this specific portfolio.

4.1 Natural Gas Demand and its Forecasting

Considering the demand side of the natural gas market, the households and commercial users have the consumption pattern of the natural gas depending on the weather variable. In order to add the weather variables, we check effects of the average monthly temperatures and other variables. Moreover, natural gas used for the electricity generation purpose, we will expect that the electricity generators have a seasonality. In other words, the natural gas use for electricity production expect to increase on summer season depending on the amount of long term natural gas agreements and expect decrease in the winter season because of the high amount of residential and commercial demand depending on the customer's profile of the distribution company. For the industrial users we expect to have an increasing linear pattern of the natural gas demand.

For the LDCs, there will be priority for the household and commercial users especially in the winter times because of the reason that "the household and commercial users have to heat their spaces or houses" [26]. Considering the winter natural gas consumption, if we are relying on the assumption that there will be no interruption for main consumers then, for the case of a sudden increase in the natural gas demand the LDCs must supply the additional demand from different sources such as buying from the spot market, increasing their PNG purchases or buying more LNG. However, buying the natural gas at winter times from the spot market or as LNG will increase the companies' costs which will decrease the company's revenue. Although we assume that there will not be any natural gas interruption in the model, for some cases such as incapacity of the natural gas sources there will be an interruption with penalty cost.

The LDCs have the opportunity to store the natural gas. The LDC buy the natural gas from different sources when the price of natural gas is low; and sell the stored natural gas when the natural gas prices high or meet the demand for the sudden increases in the natural gas. The PNG purchases, storage facilities and LNG trading might create the excess natural gas supply. The excess amount of natural gas may also create a market for natural gas in which the customers have the opportunity to choose the natural gas supplier which offers the lowest price. In other words, the excess amount of natural gas will be considered as one of the main factor for the liberalized natural gas market.

As mentioned before, for the proposed model that appearing in next sections, the security of natural gas supply and the natural gas supply-demand equilibrium are two main restrictions. So, LDCs have to meet these rules in order to trade the natural gas. There will be penalties for the LDCs which will not be able to meet the natural gas demand. By adding penalty cost to the model, we will guarantee the supply security of natural gas otherwise the LDCs will have to pay penalties which will cost more than increasing the natural gas supply capacity.

Natural gas demand forecasting is one of the main concern for LDCs. To determine their long term natural gas purchase quantities, prediction on natural gas demand is vital for LDCs. Due to the seasonality effect in natural gas demand, the multivariate nonparametric regression procedure, MARS is applied.

4.1.1 MARS Model

MARS is a multivariate nonparametric regression procedure which was first illustrated by Jerome Friedman in 1991 [21]. MARS builds a regression model by using basis functions (BFs) as predictors which includes original data. By using MARS algorithm, all possible scenarios, all predictors and possible interactions are explored and

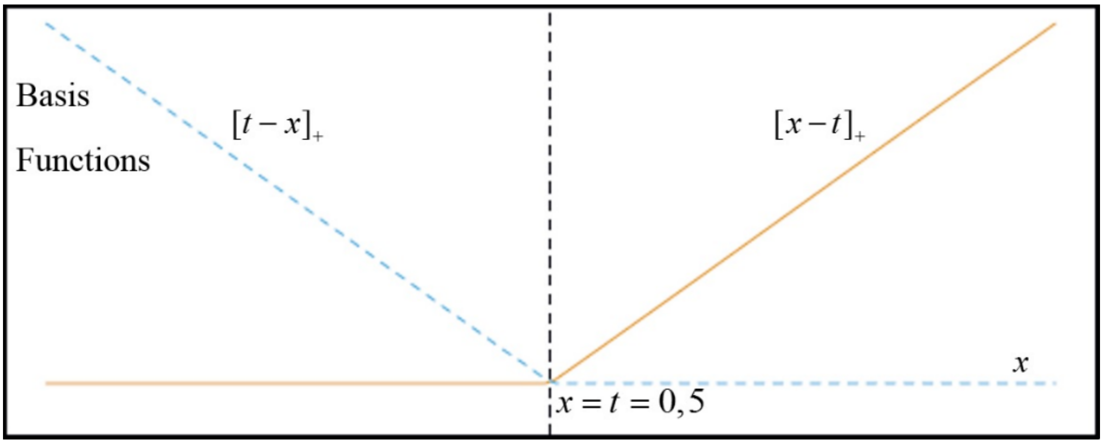

Figure 4.2: Sample Truncated Function.

determined. Moreover, the MARS model illustrates the interactions between the independent variables, determines the optimum quantities of basis functions and chooses the best model to fit the function by using least squares method. MARS develops an additive model in two-stages which are forward stage and backward stage [42]. In the forward stage of the MARS, an over fitting model will be generated by users defined maximum number of BFs (M_{max}). On the other hand, at the backward stage of the MARS, the programme diminishes the complexity of the model while keeping the data fitting purpose. In other words, at backward stage, the model takes out the BFs which indicate the smallest escalation in the residual sum of squares (RSS) and at the end the optimal model is formed as it is mentioned in [27], [32] and [35]. "The stopping criterion for the backward stage is the achievement of the optimal balance between bias and variance" [50].

MARS illustrates the piecewise linear expansions of BFs relying on the data set. The form of BFs emphasized by [27] is;

$$[x-t]_+ = \begin{cases} x-t, \text{if } x>t, \\ 0, \text{otherwise}, \end{cases} \qquad [t-x]_+ = \begin{cases} t-x, \text{if } x<t, \\ 0, \text{otherwise}, \end{cases} \tag{4.1}$$

where t represents the univariate knot obtained from data set. These functions illustrated as truncated function. MARS algorithm indicates that function as piecewise linear; with a knot at the value t and which is demonstrated as reflected pair. The main purpose is to form reflected pairs for each inputs. Figure 4.2 illustrates basis function pairs for $t = 0.5$ as an example.

Let X_j $(j = 1, 2, 3, \ldots, p)$ with p dimensional knots be the observed values $x_{i,j}$, for inputs of $i = 1, 2, \ldots, N$ ([35]). Accordingly, the set B;

$$B := \left\{ [X_j - t]_+ , [t - X_j]_+ \,|t \in \{x_{1j}, x_{2j}, \ldots, x_{Nj}\} \quad j = 1, 2, 3, \ldots, p \right\} \tag{4.2}$$

where N is the number of observations and p is the dimension of input space that there exists $(2Np)$ BFs in case of all input values are different. Considering the forward stage for MARS, the model fits the data set by using BFs from set B. The model is illustrated as;

$$Y = E(\alpha_0 + \sum_{m=1}^{M} \alpha_m T_m(X) \mid X = \mathbf{X}) + \varepsilon \tag{4.3}$$

where M is the set of BFs in the present model and ε is the additive stochastic component with zero mean and constant variance. The form of M_{th} BF is illustrated as;

$$T_m(X) = \prod_{k=1}^{K_m} [S_{km}.X_{v(k,m)} \; - t_{km}]_+ \tag{4.4}$$

where K_m represents the number of truncated linear functions with the multiplication of m^{th} BFs. $X_{v(k,m)}$ is the input variable and t_{km} is the knot value confirming to the variable x_v(k,m) and s_{km} = ± 1 [35].
In final stage, MARS gives the estimated best model f_μ of each number of terms μ which constitutes the ultimate model. Considering MARS, the generalized cross-validation implemented in order to determine the optimal number of terms μ. The lack-of-fit (LOF) criterion or generalized cross-validation (GCV) which is introduced by [21] is given as;

$$LOF(\hat{f}_\mu) = GCV(\mu) = \frac{\sum_{i=1}^{N} (y_i - \hat{f}_\mu(\mathbf{x}_i))^2}{(1 - \frac{M(\mu)}{N})^2} \tag{4.5}$$

where N represents the number of sample observations and $M(\mu)$ is the effective number of parameters. The demand estimation is vital for LDCs because, LDCs have to determine their natural gas supply contracts with an uninterruptible basis, and provide enough natural gas supply in order to meet the natural gas demand for all cases.

