THE REPUBLIC OF TURKEY
BAHCESEHIR UNIVERSITY

NATURAL GAS CONTRACT PORTFOLIO PLANNING AND OPTIMIZATION WITH STOCHASTIC MODELLING

Master Thesis

SEFA FURKAN GÜL

ISTANBUL, 2016

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Name of the thesis: Natural Gas Contract Portfolio Planning and Optimization with Stochastic Modelling

Name/Last Name of the Student: Sefa Furkan GÜL
Date of the Defense of Thesis: 23.05.2016

The thesis has been approved by the Graduate School of Natural and Applied Sciences.

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

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ACKNOWLEDGEMENT

First and foremost, my deepest thanks to my wife and my beautiful daughters for supporting me during the completion of the thesis. Their understanding and encouragement gave me the confidence I needed to complete master thesis. Their patience was admirable.

Also, I would like to express my sincere gratitude to Assist. Prof. Ethem Çanakoğlu for his supervision and guidance.

Finally, I would like to thank my current manager Mr. Mehmet Can and my dearest friend Mr. Burak Aktel for their valuable supports during whole Industrial Engineering master's program.

İstanbul / 20.06.2016 Sefa Furkan GÜL

ABSTRACT

NATURAL GAS CONTRACT PORTFOLIO PLANNING AND OPTIMIZATION WITH STOCHASTIC MODELLING

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Industrial Engineering Program

Supervisor: Assist. Prof Ethem Çanakoğlu

May, 2016, 49 pages

This master thesis is motivated from risks in Turkish Natural Gas Market structure. It includes several risk factors like price mechanism and exchange ratio. Contract management in such an environment is not as easy as it is supposed to be. Therefore, it is important for the importer companies to manage their supply and sales contracts cautiously. However, supply and sales prices have different mechanism. Even though supply prices are oil-indexed with United States Dollars (USD) currency, sales prices are generally fixed price with Turkish Liras (TL) currency. Therefore, importer companies should calculate their risks accurately and take actions towards them. In this thesis, we assumed supply contracts as import contracts those constraints such as take-or-pay are included. Sales contracts contain prices and profiles. Prices are taken from incumbent player of the system, BOTAS, and profiles are obtained from several companies. Hedging and storage utilization are another options for company. Risk management is another factor of the thesis. CVaR risk index is used to reduce and measure the risk. The Proposed model aims to find optimal supply and sales portfolio under risk index CVaR.

Key Words: CVAR, Portfolio optimization, Stochastic Modelling, Natural Gas

ÖZET

STOKASTİK MODELLEME İLE DOĞAL GAZ KONTRAT PORTFÖYLERİNİN PLANLANMASI VE OPTİMİZASYONU

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Tez Danışmanı : Yrd. Doç. Dr. Ethem Çanakoğlu

Mayıs, 2016 , 49 sayfa

Bu yüksek lisans tezi Türkiye Doğal Gaz Piyasanın yapısından kaynaklanan risklerden esinlenerek hazırlanmıştır. Türkiye Doğal Gaz Piyasası fiyat mekanizmaları ve kur gibi çeşitli riskler içermektedir. Bu belirtilen ortamda kontrat yönetimi beklendiği kadar kolay olmamaktadır. Bu sebeple, ithalat şirketlerinin alım ve satış kontratlarını dikkatli bir şekilde yönetmesi elzemdir. Fakat alım ve satış fiyat mekanizmaları farklılık göstermektedir. Alım kontrat fiyatları genellikle petrol endeksli ve Amerikan dolar kuru ile alınmakta iken satış fiyatları sabit ve Türk Lirası ile olmaktadır. Bu sebeple ithalat şirketleri risklerini en doğru şekilde hesaplamalı ve bu doğrultuda önlem almalıdır. Bu tezde, alım kontratları ithalat kontratları gibi düşünülmüştür. İthalat kontratlarının al ya da öde gibi hükümleri teze dahil edilmiştir. Satış kontratları fiyat ve profilleri içermektedir. Fiyatlar sistemin tekel oyuncusu olan BOTAS fiyatlarından, profiller ise sektör oyuncularından alınmıştır. Hedge ve depo kullanımı da ithalat şirketi için farklı opsiyonlar kabul edilmiştir. Risk yönetimi ise tezin bir başka faktörüdür. CVAR riski düşürmek ve ölçmek için kullanılmıştır. Önerilen model bu risk faktörü altında en iyi alım ve satış portföyünü bulmayı amaçlamaktadır.

Anahtar Sözcükler: CVAR, Portfolyo optimizasyonu, Stokastik Modelleme, Doğal gaz

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ABBREVIATIONS

Annual Contract Quantity	:	ACQ
Billion Cubic Meter	:	BCM
Botas Petroleum Pipeline Corporation	:	BOTAS
Conditional Value At Risk	:	CVAR
Energy Market Regulatory Board	:	EMRA
European Union	:	EU
Geometric Brownian Method	:	GBM
Liquid Natural Gas	:	LNG
Local Distribution Company	:	LDC
Minimum Annual Quantity	:	MAQ
Minimum Summer Quantity	:	MSQ
Modern Portfolio Theory	:	MPT
Take or Pay	:	TOP
Transmission System Operator	:	TSO
Turkish Lira	:	TL
United States Dollar	:	USD
Value at Risk	:	VAR

SYMBOLS

Annual contract quantity	:	ACQ
Balancing gas price during the month i	:	BF_i
Balancing gas supply amount of i month	:	B_i
Brent future price in USD of i month	:	BRf_i
Brent price in USD of i month in scenario s	:	BR_{is}
Confidence level of risk measure	:	a
CVaR risk index value	:	$CVaR$
Hedging volume of Brent in month i	:	KB_i
Injection to storage in month i	:	IN_i
Intermediate Variable	:	η_s
Maximum amount of supply during the month i	:	C_i
Maximum sales volume for customer type k	:	$LMTY_k$
Minimum annual quantity or Take-or-Pay	:	MAQ
Minimum summer quantity	:	MSQ
Offtake ratio of the costumer k during the month i	:	M_{ik}
Probability of each scenario	:	p
Profit of scenario s	:	PR_s
Selling price of the costumer 8 during the month i in scenario s	:	$P8_{is}$
Selling price of the costumer k during the month i	:	P_k
Storage volume end of the month i	:	ST_i

Summer penalty	:	KS
Summer penalty volume	:	SP
Supply amount of i month	:	S_i
Supply price during the month i in scenario s	:	F_{is}
Take-or-Pay penalty	:	KY
Take-or-Pay Penalty Amount	:	YP
The drift	:	α
USD/TL exchange of i month in scenario s	:	USD_{is}
USD/TL future price of i month	:	$USDf_i$
Value at Risk	:	ε
Volatility	:	σ
Withdraw to storage in month i	:	WT_i
Yearly offtake amount of k type costumer	:	Y_k

1. INTRODUCTION

Natural gas has been among the major topics for policy makers since 1970's. However, it was generally considered as a substitute of oil but this situation has changed after natural gas markets are created (Bianco, Scarpa, & Tagliafico, 2015). Creti and Villeneuve (2004, p. 85) stated that United Kingdom created National Balancing Point when market was deregulated in the middle of the 90's. After that, some European countries established their own gas market. Zeebrugge in Belgium, TTF in Nederland and Germany were few examples of the gas markets. These attempts are thought as the first liberalization step for natural gas to be an independent asset for energy sector. Since important regulatory changes were took place in the world, market activities and competition and liquidity have boost. (Shao, Bhar, & Colwell, 2015) Pricing and portfolio management were becoming more important to minimize risk and maximize revenue. Nonetheless, most of European countries signed long-term supply contracts with Russian Company Gazprom with oil-indexed price in the middle of the 90s. Oil-indexed price is the price that is calculated from oil products prices, whatever Market price is. Turkey was the one of the importer countries which has oil indexed formula. Although European countries have negotiated their contracts with Gazprom then started to change price formula from oil-indexed to market based, Turkish companies still import natural gas with oil-indexed price.

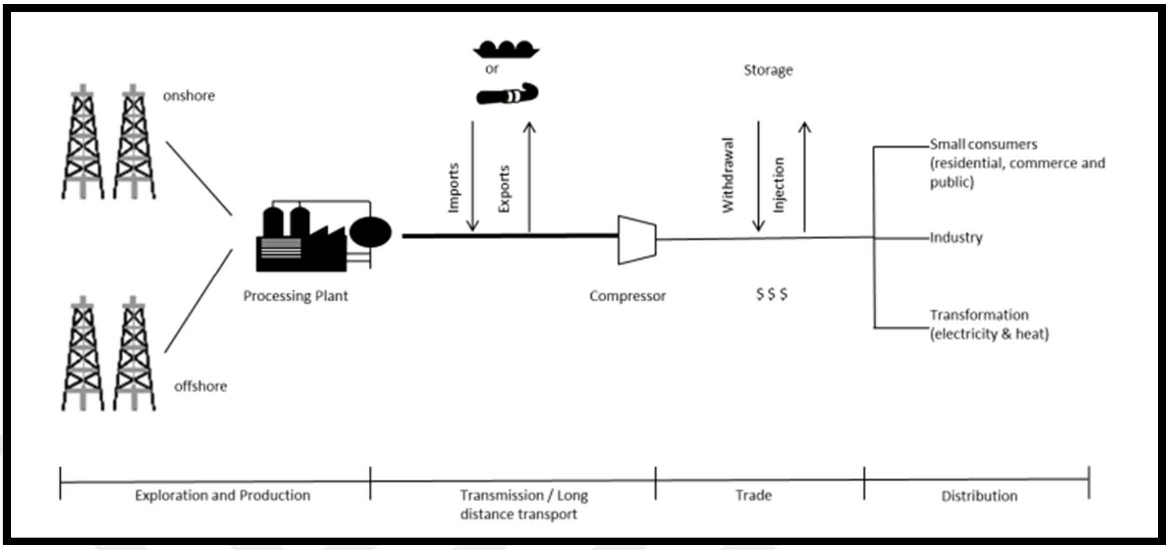
Turkey signed its first contract in 1986 and started to import natural gas in these years. As Erdogdu (2010, p. 806) mentioned, 2001 was an important year for Turkish Natural Gas Market with reform process to be more liberalized and competitive, however, the reform has not been applied as expected so far. Another big step for liberalization was taken in 2005. Four private natural gas companies won auction to take Botas contracts with Gazprom, and total amount of contracts was 4 billion metric cubes. However, first private company, Shell, entered system in 2008 and other importer companies entered in 2009 due to unpredictable market conditions. Regulatory Authority published first Network Code for Turkish Natural Gas Market in 2009. Turkish Law 4646 accepted in 2001 to unbundle Botas but Network Code has still mentioned that Botas is not only State Importer Company but also Transmission System Operator. Network Code and Law 4646 regulates each party's roles as well. Four new import contracts and three new importer companies entered system in 2013. They signed new contracts with Gazprom because of the fact that Botas' contract with Gazprom expired and Botas was not allowed to sign new contract by Law 4646. Total volume of import from Private sectors increased to 10 bcm. It increased total share of private sector to 20 percent which was supposed to be 80 percent according to Law 4646. Although volumes and shares have grown since 2001, they have fallen short of the expectations. According to Botas Electronic Bulletin Board (EBB)[1], 36 shippers are in the system.

