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OPTIMALITY ANALYSIS of FINANCIAL DERIVATIVE PRODUCTS in TURKISH MARKET

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Optimality Analysis of Financial Derivative Products in Turkish Market

Türkiye Piyasasında Finansal Türev Ürünlere İlişkin Uygulamaların Optimalite Analizi

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5) Swapler	5) Swaps

FOREWORD

I would like to thank my wife Kübra Eminoğlu due to her patience, support and intellection on my thesis process.

Cem Eminoğlu, Istanbul

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ABBREVIATIONS

CBOT: Chicago Board of Trade

CBOE: Chicago Board Options Exchange

CME: Chicago Mercantile Exchange

BIST: Borsa Istanbul

DTB : German Exchange Traded Market

SOFEX: Switzerland Stock

VIOP: Derivative Market of Turkey

OTC: Over-the-Counter

GDP: Gross Domestic Product

CAPM: Capital Asset Pricing Model

SPK: Capital Markets Board of Turkey

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ABSTRACT

Optimality Analysis of Financial Derivative Products in Turkish Market

Financial derivative applications are purchased from abroad by Turkish institutions. However, critical point is whether these programmes are optimal in Turkish market.

Firstly, common types of derivatives and their applications are going to be stated in global market. After that different financial derivative applications are going to be considered and analyzed. In conclusion, optimality test of financial derivatives in Turkish market is going to be conducted at Matlab progmamme.

Keywords: *Derivatives, Financial Derivatives, OTC and Exchange Traded Markets, Options, Swaps*

ÖZET

Türkiye Piyasasında Finansal Türev Ürünlere İlişkin Uygulamaların Optimalite Analizi

Türkiye'de finansal türev uygulamaları bankalar tarafından yurtdışından hazır olarak alınmaktadır. Buradaki en kritik nokta hazır alınan program uygulamalarının Türk finansal türev piyasası için optimal olup olmadığıdır.

Öncelikle dünyadaki genel türevler ve farklı finansal türevler uygulamalarından bahsedilecek ve sonra dünyadaki farklı finansal türev uygulamaları araştırılıp, analiz edilecektir. Daha sonra Türk piyasasındaki finansal türev uygulamaları farklı senaryolarla Matlab programında kod yazılarak optimalite testi yapılacaktır.

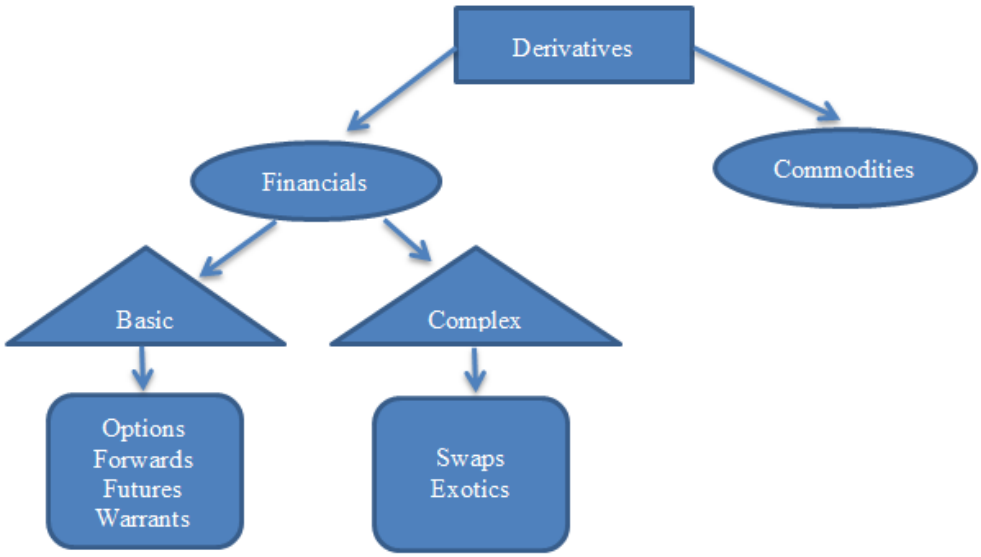
Anahtar Kelimeler: *Türev Ürünler, Finansal Türevler, Organize Olan ve Olmayan Vadeli İşlem Piyasalar, Opsiyonlar, Swaplar*

INTRODUCTION

There had been an intensive globalization wave in the world from beginnings of 1990's to 2016, when Trump was elected in the United States and Britain decided to leave the European Union. International commerce and business volume had increased rapidly in this period. Consequently, demand for money had surged and some financial instruments had rallied. Financial risks had gone up due to changes in prices of stock markets and exchange rates. Financial engineering instruments or financial derivatives were come to exist to mitigate increased financial risks.

There are four types of financial derivatives; forward at over the counter markets, futures at exchange traded markets, options and swaps at both of markets. Furthermore, derivatives are not only financial products, there are many non-financial derivatives such as cotton, wheat, corn, soy bean, oil, natural gas, gold, silver, copper, nickel and so on.

Figure 1: Classification of derivative products according to Gupta (2017)



When fund managers, financial institutions and treasury managers trading at over the counter markets evaluate investment opportunities or issue bonds/bills, they benefit many types of financial and non-financial derivatives.

Hull (2012) states “you could like of hate derivatives, but you cannot ignore them”.

The stock market is much smaller than derivative market according to comparison of value of their underlying assets. Moreover, value of derivative market is much bigger than world Gross Domestic Product (GDP). However, derivative products were criticized as one of vital reasons for mortgage crisis in US, 2007, because derivative products were formed with using risky mortgages as underlying asset in that period. Value of derivative products was decreased because of fall in house prices and it caused a big problem. Today, regulations on derivative products have bolstered.

Exchange traded and over the counter markets and their historical developments and size is going to be stated in next chapters. Financial derivative products are also going to be analyzed at this thesis project.

LITERATURE SURVEY

Black and Scholes (1971) option valuation model was tested by estimation of equity variances. Black and Scholes (1973) it was stated that theoretical and market prices of options are different, also option buyers buy at higher costs according to theoretical prices. Sterk (1983) it was considered that dividend payment is ignored at Black and Scholes European type option pricing model, although it is reckoned at Roll-Geske-Whaley option pricing model. Riskmetrics-Technical Document (1996) it was demonstrated that decay factor for EWMA model is 0.94. Galati and Tsatsaronis (1996) it was stated that neither implied nor historical volatility is better in long term while implied volatility is better in short term for anticipation periods of instability to predict volatility of underlying assets of currency options. Derosa (1998) Garman-Kohlhagen Option Pricing Model was stated. Chen (1998) implied volatility in foreign currency options was stated. Bjerksund and Stensland (2002) pricing model of American call and put options was explained. Zumbach (2006) it was considered that decay factor for exponential weighted moving average is 0.94 according to widen empirical studies. Qin and Li (2008) European call and put options were formulized at uncertain financial markets. Also, some pricing models were stated by coding with Matlab program. Suleimenov (2009) it was stated that theoretical and Turkish market prices may be different by using Binomial and Black and Scholes models. Jacque (2010) history of derivatives and malpractices of financial derivatives were demonstrated. Jabbour and Budwick (2010) financial derivatives and strategies regarding them were considered. Jaresova (2010) EWMA style estimators were compared with GARCH estimators and it was stated that EWMA style estimators were better. Chenchen (2011) Monte Carlo simulation model for call options and Binomial model for put option were used to explain differences between theoretical and market prices. Akmehmet (2012) six sub models were created with changing volatility and interest rates and their theoretical prices were compared by using Black and Scholes model. Bennet (2012) different measures of historical

volatility were stated and briefed. Akyapı (2014) it was stated that usage of Black-Scholes-Merton option pricing model is not efficient at Turkish derivative market. SPL Registry and Training Notes (2018) historical development and main differences of derivatives such as forward, futures and options were stated. Moreover, option pricing with Black and Scholes model was stated.

METHODOLOGY

There are 3 main types of options contracts, which are single stock, equity index and currency contracts, traded in Borsa İstanbul Futures and Options Market. Furthermore, single stock options have 30, index options have 3 and currency options have 6 types of underlying equities. The underlying asset prices for the related options and Turkey one month swap, USA one month swap and indicator interest rate data will be provided from the Bloomberg terminal.

Firstly, daily returns of listed underlying assets of options will be calculated. After that their daily variances and standard deviations will be reckoned. Then, annual volatility, which equals to daily standard deviation product by square root of 252 days, will be estimated by using of daily standard deviations. Later, estimated and enabled data will be run by Matlab application. Consequently, theoretical prices with regard to Black and Scholes, Roll-Geske-Whaley, Garman-Kohlhagen and Bjersund and Stensland models will be measured. In conclusion, it will be determined and interpreted whether there is difference between theoretical and market prices.