To implement MARS for predicting the amount of natural gas supplied to the customers (NGS), we analyze the effect of the Heating Degree Days (T_1), one–period earlier supply (T_2), Cooling Degree Days (T_3), monthly number of holidays(T_4). Heating Degree Days (HDD) and Cooling Degree Days (CDD) are defined as the number of the average temperature falls below and above a pre-specified limit temperature, respectively. Even though these indicators may change, many of the countries like Turkey accepts Eurostat [20] definitions which are as follows:

(i) HDD = 18°C - T in which, T is the average temperature of minimum T_{Min} and maximum T_{Max} realizations in a day. HDD is applied under the condition when the temperature is below 15° C.

(ii) CDD= T - 22° C where T is the average temperature. Threshold in CDD is set to 22° C.

The data consists of monthly natural gas supply for the years 2010-2014 for 5 different consumer classes. MARS algorithm is applied to the data to determine the impact of these variables on the NGS [1]. The significance of the parameters are tested and illustrated in Table 4.1. As it is seen in Table 4.1, only T_1 and T_2 have an effect on the natural gas supply function, whereas the cooling degree days and holidays are non-significant in the model which is presented in Equation 4.6. For demand forecasting using MARS, we assume that the weather conditions will be at their seasonal average level for the whole forecasting period. The coefficients of the fitted model agree with their contribution to the supply as expected.

$$
\begin{aligned}
NGS &= (5.98 \times 10^8) + (4 \times 10^{-3}) \times max(0; 6.43 \times 10^8 \times T_2) \times max(0;\ T_1) \\
&+ \ 0.32 \times max(0;\ T_2 - (4.88 \times 10^8)) - 1.26 \times max(0; (4.88 \times 10^8) - T_2) \\
&+ \ (2.32 \times 10^6) \times max(0; T_1 - 272) \times (-3.3 \times 10^{-3}) \times max(0; T_2 - 1.15 \times 10^8) \\
&\times \ max(0;\ 272 - T_1)
\end{aligned} \tag{4.6}
$$

Table 4.1: Significance of the Variables in MARS model

Variables in the model	Coding	Significant
Heating degree days	T_1	Yes
A Period earlier supply	T_2	Yes
Cooling degree days	T_3	No
Holidays	T_4	No

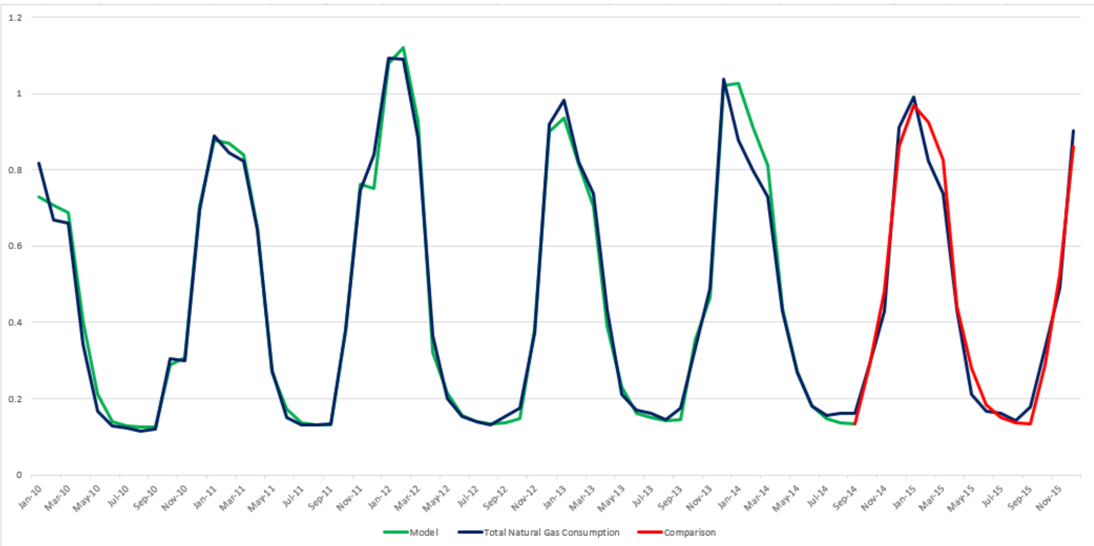

Figure 4.3: Original and estimated monthly NGS values between 2010-2015 (Bcm)

Figure 4.3 illustrates original and fitted values of NGS for the years 2010 and 2015. The blue line in the graph gives the total natural gas supplied to the customers, the green line illustrates the in sample fitted model and the red line is the MARS forecast for next period natural gas demand. It is concluded that the model follows the same pattern as the supply curve except 2014 winter. This may be because of insufficient delivery from the gas sources or curtailment as a result of the lack of natural gas supply. The recognition of undelivered gas is vital, as it enables us to forecast the actual gas demand. Moreover, the MARS forecast results clearly indicates that the model catches the natural gas demand pattern except for the 2015 winter which might be result of undelivered natural gas. The demand estimation is vital for LDCs that to determine their natural gas supply contracts with an uninterruptible basis and provide enough natural gas supply in order to meet the natural gas demand for all cases.

4.1.2 Flexibility Analysis

The model concentrates on finding the optimal amounts of natural gas purchases for different sources. The price component is the most significant one, considering the selection of the cheapest natural gas supply for the natural gas distribution company. The concept of flexibility is important in this content. According to Doege et al. [13] and Doege [14] flexibility is the "ability of an economic system to react to unexpected changes in order to limit the associated threat of losses". The model should be flexible enough to choose the cheapest purchase source and minimize the company's total cost of purchasing the natural gas. The availability of the natural gas storage facility complicates the supply planning, in which this variable also creates flexibility for the natural gas market. In other words, with the storage facilities the LDCs react to the unexpected demand jumps or sudden fall in the demand of the natural gas. Moreover, the model should react to the sudden price change in the natural gas source that if the price of the spot LNG suddenly falls to the level which is smaller than the other resource, the model should choose the spot LNG as the main supply resource. One of the main assumptions in the model is that the long term natural gas purchase agreements is the main natural gas source. Considering the spot LNG and spot market natural gas price, the sudden price decrease will affect the purchase agreements of spot market natural gas purchases. In other words, the sudden price fall in the spot LNG will increase the spot LNG purchase amount, decrease the other natural gas source purchase amount and vice versa.

4.1.3 Natural Gas Supply Optimization

The natural gas supply is the other main body for the natural gas market. In order to determine the PNG price curves, we use Mixed Integer Linear Programming (MILP) which is a mathematical optimization program with integer variables. The LDCs have 4 main natural gas supply sources which are PNG purchases (X_1), LNG purchases (X_2), spot market natural gas purchases (X_3) and storage natural gas output (X_4). In the model, LDCs are assumed to act as the main supplier in order to trade the natural gas without legal restrictions. The data used in the analyses contain the observations of İstanbul taken online from BOTAŞ. The pipeline capacities and storage capacities are determined for İstanbul and add to the model as restrictions. The model determine different natural gas purchase amount for different PNG contracts with different ToP levels.

The PNG purchases is the long term natural gas contracts in this study. Considering Turkish natural gas market almost 86% of the natural gas agreements are PNG purchases, followed by LNG (13%) and Spot LNG (3.4%) [18]. There are restrictions such as Daily Contract Quantity (DCQ), Monthly Contract Quantity (MCQ) and Annual Contract Quantity (ACQ) for PNG purchases. The DCQ illustrates the daily maximum amount of natural gas purchases. Moreover, the MCQ represents the minimum monthly natural gas purchases and the ACQ is the annual natural gas purchase amount. If the natural gas purchases amount is higher than the ACQ contract rate, the LDCs pay penalty because of the reason not to comply with the contract terms. On the other hand, if total natural gas purchase is below ACQ amount, then LDCs will able to purchase excess amount of natural gas in the next period with paying all PNG contract payments on the current day. Therefore, flexibility is vital for LDCs to respond to unforeseen changes easily and react to the price changes of different natural gas sources [13].

The LNG purchases are considered as the other natural gas supply source. The LNG purchases are also a long term agreement and because of that reason the demand forecasting for the next period is vital. The assumption considering the LNG purchases in this study is that, there will be enough LNG supply for winter cases and sudden increases and ACQ and MCQ rates use for only PNG purchases. The LNG is an expensive natural gas supply source comparing with the PNG purchases in real world cases. Even though, LNG is an expensive natural gas supply source we assume that LDCs react to the price of different natural gas supply sources. To be more precise, if spot LNG price is lower than spot natural gas purchases, spot LNG is used as the first natural gas supply source relying on the spot LNG supply capacity referring to flexibility. The Spot natural gas purchase is the third natural gas supply source in this study. It is evident that the natural gas market is influenced by oil prices. For this reason, six different oil price scenarios regarding to natural gas market are taken into account.