Despite the fact that more shippers are desired for the sake of market, their risk perception is not convenient compared to other markets. Authorities do not concern with private sector risk management and it also creates additional risks. For example, Botas subsidized the consumers between the years 2012 and 2015 rather than using price mechanism which can help transferring the risks to end user. Price regulations create another non-pricing competitions and risks to suppliers and buyers in the markets. (Crocker & Masten, 1988, p. 327) Private sector and importers tried to negotiate price with Gazprom during these years because reference selling price to costumers was Botas' prices. Law 4646, in addition, limited shippers to sell LDC by indicating that Local distribution companies cannot buy gas over Botas tariff. Price is not only risk factor for sector, contract obligations like take or pay amount should also be considered. As Crocker and Masten (1985, p. 1083) mentioned; if a shipper does not offtake until Take or Pay amount, it has to pay penalty to the supplier. Authorities unwillingness to take more liberalization steps has created unexpected and unpredictable risk factors and each company should deal with it.

Supply chain of Natural Gas is shown in figure 1. In the thesis, a company which has an import contract is chosen to optimize its supply and sales contracts with stochastic modelling.

[1] BOTAS Electronic Bulletin Board (EBB). http://ebt.botas.gov.tr

Figure 1.1 - Natural Gas Supply Chain



Source: (Neumann, Rüster, & Hirschhanusen, 2015)

Sales prices, weather, exchange ratio, oil prices are some examples of risk elements for natural gas companies. Weather risk can create imbalance for natural gas companies due to uncertainty. Also, import price include huge risk factor. As mentioned above, price mechanism is not worked. Although import price is calculated from exchange ratio and Brent oil prices, sales prices are constant Turkish Lira during the year.

In the thesis, weather conditions' change is ignored for household consumption. Profiles are specified for each costumer type regarding to consumption and prediction data gathered from different companies. Offtakes of costumers, however, are thought monthly rather than daily. Therefore, all profiles include share percentage of 12 months of the year. Household profile, for example, has the highest share in January.

As mentioned above import prices are not perfectly predictable. Thus, Brent prices and exchange ratio are simulated by Geometric Brownian Motion and Monte-Carlo simulation. 100 different price scenarios are generated. Selling prices and balancing gas prices are calculated from existing Botas prices.

Constraints and penalties are also identified. Natural gas contracts contain different clauses and penalties. Minimum summer quantity, take or pay clauses are few of them. In the thesis, some assumptions for constraint are considered and some others are ignored. They are explained later in the section Model.

Storage activities are also identified for the model. There is an active storage whose capacity is 2.7 BCM in Turkey. Costs and other information for the model are taken from this storage. Hedging is another tool for company. Both of them are included in proposed model.

Model is based on modern portfolio theory which deals with the trade-off between risk and return. Resulting stochastic model is linear programming problem. CVaR method is used to reduce risks when model determines sales and supply offtake amounts for each month of the year to solve the stochastic model by using linear programming. Models and solution procedures are mentioned below. Then, there are results and conclusion sections respectively.

2. LITERATURE REVIEW

The literatures on natural gas markets, contracts and pricing cover over 30 years of research. Firstly, researcher studied on long-term contracts, their clauses, effects and economic impacts. Crocker and Masten (1985) studied on incidence of take-or-pay clauses on long term contracts in American Natural Gas Market. In the paper take-or-pay is defined as contractual minimum quantity of offtake from costumer which is the same as mentioned in the thesis. Take-or-pay forces costumer to take gas even if market conditions are not satisfied. Crocker and Masten (1985) offered new formula of take-or-pay percentage to solve this problem. In the formula, value of the well is calculated from different components like number of buyers and pipelines around. It means that if only one buyer and seller exist, take or pay percentage is expected to be higher.

Take-or-pay clause in contracts was an interesting topic in 80's in US. Hubbard and Weiner (1986) published paper on take-or-pay provisions and pricing under unregulated and regulated markets in US. Hubbard and Weiner (1986) defined take-or-pay clauses as buyers should pay gas cost under take-or-pay percentages even if they don't offtake whole amount. In the article, it is mentioned that sellers need to guarantee themselves about satisfying costs. Hence, take-or-pay clauses are created to meet this demand. They examined data from US industry and discussed about contracting. They found that price regulation may cause reliance on non-pricing compensation like take-or-pay to increase in contract bargain. Hubbard and Weiner (1986) also offered two different methods to deal with take-or-pay clauses for unregulated and regulated markets.

Crocker and Masten (1988) studied on contractual design and length of contract after they issued on take-or-pay in 1985. They analyzed regulatory distortions and their effects on contract design. The more regulatory distortions are, the shorter long-term contract duration is expected. Price regulation, as they mentioned in article, is one of them. Turkish natural gas market still has same problem. Price mechanism is not defined; therefore, new investors avoid entering market, especially they do not want to give a commitment for long years. Crocker and Masten (1988) analyzed American Natural Gas Market data and find markets attitudes like take-or-pay percentage, contractual length. One of their findings is price regulation create distortion which raise expected cost of contracts and lead to shorter-term contracts.

Creti and Villeneuve (2004) examined American natural gas market experiences then surveyed on long-term contracts, take-or-pay clauses and price mechanism in EU natural gas markets. It is mentioned that natural gas contracts are good examples of transaction-cost theory. Both sides of the agreement have great upfront capital investment and this risk forces them to sign long-term contract whose duration is about 20-25 years. As said at the beginning of the paragraph, Creti and Villeneuve (2004) gave examples from Hubbard and Weiner (1986), Crocker and Masten (1985) (1988). However, all articles suggested model in price regulation and no price regulation exists anymore. Creti and Villeneuve (2004) also mentioned that EU countries signed long-term contract before 2000's. Price was calculated from average of oil products (mostly fuel oil, gas-oil). Then, EU trend was changed and they expressed that EU countries changed their contract structure from long term to short term, price mechanism from oil-indexed to mixed price which include oil prices, market prices and even electricity prices in some agreements. In addition, there is a dilemma on approach to long term contracts in EU Directives and Commissions opinions, they are against long term contract because;

i. New entrance to the market would be difficult,
ii. Long-term contracts may be a barrier for liberalization
iii. Gas-to-gas competition is desired so price mechanism and contract duration should adapt the regime

Nevertheless, Commissions also states that security of supply is important and long-term contracts serve to overcome this concern. They suggested EU opinions about long term contracts with American experiences. Their finding is that pressure on contract negotiations could not lead to shorter contract duration but decrease take-or-pay level because of the alternative selling options.

Long-term contracts were being reviewed in the first decade of this millennium. Hirschhausen and Neumann (2008) enlarged discussion on long-term contracts the scope of world-wide trading. They studied on duration of natural gas contract with developing conditions. They tested two related hypotheses;

i. Liberalization degree and contract duration have negative relationship
ii. Investment and contract length have positive relationship because of the transaction-cost theory

Hirschhausen and Neumann (2008) used 311 different contracts' information to test hypotheses and found strong support for them.

Data documentation report about Long-Term Contracts was published in 2015. (Neumann, Rüster, & Hirschhanusen, 2015) Report includes 426 contracts data and literatures about Long-Term contracts. It is mentioned that long-term contracts helped to share the risks as well as to secure monopolistic rent. Thus, buyers and seller choose price indexation to oil products to avoid long-term price competition against other oil products. This explanation helps to understand current Turkish Natural Gas Market structure. Botas still has 80 percent of market share and this leads players to stick around oil-indexed price.

In 2000's discussions about natural gas have generally changed from monopolistic markets which have long-term contracts to hub structures, future of natural gas markets and price mechanism. It is because natural gas has been thought as a different product than oil substitute. Bianco, Scarpa and Tagliafico (2015) discussed about future of natural gas in Europe. They mainly mentioned about developments of markets and importance of natural gas for EU. It is also issued that oil-indexed supply agreements still have an impact on European natural gas prices. However, their claim is that there is no correlation between oil-indexed and hub prices. Oil-indexed prices may be higher lever for natural gas hubs.

According the Yorucu and Bahramian (2015), it is claimed that crude oil price, natural gas price and taxes on gas have relationship. It is stated that many long-term contracts have oil-indexed prices and EU countries have some of them. They studied on 12 different EU countries by data collected from IEA/OECD between 2001 and 2012. They used a panel cointegration technique to prove the dynamic relationship between crude oil and natural gas prices. They found there is a long-run relationship at 1 percent significant level by panel cointegration test. Yorucu and Bahramian (2015) also tested data with different techniques and all techniques found this relationship. In the thesis, natural gas import price is calculated from Brent oil prices.

Kamal (2015) studied on gas price mechanisms and possible hub opportunities in South Asian region. In his paper, types of gas contracts and price mechanisms are examined, then why hub will be important for South Asia is discussed. According to Kamal (2015) take-or-pay clauses of Long term contracts still exist in Asian contracts but remain clauses are generally hidden from public. Beside, most of contracts have oil-linked price. It is highlighted that Asian LNG contract price is much higher than Henry Hub prices due to oil-linked price. Kamal (2015) suggested South Asian gas hub and highlighted its benefits.

Turkish Natural Gas Market is also one of the topics discussed by researchers. Hacisalihoglu (2008) expressed Turkish natural gas policy in his paper. Paper started with information about energy statistics of Turkey. It is mentioned that Turkish imports of natural gas mainly depended on Russia and Botas signed long-term agreement with Russia. Then other agreements are summarized, Iran, Algeria, Caspian Sea agreements are discussed in the paper. Hacisalihoglu (2008) also said that Law No. 4646 is applied in 2001 but it is not worked out well as Erdogdu (2010, p. 806) mentioned. He concluded his paper as Turkey needed long-term planning about natural gas to reduce other fossil fuel consumption.

Kilic (2006) also discussed about Natural gas policy and future of Turkey. Information about Turkey energy consumption and World energy consumption is given in the paper. Then Turkey needs for foreign resources are identified because Turkey has limited potential to produce energy for itself. It is also said that Industrial consumption of natural gas is expected to increase year by year. Electricity consumption was 66 percent of total consumption and it would decrease in 2010 because of increasing total consumption according the Kilic (2006). Pipeline projects are also mentioned. Turkey can become an energy corridor if it succeeds to link East production to West consumption.

Besides, Cetin and Oguz (2007) studied on Turkish natural gas market reform. Paper gives information about Turkish market reform and history. Cetin and Oguz (2007) explained about Law 4646 which was accepted in 2001 and its possible effects on Turkish Natural Gas Market. Energy Market Regulatory Authority (EMRA) and its duties are mentioned. EMRA was established in 2001 to regulate and liberalize Natural Gas Market. EMRA can give licenses to new entrances, inspect existing market participants, and change regulations. It is also said that Botas is monopoly on Turkish Natural Gas Market and its share is expected to decrease. Botas is not monopoly now but has highest share 80 percent (EMRA, 2015). Cetin and Oguz (2007) summarized other components of Natural Gas Market and implied that Turkey should diversify Natural Gas Sources, create liberal market and decrease Botas dominant role.