SECTION ONE

1. EXCHANGE TRADED MARKETS AND ITS HISTORICAL DEVELOPMENT

Traders always want to solve some difficulties such as financing shipping of products, insuring cargo of them and how to hedge price variations at the cargo process. History of derivate products is classified according to SPL Registry and Training Notes and Jacque below.

1.1. Ancient Times

History of trade is as old as humanity. It has been a resource of economic and political wealth for people focused on trade. So, it can be said that international trade has been a pioneer for development of humanity. For instance, Phoenicians, Greeks, and Romans were one of best traders that have regular places and time periods for exchanging goods at their markets. Some historians consider that primitive form of contracts with future delivery was conducted at early periods of BC. Traders borrowed with a higher cost in comparison with regular loans because of additional cost for cargo loss etc. at Babylonia trading system.

1.2. Middle Ages

Economic recovery started in twelfth century at two points in Europe, Holland, Belgium and Italy after extinction of Roman Empire. However, some disputes between traders began. Consequently, commerce law was improved. An innovation appeared at medieval fairs like “lettre de faire” which means a forward contract, delivery of goods were not spot, at later time. For example, insurance of transportation and option to default costs were reckoned at some of transactions in Europe. So, spot and forward prices were not same due to additional risks.

1.3. Renaissance

Deficiency of medieval fairs was not organized and centralized. Initial centralized market was Dojima rice market in Osaka, Japan, continued to develop from beginnings of 1700s to World War II.

It was important for income of landlords, because price of rice crops was volatile. Landlords could get more cash or exchange for other goods with bringing their surplus rice inventory receipts to Osaka. There were problems for merchants and landlords due to instant increase or decrease of rice prices. So, Futures trading market was established to hedge against variations in rice prices in 1730. Moreover, all of up-to-date futures contracts were found in rice futures market of Dojima. All of trades were saved in book transaction system in which names of contracting parties, amount of exchanged rice, futures price, and terms of delivery were entered. Transactions were cash based at the close of the trading term and delivery of physical rice was unnecessary.

1.4. Industrial Revolution and After

In 1700s, the city, Chicago in USA had a special place. Because, it had a strategic importance due to its location like easy transportation facility to anywhere in USA. So, it became commerce center after some time. Agricultural products that grows near Chicago transfer and stock to there and they are traded in Chicago.

Prices were fluctuating too much because of waves in the supply and demand. For instance, producers got less profit when demand is more than supply, but goods could not be found in reverse situation. Warehouses are not sufficient and transportation were difficult and high costly at that time.

Consequently, producers and traders began to make commercial contracts for forward. First recorded modern forward contract was done with delivering 3000 kg corns in Chicago 13th March 1851.

Forward contracts did not compensate completely the needs. Because, the side who is disadvantageous at contract did not fulfill the obligation on contract. After that 82 traders leagued together and found the Chicago Board of Trade (CBOT) in 1848 to provide buyers and sellers making transactions on a central place and developing the trade. Parties did not fulfill the obligations again .Then it is decided that contracts will be standardized and the stock market will be guarantor.

The major mission of CBOT was to standardize the qualities and quantities of grains. First futures type contract also was improved. In a brief, the quality, quantity, price, maturity and delivery place are determined freely by parties; but in futures contracts they are not freely, standardized.

Furthermore, Chicago Mercantile Exchange (CME), which is rival futures exchange of CBOT, was found in 1919. Then CBOT and CME have combined to CME Group that also involves the New York Mercantile Exchange.

Moreover, first futures contracts about exchange currencies were formed in 1973 and at the same year CBOE (Chicago Board Options Exchange) began to trade call option contracts on 16 stocks. Put option contracts started in 1977. Standardized option contracts are formed in 1980s. Today, CBOE trades on more 2500 stocks and a lot of various stock indices.

Finally many assets, which futures and options are embedded in, are varied. For example, the contracts that are adjusted on weather situation, energy, risk of insurance, live cattle and so on. New generations of contracts are continued due to every risk in the economic system.

1.5. Electronic Markets

Traders made their transactions on derivative exchanges with open outcry system at before. Traders physically meets on the floor of exchange, shouts and uses a complicated hand of signals to show trades they would like to implement in open outcry system. After some time this system has replaced by electronic trading when exchanges are done. This electronic system matches buyers and sellers on computers. Today, traders that use open outcry system are little and its usage continues to decrease.

Furthermore, algorithmic trading, which is also called black box trading, automated trading, high frequency trading or robo-trading, growth is enabled by electronic trading. Algorithmic trading means beginning trades, often without human intervention with usage of computer software.

SECTION TWO

2. OVER THE COUNTER MARKETS

2.1.General Information about OTC Markets

Over-the-counter (OTC) market is a significant choice to exchanges traded markets according to trading's total volume. OTC market, where dealers have links on computer and telephone network, is larger than exchange traded market. For instance, financial institution and its clients such as corporate treasurer or fund manager trade on telephone. Trades are also done on phone among financial institutions. A bid price (price dealers prepare to purchase) and offer price (price dealers prepare to sell) are quoted by financial institutions.

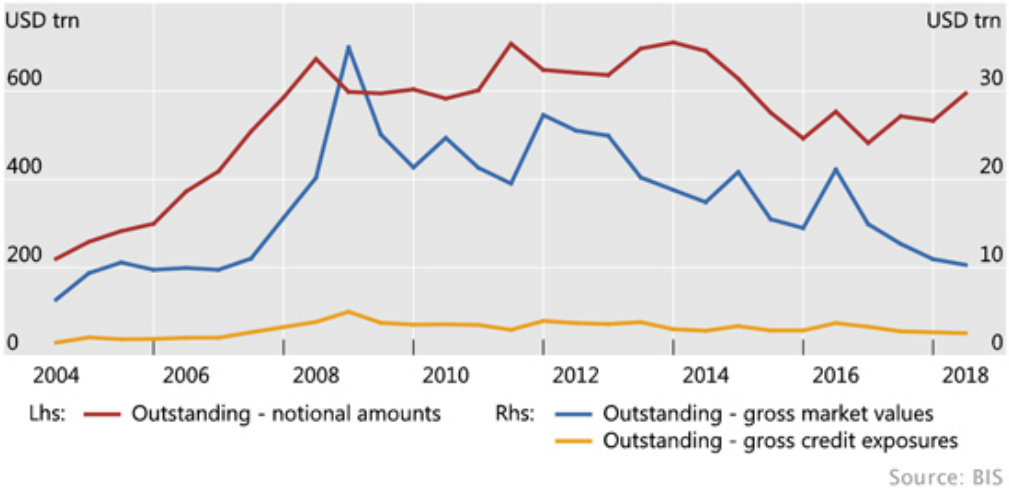
Moreover, dealers tape their telephone interviews in over-the-counter market. Dealers replay tapes to solve the problem when there is a disagreement between them.

It is stated before that OTC markets is much larger than exchange traded markets. The most beneficial thing of OTC markets is that contracts do not have to be standardized like exchange markets. Market participants can deal on good looking contract for both of them freely. However, the worst thing for OTC markets is that there is always a credit risk. For instance, the main reason of Lehman Brothers' bankruptcy is being very active on OTC market, in 2008 global economic crisis.

2.2. Market Size

It is stated before that over-the-counter markets and exchange traded markets are too large and OTC markets are larger than exchange traded markets; although two markets are not completely comparable according to statistics, that were began to collect on markets by Bank for International Settlements[1] in 1998.

Table 1: Size and Market Value of OTC markets



[1] The Bank for International Settlements (BIS) is an intergovernmental organization of central banks which "fosters international monetary and financial cooperation and serves as a bank for central banks." It is not accountable to any national government.

According to Table 1, there is a leverage effect. For instance, an agreement to buy 200 million USD with British pounds at a predetermined exchange rate in 1 year in OTC market. The total principal amount in this transaction is $200 million, but value of contract ought to be just $2 million.

According to Table 1, there is no an exponential shift on the OTC market like before the crisis. However, there is decrease in market size and value of global OTC market. This shows the effect of crisis and regulations to OTC market. The last detailed and updated information that is about the size of OTC derivative market is at Appendix 1. Furthermore, value of open interest of exchange traded markets is about USD 95.5 trillion. The last updated information about the size of exchange traded derivative market is at Appendix 2.

SECTION THREE

3. INSTRUMENTS OF RISK HEDGING

3.1.Forwards

3.1.1. Forward Contracts

Forward contract means a deal to purchase or sell an asset at a certain price for future time. It is opposite of spot contract that is an agreement to buy or sell an asset today. Financial institutions or a financial institution and its client use forward contracts and this shows that they are traded in the over-the-counter market.

If a dealer agrees to buy an asset at a specified certain price for a special future date, this is called “long position”. And if other dealer agrees to sell an asset at a same specified certain price for a same special future date, this is called “short position”.