The price of the spot and LNG sources will be pre-determined based on oil price scenarios. In this study, we determine the long term contract prices for different ToP levels of PNG purchases. Total natural gas supply is expressed as follows;

$$X_T(n) = \sum_{k=1}^{n} X_1(k) + \sum_{k=1}^{n} X_2(k) + \sum_{k=1}^{n} X_3(k) + \sum_{k=1}^{n} X_4(k) \tag{4.7}$$

where $k = 1, \ldots, n$ represents the number of periods.

The price of LNG purchase (Z_1) and the price of spot natural gas purchase (Z_2) have important impact on deciding whether LNG will be used as the first natural gas supply source or not. The prices of LNG and Spot natural gas are also assumed to change with respect to the oil price movement. Moreover, the price of natural gas sources determines the source of natural gas that will be put into the storage in order to meet the next period's natural gas demand.

The natural gas transportation is one of the main costs for the LDCs whose cost is determined by only with the amount of natural gas that is transported. Moreover, the transportation cost is assumed to be sensitive to the changes in the price of oil scenarios. The possible transportation routes for LDCs are listed as below:

- PNG transportation cost from the source to the customers.
- PNG transportation cost from the source to the storage facility.
- Any Transportation cost from the storage to the customers.
- LNG Transportation cost from the source to customers.
- LNG Transportation cost from the source to the storage facility.
- Spot Market Natural gas purchases transportation costs from source to customers.
- Spot Market Natural gas purchases transportation costs from source to the storage facility.

The estimated cost for the LDC in the model, is the sum of the cost of the PNG, LNG and Spot natural gas purchases, transportation cost from the natural gas source to the customers, the storage natural gas transportation cost from the natural gas source to the storage facility and the transportation of the storage natural gas to the customers for the case of inadequate natural gas supply or the sudden natural gas demand increase. In addition to the transportation cost of the natural gas, LDCs have to deal with the capacity restrictions of the natural gas supply sources and the storage facility. The restriction regarding the capacity of natural gas purchases are given below. For the LDCs the pipeline capacity is vital because of the cost minimizing purpose. In other words, the LDCs purchase the natural gas from the cheapest source but the pipeline capacity will determine the amount of natural gas supplied by using the cheapest source.

The capacity restrictions of the natural gas purchases are:

- The Maximum Amount of Natural Gas purchase from the Pipeline cannot exceed the maximum capacity of monthly PNG purchases.
- The Maximum Amount of Natural Gas purchase from the Storage cannot exceed the maximum capacity of monthly storage purchases.
- The Maximum Amount of Spot natural gas amount cannot exceed the maximum capacity of monthly Spot purchases.
- The Maximum Amount of LNG amount cannot exceed the maximum capacity of monthly LNG purchases.
- The Maximum Amount Storage capacity at the end cannot exceed the maximum amount of capacity reserved yearly.

Based on the assumptions above, the total transportation cost, C_T, is given

$$\begin{aligned} C_T(n) = \sum_{k=1}^{n} Z_3(k) \times X_1(k) \quad &+ \quad \sum_{k=1}^{n} Z_3(k) \times X_2(k) \\ + \sum_{k=1}^{n} Z_3(k) \times X_3(k) \quad &+ \quad \sum_{k=1}^{n} Z_3(k) \times X_5(k) + \sum_{k=1}^{n} Z_3(k) \times X_6(k) \end{aligned} \tag{4.8}$$

where k denotes number of periods, Z_3 indicates the cost of transportation, X_5 is the total natural gas put into storage and X_6 denotes the total natural gas withdrawn from the storage. In addition to the transportation cost of the natural gas, LDCs have to deal with the capacity restrictions of the natural gas supply sources and the storage facility for cost minimizing purposes. As the pipeline capacities are assumed to be known, LDCs will purchase natural gas from the cheapest possible source, which are limited by the pipeline capacities. The pipeline capacities are given as follows:

$$\begin{aligned} 0 &\leq X_1 \leq C_P \\ 0 &\leq X_2 \leq C_L \\ 0 &\leq X_3 \leq C_S \end{aligned} \tag{4.9}$$

where C_P is the maximum PNG capacity, C_L denotes the maximum LNG capacity and C_S represents the maximum amount of spot natural gas purchases. We assume LDCs must have the long term PNG agreements, having a guaranteed supply of natural gas, because the other natural gas supply sources are not able to compensate demand without PNG supply.

4.1.3.1 The Storage Use

LDCs determine the reserved storage capacity depending on natural gas demand in the next period. The storage capacity is reserved by annual contracts and the capacity will be used several times through the year by paying the injection and withdraw costs. We assume that the use of storage facility is only for natural gas storage purposes and the LDCs are not allowed to trade natural gas in the storage. Moreover, total cost of the storage will determine whether the storage will be used as the first natural gas supply or not. Here, the swap operations are ignored. The natural gas input and output capacity for storage changed over time; but in this study we assume that these capacities and the total storage capacity is constant. The Storage capacity restrictions are given below:

- The maximum amount of monthly injecting natural gas into natural gas storage cannot exceed the maximum amount of input capacity of the storage facility
- The maximum amount of monthly withdrawals of natural gas from storage cannot exceed the maximum amount of output capacity of the storage facility
- The maximum storage capacity on annual contracts cannot exceed the maximum amount of annual capacity of the storage facility.

Under these constraints, the bounds on the storage natural gas input, X_5, and storage natural gas output, X_6, are expressed as;

$$\begin{aligned} 0 &\leq X_5 \leq C_I \\ 0 &\leq X_6 \leq C_O \end{aligned} \tag{4.10}$$

where C_O illustrates the maximum amount of storage output capacity and C_I is the maximum storage input capacity. The storage use is considered as an important supply source to meet the natural gas demand for LDCs in case of sudden increase in natural gas demand. But the storage use as a supply source creates an additional cost for them. The storage use decision depends on the price of the natural gas supply sources. Therefore, the cost of the storage use and the demand necessity has to be predicted for the next period. In other words, the storage natural gas use might be considered as the first option for the natural gas supply, if total cost of the storage use will be lower than

LNG and Spot natural gas purchase costs. Here, we determine the breakeven points of storage use for different natural gas supplies, depending on the forecasted prices of natural gas supply sources and storage use costs. LDCs decide whether to use the storage as the first natural gas supply source or not to use the storage facility at all. Moreover, LDCs choose the scenario which yields the minimum cost in storage use. Therefore, the total storage cost, SC, is expressed as the sum of natural gas supply source cost, storage input, output costs and the storage capacity reserved cost.

$$\begin{aligned} SC(n) = &\sum_{k=1}^{n} X_6(k) \times Z_4(k) + \sum_{k=1}^{n} X_5(k) \times Z_5(k) \\ &+ \sum_{k=1}^{n} X_6(k) \times Z_6(k) + \sum_{k=1}^{n} X_5(k) \times Z_6(k). \end{aligned} \tag{4.11}$$

Here, Z_4 is the cost of taking out the natural gas from storage, Z_5 denotes the cost of natural gas put into storage and Z_6 indicates the cost of reserved capacity of storage.

4.1.3.2 Penalty Cost

The LDCs have to pay penalty if the amount on natural gas that will be supplied is greater than the ACQ or not meet the MCQ restrictions. In the model, we assume that the LDCs consider only the ACQ. In other words, if the LDCs meet ACQ requirements for different levels of ToP there will be no penalty cost. Moreover, the other penalty cost in the model is used for the case that the total supply natural gas supply from different sources will be insufficient to meet the total natural gas demand. In other words, the LDCs have to pay penalty for every amount of natural gas demand that is not compensated by its supply. The penalty cost of natural gas demand that is not supplied by LDC, is given constant and higher than the cost of the supply sources and storage use. Because of that reason, the company must have to buy the excess amount of natural gas in order to maximize its profit. In the model, we will expect that the penalty cost will be zero because of the restriction that the LDC must meet the natural gas demand in all cases and profit maximization purpose and high costs of penalty which affect the profit margin level of the LDC.