Supply and demand contracts are supposed to be optimized to increase revenues and minimize costs. When looking up to literature, there are limited researches about natural gas contract management and most of related papers are to choose best supply options. Guldmann and Wang (1999) used mixed-integer linear program to solve the problem of optimizing natural gas supply of local distribution companies (LDCs). Demand can vary during the year and it is not known perfectly. Weather, for example, can change household demand. LDCs select their suppliers to satisfy elastic demand and each supplier has different condition like take-or-pay clauses. In Guldmann and Wang (1999) model different weather scenarios are defined. For each scenario, total cost is calculated by Mixed integer linear programming and scenarios have different probabilities and total cost formula is calculated from these probabilities. When solving the model, Take-or-pay clauses and some charges and penalties are defined for each contract. They used actual data from Unites State LDCs. In the paper, results are shown and they also made trade-off analysis of contracts.

Modern portfolio theory is firstly applied to natural gas supply and demand management by Du and Hu (2003). As mentioned in the paper, Modern portfolio theory suggests that there is a trade-off between risk and return. Companies have an option to buy gas from long-term fixed price contracts or spot market price which has volatility. Therefore, they apply quadratic utility function to portfolio problem and formulated framework to solve the problem. Du and Hu (2003) show that risk approaches can change supply portfolio and different approaches can be applied.

Chen and Baldick (2007) worked on optimizing short-term supply portfolio for Electric Utility Companies (EUCs). Their model is based on modern portfolio theory; hence they added some risk factors to traditional approaches like Guldmann and Wang's (1999) approach and proposed utility-maximization-based framework to optimize natural gas supply for EUCs which have natural gas fired power plants (NGFPP). Proposed model also includes relations between natural gas spot market and electricity spot market. In the paper, companies could sell or buy gas to natural gas spot market, could sell or buy electricity to electricity spot market and could inject or withdraw natural gas to storage. For each transaction has own cost which defined. Companies could also use intra-day contract by deciding within day. Objective of model is maximizing expected utility function. To solve problem, Algorithm contains Monte Carlo simulation and dynamic programing. Chen and Baldick (2007) use Monte Carlo simulation to calculate daily demands, to obtain natural gas price and electricity price scenarios. Texas region data is selected and applying to the model. Model's company profile is selected as risk averseness and results are agreeable.

Asif and Jirutitijaroen (2009) enlarged Chen and Baldick (2007) study by adding future electricity contracts to the model. In their model, Electricity company could buy or sell energy from future markets and it should be decided before the period. Algorithm works for a month and they noted that it can be extended. CVar methodology is utilized to manage risk factors of portfolio. They defined cost and revenue formulas and constraints.. Chen and Baldick (2007) and Conejo et al. (2008) 's data is taken for application and mixed-integer linear programming is used to model the problem. They found that forward contracts are essential for companies to hedge against their risk from volatility.

Zhuang, Jiang and Gan (2011) proposed two-step simulation-optimization framework to find best nomination for gas purchase. In first step, optimal generation is obtained by profit optimization including different buying scenarios. Monte Carlo simulation is then used to find profit distribution for each feasible nomination option. After that, second step is applied. Optimal gas nomination is calculated by utility maximization in modern profit theory. Finally, they compare their findings with three different purchasing strategies which are purchasing from only long-term contract, full capacity production and market-free production. Zhuang et al (2011) model helps companies to find most desirable trade-off based on their risk approaches

Natural gas contract management for Electricity companies which have different sources to produce electricity is studied by Duenas, Barquin and Reneses (2012). In the paper, electricity generation companies (Genco) are examined. Gencos have not only coal and nuclear but also long-term natural gas contracts for combined cycle gas turbine (CCGT) which should be optimized for each year. CCGT is not near the gas wells, therefore costs like transmission and capacity allocation are also considered. Duenas et al. (2012) combined medium-term electricity market model and natural gas contracts, and then find best offtake period for natural gas contracts. In electricity market model, Gencos tries to maximize its profit, by choosing best product which can be coal, CCGT, nuclear to satisfy demand. However, natural gas contracts may not fit electricity market model. Duenas et al. (2012) describe some of natural gas market differences as follows;

a. Natural gas prices are exogenous variables. Contract prices may be oil-linked or linked to spot prices like NBP and TTF. Gencos do not have enough power to change spot prices or oil prices.
b. Some physical constraints exist in natural gas infrastructure. Capacity is one of them. Consumers need to allocate capacity to supply natural gas.
c. Natural gas can be injected to storage unlike electricity. Storage may help natural gas contracts to be managed better. Take-or-pay clauses can be satisfied by using storage. Natural gas market participants also use storage to meet seasonal demand.

In summer period, natural gas stored than they withdraw natural gas for winter period.

Duenas et al. (2012) also mentioned natural gas contract's characteristics. ToP clauses, as said before, is one of them. Gencos must satisfy this clause. Offtakes are limited for each period (e.g. daily, weekly, monthly, yearly). In Duenas et al. natural gas contract model (2012, p. 774), Price formulation of natural gas, storage and infrastructure constraints are ignored. Gencos can buy natural gas to the market whose price is known but they must satisfy take or pay clause. Gencos also have different alternatives to produce electricity. They found that natural gas is off taken even if contract price can be insufficient. Also Gencos can buy natural gas from markets when it is fulfilled costs. They suggested that natural gas management can be better by enhancing model and adding other constraints and opportunities.

3. MODEL

The major goal of this master thesis is to find optimum sales strategy and reduce risks by CVaR method. Brent price and exchange ratio is unknown before gas year and sales are Turkish Lira and fixed price as mentioned above. Stochastic modelling is used to represent model of problem. A hundred different scenarios are generated by Geometric Brownian Motion and Monte-Carlo Simulation. Calculation and simulation results are under "Application" chapter.

Import contracts include several constraints and penalties. Minimum Summer Quantity, Minimum Annual Quantity also called Take or Pay level, Annual Contract Quantity and Daily Contracted Quantity are contracted constraint. There are also transmission constraints which are obligated by Transmission System Operator. Total sales constraint is one of them. All of these constraints are explained below.

Some of constraints introduced above are flexible constraints. Importer Company is allowed to violate constraint by paying penalties. Minimum Summer Quantity and Minimum Annual Quantity are contracted constraint with penalties. However, Importer Company cannot exceed Annual Contract Quantity. In the models, offtakes and sales are assumed monthly rather than daily. Daily Contract Quantity is changed to Monthly Contract Quantity by multiply number of days in the month.

Proposed model aims to solve problem by using several options. Under mentioned constraints, company can buy natural gas from its supplier or balancing and sell to 8 different costumers. Beside, Importer companies can use storage facilities. It may be feasible to inject gas to storage to use another months. Storage operations are also included in the proposed model. Model is trying to find best supply and sales decisions under CVaR risk approach index.

3.1 CONSTRAINTS AND PENALTIES

Two type constraints are expressed above. Some of contracted constraints are included in the model. Others are assumed as constant or ignored. Constraints are listed below.

a. Annual Contract Quantity (ACQ)

ACQ means maximum amount of offtake in a year for Importer Company. In the model it is 1 billion cubic meter.

b. Minimum Summer Quantity (MSQ)

Each import contract contains MSQ constraint to encourage buyers to sell natural gas in summer period in which consumption is dropped. In the model, MSQ level is determined as below.

$$MSQ = ACQ * 0{,}35 \tag{3.1}$$

If total offtake of summer period is not greater than MSQ, MSQ Penalty is applied. MSQ penalty is determined as 0,080 TL/m³.

c. Minimum Annual Quantity (MAQ) or Take or Pay

Take or pay means that buyer should pay price of rest of MAQ and have to use next years. In the thesis, this obligation is changed to penalty. Penalty is determined as 0,100 TL/m³ and MAQ is settled as below

$$MAQ = ACQ * 0{,}80 \tag{3.2}$$

d. Maximum Amount of Monthly Offtake

Most of the contracts have a Daily Contract Quantity (DCQ) that is maximum amount of offtake in a day. Nonetheless, model does not involve DCQ. It is assumed that costumers consume same amount of natural gas within day in a specific month. DCQ is describes as below and used to calculate maximum monthly amount C_i .

$$DCQ = \frac{ACQ}{365 * 0{,}925} \tag{3.3}$$

$$C_i = DCQ * number\ of\ days\ in\ a\ month\ i \tag{3.4}$$

Beside contracted constraints, transmission constraints are included in the models.

e. Total Sale Constraint

Transmission Company does not allow selling over ACQ volume. Before the year, all shippers have to notify TSO their supply and sales volumes.

3.2 ASSUMPTIONS

In addition, some assumptions have to be made to solve problem. Supply prices, profiles, sales and balancing prices and some additional assumptions are expressed below.

3.2.1 Supply Prices

Price is the one of the key elements of natural gas trading. Two main calculation methods called Oil index and market based price are in use in Europe. Before markets were created, oil-indexed prices are commonly preferred. According to Creti and Villeneuve (2004, p. 75) , price is the one of drawbacks of contracts and buyers and sellers agreed on price formulas like predefined increases per year or oil-indexed. Most of long term import contracts still include oil-indexed price formation. According to Heather (2012, p. 37), although it is painful, European countries have started to change their old contracts. Price formation is major point and new contracts propose new price structure which is market based. Due to the fact that Turkey imports gas with an oil-indexed price formation, in this thesis, price formation of problem is assumed as an oil-indexed price. Firstly, USD price is calculated than exchange ratio is used to change it to Turkish Lira. The assuming formula is below:

$$F_i = USD_i * pk * (\sum_{m-6}^{m-1} BR_i)/6 \quad (3.5)$$

P means price in USD. pk is assumed by Eurostat data.[2] BR_i represents average Brent price of i^{th} month. Price formula uses average of last six month's Brent prices for each quarter. Oil indexed prices are quarterly prices and USD prices. In the thesis prices are calculated by multiplying USD_i to exchange to Turkish Lira for each month.

Monte Carlo simulation is used to calculate supply prices for each scenario. It is mentioned below in section Application.

3.2.2 Profiles

In the thesis, costumers' yearly consumptions are divided into 12 month by different profiles. Therefore, 8 different customer types are identified. Y_k represents yearly offtake amount of k costumer and M_{ik} shows offtake profiles of k costumer. Each customer profile has different consuming behavior. For example, residential consumption occurs generally in winter period. However, electricity plants consume natural gas nearly equal for each month. For each profile, data are gathered from different companies. Residential consumer profiles are taken from two big LDC's. These two big cities consume approximately 1 billion metric cubes natural gas for warming. Wholesaler profile is taken from five big wholesale and importer companies. Wholesale contracts are usually back to back of import contracts. It means that wholesale companies have same profile as importer companies. Electricity profile is obtained from two power plants consumption. Organized Industrial Sites are representing Industrial Profile. Other profiles are procured from another participant of Turkish gas market. All of profiles are shown in Table 3.1.

[2] EUROSTAT, http://ec.europa.eu/eurostat.