Forward contracts on foreign exchange are well liked. Forward and spot foreign exchange traders are employed by many large banks. A foreign currency for sudden delivery is traded by spot traders. Delivery for a future time is traded by forward traders.

Table 2 enables quotes, which are for number of USD per GBP, on exchange rate between US dollar (USD) and British pound (GBP). It is ought to be made by a big international bank on May, 2010.

Table 2: Forward and spot quotes for the GBP/USD exchange rate, May 24, 2010 (GBP=British pound; USD= US dollar; quote is number of USD per GBP)

	Bid	Offer
Spot	1.4407	1.4411
1-month forward	1.4408	1.4413
3-month forward	1.4410	1.4415
6-month forward	1.4416	1.4422

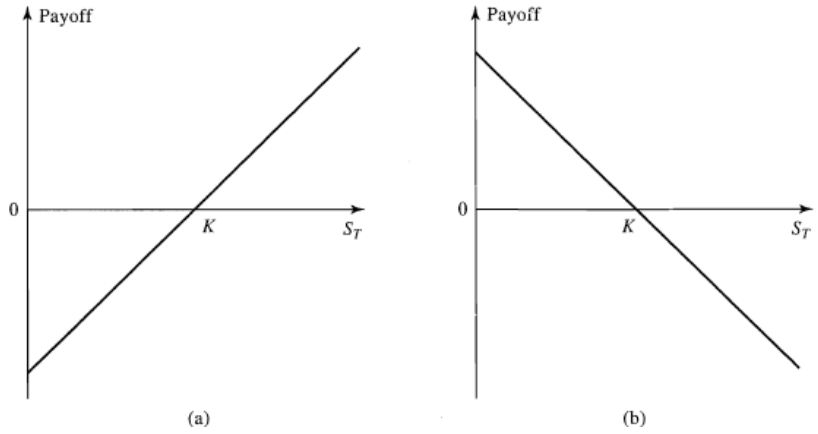
First row demonstrates that at rate of $1.4407 bank is prepared to purchase GBP and it is prepared to sell GBP at a rate of $1.4411 in the spot market. Second row shows that bank is prepared to buy GBP in 1 month at a rate of $1.4408 and it is prepared to sell GBP at a rate of $1.4413. Third row points that bank is prepared to purchase GBP in 3 months at a rate of $1.4410 and it is prepared to sell GBP at a rate of $1.4415. Fourth row determines that bank is prepared to buy GBP in 6 months at a rate of $1.4416 and it is prepared to sell GBP at a rate of $1.4422.

Hedging foreign currency risk could be provided by using of forward contracts. An example of Hull (2012); on May 24, 2010, treasurer of a US corporation has information that is company will pay £1 million pounds in 6 months (i.e. on November 24, 2010) and wants to hedge against exchange rate moves. Using the quotes in Table 2 the treasurer can agree to buy £1 million 6 months forward at an exchange rate of 1.4422. The company then has a long forward contract on GBP.

It has agreed that on November 24, 2010, it will buy £1 million from bank for $1.4422 million. The bank has a short forward contract on GBP. It has agreed that on November 24, 2010, it will sell buy £1 million for $1.4422 million. Both sides have a deal.

3.1.2. Payoffs from Forward Contracts

Figure 2:Payoffs from forward contracts; (a) long position, (b) short position. Delivery price=K; price of asset at contract maturity=ST



Before it is stated that company is obligated to buy £1 million for $1,442,200 due to forward contract. And there can be 2 different scenarios. For example, the spot exchange rate increased to 1.500 at end of 6 months and value of the forward contract is ($1,500,000-$1,442,200) = $57,800 to company. It would provide £1 million to be bought at an exchange rate of 1.4422 rather than 1.500. Or it is assumed that spot exchange rate decreased to 1.3500 at end of 6 months. Now, forward contract value is negative. ($1,350,000-$1,442,200)= -$92,200. Because, the contract would lead the company pay extra $92,200.

Basically, payoff from a long position in a forward contract on one unit of an asset is

$$= S_T - K$$

Basically, payoff from a short position in a forward contract on one unit of an asset is

$$= K - S_T$$

Where K is delivery price and St is spot price of an asset at maturity of contract. This payoffs or profit can be negative or positive. It can be easily seen at Figure 2. In the forward example, K=1.4422 and company has a long contract. When St=1.500, payoff is $0.0578 per £1; when St=1.3500, payoff is -$0.0922 per £1.

In a brief, people that think prices will go up takes a long position; people which thinks prices will go down, takes a short position

3.1.3. General Features of Forward Contracts

- Forward transactions are done not on exchange traded markets, on OTC markets and they are done between financial institutions or a financial institution and its client.
- Forward transactions can be done by helping different connection tools such as telephone, face to face.
- Prices can change according to credibility of dealers.
- Forward transactions are not standardized.
- Forward transactions cannot be assigned to third people.
- Dealers must fulfill the obligations of contracts when maturity of contract is due date.
- Forward transactions are usually divided two such as exchange rate forwards and interest rate forwards.

3.2.Futures

3.2.1. Futures Contracts

A future contract that is an agreement between two dealers to purchase or sell an asset at a certain price for a certain time in future is similar to a forward contract. However, future contracts are traded on exchange traded markets, not on OTC

markets. Dealers do not have to know each other, exchange traded market enables a guarantee that obligations in contract will be confirmed. Furthermore, one of most important things of a well working futures market is exchange center that is named “Clearing House”. Brokers fulfill the customers’ orders in this center.

It is stated before that futures contracts were traded are Chicago Board of Trade (CBOT) and Chicago Mercantile Exchange (CME), today emerged form of them is CME Group.

There are very kinds of commodities, which involve live cattle, sugar, wool, pork bellies, lumber, copper, aluminum, gold, tin etc., and financial assets, that include stock indices, currencies and Treasury bonds, form underlying assets in the various contracts.

Futures prices are also routinely reported in financial press. For instance, on October 1, January futures prices of copper are quoted as $3.5835. That is the price, exclusive of commissions, at which traders could agree to purchase or sell copper for January delivery. It is demonstrated same as other prices that are determined by the rule of supply and demand. Prices increase when more traders want to take long position, prices decrease when more traders want to take short position.

3.2.2. General Features of Futures Contracts

In a brief, the general features of futures contracts:

- Future contracts are traded on exchange traded markets.
- Parties on the contract are not responsible to each other, they are responsible to exchange center. So, there is no credit risk for two sides.
- Future contracts are standardized and they can be bought or sold until delivery date.

- The goods on the futures contracts must be homogenous, have raw material ability, prices of them should be determined in response to supply and demand, they can be stored, and the quality test of them could be easy.
- Moreover, the liquidity of goods on the futures contracts ought to be high.

In practice, futures contracts are done on agricultural products, natural resources, foreign exchanges, fixed interest rate debt tools and stock indices.
Moreover, futures contracts which are done on foreign exchanges, fixed interest rate debt tools and stock indices are called “financial futures contracts” in practice.

3.2.3. Standard Elements of Futures Contracts

- Product, Security or Financial Indicator on The Contract
- Delivery Months

Delivery month is the date for cash agreement or physical exchange. Generally standard dates are determined like March, May, June, September and December periods. There can be different periods for different countries.

- Contract Size

Contract size is minimum transaction amount of product in the contract.

- Delivery Arrangements

Delivery arrangement shows which way will be used on the due date, cash agreement or physical delivery.

- Settlement Price

Settlement price is the price that is used in calculation of daily gain or loss and margin liabilities.

- Maturity Date

Maturity Date is the last day for transaction on the contract.

- Margin Rates

Margin rate is the ratio that must be kept available at account for initial and continuous margins.

- Tick Size / Minimum Price Movements

Tick size or minimum price movements are the minimum price movements.

- Daily Price Movement Limits

Daily price movement limits are the lower and upper limit for price of a future contract in a day.

- Position Limits

Position limits are the maximum number of positions that are owned by a firm or an account.

3.3.Options

3.3.1. Option Contracts

Options can be traded both on over-the-counter and in exchange traded markets. An option generally includes the information below:

- Type of Option: European or American Option

In European options, investor that buys the option has a right to sell or purchase only at the maturity date. In American options, investor that buys the option has a right to sell or purchase at any time (maturity date also can be possible). Moreover, European options do not mean they are sold in Europe or American options do not mean they are sold in USA. Today, two types of options are traded both on Europe and America.

- Type of Contract: Call or Put Option

There are two kinds of options that are "call option" and "put option". If investor that has the right to buy underlying asset at a certain price for a certain date in future, this situation is called "call option". Moreover, if an investor that has the right to sell underlying asset at a certain price for a certain date in future, this situation is called "put option".