4.1.3.3 Total Cost and Total Revenue

Based on all those definitions and assumption above, the next step is to determine the total cost and the total revenue for LDCs to find the equilibrium price. Total cost, TC, is the sum of the total transportation cost, storage cost and the natural gas supply cost. The flexibility to switch different natural gas sources is implemented into the model so that LDCs can choose 'the least costing' supply sources in their portfolios. At this point, the supply security which refers to uninterrupted gas supply is also considered. Thus, the LDCs minimize their TC considering all constraints. Therefore, the total cost of LDCs is determined by;

$$\begin{aligned}\min \ TC(n) = \sum_{k=1}^{n} X_2(k) \times Z_1(k) \ &+ \ \sum_{k=1}^{n} X_3 \times Z_2(k) + \sum_{k=1}^{n} SC(k) \\ &+ \ \sum_{k=1}^{n} C_T(k) \end{aligned} \tag{4.12}$$

subject to;

$$\begin{aligned} X_4(k) &\geq 0; \\ Z_1(k) &\geq 0; \\ Z_2(k) &\geq 0; \\ SC(k) &\geq 0; \\ C_T(k) &\geq 0; \\ C_L \geq X_2 &\geq 0; \\ C_S \geq X_3 &\geq 0; \end{aligned}$$

The total revenue, TR, is calculated as the natural gas amount distributed to the customers multiplied with its selling price. Determining the selling price of the natural gas is also a critical issue for LDCs. Natural gas selling prices change depending on the consumption level. In other words, LDCs decrease the selling price of natural gas if the total consumption increases. Based on this setup the TR is given as;

$$\begin{aligned} TR(n) = \sum_{k=1}^{n} D_5(k) \times P_5(k) \ &+ \ \sum_{k=1}^{n} D_3(k) \times P_3(k) \\ + \sum_{k=1}^{n} D_2(k) \times P_2(k) \ &+ \ \sum_{k=1}^{n} D_4(k) \times P_4(k) \\ + \sum_{k=1}^{n} D_1(k) \times P_1(k). \end{aligned} \tag{4.13}$$

Here, P_i, i=1,...,5, represents the selling price of natural gas for 5 different consumer classes such as residential, commercial, industrial, electricity generation and others. In addition, D_i, i=1,...,5, denotes the amount gas that will be supplied to each consumer classes. The natural gas selling price depends on the oil price scenarios as it is mentioned before. These scenarios yield 6 different total revenue curves according to 6 different oil price scenarios. After determining the total revenue and total cost curves for different level of ToP as a percent of total demand, the model calculates the net revenue and illustrates the long term natural gas price curves under different oil price scenarios and varying level of ToP.

CHAPTER 5

NATURAL GAS FLEXIBILITY IN İSTANBUL

The multidimensional variables required for the analyses are collected from BOTAŞ, Turkish Petroleum Corporation (TPAO) and İGDAŞ for İstanbul. As most of the monetary units are given in Turkish Lira (TL), the exchange rate is assumed to be fixed on average to 1 USD = 2.90 TL for the following 10 years and the results are presented in USD. The maximum PNG capacity amount is taken from BOTAS and the daily natural gas capacities are converted into monthly capacities. The pipeline capacities are assumed to be fix for the next 10 years. For the LNG purchase capacity, the data from Marmara Ereglisi LNG facility is taken which represents 5.6 Bcm yearly capacity. Moreover, TPAO storage facility which is located in North-West of Turkey is used to determine the maximum capacity amount of annual storage, monthly input and output capacity. Natural gas selling price data is taken from İGDAŞ. The MATLAB Software is used to run the codes.

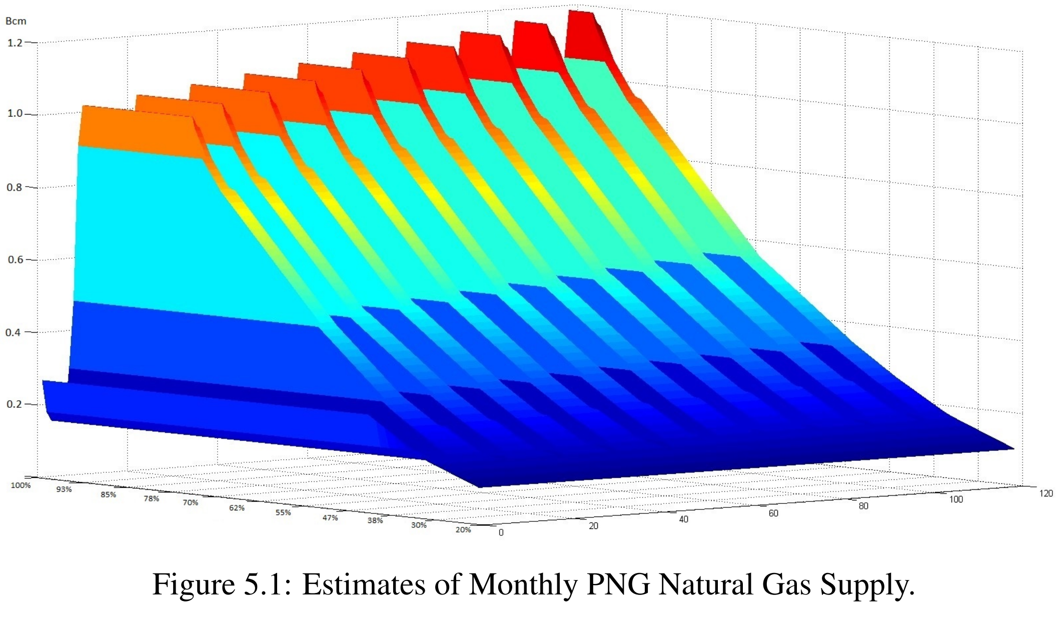

Figure 5.1: Estimates of Monthly PNG Natural Gas Supply.

The model starts at 100% ToP supply level and it reduced to 20% gradually. At 100% ToP, PNG meets the total natural gas demand. Then, the model gives the optimal natural gas purchase amounts and storage use under varying levels of ToP percent's. The

PNG supply for different ToP levels are estimated for next 10 years and plotted in Figure 5.1. The left vertical axis shows the amount of natural gas supplied by PNG. The lower right axis shows the time (number of periods) and the lower left axis refers to the ToP levels. As it is seen in plots, the PNG supply has a decreasing trend as the ToP level decreases. Figure 4.1 shows that the demand in winter terms is about 15 times higher than the demand in summer terms between years 2010-2015 in the details of consumer classes. The natural gas supply for electricity generation constitutes the second least compared to residential, commercial and industrial classes. Because of discrepancy in winter and summer, PNG supply source should be enough to meet the natural gas demand in winter times and at the same time should keep the ACQ condition. As the ToP level decreases, the natural gas demand supplied by PNG decreases (Figure 5.1). As a result of this, LDCs have to switch to the other natural gas sources to meet the demand. The storage decision is important because, it is the other natural gas source and may be the cheapest comparing with the other ones depending on the price of natural gas sources and total storage costs. The graph on the yearly LNG supply (Figure 5.2) demonstrates that, as the ToP level decreases, LDCs tend to move to the other natural gas supply sources. Depending on the price and pipeline capacity LDCs decide on the least cost supply source. In the graph, the yearly LNG supply in the vertical axis increases as the ToP percentage on the right lower axis decreases.