Table 3.1 : Profiles of Costumer Types and Maximum Sales Volumes

	Industry	Summer Customer	Electricity	Industrial Parks	Hotel	Iron and Steel	LDC	Wholesaler
January	8,3%	2,8%	8,7%	10,5%	0,8%	8,6%	19,5%	9,2%
February	7,8%	3,1%	8,2%	9,6%	0,8%	7,8%	17,2%	8,3%
March	8,4%	2,5%	5,7%	9,7%	1,6%	8,6%	14,1%	9,2%
April	8,5%	2,6%	6,8%	8,4%	3,2%	8,4%	8,0%	7,6%
May	7,8%	5,4%	7,4%	7,8%	6,3%	8,6%	2,6%	7,8%
June	7,9%	8,0%	8,3%	7,4%	25,4%	8,4%	2,0%	7,6%
July	8,6%	11,3%	9,8%	7,0%	25,4%	8,4%	1,8%	7,8%
August	8,4%	29,2%	9,9%	6,5%	25,4%	8,4%	1,7%	7,8%
September	8,8%	27,5%	9,1%	7,4%	6,3%	6,9%	2,0%	7,6%
October	8,2%	4,2%	6,8%	6,9%	3,2%	8,5%	3,9%	9,2%
November	8,6%	1,9%	9,7%	9,1%	0,8%	8,5%	9,6%	8,9%
December	8,6%	1,4%	9,7%	9,8%	0,8%	8,6%	17,6%	9,2%
Max Sales Volumes	500 bcm	50 mcm	500 mcm	500 mcm	20 mcm	100 mcm	1 bcm	1 bcm

3.2.3 Sales and Balancing Prices

According the Natural Gas Market Report of EMRA, BOTAS has about 80 percent share of total market volume in the Turkish Gas Market. (2015) Also, distribution companies have to buy gas from most economical price, so Botas Price for LDC and end users is reference price for all market participants. Botas prices since 2012 are examined then prices for each costumer type are assumed as Table 3.2. Wholesaler price is calculated from import prices as below.

$$P8_{is} = F_i + 0{,}030\, TL/sm^3 \tag{3.6}$$

Table 3.2 : Prices for Profile Types

	Industry	Summer Customer	Electricity	Industrial Parks	Hotel	Iron and Steel	LDC	Wholesaler
Price(TL/sm³)	0,738	0,738	0,738	0,738	0,738	0,738	0,770	F_i + 0,030

Botas TSO also sells Balancing Gas to the market users when they are short position during the month. Balancing gas price is accepted as Botas Residential Price during the winter period and Botas Industry Price during the summer period.

3.2.4 Hedging

Hedging is limited with total contract volume. It is calculated by multiplying expected contract price and ACQ then dividing by expected brent oil price. By this calculation, natural gas contract value is transformed to Brent oil product. In the thesis, limit is assumed as 50.000 barrel per month;

3.2.5 Storage

Storage is one of the portfolio management tools in Turkish Natural Gas Market. TPAO has 2.7 bcm storage facility and all of players can access there. In proposed model, storage operations are defined as injection and withdraw. Capacity allocation is ignored. Injection and withdraw costs are 0,050 TL/sm3. Storage cost is equal to 0,010 TL/sm3/month. These costs are calculated from TPAO tariff[3].

3.2.6 Other Assumptions

1. Sales to some profiles are restricted as given in Table 3.1 due to market conditions
2. Sales to wholesaler are assumed with same margin.
3. Botas does not change its prices during the year.
4. Pipeline maintenance is ignored.
5. Weather conditions are ignored. Because, it can change residential consumption when temperature is low.
6. Selling Prices include transmission fees.

[3] TPAO Tariffs. http://depolama.tp.gov.tr/index.php/en/rates

3.3 PROPOSED MODEL

Uncertainties and risk factors are given above in Introduction. Modern portfolio theory (MPT) is the main approach of the thesis. Du and Hu (2003) describe MTP as the trade-off between risk and return. Risk index to manage sales and supply portfolio of the proposed model is CVaR. Asif and Jirutitijaroen (2009) used CVaR index to find optimal supply of generation companies in their framework.

Parameters table of given model is below. Costs and incomes are defined next.

Table 3.3 : Parameters Table of the Model

Indices	
i	Months
k	Customer Types
s	Scenarios
Input Parameters	
F_{is}	Supply price during the month i in scenario s
P_k	Selling price of the costumer k during the month i
$P8_{is}$	Selling price of the costumer 8 during the month i in scenario s
BF_i	Balancing gas price during the month i
$LMTY_k$	Maximum sales volume for customer type k
M_{ik}	Offtake ratio of the costumer k during the month i
C_i	Maximum amount of supply during the month i
USD_{is}	USD/TL exchange of i month in scenario s
BR_{is}	Brent price in USD of i month in scenario s
BRf_i	Brent future price in USD of i month
$USDf_i$	USD/TL future price of i month
KS	Summer penalty
KY	Take-or-Pay penalty
a	Confidence level of risk measure
p	Probability of each scenario

ACQ	Annual contract quantity
MAQ	Minimum annual quantity or Take-or-Pay
MSQ	Minimum summer quantity
Variables	
Y_k	Yearly offtake amount of k type costumer
S_i	Supply amount of i month
B_i	Balancing gas supply amount of i month
KB_i	Hedging volume of Brent in month i
SP	Summer penalty volume
YP	Take-or-Pay Penalty Amount
WT_i	Withdraw to storage in month i
IN_i	Injection to storage in month i
η_s	Intermediate Variable
ε	Value at Risk
Output Parameters	
PR_s	Profit of scenario s
ST_i	Storage volume end of the month i
$CVaR$	CVaR risk index value

3.3.1 Profit Formula

Supply gas price is the major cost of the companies. Besides, companies could buy balancing gas from TSO for short positions for each month. Balancing gas price is defined from TSO for each month before the relevant month. In the thesis, balancing price volatility is ignored and balancing gas price is defined according to historic data of Botas. Companies, also choose summer penalty and take-or-pay penalty instead of selling whole amount. Penalties are another cost of proposed model. Cost related to sales is formulated below.

$$\boldsymbol{Cost\ of\ sales} = \sum_{i} S_i * F_{is} + \sum_{i} B_i * BF_i + \boldsymbol{SP} * \boldsymbol{KS} + \boldsymbol{YP} * \boldsymbol{KY} \tag{3.7}$$

Income from selling gas is only sales related income for companies. Formulation of income is below. 8th of costumer is wholesaler and its price is based on supply price. Therefore, it is written separated from general income formula.

$$\boldsymbol{Income\ from\ sales} = \sum_{\boldsymbol{i}} \sum_{\boldsymbol{k}:\mathbf{1},\mathbf{7}} P_k * Y_k * M_{ik} + \sum_{\boldsymbol{i}} P8_{is} * Y_8 * M_{i8} \quad (3.8)$$

Storage costs are mentioned above. Cost formulation is given as;

$$\boldsymbol{Cost\ of\ storage} = \sum_{\boldsymbol{i}} WT_i * 0{,}050 + \sum_{\boldsymbol{i}} IN_i * 0{,}050 + \sum_{\boldsymbol{i}} ST_i * 0{,}010 \quad (3.9)$$

Hedging is a good alternative for importer companies to minimize their risk related to exchange rate or Brent price. Turkish gas market includes exchange rate risk due to fact that sales currency is Turkish Lira. Future prices of Brent and USD/TL are taken from Bloomberg. Also, there is hedging constraint mentioned above.

$$\boldsymbol{Hedging\ Income} = \sum_{\boldsymbol{i}} \boldsymbol{KB_i} * \left(\boldsymbol{BR_{is}} * \boldsymbol{USD_{is}} - \boldsymbol{BRf_i} * \boldsymbol{USDf_i}\right) \quad (3.10)$$

$$\boldsymbol{KB_i} \leq 50.000 \quad \forall i \quad (3.11)$$

Total return formula can be written as below related to aforementioned costs and income (3.7, 3.8, 3.9, 3.10).

$$\begin{aligned} PR_s = & \sum_{i} \sum_{k:1,7} P_k * Y_k * M_{ik} + \sum_{i} P8_{is} * Y_8 * M_{i8} - \sum_{i} S_i * F_{is} - \sum_{i} B_i * BP_i - SP * KS \\ & - YP * KY + \sum_{i} KB_i * (BR_{is} * USD_{is} - BRf_i * USDf_i) - \sum_{\boldsymbol{i}} WT_i * 0{,}050 \\ & - \sum_{\boldsymbol{i}} IN_i * 0{,}050 - \sum_{\boldsymbol{i}} ST_i * 0{,}010 \end{aligned} \quad (3.12)$$

3.3.2 Constraints

Most of the constraints are described above under "Constraints and Penalties" section. These are generally contract and TSO related constraint. Contractual constraints can be written as below,

$$S_i \leq C_i \;\; \forall i \tag{3.13}$$

$$\sum_i S_i \leq ACQ \tag{3.14}$$

$$\sum_i S_i + YP \geq MAQ \tag{3.15}$$

$$\sum_4^9 S_i + SP \geq MSQ \tag{3.16}$$

ACQ, MAQ, MSQ and C_i are defined in natural gas contracts. Summer and Take-or-Penalties are identified.

Besides, gas incomes and outcomes must be equal for each month. Equilibrium constraint is represented as below;

$$\sum_k M_{ik} * Y_k + IN_i = B_i + S_i + WT_i \quad \forall i, \tag{3.17}$$

Storage equilibrium must be also satisfied. Equation is below;

$$IN_i + D_{i-1} = D_i + WT_i \quad \forall i, \tag{3.18}$$

TSO also do not allow players to sell gas above their contractual supply amount. It is called Total Sale Constraint.

$$\sum_k Y_k \leq ACQ \tag{3.19}$$

There is also limitation for sales volume of customer types. Related formula is given below.

$$Y_k \leq LMTY_k \qquad \forall k, \tag{3.20}$$

3.3.3 Risk Management Formula

Finance industries used Value at risk (VaR) risk measure to obtain possible loses of their portfolio. It is described as the expected loss for exact a percent confidence level. However, it is independent from cost which is higher than a percent confidence level. However, it is not satisfied coherent risk measure's properties which are monotonicity, sub-additivity, homogeneity and translational invariance. Conditional Value at Risk (CVaR) is an alternative of VaR. CVaR is coherent risk measure. It is defined as expected losses of greater than a percent confidence level. It can be defined by formula as below:

$$\varphi_\alpha(x) = (1-\alpha)^{-1} \int_{f(x,y) \geq \varepsilon_\alpha(x)} f(x,y)p(y)dy \tag{3.21}$$

where loss function for an outcome y is (x, y) . ε is value at risk threshold represented as VaR_α. A convex and continuously differentiable representation for the $CVaR_\alpha$ can be defined as

$$F_\alpha(x,\varepsilon) = \varepsilon + (1-\alpha)^{-1} \int_{y \in R} [f(x,y) - \varepsilon]^+ p(y)dy \tag{3.22}$$

where $[f(x,y) - \varepsilon]^+$ is the positive part of expression defined as $\max(f(x,y) - \varepsilon, 0)$. If the uncertainty is defined using discrete scenarios, Asif and Jirutitijaroen (2009) show that the CVaR function can be written as

$$CVaR = \varepsilon - \frac{1}{1-a} * \sum_s p * [\varepsilon - PR_s]^+ \tag{3.23}$$

and since the expression is summation of convex and continuously differentiable functions an equivalent formulation for the CVaR maximization problem for contract portfolio planning can be derived as in model P_{CVaR}.