- Commodity or Security in the Option Contract: Stock, Bond etc.
- Premium of Option: Price of an Option

Price of option in the contract is the amount per share that an *option* buyer pays to the seller. Furthermore, most of options that are traded on exchanges are American. There are 100 shares to buy or sell in the contract in the exchange

traded equity option market. The analysis of European options is also easier than American options.

Option contracts are very similar to payment of insurance premiums. For example, houses and materials in the home are insured due to risks of theft or fire and so insurance premium is paid. If house is fired or materials in house are stolen, insurance company pays the loss of person who paid premium before. Now, a portfolio manager buys a put option to make loss at minimum due to negative changes or price declines in the spot market. This shows that house insurance is too similar to buying a put option.

Moreover, when a portfolio manager buys a put option, this transaction is called "portfolio insurance" in the literature of finance.

3.3.2. Payoffs from Options Contracts

Table 3: Prices of Call Options on Google, June 15, 2010; stock price: bid $497.07; offer $497.25 (Source: CBOE)

Strike price	July 2010		September 2010		December 2010	
($)	Bid	Offer	Bid	Offer	Bid	Offer
460	43.30	44.00	51.90	53.90	63.40	64.80
480	28.60	29.00	39.70	40.40	50.80	52.30
500	17.00	17.40	28.30	29.30	40.60	41.30
520	9.00	9.30	19.10	19.90	31.40	32.00
540	4.20	4.40	12.70	13.00	23.10	24.00
560	1.75	2.10	7.40	8.40	16.80	17.70

Table 3 considers bid and offer quotes for a few of call options trading on Google. This table also demonstrates that the price of call option goes down when strike price goes up. There is a reverse proportion between them.

For example, it is assumed that an investor decides to buy a December call option contract on Google with an exercise price 520$. According to Table 3, offer price is $32, but this is a price for a share of option. It is also stated that options contracts are done with 100 shares in the USA. So, investor will have a cost $3200 and a right to purchase 100 Google shares for $520 each one. If the price does not increase above the $520 by 18th December, 2010, investor will have a negative profit - $3200. Because, option is not exercised.

Or it is assumed that bid price of stock is $600. Consequently, investor will buy 100 shares at $520 and suddenly sell at $600 then profit is $8000, but when the initial cost of option is calculated, net profit is $4800.

Table 4: Prices of Put Options on Google, June 15, 2010; stock price: bid $497.07; offer $497.25 (Source: CBOE)

Strike price	July 2010		September 2010		December 2010	
($)	Bid	Offer	Bid	Offer	Bid	Offer
460	6.30	6.60	15.70	16.20	26.00	27.30
480	11.30	11.70	22.20	22.70	33.30	35.00
500	19.50	20.00	30.90	32.60	42.20	43.00
520	31.60	33.90	41.80	43.60	52.80	54.50
540	46.30	47.20	54.90	56.10	64.90	66.20
560	64.30	66.70	70.00	71.30	78.60	80.00

Table 4 considers bid and offer quotes for a few of put options trading on Google. Moreover, this table determines that price of a put option increases when strike price rises. There is a directly proportional between them.

For example, it is assumed that an investor decides to sell a September put option contract on Google with an exercise price 480$. According to Table 4, bid price is $22.20 and with 100 shares on the contract, cash inflow is 100*$22.20= $2220. If the stock price of Google remains above $480, option is not exercised and

investor will have a profit $2220 at the end. However, when stock price of Google decreases to $420, then investor will have a negative profit ($420-$480)*100= $6000, but if initial profit is taken account, total loss or negative profit is $3780 (= -$6000+$2220)

Figure 3: Net profit per share from (a) purchasing a contract consisting of 100 Google December call options with a strike price of $520 and (b) selling a contract consisting of 100 Google September put options with a strike of $480.

3.3.3. Basic Elements That Determine Option Prices

- Cash Market Price of the Product on the Contract (S)
- Price of Option Usage (K)
- Volatility (σ)
- Remaining Time to Use the Option (t)
- Risk Free Rate (r)

Table 5: The Effect of Basic Elements That Determines Option Prices to Option Premium

	C (Call Option)	**P (Put Option)**
S	Increases	Decreases
K	Decreases	Increases
σ	Increases	Increases
t	Increases	Increases
r	Increases	Decreases

3.3.4. Main Two Differences of Options from Forward-Futures:

There are two very important things to distinguish options from forwards and futures; an investor has a right to do something on option. But, investor does not have to exercise the right. Second one is that there is no cost to enter a forwards or futures contracts. However, there is a cost of getting an option.

3.4.Comparison of Forward-Futures-Option

Table 6: Comparison of Forward-Futures-Option

Basic Features	Forward	Futures	Option
1) Tool for Hedging Risk	Yes	Yes	Yes
2) Standard Contracts	No	Yes	Yes
3) Exchange Traded / OTC	OTC	Exchange Traded	Exchange Traded and OTC
4) Physical Delivery	Yes	Generally No	If right is used, Yes
5) Obligation for Margin	Generally No	Yes	Yes for Seller
6) Cash Flow until Maturity Date	No	Yes	Yes for Seller
7) Credit Risk	Yes	No	No
8) Leverage Effect	There is no Importance	Yes	Yes
9) Combination of Rights and Obligations	Yes	Yes	No

3.5.Types of Traders Which Make Transactions on Derivative Market

Traders are categorized to three such as hedgers, speculators and arbitrageurs.

3.5.1. Hedgers

Derivatives are used by hedgers to decrease the risk due to negative changes in the future. Investors take long position futures contracts to avoid price increments in the future. When investors have expectations of price decrements in future, they take short position of futures contracts.

Hedging transactions are used by portfolio managers, bankers in financial markets and they are also used by firms that use some goods like raw materials in goods markets. For instance, a portfolio manager can sell futures contracts on stock indices instead of selling portfolio stocks in the spot market to increase the performance of portfolio, to decrease the risks that are owned and to diversify portfolio. So, company cannot be affected by possible price decrements in the spot market. Moreover, especially foreign traders sometimes use futures markets products to hedge the risks that are originated by spot markets in developing countries.

Example: Hedging Using Options

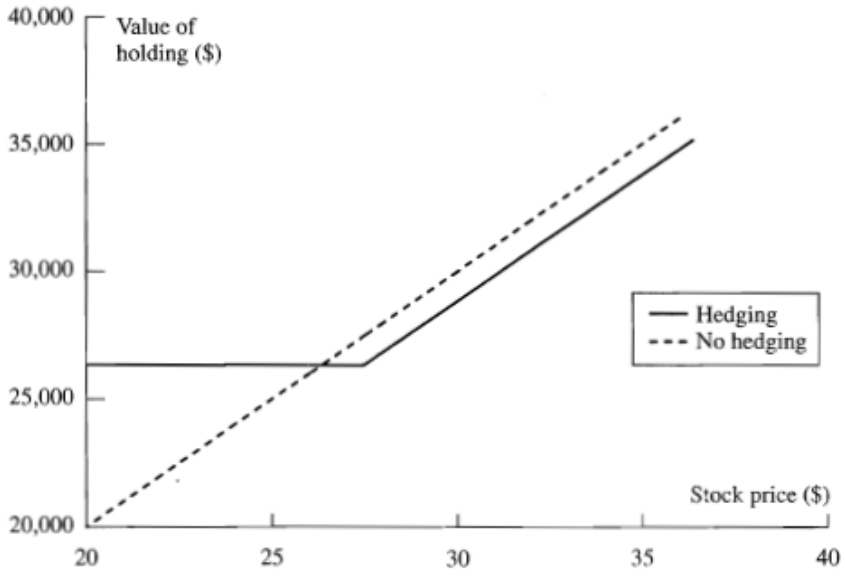
It is assumed that a trader has 1000 Microsoft shares in May of 2004 and the share price is $28 for one share. Trader has a negative expectation for share prices in next 2 months and wants to be protected. Trader buys 10 July put option contracts at $27.5 strike price on CBOE. Now, trader has a right to sell 1000 shares with the price $27.5. Quoted option price is $1 and then each option contract will cost $100 (=100*$1), then total cost will be $1000 (=10*$100).

The cost of this hedging strategy is $1000, however it is guarantee that shares could be sold at minimum $27.5 for each share until maturity date of option. When market price of Microsoft shares go down of $27.50, option will be used

and $27500 will be gained. But, if initial cost is taken account, at total $26500 ($27500-$1000) will be gained.

But, when market price is above the $27.5, options will not be used. Net value of portfolio that is relevant with stock price of Microsoft is considered at Figure 4.

Figure 4: Value of Microsoft holding in 2 months with hedging and without hedging.



3.5.2. Speculators

Derivatives are used by speculators to bet the future market variables. Speculators have significant advantages in the futures markets due to leverage effect. Furthermore, transactions of speculators increase the liquidity of the market and volume of transactions, although they sometimes cause immediate price movements.