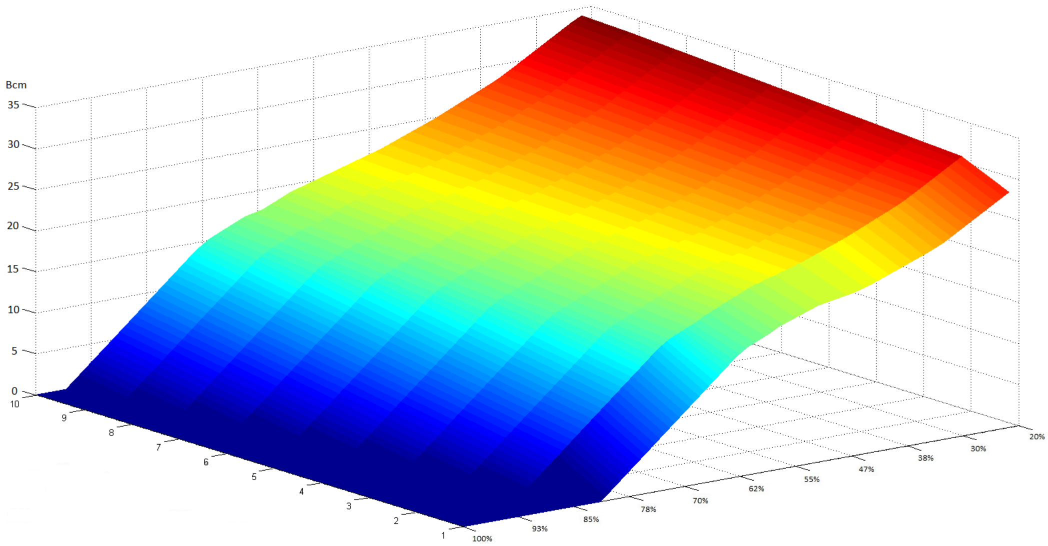

Figure 5.2: Estimates of Yearly LNG Supply.

Figure 5.3 indicates the monthly LNG supply which increases to and is fixed at a certain pipeline capacity level. ToP level (right lower axis) switches to the other sources if the capacity for LNG is not enough to meet the demand. The monthly LNG capacity clearly indicates that LDCs continue to take the natural gas until it reaches to its highest limit.

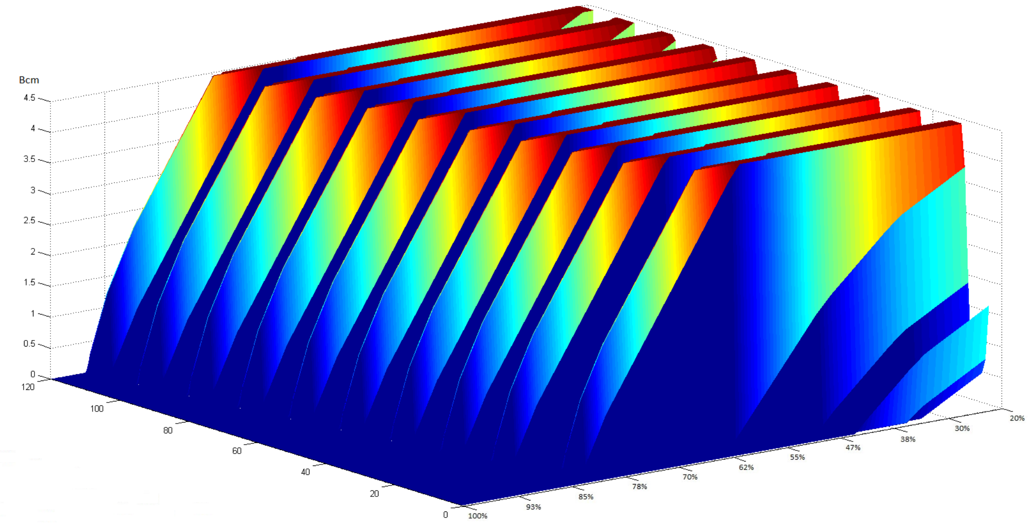

Figure 5.3: Estimates of Monthly LNG Supply

The yearly Spot natural gas supply behaves similar to the yearly LNG supply. As ToP level decreases, LDCs move to the cheapest and available alternative resource which is Spot natural gas purchase. Figure 5.4 and Figure 5.5 indicate yearly and monthly Spot natural gas purchase amounts, respectively. The left vertical axis shows again the amount of natural gas supplied by Spot natural gas purchases. For some cases, spot and LNG purchases reach to its maximum capacity and LDCs start to procure natural gas from storage.

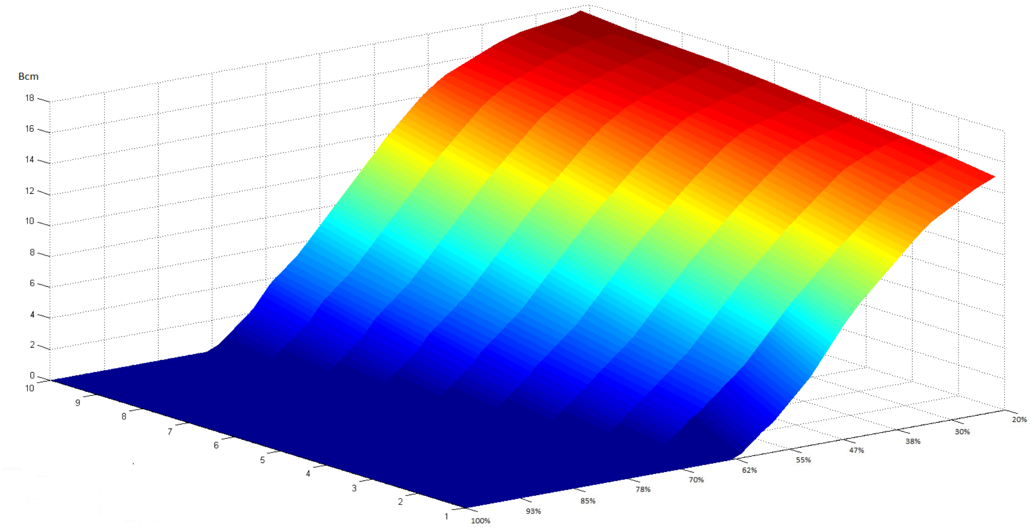

Figure 5.4: Estimates of Yearly Spot Supply

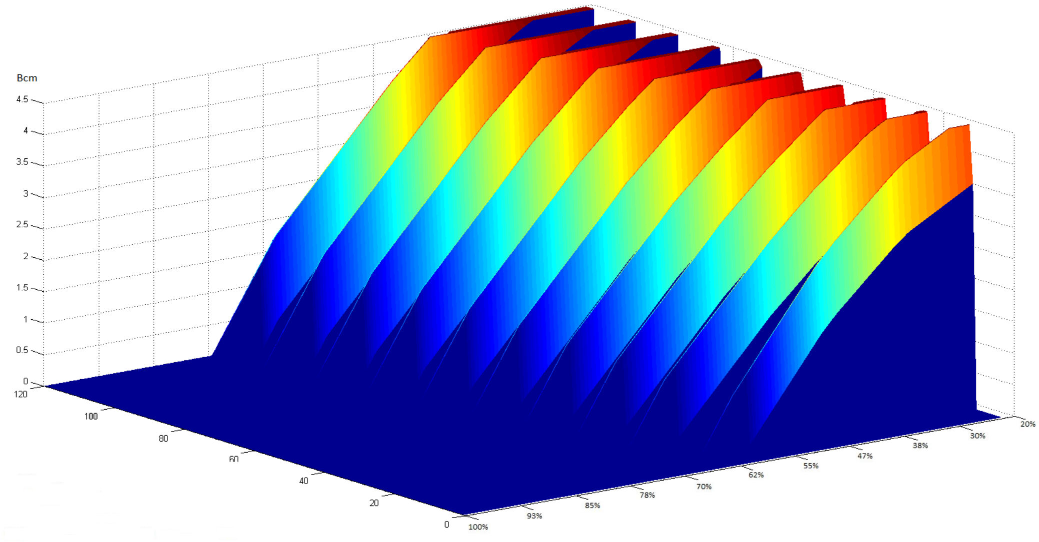

Figure 5.5: Estimates of Monthly Spot Market Natural Gas Supply

The storage use is found to be the most expensive supply for the LDCs. Figures 5.6 and 5.7 illustrate the pattern of storage use with respect to time, ToP level and supply level, on monthly and yearly bases, respectively. LDCs use the storage in order to meet the natural gas demand. Therefore, they store the natural gas when there is a sudden decrease in the price of natural gas and then take out the gas from storage when the necessity in natural gas increases. However, because of the higher costs of storage use, LDCs are not reluctant to keep natural gas in storage. On the other hand, in the cases of the lowest ToP levels (around 20-25%), LDCs use every natural gas supply option in order to meet the natural gas demand requiring them to use the storage contrary to, its additional high costs.