P$_{\mathbf{CVaR}}$:

$$Maximizing\ CVaR = \varepsilon - \frac{1}{1-a} * \sum_{s} p * \eta_s \tag{3.24}$$

Subject to;

$$\eta_s \geq 0 \tag{3.25}$$

$$\eta_s \geq -PR_s + \varepsilon \tag{3.26}$$

(3.11), (3.12), (3.13), (3.14), (3.15), (3.16), (3.17), (3.18), (3.19), (3.20)

$Y_k, S_i, B_i, KB_i\ SP\ , YP\ WT, IN_i, ST_i \geq 0$

In the proposed model PR_s is calculated from return formula. ε is value at risk of the model and η_s is an auxiliary variable in order to satisfy the positive part conditions. The objective of the model is to maximize CVaR subject to the model constraints.

4. APPLICATION

Application of proposed formula has two parts. First part is about uncertainty. Stochastic processes are included in first part. Second part is about linear programming and modelling in GAMS application.

4.1 ESTIMATIONS - STOCHASTIC PROCESSES

As mentioned in Introduction, contract management is a stochastic process. Turkish natural gas market includes Brent oil and USD exchange risks. Importer companies should estimate these two financial instruments well. In this thesis, 100 different natural gas price scenarios are created by Monte Carlo simulation. Geometric Brownian Motion (GBM) model is selected. Besides, Brent prices and USD/TL estimations are taken for Hedging contract.

4.1.1 Brent and TL/USD Estimations

Al-Harthy (2007) used GBM as a stochastic process to make assumption oil prices. In the paper, other stochastic models are also used to calculate oil prices. GBM equation is described as below;

$$dP = \alpha P\, dt + \sigma P\, dz \tag{4.1}$$

Where:

$dz = \varepsilon \sqrt{dt}$, ε is Wiener process, which is normally distributed with a mean of zero and standard deviation of 1,

P= the current oil price;

dt = the change in time;

dP = the change in price;

α = the drift and σ = volatility.

Al-Harthy (2007) selected *the drift 2 percent* and *volatility 20 percent.* These two parameters are used as GBM parameters in Monte Carlo simulation to make assumption of Brent oil price. 10 different scenarios for 12 months are created. Current oil price is taken as 35 USD/barrel. Calculated 10 different estimations (USD / Barrel) are shown in Table 4.1.

Table 4.1 : Brent Estimations (USD/Barrel)

	January	February	March	April	May	June	July	August	September	October	November	December
1	37,54	43,52	39,13	42,65	43,90	38,96	40,82	37,38	35,53	35,32	34,65	31,99
2	35,55	32,52	28,92	33,02	28,67	30,13	28,00	29,33	27,72	26,50	29,16	27,80
3	33,91	32,94	35,18	35,75	36,17	35,16	38,08	39,57	40,83	39,89	41,83	44,54
4	33,40	35,88	31,03	29,17	29,59	31,03	32,31	31,68	33,34	34,58	36,89	36,01
5	43,04	43,71	45,85	50,84	51,65	56,56	55,98	52,81	56,74	53,53	49,81	46,58
6	32,42	31,19	29,61	27,95	26,50	28,37	29,99	28,19	28,70	32,86	36,57	39,13
7	33,33	30,74	29,94	27,74	29,24	28,35	25,71	25,48	25,65	26,06	25,07	22,75
8	31,38	35,82	37,99	40,25	39,36	34,02	35,47	29,63	31,49	32,16	29,55	28,88
9	38,21	34,46	35,18	37,62	34,79	39,07	38,29	34,87	34,39	31,96	33,86	31,18
10	41,30	46,00	49,73	51,48	58,82	67,40	80,05	82,79	76,10	72,11	72,77	67,89

USD/TL Exchange scenarios are also calculated by Monte Carlo simulation. GBM model is selected. There are few studies about prediction of USD/TL exchange ratio. Gozgor (2013) studied on stochastic processes in exchange rate forecasting. USD/TL and EURO/TL are considered in the paper. Gozgor (2013) forecasts exchange ratios by different techniques. One of them is GBM. However, study's data is between 1999 and 2011. Considering last 5 years, USD/TL exchange ratio has different behavior. In the thesis, 2012-2015 data is used to calculate the drift and volatility. Data is obtained from Central Bank of the Republic of Turkey[4]. *The drift* and *volatility* is found as *12 percent* and *4 percent* respectively. Initial

[4] TCMB - http://www.tcmb.gov.tr/

exchange is 2, 95 USD/TL. Calculated estimations of exchange rates for 10 scenarios are given in Table 4.2.

Table 4.2 : TL/USD Exchange Rate Estimations

	January	February	March	April	May	June	July	August	September	October	November	December
1	3,00	3,02	3,06	3,07	3,15	3,25	3,25	3,24	3,33	3,39	3,47	3,55
2	2,97	3,00	3,08	3,12	3,13	3,18	3,22	3,19	3,28	3,28	3,32	3,38
3	2,96	3,05	3,08	3,09	3,10	3,18	3,24	3,28	3,26	3,34	3,41	3,49
4	2,96	2,98	3,04	3,09	3,06	3,12	3,10	3,13	3,13	3,14	3,14	3,08
5	2,98	3,08	3,16	3,19	3,20	3,25	3,31	3,40	3,50	3,56	3,59	3,66
6	3,03	3,10	3,19	3,20	3,28	3,31	3,34	3,39	3,41	3,40	3,44	3,50
7	2,99	3,06	3,16	3,17	3,21	3,30	3,31	3,33	3,39	3,41	3,42	3,47
8	2,96	3,04	3,05	3,07	3,15	3,17	3,24	3,26	3,20	3,17	3,23	3,27
9	2,98	3,04	3,08	3,06	3,09	3,11	3,18	3,27	3,27	3,26	3,24	3,29
10	3,01	3,02	3,04	3,01	3,01	3,06	3,04	3,11	3,13	3,17	3,17	3,21

4.1.2 Brent and USD/TL futures

Brent and USD/TL futures are taken from Bloomberg financial boards. Hedging equation is using Brent estimations to calculate hedging costs. Future prices in USD are given in Table 4.3. USD/TL future prices are also given in Table 6.

Table 4.3: Brent and USD/TL Futures

Months	Brent Future Prices (USD)	USD/TL Future Prices
January	35,17	2,97
February	35,14	2,99
March	35,34	3,01
April	35,49	3,04
May	35,72	3,06
June	35,97	3,08
July	36,17	3,11
August	36,43	3,13
September	36,58	3,16
October	36,90	3,18
November	37,01	3,20
December	37,20	3,22

4.1.3 Price Scenarios

TL/USD and Brent estimations are computed to find Price scenarios. Price formulation is given above (formulation 3.5). α is 0,004. It is acquired from German Border Prices from Eurostat. For calculating first six month price, Brent oil prices of last six month of 2015 is used. Brent oil price estimations for 100 scenarios are given in Appendix 1.

4.2 GAMS APPLICATION

Proposed model is explained in Model section above. GAMS application is used to solve this model. GAMS code is given below. Scenarios table is not included due to its size. Price, USD/TL and Brent oil scenarios are not included. They are mentioned as Table.

```
sets i month / 1*12 /
k consumer type / 1*7/
s scenario /1*100/
;

scalars
MSQ min summer quantity / 350000000 /
MAQ min annual quantity /800000000 /
ACQ annual contract quantity / 1000000000 /
KS summer penalty /0.08/
KY yearly penalty /0.100/
a confidence level of risk measure /0.95/
;

parameters


bf(i) balancing price of i

/
1       0.848
2       0.848
3       0.848
4       0.782
5       0.782
6       0.782
7       0.782
8       0.782
9       0.782
10      0.848
11      0.848
12      0.848
/
c(i) max cont amount of i
```

/
1 91817845
2 82932247
3 91817845
4 88855979
5 91817845
6 88855979
7 91817845
8 91817845
9 88855979
10 91817845
11 88855979
12 91817845
/
p(k) price of k consumer
/
1 0.738
2 0.738
3 0.738
4 0.738
5 0.738
6 0.738
7 0.770

/

m8(i) share by month of cust 8

/

1 0.09
2 0.08
3 0.09
4 0.08
5 0.08
6 0.08
7 0.08
8 0.08
9 0.08
10 0.08
11 0.09
12 0.09
/
BRf(i) brent futures
/
1 35.17
2 35.14
3 35.34
4 35.49
5 35.72
6 35.97
7 36.17
8 36.43
9 36.58
10 36.90
11 37.01
12 37.20
/
USDf(i) usd exc futures
/
1 2.97
2 2.99
3 3.01
4 3.04
5 3.06
6 3.08
7 3.10

```
8  3.12
9  3.15
10 3.17
11 3.19
12 3.21
/
LMTY(k)  limited volumes of customers
/
1 500000000
2 50000000
3 500000000
4 500000000
5 20000000
6 250000000
7 1000000000

/
;

table m(i,k) share by month of k

     1      2      3     4       5       6       7
1   0.08   0.03   0.09  0.10    0.01    0.09    0.20
2   0.08   0.03   0.08  0.10    0.01    0.08    0.17
3   0.08   0.03   0.06  0.10    0.02    0.09    0.14
4   0.09   0.03   0.07  0.08    0.03    0.08    0.08
5   0.08   0.05   0.07  0.08    0.06    0.09    0.03
6   0.08   0.08   0.08  0.07    0.25    0.08    0.02
7   0.09   0.11   0.10  0.07    0.25    0.08    0.02
8   0.08   0.29   0.10  0.06    0.25    0.08    0.02
9   0.09   0.28   0.09  0.07    0.06    0.07    0.02
10  0.08   0.04   0.07  0.07    0.03    0.09    0.04
11  0.09   0.02   0.10  0.09    0.01    0.08    0.10
12  0.09   0.01   0.10  0.10    0.01    0.09    0.18

;

table f(s,i) supply price of i s
;

table USD(s,i)  exchange scenarios
;

table BR(s,i) brent scenarios

;
Parameter p8(s,i) price of 8 customer in i s;

p8(s,i) = f(s,i) + 0.030
;

Positive variables
y(k) yearly amount of k
SP(i) supply of i
H penalty amount of summer
T penalty amount of year
b(i) balancing amount of i
y8 yearly amount of customer 8
n(s) intermediate variable
KB(i) hedging volume
ST(i) storage volume
WT(i) withdraw from storage
IN(i) injection to storage   ;

variables
PR(s) total revenue of scenario s
e value at risk
```

```
cvar risk index
avrev
;
equations

hedging(i) hedging cons
offtake(i) monthly balance
ancq  ACQ cons
misq  msq cons
miaq  maq cons
supply(i) monthly supply cons
revenue(s) revenue of s
totalsale total sale cons
inter cvar inter
Cvarform cvar
maxvol(k)
totrev
revcont
storage(i)
;

storage(i).. ST(i-1) + IN(i) =e= ST(i) + WT(i);
maxvol(k).. Y(k) =l= LMTY(k) ;
hedging(i).. KB(i) =l= 50000;
ancq.. sum(i,SP(i)) =l= ACQ    ;
misq.. SP('4') + SP('5') + SP('6') + SP('7') + SP('8') + SP('9')+ H =g= MSQ ;
miaq.. sum(i,SP(i))+ T =g= MAQ;
supply(i).. SP(i) =l= c(i);
offtake(i).. sum(k,y(k)*m(i,k))+ m8(i)*y8 + IN(i) =e= SP(i)+b(i) + WT(i) ;
totalsale.. sum(k,y(k))+y8 =l= ACQ   ;

revenue(s).. PR(s) =e= sum(k, p(k)*y(k)) -
sum(i, (IN(i)+WT(i))*0.05 + ST(i)*0.01)+ sum(i,p8(s,i)*m8(i)*y8)-
sum(i,SP(i)*f(s,i))- sum(i,b(i)*bf(i))- T*KY - H*KS + sum(i,KB(i)*(BR(s,i)*USD(s,i)-BRf(i)*USDf(i))) ;

inter(s).. n(s)=g= e - PR(s);
Cvarform.. cvar =e= e - sum(s,n(s)) / 5 ;
totrev..  avrev=e=sum(s,PR(s))/100;
revcont..          avrev=g=0;
;


model tez /all/;

solve tez using lp maximizing cvar;

display y8.l, y.l , ST.l , WT.l, IN.l , KB.l, SP.l;
```

5. RESULTS

Proposed model use simulations outputs and data collected from Turkish Natural Gas System players to solve problem. Model suggests optimal supply and sales portfolio to the company under CVaR risk index with α = 0,95. Storage using and hedging are another variables. Storage costs are taken from TPAO Silivri Underground Storage Services. Capacity allocation of storage ignored, but total cost including capacity cost is divided between Withdraw and Injection costs. Contractual parameters are assumed by using literature. All parameters and their values are shown in Table 5.1.