Example: Speculation Using Options

It is assumed that a speculator demonstrates that a stock will increase in 2 months, now in October. Current stock price is $20 and strike price $22.50 of a 2 month call option is sold now for $1. Two choices are showed in Table 8. Speculator also plans to invest $2000. First alternative is buying 100 shares and second one is buying 2000 call options that mean 20 call option contracts. It is assumed that

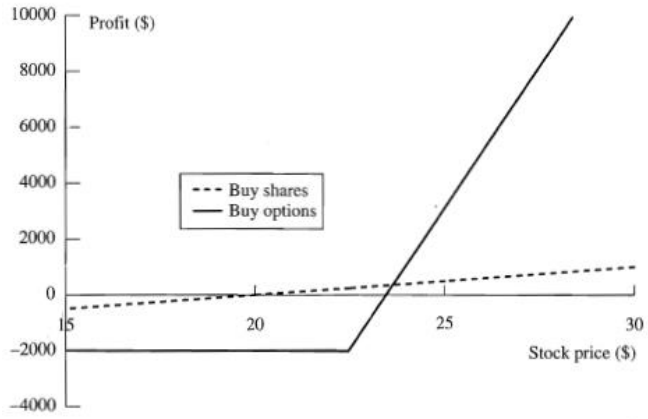
speculator is right and stock price increased to $27 in December. Profit of the first choice is 100*($27-$20) = $700. Second one's gross profit is 2000*($27-$22.5) = $9000. But, if options premium is included net profit is $9000-$2000= $7000.
In here, options are 10 times more profitable according to directly buying the stock. However, options can be cause more loss according to directly buying the stock. For example, stock price decreases to $15 in December. Profit of first choice is 100*($20-$15) = $500. If second choice is considered, option will not be exercised; this will cause a loss of $2000. Figure 5 demonstrates profit or loss of strategies.

These results show that options enable leverage like in futures. In options, good results become very good, but bad outcomes cause loss of all initial investment.

Table 7: Comparison of profits from two alternative strategies for using $2000 to speculate on a stock worth $20 in October.

	December stock price	
Investor's strategy	$15	$27
Buy 100 shares	-$500	$700
Buy 2000 call options	-$2000	$7000

Figure 5: Profit or loss from two alternative strategies for speculating on a stock currently worth $20



3.5.3. Arbitrageurs

Positions in two or more instruments are equalized by arbitrageurs to lock in a profit. Arbitrageurs aim to gain risk free profit with benefiting from price inequalities between markets. For example, if a good is traded in different regions, arbitrageur purchases good from the cheap place and sells good to expensive region and so risk free profit is gained. Similarly, when there is a different price from the price that should be included the transportation cost between spot and futures markets, arbitrageurs start to buy cheap region and to sell the expensive region, then markets are equalized. These transactions make the market to be real price. However, there is no way to get risk free profit with arbitrages in efficient markets.

3.6.Swaps

Swap means exchange. Swaps are financial transactions in which 2 parties change their payments with each other at a certain time period. The basic purpose of swaps is decrease the risk and uncertainty due to changes in interest rates and exchange rates with benefiting from different advantages of different markets of parties.

Generally, swaps provide financial managers to decrease risk and increase their revenue.

General reasons for swaps transactions:

- Difficulties or easiness of reaching exchange rate funds.
- Difficulties to obtain fixed interest rated funds versus easiness of getting variable interest rate funds.
- Existence of different corporate and structural at different financial markets.
- Parties have different credit ratings at different markets.

Counterparties in swap transactions are generally categorized into two groups that are fund users and brokers. Fund users make swap transactions because of decreasing the interest rate and exchange rate risk that are caused by economic and fiscal reasons. Brokers make swap transactions due to gaining commission and profit. Counterparties of swap transactions:

- Enterprises
- Financial companies
- International companies
- Agents that give loan credits
- Governments agents

3.6.1. Interest Rate Swaps

Two parties, that have different credit ratings, exchanges their interest rate payments which have different interest rate conditions, but at same amount. In interest rate swaps just interest rate payments due to debts are changed, capitals are not altered. Maturity is differs from 1 year to 15 years. General interest rate swap types are fixed-variable interest rate swaps, variable-variable interest rate swaps and variable-variable interest rate swaps.

3.6.1.1.Fixed-Variable Interest Rate Swaps

Counterparties have different credit ratings and they make the swap transaction with changing debts' interest rates at same maturity and amount. With this transaction, one of counterparty gives up variable interest debts and it obtains a fixed interest debt structure. This protects itself to possible risks in future. Other counterpart, who has an expectation of decrease in interest rates in future, gives up fixed interest debts and it obtains a variable interest debt structure.

3.6.1.2.Variable-Variable Interest Rate Swaps

These types of swap are also known as "basis swap". The aim is to benefit from differences in different variable interest rate markets. These swaps are used to

hedge or make arbitrage. For instance they are applied in between LIBOR and TIBOR, or in between USD PRIME RATE and LIBOR.

3.6.1.3.Fixed-Fixed Interest Rate Swaps

Fixed interest rate debts that are at different currencies are exchanged. The basic purpose is to decrease uncertainty and risk due to changes in foreign exchange rates.

3.6.2. Currency Swaps

This means the two money movements, which are in same amounts and are different currencies, are exchanged with a predetermined rate until maturity date, money are paid back to original owners after maturity date.

Main reasons for usage of currency swaps:

- A corporation cannot find a loan with desired currency.
- A corporation can find a lower cost loan with a different currency

A currency swap could be implemented like:

a) Exchange of money
b) Changing and paying interest rates
c) Paying back capital money at maturity date.

3.6.3. Commodity Swaps

Reasons of companies for commodity swaps:

- Protecting themselves due to price fluctuations
- Closing the open positions related to commodities.

Commodity swaps are especially used in petroleum futures contracts to 5 years. This method means counterparties change fixed and variable price of a commodity, which is determined amount and quality, with a contract in a determined period. Furthermore, both producers and consumers protect themselves due to price movements with this application.

3.7.New Generation Derivatives

3.7.1. Warrants

- Warrants, which are organized after bond issues, are a kind of call options.
- Maturity long of warrants is usually a year.
- After warrants are organized, they can be bought or sold apart from bonds in some situations.

3.7.1.1.Stock Warrants

- A corporation, that has N stocks on circulation, issues M warrants.
- Each warrant includes a right to buy Y stocks.
- This buying right is given at time T and at price X.
- If the net asset value of company is V and if warrant owner uses right of buying, cash inflow to the company will be equal to MYX.
- The net asset value of company goes to V + MYX
- The net asset value of company will be divided to (N + MY) stocks.
- After usage of warrant, immediately stock price will be (V + MYX) / (N + MY)
- The amount that will go to warrant owner:

  Y [(V + MYX) / (N + MY) – X]

If this amount positive (+), warrant is used; reverse warrant is not used.

3.7.2. Exotic Options

- Exotic options are organized to compensate the specific needs of companies.
- They have more complex structure than classical European and American option types.
- They are generally sold or purchased in OTC markets.

3.7.2.1.Types of Exotic Options

They are not transacted in stock market exchange. They come to forefront with creative attributes.

Types of Exotic Options:

- Equity collars
- Equity warrant
- Chooser option-as you like it
- Compound options on options
- Installments options
- Pay-later options
- Asian options
- Barrier options
- Lookback options
- Rainbow options
- Basket options
- Quantos
- Forward start options etc.

3.7.3. Futures Options

The asset, which is subject of the option, is futures contracts in these types of options. The most popular examples are options organized on treasury bills futures contracts in CBOT and options organized on Eurodollar futures contracts.

SECTION FOUR

4. FINANCIAL DERIVATIVE PRICING MODELS

4.1.Forward Pricing Model

The formula of a forward pricing is like:

$$F_0 = S_0 e^{rT}$$

It is assumed that a forward contract on an investment asset at price S_0 that enables no income.

r= risk free rate

T= time to maturity

F_0= forward price

Example: It is assumed that a long forward contract to buy a non-dividend paying stock in 3 months. Current stock price is $80 and risk free rate is 5% is per year.

Situation 1:

If forward price is too high at $90. An arbitrageur could borrow $80 and r= 5 % per year, buy a share and short a forward contract to sell a share in three months. Arbitrageur gets $90 from selling the share after 3 months. Sum of money required to pay the debt:

80*e^ (0.05*3/12) = $81

So, arbitrageur gets $90-$81 = $9 profit.

Situation 2:

If forward price is too low at $70. An arbitrageur can short a share, makes a short sale at 5% risk free rate per year, for 3 months and gets a long position in a 3 months forward contract. The cost of short sale is 80*e^ (0.05*3/12) = $81 in 3 months. However, arbitrageur pays $70 and then net profit is $81-$70= $9 at end of 3 months.