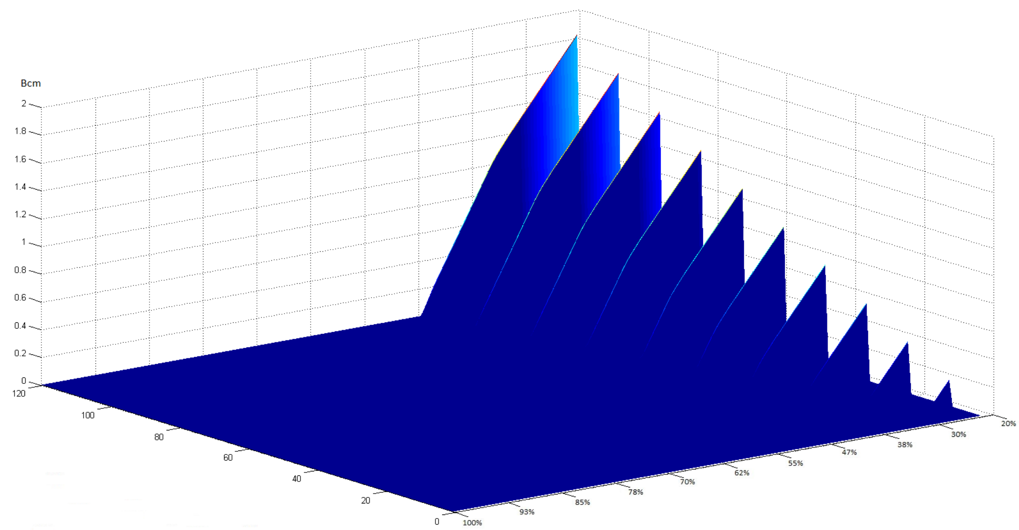

Figure 5.6: Estimates of Monthly Storage Natural Gas Supply

Additionally, the resutls on yearly storage supply (Figure 5.7) support our approach that the storage use level is limited and does not even reach to the level of maximum storage capacity as can be seen in Figure 5.6. It is concluded that, LDCs are able to meet the natural gas demand in all natural gas supply scenarios under different ToP levels.

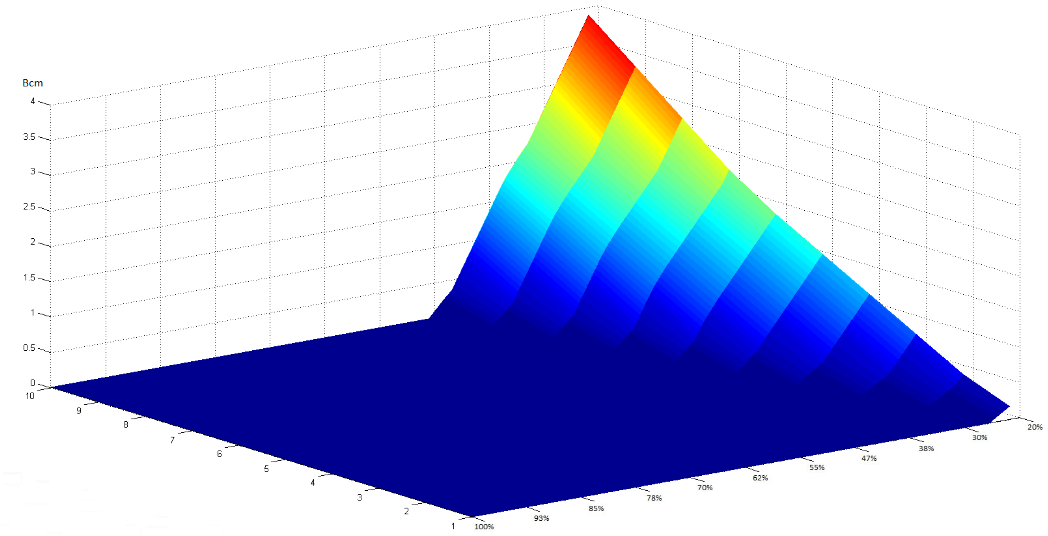

Figure 5.7: Estimates of Yearly Storage Natural Gas Supply

Table 5.1: Long Term Natural Gas Contract Prices for 20% ToP Contracts (in USD).

%20 ToP Level	Current Pol. Oil Price Scenario	New Pol. Oil Price Scenario	450 Pol. Oil Price Scenario	Low Oil Price Scenario	World Bank Oil Price Scenario	ARIMA Oil Price Scenario
PNG Max. Price	607	535	368	873	1035	445
1% Profit Margin	601	529	364	865	1025	441
5% Profit Margin	577	508	349	830	984	423
10% Profit Margin	546	481	331	786	932	401
15% Profit Margin	516	455	313	742	880	378
20% Profit Margin	486	428	294	699	828	356

Table 5.2: Long Term Natural Gas Contract Prices for 100 ToP Contracts (in USD).

%100 ToP Level	Current Pol. Oil Price Scenario	New Pol. Oil Price Scenario	450 Pol. Oil Price Scenario	Low Oil Price Scenario	World Bank Oil Price Scenario	ARIMA Oil Price Scenario
PNG Max. Price	405	382	324	400	469	300
1% Profit Margin	401	378	320	396	465	296
5% Profit Margin	385	363	307	380	446	284
10% Profit Margin	364	344	291	360	423	269
15% Profit Margin	344	325	275	340	399	254
20% Profit Margin	324	306	259	320	376	239

The outcomes of the analyses are summarized and tabulated only for 100% and 20% ToP levels. The maximum 100% and the minimum 20% levels are chosen to illustrate the impact of flexibility on the LDCs willingness to pay under different oil price scenarios.

As it is seen in Table 5.2 for 100% ToP levels; i.e, no flexibility in natural gas supply sources, the firms' willingness to pay fluctuates between 239 USD and 469 USD. On the other hand, if the flexibility increases, i.e. the ToP level decreases to 20%, LDCs willingness to pay in order to procure natural gas increase to the levels of around 1035 USD (Table 5.1). As a result, LDCs flexibility and willingness to pay increases proportionally. Considering LDCs profit margin levels, we realize that as targeted profit ratio increases, the willingness to pay for natural gas contracts decreases. Moreover, the storage use decreases the firm's willingness to pay in all cases. In addition, the fluctuation in oil prices (ARIMA(1,1,1) oil price) decreases the firms willingness to pay ratio due to the uncertainty as is it presented in Figure 5.13 that for 100% the willingness to pay decreases to the levels of 250 USD and with the highest flexibility (20% ToP) it reaches to the levels of 350 USD with an rising slope.

The ToP levels other than these two selected values are presented graphically in Figures 5.8, 5.9, 5.10, 5.11, 5.12, 5.13. It should be noted that, based on the oil scenarios, the willingness to pay increases with varying slopes. The flatter trend is achieved in the 450 oil price scenario and ARIMA(1,1,1) oil price scenario, whereas an exponential increase is observed in the trend with respect to the World Bank and Low oil price scenario scenario.