Table 5.1 : Parameters of Model

Parameters	
ACQ	1.000.000.000
MAQ	800.000.000
MSQ	350.000.000
KS – Summer Penalty	0,080
KY – ToP Penalty	0,100
α – Confidence Level of risk measure	0,95
Withdraw and Injection Cost	0,050
Storage Holding Cost	0,010
Hedging Limit per Month	50.000

Prices and other related parameters are explained and given above. Only scenarios are shown in Appendix 1. It should be highlighted that it is risk-averse approach. Model tries to maximize worst 5 scenarios' revenue.

5.1 RESULTS OF THE GAMS - OUTPUTS

5.1.1 Risk Variables and Average Revenue

Table 5-2 display results of the CVaR and Average Revenue

Table 5.2 : Results of CVaR

	Level (TL)
e	83.004.000
CVaR	75.928.000
Average Revenue	154.830.000

It is seen that Average Revenue of the proposed model is 154.830.000 TL. CVaR represents average revenue of worst 5 scenarios. Comparison of average revenues of different models is mentioned below.

5.1.2 Sales Amounts

Sales amount of the customers is shown in Table 5-3.

Table 5.3 : Sales Amounts

Customer Type	Volume(m3)
Industry	0
Summer Customer	50.000.000
Electricity	0
Industrial Parks	500.000.000
Hotel	20.000.000
Iron and Steel	250.000.000
LDC	77.973.000
Wholesaler	0
Total	897.973.000

As seen in the table, Model suggests selling summer consumption and smooth profiles. Although LDC price higher than others, limited volume of total sales is chosen. It is because that LDC consumption is high in winter period and it causes to MSQ penalty. Also, total sales are less than its limitation because supply prices of worst five scenarios are high in last 3 months of the year due to Brent oil price increasing.

In addition to Industry and Electricity, Wholesaler is not preferred. Importer Company can sell all contracted gas to wholesaler with limited premium. However, it is not optimal if there are enough premiums between supply and sales prices. Even this model is risk-averse model, there is not such risk in scenarios.

5.1.3 Storage Utilization

Table 5.4 demonstrates storage utilization.

Table 5.4 : Storage Utilization

Month	Injection(m3)	Withdraw(m3)	Storage(m3)
January	2.023.200,00		2.023.200
February	-	2.023.200,00	0
March	6.501.593,00		6.501.593
April	20.518.120,00		27.019.713
May	23.278.650,00		50.298.363
June	23.296.510,00		73.594.873
July	24.758.380,00		98.353.253
August	20.758.380,00		119.111.633
September	19.596.510,00		138.708.143
October	-	63.218.926,00	75.489.217
November	-	73.997.315,00	1.491.902
December	-	1.491.902,00	0
Total	140.731.343,00	140.731.343,00	592.591.890,00

It is clearly understood that Model trying to use storage to avoid price risks of last quarter of the year although storage costs are too expensive. As mentioned above, supply prices are calculated from average of last six months oil products prices. Some scenarios include increasing Brent oil prices and these increasing effects to last quarter prices. Storage, therefore, is becoming good alternative for market players when price rise.

5.1.4 Hedging

Hedging volume per month is seen in Table 5.5.

Table 5.5 : Hedging Volumes

Month	Hedging Volume (Barrel)
January	50.000
February	
March	
April	
May	
June	50.000
July	29.811
August	
September	
October	4.543
November	50.000
December	50.000
Total	234.354

Model obviously tries to hedge when risk exists. It is because volatility of USD/TL is too high in related months in worst five scenarios. Total amount of hedging is 234.354 barrel.

5.1.5 Supply

Supply and balancing volumes are in Table 5.6.

Table 5.6 : Supply and Balancing Volumes

Month	Supply (1000 m³)	Balancing (1000 m³)
January	91.818	-
February	82.932	-
March	91.818	-
April	88.856	-
May	91.818	-
June	88.856	-
July	91.818	-
August	91.818	-
September	88.856	-
October	-	-
November	-	-
December	-	85.743

As mentioned above, storage withdraw is preferred rather than supply from import due to their price uncertainty. First ten months, all available amounts are taken from supplier, and rest of the gas sold is injected to storage as seen in Table 5-4 and Table 5-6. Also, balancing gas is used last month due to high supply prices. Total supply purchase is approximately 808 million m^3 which is little above from take-or-pay level and far below contracted volume, 1 billion m^3. However, total sales are 897 mcm by using balancing gas in December.

5.1.6 Results of Maximizing Expected Value

Results mentioned above are about the outputs of CVAR approach. Maximizing expected value is another optimization method but it is more risky than CVAR approach. In proposed model, each scenario has same probability, 1 percent. Thus, expected value of the scenarios is equal to average of them. Problem is solved according to model below

$$Maximizing\ z = \sum_{s=1}^{100} p * PR_s \qquad (5.1)$$

Subject to

(3.11), (3.12), (3.13), (3.14), (3.15), (3.16), (3.17), (3.18), (3.19), (3.20)

$Y_k, S_i, B_i, KB_i\ SP\ , YP\ WT, IN_i, ST_i \geq 0$

Results are given in tables below.

Table 5.7 : Results of Maximizing Expected Value

	Level (TL)
Expected CVaR	42.000.000
Average Revenue	224.600.000

Table 5.8 Sales Profile of Maximizing Expected Value

Customer Type	Volume(m3)
Industry	0
Summer Customer	50.000.000
Electricity	238.330.300
Industrial Parks	441.669.700
Hotel	20.000.000
Iron and Steel	250.000.000
LDC	0
Wholesaler	0
Total	1.000.000.000

Table 5.9 : Storage - Hedging - Supply of Maximizing Expected Value

Month	Injection (m^3)	Withdraw (m^3)	Storage (m^3)	Hedging Volume (Barrel)	Supply (m^3)	Balancing (m^3)
January	2.001.147		2.001.147	50.000	91.818.000	0
February	0	2.001.147	0	50.000	82.932.000	0
March	0	0	0	50.000	82.866.000	0
April	0	0	0	50.000	74.116.000	0
May	0	0	0	50.000	78.216.000	0
June	0	0	0	50.000	78.983.000	0
July	0	0	0	50.000	85.249.000	0
August	0	0	0	50.000	89.833.000	0
September	0	0	0	50.000	85.066.000	0
October	0	0	0	50.000	72.700.000	0
November	0	0	0	50.000	84.783.000	0
December	0	0	0	50.000	91.200.000	0
Total	2.001.147	2.001.147	2.001.147	600.000	1.000.000.000	0

Average revenue is higher than proposed model's result. It is another evidence of that CVaR approach is risk averse. Expected CVaR is also calculated and it is much less than model's solution. Detailed graph about CVaR-Average revenue relationship is given next section.

Also, supply and sales are reached to their limits. It is not preferred to sell whole amount and not supply in last quarter in the proposed model. Hedging, beside, is used whole years by contrast with prosed model.

5.2 COMPARISONS AND ANALYSIS

5.2.1 Effects of CVAR

In order to see the effect of risk-profit tradeoff we have expanded our model with a minimum profit constraint where the average profit is required to be above profit level PL. The proposed model can be written as

$$Maximize\ CVaR = \varepsilon - \frac{1}{1-a} * \sum_{s} p * \eta_s \tag{5.2}$$

Subject to;

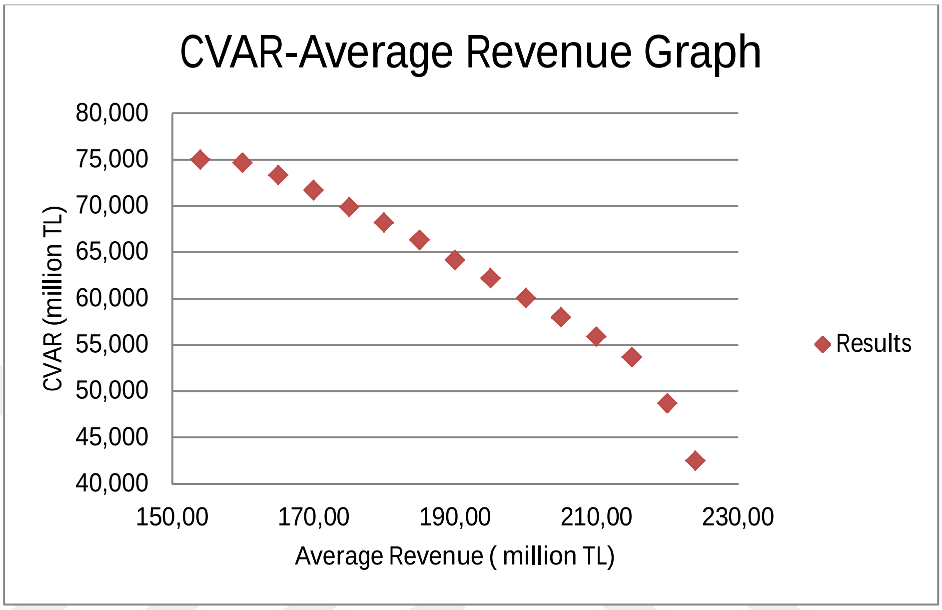
$$\sum_{s=1}^{100} p_s * PR_s \geq PL \tag{5.3}$$

(3.11), (3.12), (3.13), (3.14), (3.15), (3.16), (3.17), (3.18), (3.19), (3.20), (3.25), (3.26)

$Y_k, S_i, B_i, KB_i\ SP\ , YP\ WT, IN_i, ST_i \geq 0$

Proposed model include risk averse approach; CVaR. It provides to reduce risk by maximizing worst five scenarios' profits while maintaining an acceptable level of average profit PL. We solve the model various times by changing the value of PL and the corresponding CVaR and average profit values are presented in Figure 5-1. Risk index effect is clearly seen in Figure 5-1. When, model tries to increase average revenue, worst five scenarios average profits (CVaR) decrease.

Figure 5.1 : CVAR – Average Revenue Comparison



Maximizing average revenue is another proof of the CVaR effects. Model is risk averse and it reasons to decrease average revenue. When model aims to maximize average revenue, solution is approximately 224.000.000 TL where expected CVaR is only 42.500.000 TL.