4.2.Futures Pricing Models

4.2.1. Cost of Carry Model

Pricing of futures contracts is based on Cost of Carry Model. This model is used to determine value of futures contracts on products that are not financial. It also used in determining value of future contracts on financial products.

The model measures the relationship level between price of products or financial assets and futures price. Futures price should be higher than cash price at any time period before delivery time. Because, there is a cost of carry. Cost of carry includes:

- Cost of financing to purchase (interest rate cost)
- Stock cost
- Insurance cost
- Freight cost
- Potential other costs when carrying period

The model is formulized like:

Futures Price = Cash Price + Unit Financing Cost + Unit Stock Cost

$F_{ct} = S_t + (S_t * R_{t,T}*(T-t)) / 365 + G_{t,T}$

F_{ct} = Futures price at time t , that will be delivery at T.

S_t = Cash price at time t

$R_{t,T}$ = Risk free rate that can be loaned at time t for T-t period

$G_{t,T}$ = Stock cost of the product at period T-t

This model is valid when some assumptions are applied. They are:

- There should not be the cost of information or transaction that can affect buying or selling the quantity of product or futures contract.
- There should not be any restriction on the amount of lending or borrowing.
- Lending or borrowing rate should be done on same risk free rate.
- There should not be any margin risk.
- There should not be a change in features of products until maturity date.
- There should not be taken any tax.

Relationship between cash price and futures price can be formulized in Cost of Carry Model as:
Cost of Carry = Futures Price – Cash Price

In developed futures markets, there is no difference between futures price that is occurred and futures price that is calculated theoretically. First reason of that is the efficiency level of market is too high. Second reason is that arbitrage facility prevents this difference.

Consequently, arbitrage relationship between cash and futures market is very important to price future contracts.

Example:
Purpose: buying a C. gold after a month.
How can it be bought?

- An agreement now and buy the gold at F price at end of month.
- Loan can be taken now, can be purchased the gold and loan can be paid at end of month.

Situation is same for two choices. These two alternatives mean different portfolios, but the result is same and so costs should be same.
Spot price = TL 300
Interest rate per month = 1%
Expiration date = 1 month
2nd choice: A loan is taken at TL 300 and gold is bought for TL 300… Loan is paid at end of month. 300*1.01 = 303 TL After transactions a gold is bought and TL 303 is paid.
Two portfolios have same results; this means gold price after a month is TL 303.
Arbitrage facility with different price:

Situation 1:
If price is not TL 303, it is TL 305:

A futures contract is sold (short position). TL 300 is loaned from bank and a gold is boght at TL 300. Then futures contract is sold at TL 305 after a month and the loan TL 303 is paid and then profit is TL 2 (= TL 305 - TL 303)

Situation 2:
If price is not TL 303, it is TL 300:
Gold is short sold and futures contract is bought to close it. TL 300 is deposited at bank. Value of money is TL 303 after a month. TL 300 is paid for future contract. Net profit is TL 3 (= TL303 – TL 300)

Two situations show the arbitrage. So, futures price should be at TL 303 not to be an arbitrage.

4.2.2. Stock Indices Model

A significant feature is taken account in determination the value of stock indices futures contracts in developed country stock markets. The important feature is that two different portfolio investments are equivalent. First portfolio is consisted with buying assets that forms the indices. Second portfolio is consisted with purchasing stock indices futures contracts and stocking treasury bills whose value is equal to initial value of indices.

1st way: Value of indices at the end of period + Dividend payment
2nd way: (Value of indices at the end of period – Value of indices that is considered in contract) + Value of T bill at the end of period.

E_t : Value of indices at initial date of period
E_{t+1} : Value of indices at end of period
E_s : Futures price of indices in contract
T : Dividend payment
HB_{t+1} : Value of T bill at end of period.
r : Effective interest rate
d : Dividend Yield

Derivation of futures price of indices is showed below step by step:

1. $E_{t+1} + T = E_{t+1} - E_s + HB_{t+1}$ (Value of 1st portfolio at end of period = Value of 2nd portfolio at end of period)
2. $T = - E_s + HB_{t+1}$
3. $HB_{t+1} = (1+r)* E_t$
4. $T = - E_s + (1+r)* E_t$
5. $E_s = (1+r)* E_t – T$
6. $d= T / E_t \Rightarrow T= E_t * d$
7. $E_s = (1+r)* E_t - E_t * d$
8. $E_s = E_t + (r-d)* E_t$ (General Formula of Futures price of indices)

Example:

E_t = TL 23000

r= 80 % (with simple interest rate 20 % for 3 months)

d= 16 % (4 % for 3 months)

Date= 3 months

$E_s = E_t + (r-d)* E_t \Rightarrow E_s = 23000 + (0.20-0.04) * 23000$

E_s = TL 26680

The proof of stock indices futures pricing method is below:

Cost of Debt for 3 months = 80% * 23000 * (90/360) = TL 4600

Dividend Yield for 3 months = 16% * 23000 * (90/360) = TL 920

Balance Contract Price is = 23000 + 4600 – 920 = TL 26680

In addition to above explanations and example, formula of theoretical exchange rate futures pricing is like $\mathbf{F = S*[(1+r_dT/365)/(1+r_fT/365)]}$

4.3.Option Pricing Models

4.3.1. Black and Scholes Model

In the world, Black and Scholes Model, is developed by Fischer Black and Myron Scholes in 1973, consists the basic of most of derivative pricing models. The Black-Scholes model is one of the most commonly used models to price European

calls and puts. It serves as a basis for many closed-form solutions used for pricing options. The standard Black-Scholes model is based on the following assumptions:

- There are no dividends paid during the life of the option.
- The option can only be exercised at maturity.
- The markets operate under a Markov process in continuous time.
- No commissions are paid.
- The risk-free interest rate is known and constant.
- Returns on the underlying stocks are log-normally distributed.

The basis of the model is to make a portfolio that has a return of risk free rate with taking a long position at call option account and taking a short position at put option account. It is arbitrage theorem with a different point of view.

The value of call option, C, is calculated like:

$C = SN * d_1 – K * (e^{(-rt)}) * Nd_2$ =>>

$d_1 = \ln(S/Ke^{(-rt)}) / \sigma (t^{1/2}) + 0.5 \sigma(t^{1/2})$

$d_2 = d_1 - \sigma (t^{1/2})$

ln = natural logarithm

N (.) = cumulative probability distribution function for standard normal variables

S= Cash Market Price of the Product on the Contract

K= Price of Option Usage

σ= Volatility

t= Remaining Time to Use the Option

r= Risk Free Rate

All the variables are expressed above. Four factors that are desired for model can be easily gathered. However, only volatility (σ) cannot be calculated exactly.

The value of put option, P can be calculated with using the pricing relationship between call option and put option (put-call parity).

$P= C + K* (e^{(-rt)}) – S$

If relationship between values of call and put options remove, then there will be an arbitrage opportunity.

When pricing relationship between call-put options and value of call options are combined, the value of put option is calculated like:
$P= Ke^{(-rt)} * (1 – Nd_2) – S * (-Nd_1 + 1)$

Moreover, Morton developed the Back and Scholes Model. Morton did not use capital asset pricing model (CAPM) in his technique while Black and Scholes had used CAPM model to price options.

4.3.2. Addition to Option Pricing-Factors that affect the Option Premium

Black Scholes Model is demonstrated in previous parts. It is not easy to understand the model and to calculate without a calculator. So, knowing how to comment factors affecting the option premium will be beneficial, instead of knowing details of how model works. Because, there are many calculators that calculates option premiums according to this model on internet or stock market websites.

Basic elements that affect the option premium are stated before, but not in detail. Now, direct factors affecting option premium, possible changes with these factors will be considered.

Firstly, main content of an option premium is intrinsic value and time value.

Factors of Intrinsic Value:	Factors of Time Value:
Type of option (Call/Put)	Time to maturity
Underlying Asset Price	Volatility rate
Strike Price of Option	Risk free interest rate
	Dividend (valid for just equities and equity indexes)

For instance, at maturity date, a call option with an underlying asset price of TL10 and strike price of TL9, so intrinsic value is TL1. Another example is a put option with a strike price of TL11 and an underlying asset price of TL10, so intrinsic value is TL1.

In addition to intrinsic value, more important thing in option pricing is to know option has how much time value. Moreover, with maturity date, options have no time value and their premium is calculated according to just their intrinsic value.