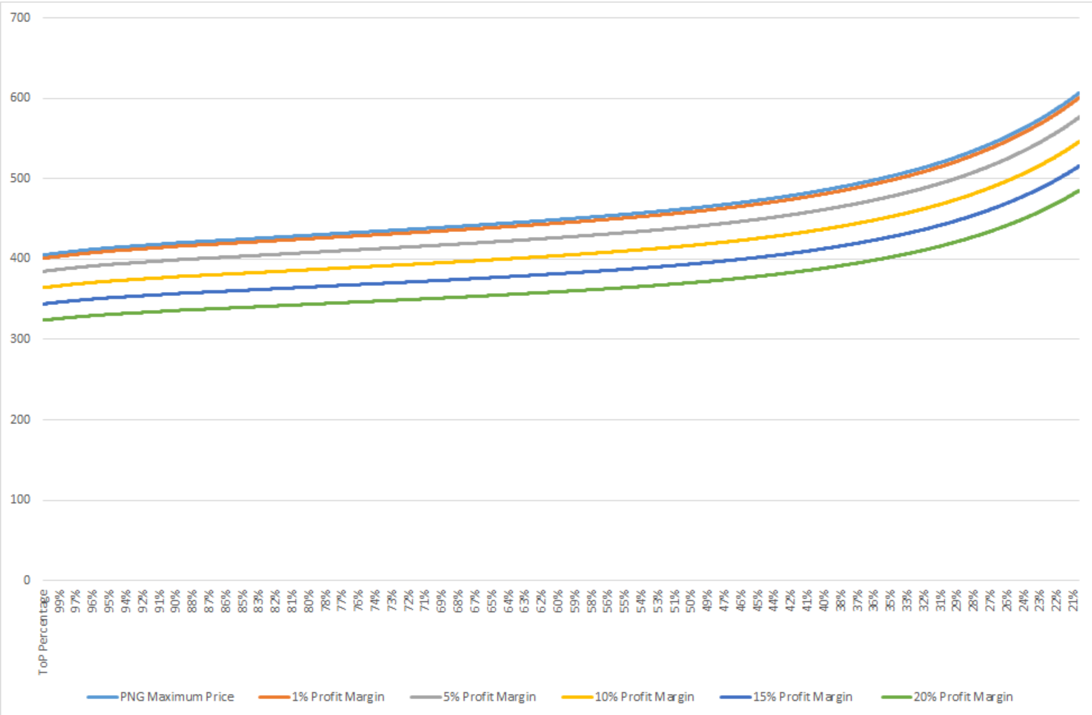

Figure 5.9: The Flexibility Based on Current Oil Price Scenario for Different ToP Levels.

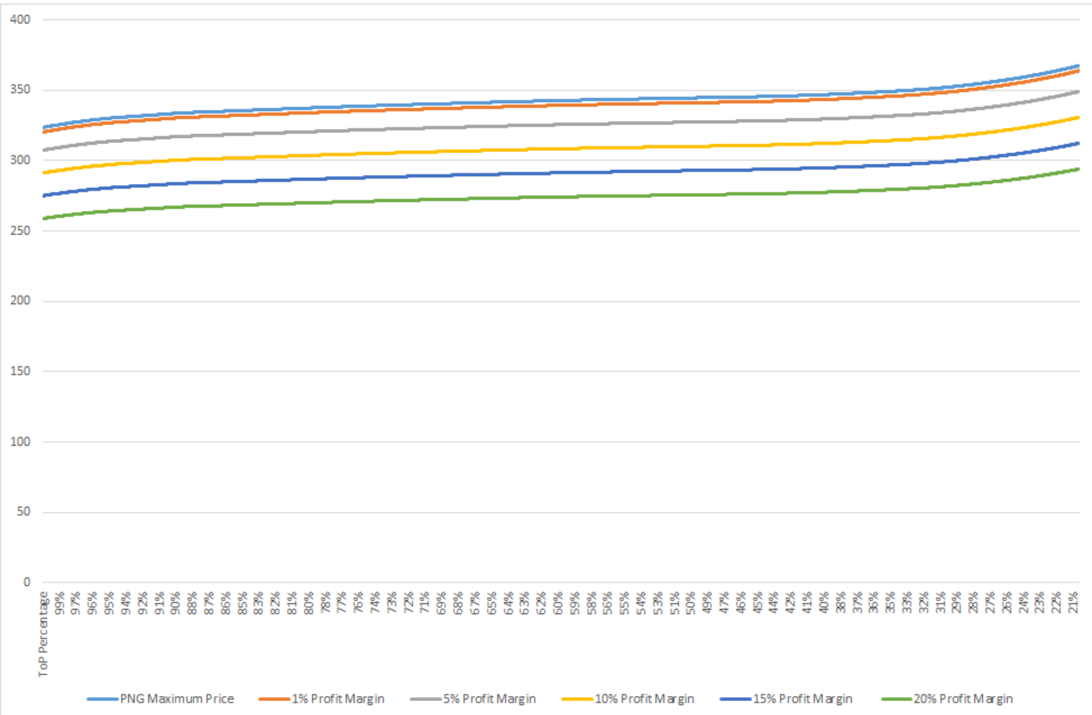

Figure 5.8: The Flexibility Based on 450 Oil Price Scenario for Different ToP Levels.

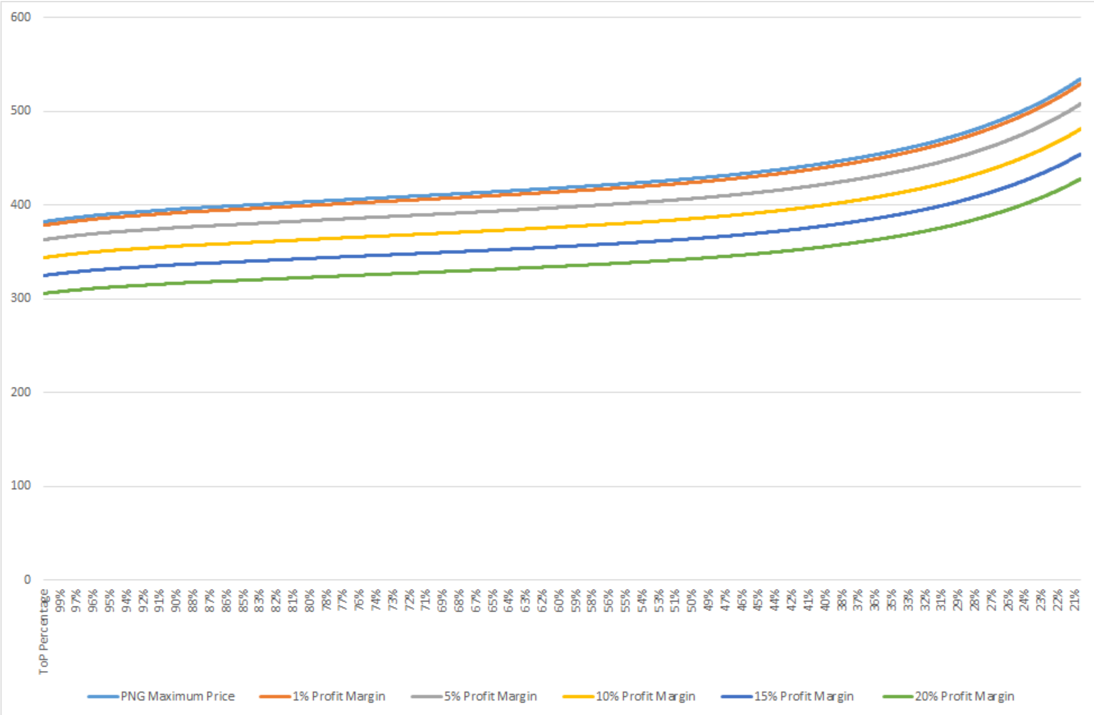

Figure 5.10: The Flexibility Based on New Oil Price Scenario for Different ToP Levels.

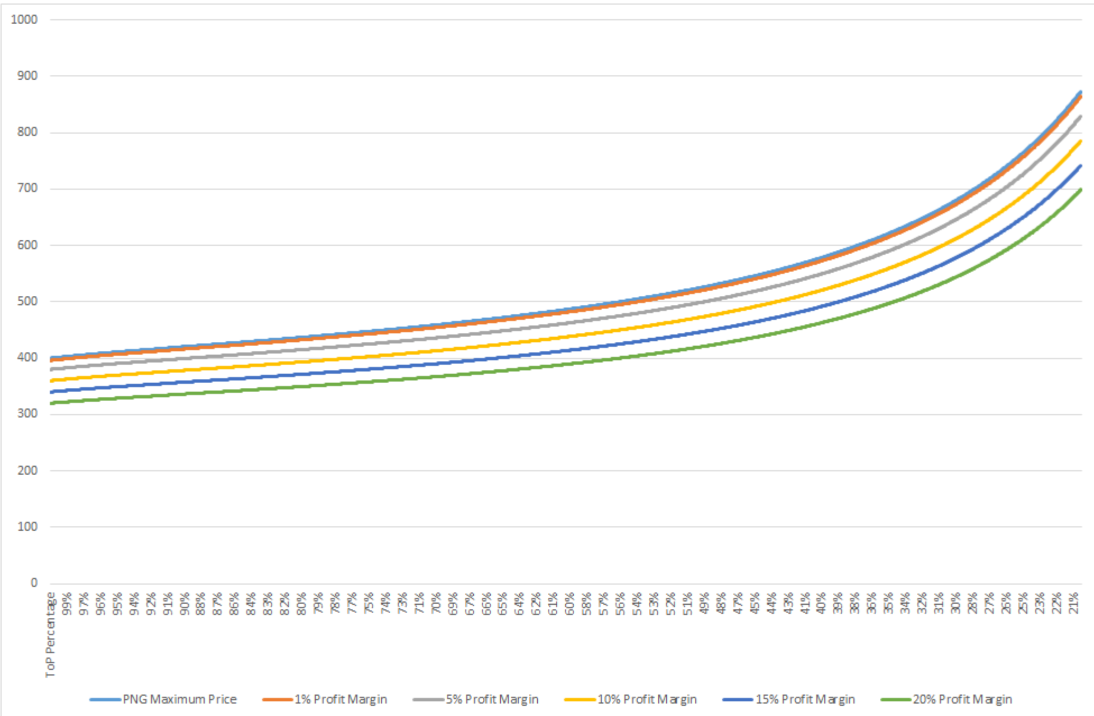

Figure 5.11: The Flexibility Based on Low Oil Price Scenario for Different ToP Levels.