5.2.2 Hedging and Storage Utilization

Hedging and Storage are both used in modelling and solution shows that both of them are needed to reduce risks. Effects of storage and hedging are seen in Table 5.10 and Figure 5.2.

Table 5.10 : Effects of Hedging and Storage

TL	Model's Solution	Solution Without Storage	Solution Without Hedging	Solution Without Storage and Hedging
e	83.004.000	72.868.000	83.260.000	69.796.000
CVaR	75.928.000	63.734.000	74.517.000	62.140.000
Average Revenue	154.830.000	145.860.000	152.430.000	122.580.000

Figure 5.2 : Effects of Hedging and Storage

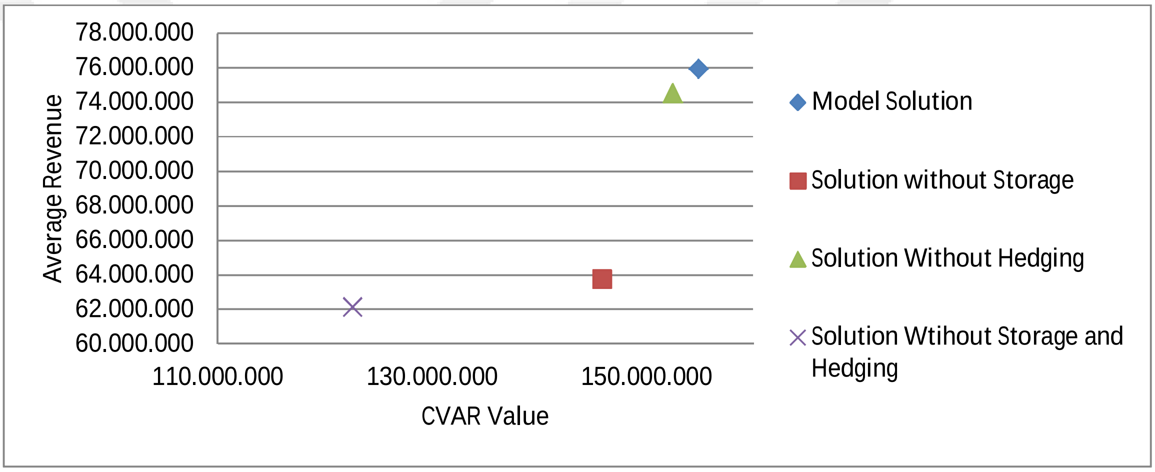


Figure 5.2 supports claims about the importance of hedging and storage. However, storage has huge effects on revenue where hedging has limited.

5.2.3 Sensitivity Analysis of Drift Levels

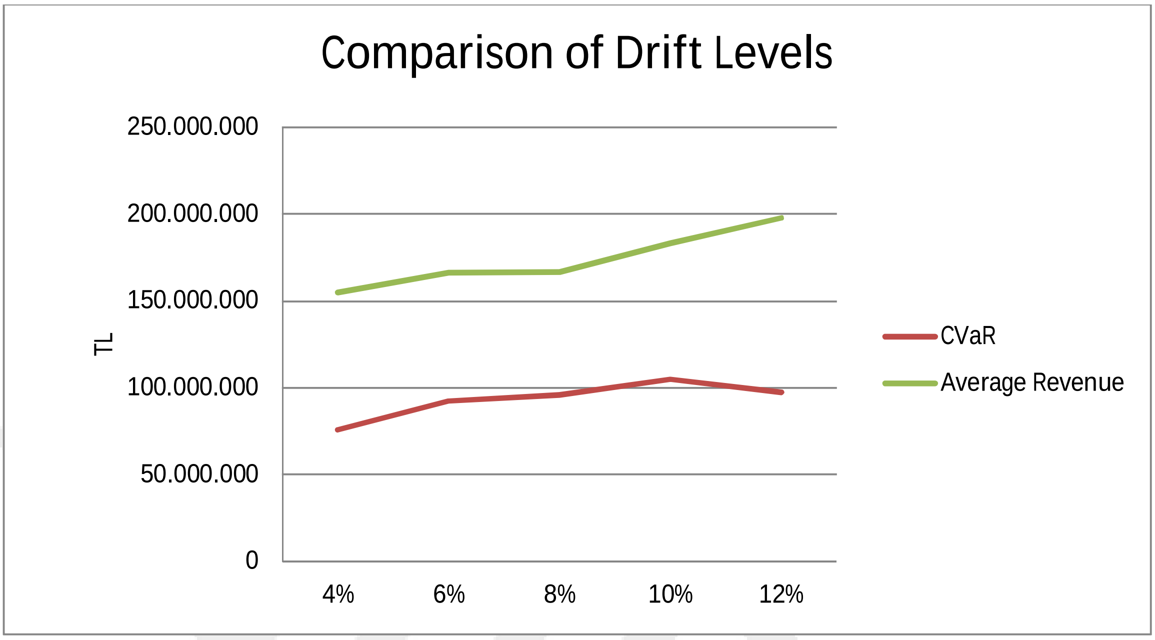
Forward prices are generally calculated from related countries interest rate. Forward prices which are used in the model have 8 percent yearly change (also called as the drift). Still, 12 percent is taken for GBM method. It is found by analyzing between 2012 and 2015. It is also claimed that hedging could be effective where the drift of the model is under 8 percent. For four different drift values, new scenarios are generated. Results are given in Table 5.11.

Table 5.11- Results of Different Drift Levels

TL	12% - Base Scenario	10%	8%	6%	4%
e	83.004.000	97.011.000	100.410.000	112.830.000	110.500.000
CVaR	75.928.000	92.264.000	96.072.000	104.880.000	97.285.000
Average Revenue	154.830.000	166.240.000	166.830.000	183.280.000	197.800.000
Hedging Volumes (Barrel)					
Month\Drift Level	12% - Base Scenario	10%	8%	6%	4%
January	50.000				
February		50.000	50.000		50.000
March					
April		28.327	1.752	50.000	
May				344	
June	50.000				
July	29.811	50.000		44.469	
August					
September					
October	4.543	28.712			
November	50.000	50.000		1.830	
December	50.000	22.731			
Total	234.354	229.770	51.752	96.643	50.000

Table 5.11 supports the given idea above. Hedging volume decreases dramatically if the drift is fewer than 8 percent. All prices and USD/TL exchanges are generated from Monte-Carlo simulation so results may change like 6 percent. However, it is still less than half of the drift volumes higher than 8 percent. In addition, the less the drift volume is, the more revenue company gains. Due the fact that supply prices depend on USD/TL, prices are decreasing while USD/TL is low. Results given above show that average revenue is highest at the drift level 4 percent. Figure 5.3 shows comparison of drift levels.

Figure 5.3 -Comparison of Drift Levels



Sales portfolio, supply volumes per months and storage utilization are not different than proposed solution. Because, fourth quarter prices are much higher than first three quarter for each drift level. Therefore, it is meaningless to supply from import contracts rather than using storage.

5.2.4 Statistical Tests of the Scenarios

A hundred scenarios are generated by Monte Carlo simulation. Results are found by these scenarios. To prove its validity, nine different scenarios set are created then results are obtained from each data set. Mean and standard deviation of ten scenarios (including model's set) are calculated. Proposed model solution is in 95 percent confidence interval as seen in Table 5.12. Results are given below.

Table 5.12 – Statistical Tests Results

	Model's Solution	1st Set	2nd Set	3rd Set	4th Set
e (TL)	83.004.000	89.676.000	93.050.000	81.522.000	85.976.000
CVaR (TL)	75.928.000	81.739.000	86.932.000	77.016.000	79.333.000
Average Revenue (TL)	154.830.000	156.780.000	161.680.000	153.810.000	158.910.000
	5th Set	6th Set	7th Set	8th Set	9th Set
e (TL)	91.515.000	87.988.000	84.863.000	89.193.000	85.188.000
CVaR (TL)	85.834.000	81.252.000	77.847.000	80.077.000	78.549.000
Average Revenue (TL)	160.840.000	155.780.000	156.140.000	161.640.000	155.440.000
Mean	157.202.000				
STD Deviation	3.173.322				
95% Confidence Interval	151.814.974 - 163.355.026				

6. CONCLUSION

Turkish Natural Gas Market is one of the developing gas markets. Nevertheless, liberalization of market is not satisfied. In 2001, 4646 Natural Gas Law was published but it was not processed as expected. Prices mechanism, for example, is not available since 2012. It has forced companies to take extra cautions.

Risk management is essential for importer companies. Beside natural gas contractual risks, Turkish natural gas market includes several risk factors as mentioned above. Pricing is one of them. Long-term contractual prices are generally oil-indexed. Brent oil price volatility changes prices during the years. In addition the Brent oil prices, USD/TL exchange ratio is another risk. In developed markets, selling price mechanisms or market price mechanisms exist. However, selling prices are usually referenced by BOTAS's selling prices, which are constant during the year. There are contractual constraints as well. Take-or-pay is the one of them. Companies should take above the Take-or-pay level to satisfy contract, otherwise penalties are charged.

In this thesis our model aims to find optimal solution for importer portfolio. Also, risk factors are considered. CVaR risk index is used to reduce risk. CVaR is trying to maximize five worst of the hundred scenarios' profit. Sales and supplies are determined. Supply price scenarios are calculated by Geometric Brownian Method. Monte Carlo simulation is used. Hedging and storage utilization are other options for the companies in the model.

Consequently, model finds best solution under aforementioned constraints. Due to price risk of last quarter of the year, storage is used. Injection takes place in summer period and stored gas is used in winter period to satisfy demand. Hedging is also used due to price volatility. Proposed model avoids using supply gas in the last quarter of the year and sells natural gas to the summer customers as much as possible. It is also seen that risk measure increases when expected profit increases. If model tries to maximize expected revenue, CVaR value decreases from 75 million TL to 42 million TL.

Sensitivity analysis for the drift level of USD/TL and statistical test for scenarios are included in the thesis. USD/TL ratios change hedging amounts. When it is under the future prices drift level 8.8 percent, hedging volumes decrease dramatically. 9 different price scenarios are also generated to satisfy base scenarios validity.