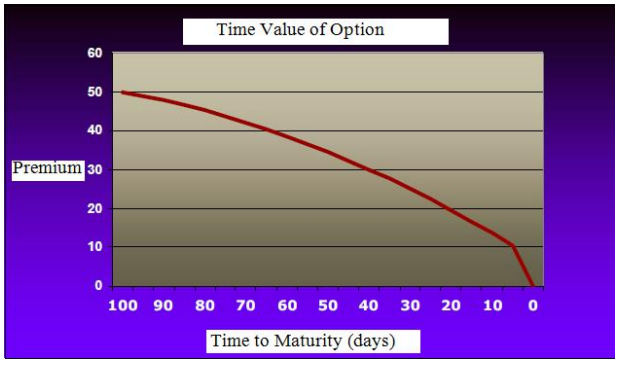
Now, factors of option's time value that affect the option premium are below to understand premium of options before maturity date.

4.3.2.1.Remaining Time to Maturity

If maturity of an option is long, then volatility probability of underlying asset and movement probability of option with a profit way to beneficiary increase. This also raises the value of option. Because, said probabilities increase the probability loss of seller investor. Consequently, seller investor demands extra premium and then price of option raise.

Moreover, when maturity of option closes, said risks decline and so they prefer to sell more and they decrease price of options. So, with this logic when maturity of option closes, time value of option decreases fast.

Figure 6: Time Value of Option Graph



Furthermore, time value of intrinsic value, non-intrinsic value and breakeven options have different contributions to their premiums. Much of high intrinsic value option premiums are covered by intrinsic value, so time value is little in premium of these types of options. In addition, very non-intrinsic value options are very far from their intrinsic value, so probability of being intrinsic value is nearly zero, so time value of options is little due to very low premium. Moreover, many probabilities can be occurred in breakeven options. So, options are sometimes intrinsic value and sometimes non-intrinsic value options and their probability to be intrinsic or non-intrinsic contributes positively to their premium. Time to maturity mostly affects premium of breakeven options.

4.3.2.2.Volatility Ratio

Volatility means that price of underlying asset goes up or down from its price level in a specified time. For instance, volatility rate is stated like 10%; it can be understood that price of underlying asset can go up or down to 10% from its level.

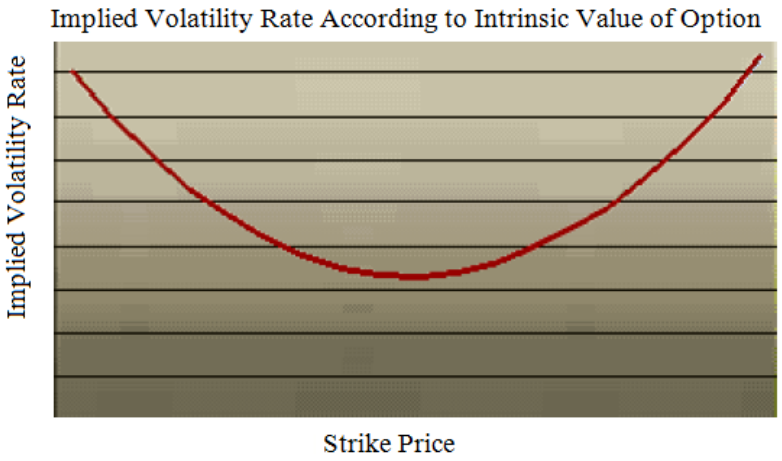
When volatility increases, premium of options raises in which it is not important call or put options. When it volatility decreases, it declines.

There are two types of volatility such as historical volatility, which is calculated according to historical price movements, and implied volatility, in which future volatilities are reflected in it. Implied volatility is used in options market.

Implied volatility of high intrinsic value options or low intrinsic value options are much than implied volatility of breakeven options. For instance, in the Figure 6, there is call option in graph. Strike price increases to right and when strike price of call option raise, it becomes more non-intrinsic value options.

Call option is high intrinsic value and high non-intrinsic value when strike price is very low or very high. Consequently, implied volatility is high. Implied volatility is very low in breakeven point. Same situation is valid for put options.

Figure 7: Implied Volatility Rate



4.3.2.3.Risk-free Rate

Increase in risk free rate decreases the present value of option strike price. So, it increases call option premium. This also means lower strike price.

Increase in risk free rate decreases the premium of put option and strike price declines. So, premium price of put option decreases.

4.3.2.4.Dividend

Dividend is a variable that is just accounted in index options and equity options. Dividend causes decrease in price of equity. So, a call option premium that is occurred by an index including dividend payer companies is lower than a call option premium that is occurred by an index involving no-dividend payer companies. Consequently, dividend decreases the call option premium.

However, dividend payment increases the value of put option premium. Because, when company pays dividend, value of equity (underlying asset) decreases and this also increases put option premium.

A brief to now: Factors affecting the Option Premium

	Call Option	Put Option
Underlying Asset Price	+	-
Strike Price	-	+
Time to Maturity	+	+
Volatility	+	+
Risk-free Rate	+	-
Dividend	-	+

4.3.2.5.Delta

If underlying asset price of an option changes one unit, Delta shows the how much decrease or increase in option premium.

Delta is stated like percent and maximum is 100% and minimum is 0%.
Delta of a high intrinsic value option is nearly 100%. Delta of breakeven value option is approximately between 40% and 55%. Delta of a high non-intrinsic value option is about 0%.

Delta of an option also differs according to change in time. For example, delta of an option whose time to maturity is 1 year is different from delta of an option whose time to maturity is 3 months. When maturity lengthens, delta of call option increases, otherwise delta of put option decreases.

If it is call option, delta is considered with positive percent numbers and if it is put option, it is reverse of before.

4.3.2.6.Gamma

If price of economic indicator or underlying asset changes one unit, Gamma shows the change how many units in delta of option.

4.3.2.7.Vega

If implied volatility of underlying asset changes 1% (It is an absolute value like from 30% to 31%), Vega shows the how much change in option premium.

Contribution of Vega to option premium also differs with time to maturity (days). When time to maturity increases, probability of volatility in broader price band is high, so contribution of volatility to option premium grows. In reverse situation, its contribution decreases.

4.3.2.8.Theta

Theta measures the option premium how much decline with one more day closer to maturity date. It is always stated with negative (-) values, as time progress decreases value of price of option.

4.3.2.9.Rho

When interest rate changes with a rate of 1%, Rho shows the how much change in option premium.

4.3.3. Black Model

Black model is used for pricing European options on physical commodities, forwards or futures. The Black model supported by Financial Derivatives Toolbox of MATLAB software is a special case of the Black-Scholes model. The Black model uses a forward price as an underlying in place of a spot price. The assumption is that the forward price at maturity of the option is log-normally distributed.

4.3.4. Roll-Geske-Whaley Model

Roll-Geske-Whaley approximation method is used to price American call options paying a single cash dividend. This model is based on the modification of the

observed stock price for the present value of the dividend and also supports a compound option to account for the possibility of early exercise. The Roll-Geske-Whaley model has drawbacks due to an escrowed dividend price approach which may lead to arbitrage.

4.3.5. Bjerksund-Stensland 2002 Model

Bjerksund-Stensland 2002 model is used for pricing American puts and calls with continuous dividend yield. This model works by dividing the time to maturity of the option in two separate parts, each with its own flat exercise boundary (trigger price). The Bjerksund-Stensland 2002 method is a generalization of the Bjerksund and Stensland 1993 method and is considered to be computationally efficient.

4.3.6. Garman-Kohlhagen Model

Garman-Kohlhagen Model is similar to Black and Scholes Model. It takes account spot exchange rate, strike price, annual remaining time to maturity, cross currency risk free interest rate, annual volatility in transaction date and base currency risk free rate respectively in MATLAB model. It is specialized for fx option pricing.

4.4.Swap Pricing Models

Swaps are generally like futures contracts collection. Moreover, they are as futures contracts each of whose periods is considered separately. Consequently, swap pricing models are not going to be demonstrated privately.

4.5.Warrant Pricing Models

The technique of warrants is same with options. They are just different from options juristically. Options are contracts while warrants are securities. So, it is not necessary to analyze warrant pricing models privately.

Note: General and historical information, which involve definitions, market types and historical development of market, about derivatives and financial derivatives are included. Analysis and research of different financial derivatives such as forward, futures, options, and swaps are also explained intensively. They are compared in different examples to understand the differences between them. Furthermore, types of traders which make transactions on derivative market are demonstrated and compared according to use of which instruments. Moreover, new generation derivatives are considered. Then different financial derivative pricing models are showed.

Now, derivative products just in exchange traded markets in Turkey will be demonstrated detailed. Because, there is no sufficient information about pricing applications of OTC market in Turkey as before stated over-the-counter market products are not standardized and so trying to find optimal pricing of them is not plausible.

SECTION FIVE

5. DERIVATIVE MARKETS in TURKEY

5.1.OTC Market

The development of futures and option market was late compared to improvement of it in the world. There was a market in Turkey like that prices and exchange rates had been determined by the government until 1980s and capital flows had not been free until 1989. Shortly, there was no a price risk that can be sell. Consequently, there was no need for derivative products as forwards, futures or options. However, usage of derivative products increased so much in parallel with high development of financial markets. Furthermore, approximately all of the derivative products are traded on OTC market.