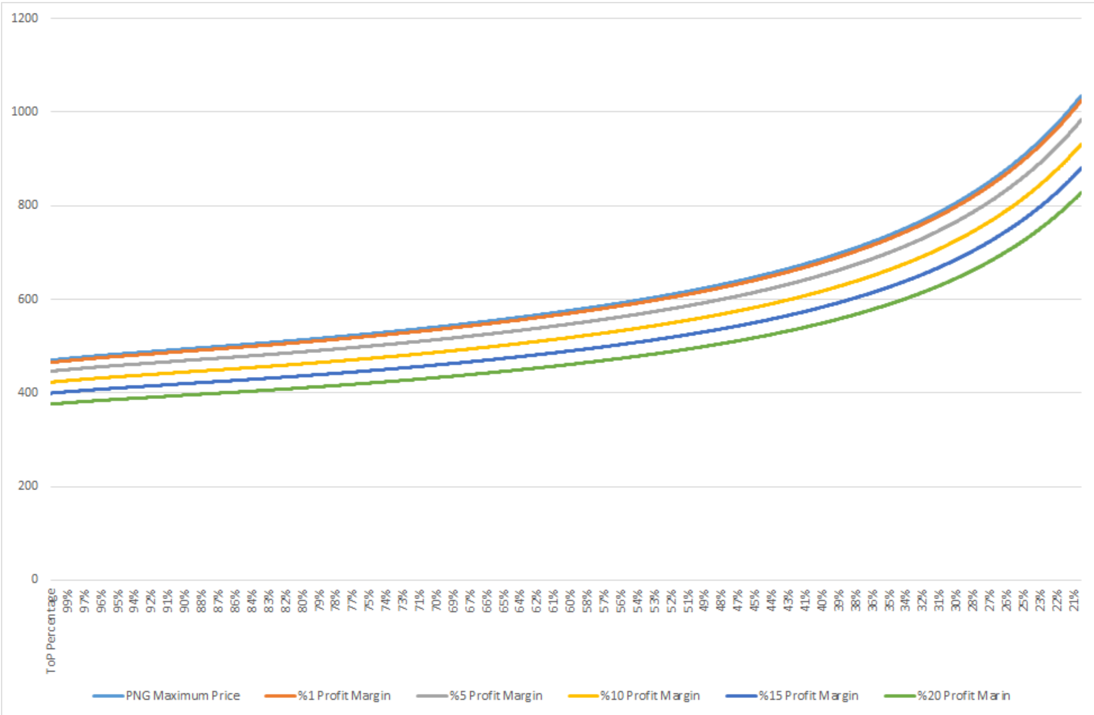

Figure 5.12: The Flexibility Based on World Bank Oil Price Scenario for Different ToP Levels.

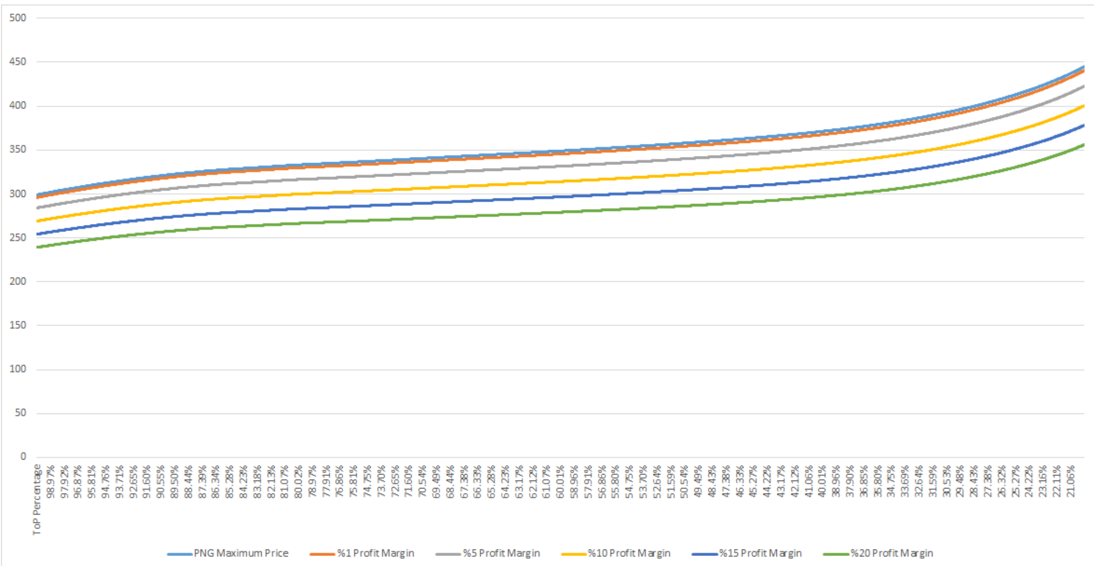

Figure 5.13: The Flexibility Based on ARIMA(1,1,1) Oil Price Scenario for Different ToP Levels.

CHAPTER 6

CONCLUDING COMMENTS AND FUTURE STUDY

In conclusion, the study aims to analyse the LDCs which act as the main supplier for the case of Turkey and determine the optimal natural gas purchase amounts in order to maximize their profits. In order to analyse optimal purchase decisions of the LDCs, we concentrate on two main parts of the natural gas market. For the demand part, we use the amount of natural gas supplied for the customers and forecast the future pattern of the natural gas demand for İstanbul portfolio. After estimating the natural gas demand pattern, we concentrate on the natural gas supply sources for the case of İstanbul. Then, we determine the possible natural gas supplies, their monthly supply capacities, the pipeline restrictions for İstanbul and possible natural gas price scenarios depending on the WEO report, World Bank and oil price forecast that we proposed. By concentrating on the flexibility concept and taking all constraints in terms of natural gas supply sources and storage use decisions, we analyse the LDCs optimal natural gas supply sources for next 10 years.

The security of natural gas supply is our main restriction so the LDCs in all cases find a source by disregarding the price of the natural gas source in order to meet the natural gas demand. For different ToP levels and scenarios, we see that the price curves for 10 year PNG contract price are between 300$ and 1035$. In all scenarios, PNG price curves have an increasing trend. The LDCs have lower willingness to pay for higher ToP levels and as the ToP rate decreases, the firms' willingness to pay has an upward trend. The storage use and determination of supply source for storing purpose are important decisions for LDCs. For the case of storage use, it decreases the LDCs' willingness to pay due to its additional costs and the volatility in oil prices decreases the firms willingness to pay.

The application of the study shows that;

(i) Natural gas demand and natural gas supply for LDCs are realistic and the model enables the user to make a strategic buy and sell decision making.
(ii) Under different oil price scenarios, the efficiency of the model can be tested and observed for different procurement decisions.
(iii) In all scenarios, the long term PNG contract price curves have an escalating trend as ToP level declines. This result indicates that; as the flexibility of the long term natural gas contract increases, the willingness of LDCs to pay unit price of natural gas also increases.

(iv) As the profit margin levels increase the willingness to pay of the company decreases.

Storage optimization considering the natural gas price movements and the market optimization as including the LDCs trading actions will be the future work for the natural gas market in Turkey.

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