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APPENDIXES

APPENDIX 1 – Price Scenarios

TL/sm³	January	February	March	April	May	June	July	August	September	October	November	December
1	0,564	0,568	0,575	0,514	0,528	0,545	0,532	0,531	0,546	0,541	0,553	0,567
2	0,558	0,564	0,578	0,522	0,524	0,533	0,527	0,523	0,538	0,524	0,530	0,540
3	0,556	0,572	0,579	0,517	0,519	0,532	0,530	0,536	0,534	0,532	0,545	0,556
4	0,555	0,560	0,571	0,518	0,512	0,522	0,509	0,513	0,513	0,500	0,501	0,491
5	0,559	0,580	0,595	0,534	0,536	0,544	0,541	0,557	0,572	0,567	0,573	0,583
6	0,569	0,583	0,600	0,536	0,549	0,555	0,547	0,555	0,558	0,543	0,549	0,559
7	0,563	0,576	0,593	0,531	0,538	0,553	0,542	0,545	0,555	0,544	0,546	0,553
8	0,556	0,570	0,573	0,514	0,528	0,531	0,531	0,534	0,523	0,506	0,515	0,521
9	0,561	0,571	0,579	0,512	0,517	0,522	0,522	0,536	0,535	0,519	0,517	0,525
10	0,566	0,568	0,571	0,505	0,505	0,513	0,498	0,509	0,513	0,505	0,506	0,512
11	0,564	0,568	0,575	0,467	0,479	0,494	0,409	0,408	0,420	0,400	0,409	0,419
12	0,558	0,564	0,578	0,474	0,476	0,484	0,405	0,402	0,413	0,387	0,392	0,399
13	0,556	0,572	0,579	0,469	0,471	0,483	0,407	0,412	0,410	0,394	0,403	0,411
14	0,555	0,560	0,571	0,470	0,465	0,474	0,391	0,394	0,394	0,370	0,370	0,363
15	0,559	0,580	0,595	0,485	0,486	0,494	0,416	0,428	0,440	0,419	0,424	0,431
16	0,569	0,583	0,600	0,487	0,498	0,504	0,420	0,426	0,429	0,401	0,406	0,413
17	0,563	0,576	0,593	0,482	0,488	0,502	0,416	0,419	0,427	0,402	0,404	0,409
18	0,556	0,570	0,573	0,467	0,479	0,482	0,408	0,410	0,402	0,374	0,381	0,385
19	0,561	0,571	0,579	0,465	0,469	0,473	0,401	0,412	0,411	0,384	0,382	0,388
20	0,566	0,568	0,571	0,458	0,458	0,466	0,383	0,391	0,394	0,373	0,374	0,379
21	0,564	0,568	0,575	0,477	0,490	0,505	0,453	0,452	0,465	0,510	0,522	0,534
22	0,558	0,564	0,578	0,485	0,486	0,495	0,449	0,445	0,458	0,494	0,499	0,509
23	0,556	0,572	0,579	0,479	0,481	0,494	0,451	0,457	0,454	0,502	0,513	0,524
24	0,555	0,560	0,571	0,480	0,475	0,485	0,433	0,437	0,436	0,471	0,472	0,463
25	0,559	0,580	0,595	0,495	0,497	0,505	0,461	0,474	0,487	0,535	0,541	0,550
26	0,569	0,583	0,600	0,497	0,509	0,515	0,466	0,472	0,475	0,512	0,518	0,527
27	0,563	0,576	0,593	0,492	0,499	0,513	0,461	0,464	0,473	0,513	0,515	0,521
28	0,556	0,570	0,573	0,477	0,490	0,492	0,452	0,454	0,445	0,477	0,486	0,491
29	0,561	0,571	0,579	0,475	0,480	0,484	0,444	0,456	0,456	0,490	0,488	0,495
30	0,566	0,568	0,571	0,468	0,468	0,476	0,424	0,433	0,436	0,476	0,477	0,483
31	0,564	0,568	0,575	0,473	0,486	0,502	0,412	0,411	0,423	0,423	0,433	0,443
32	0,558	0,564	0,578	0,481	0,482	0,491	0,408	0,404	0,416	0,410	0,414	0,422
33	0,556	0,572	0,579	0,476	0,478	0,490	0,410	0,415	0,413	0,416	0,426	0,435
34	0,555	0,560	0,571	0,477	0,472	0,481	0,393	0,397	0,397	0,391	0,392	0,384
35	0,559	0,580	0,595	0,492	0,493	0,501	0,419	0,431	0,443	0,444	0,448	0,456
36	0,569	0,583	0,600	0,494	0,506	0,511	0,423	0,429	0,432	0,425	0,430	0,437

37	0,563	0,576	0,593	0,489	0,495	0,509	0,419	0,422	0,430	0,425	0,427	0,432
38	0,556	0,570	0,573	0,473	0,486	0,489	0,411	0,413	0,405	0,396	0,403	0,407
39	0,561	0,571	0,579	0,472	0,476	0,480	0,404	0,415	0,414	0,406	0,404	0,411
40	0,566	0,568	0,571	0,465	0,465	0,473	0,385	0,394	0,397	0,395	0,395	0,401
41	0,564	0,568	0,575	0,540	0,554	0,572	0,632	0,631	0,648	0,734	0,751	0,769
42	0,558	0,564	0,578	0,548	0,550	0,560	0,626	0,620	0,638	0,711	0,719	0,732
43	0,556	0,572	0,579	0,542	0,545	0,559	0,629	0,637	0,634	0,722	0,739	0,755
44	0,555	0,560	0,571	0,543	0,538	0,548	0,604	0,609	0,608	0,678	0,679	0,666
45	0,559	0,580	0,595	0,560	0,562	0,571	0,643	0,662	0,680	0,770	0,778	0,791
46	0,569	0,583	0,600	0,563	0,576	0,582	0,649	0,658	0,663	0,737	0,745	0,758
47	0,563	0,576	0,593	0,557	0,565	0,580	0,643	0,647	0,659	0,738	0,741	0,750
48	0,556	0,570	0,573	0,539	0,554	0,557	0,630	0,634	0,621	0,687	0,699	0,707
49	0,561	0,571	0,579	0,538	0,543	0,547	0,619	0,636	0,635	0,705	0,702	0,713
50	0,566	0,568	0,571	0,530	0,530	0,539	0,591	0,604	0,609	0,685	0,686	0,695
51	0,564	0,568	0,575	0,459	0,471	0,486	0,382	0,381	0,391	0,384	0,393	0,402
52	0,558	0,564	0,578	0,466	0,468	0,476	0,378	0,374	0,385	0,372	0,376	0,383
53	0,556	0,572	0,579	0,461	0,463	0,475	0,380	0,384	0,383	0,378	0,386	0,395
54	0,555	0,560	0,571	0,462	0,457	0,466	0,364	0,367	0,367	0,355	0,355	0,348
55	0,559	0,580	0,595	0,477	0,478	0,486	0,388	0,399	0,410	0,403	0,407	0,414
56	0,569	0,583	0,600	0,479	0,490	0,495	0,392	0,397	0,400	0,385	0,390	0,396
57	0,563	0,576	0,593	0,474	0,480	0,494	0,388	0,390	0,398	0,386	0,387	0,392
58	0,556	0,570	0,573	0,459	0,471	0,474	0,380	0,382	0,375	0,359	0,366	0,370
59	0,561	0,571	0,579	0,457	0,461	0,466	0,374	0,384	0,384	0,369	0,367	0,373
60	0,566	0,568	0,571	0,450	0,451	0,458	0,357	0,364	0,367	0,358	0,359	0,364
61	0,564	0,568	0,575	0,461	0,473	0,488	0,389	0,388	0,399	0,367	0,375	0,384
62	0,558	0,564	0,578	0,468	0,469	0,478	0,385	0,381	0,392	0,355	0,359	0,366
63	0,556	0,572	0,579	0,463	0,465	0,477	0,387	0,392	0,390	0,361	0,369	0,377
64	0,555	0,560	0,571	0,464	0,459	0,468	0,371	0,374	0,374	0,339	0,339	0,333
65	0,559	0,580	0,595	0,478	0,480	0,488	0,395	0,407	0,418	0,385	0,389	0,395
66	0,569	0,583	0,600	0,480	0,492	0,497	0,399	0,405	0,407	0,368	0,372	0,379
67	0,563	0,576	0,593	0,475	0,482	0,495	0,396	0,398	0,405	0,369	0,370	0,375
68	0,556	0,570	0,573	0,460	0,473	0,475	0,387	0,390	0,382	0,343	0,349	0,353
69	0,561	0,571	0,579	0,459	0,463	0,467	0,381	0,391	0,391	0,352	0,351	0,356
70	0,566	0,568	0,571	0,452	0,452	0,460	0,364	0,371	0,374	0,342	0,343	0,347
71	0,564	0,568	0,575	0,483	0,496	0,512	0,474	0,473	0,486	0,476	0,486	0,498
72	0,558	0,564	0,578	0,491	0,493	0,501	0,469	0,465	0,479	0,460	0,465	0,474
73	0,556	0,572	0,579	0,486	0,488	0,501	0,472	0,478	0,476	0,468	0,479	0,489
74	0,555	0,560	0,571	0,487	0,482	0,491	0,453	0,457	0,457	0,439	0,440	0,431
75	0,559	0,580	0,595	0,502	0,504	0,512	0,482	0,496	0,510	0,499	0,504	0,513
76	0,569	0,583	0,600	0,504	0,516	0,522	0,487	0,494	0,497	0,477	0,483	0,491

77	0,563	0,576	0,593	0,499	0,506	0,520	0,483	0,485	0,495	0,478	0,480	0,486
78	0,556	0,570	0,573	0,483	0,497	0,499	0,473	0,475	0,466	0,445	0,453	0,458
79	0,561	0,571	0,579	0,482	0,486	0,490	0,465	0,477	0,477	0,456	0,454	0,462
80	0,566	0,568	0,571	0,475	0,475	0,483	0,444	0,453	0,457	0,444	0,444	0,450
81	0,564	0,568	0,575	0,489	0,502	0,518	0,475	0,474	0,488	0,495	0,507	0,519
82	0,558	0,564	0,578	0,497	0,498	0,507	0,471	0,466	0,480	0,480	0,485	0,494
83	0,556	0,572	0,579	0,491	0,493	0,506	0,473	0,479	0,477	0,487	0,499	0,509
84	0,555	0,560	0,571	0,492	0,487	0,497	0,454	0,458	0,458	0,458	0,458	0,449
85	0,559	0,580	0,595	0,508	0,509	0,518	0,483	0,498	0,511	0,519	0,525	0,534
86	0,569	0,583	0,600	0,510	0,522	0,528	0,488	0,495	0,498	0,497	0,503	0,511
87	0,563	0,576	0,593	0,505	0,512	0,526	0,484	0,486	0,496	0,498	0,500	0,506
88	0,556	0,570	0,573	0,489	0,502	0,505	0,474	0,477	0,467	0,463	0,472	0,477
89	0,561	0,571	0,579	0,487	0,492	0,496	0,466	0,479	0,478	0,476	0,473	0,481
90	0,566	0,568	0,571	0,480	0,480	0,488	0,445	0,454	0,458	0,462	0,463	0,469
91	0,564	0,568	0,575	0,549	0,563	0,581	0,682	0,681	0,700	0,942	0,964	0,987
92	0,558	0,564	0,578	0,557	0,559	0,569	0,675	0,669	0,689	0,912	0,922	0,940
93	0,556	0,572	0,579	0,551	0,554	0,568	0,679	0,687	0,684	0,927	0,948	0,969
94	0,555	0,560	0,571	0,552	0,547	0,557	0,651	0,657	0,657	0,871	0,872	0,854
95	0,559	0,580	0,595	0,570	0,572	0,581	0,693	0,714	0,733	0,988	0,998	1,016
96	0,569	0,583	0,600	0,572	0,586	0,592	0,701	0,710	0,715	0,945	0,957	0,973
97	0,563	0,576	0,593	0,566	0,574	0,590	0,694	0,698	0,711	0,947	0,951	0,962
98	0,556	0,570	0,573	0,548	0,563	0,566	0,680	0,684	0,670	0,882	0,898	0,907
99	0,561	0,571	0,579	0,547	0,552	0,557	0,668	0,687	0,686	0,905	0,901	0,915
100	0,566	0,568	0,571	0,538	0,539	0,548	0,638	0,652	0,657	0,879	0,881	0,893

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