Figures about foreign exchange-gold contracts and other derivatives OTC Market are stated below by source of The Bank for International Settlements (BIS), has been coordinating a Triennial Central Bank Survey of Foreign Exchange and OTC (over-the-counter) Derivatives Markets.

Figure 8: Foreign Exchange and Gold Contracts OTC Market (in millions of USD)

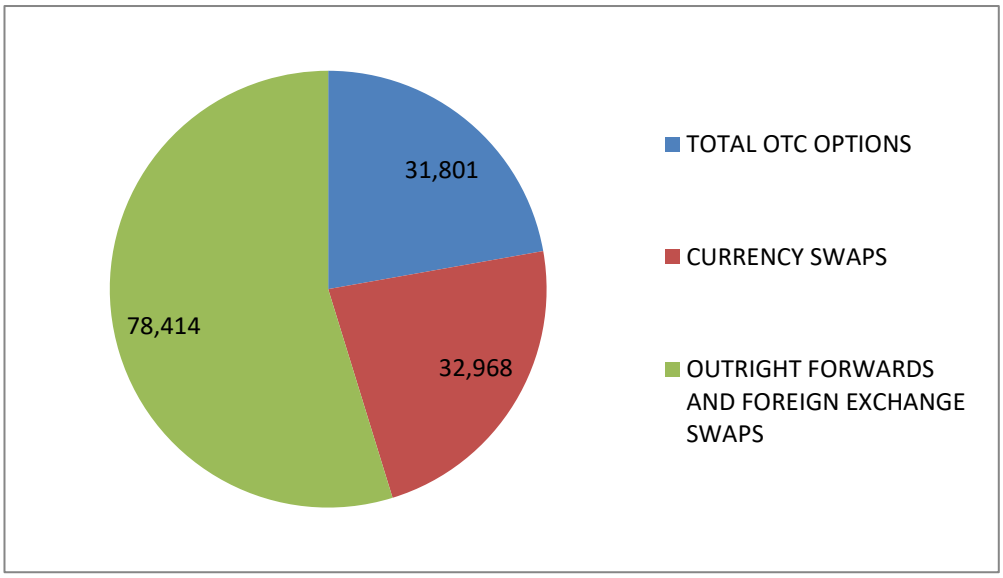
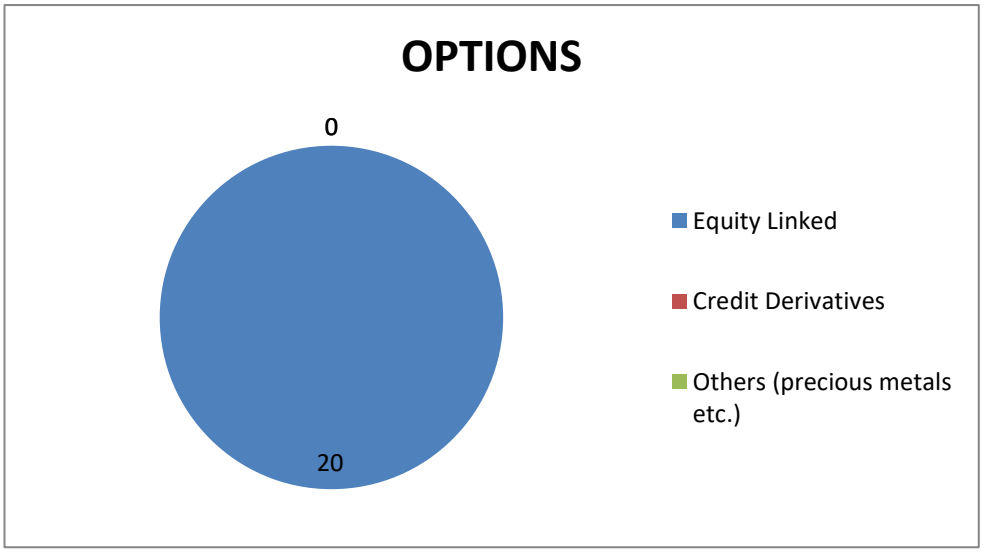
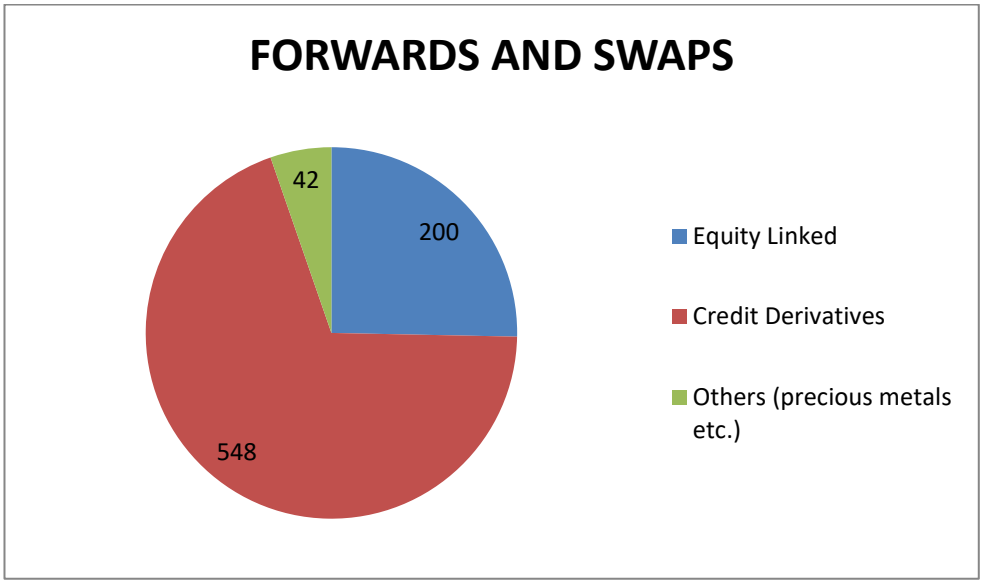


Figure 9: Equity, Commodity, Credit and "Other" Derivatives OTC Market (in millions of USD)

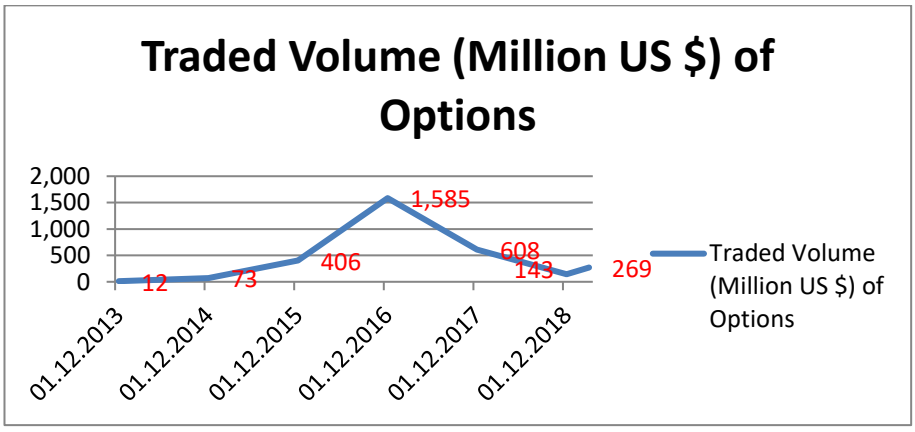


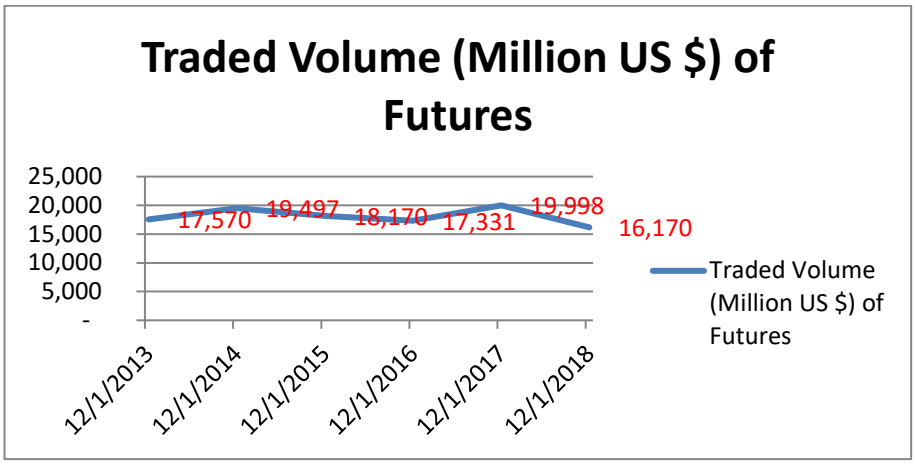


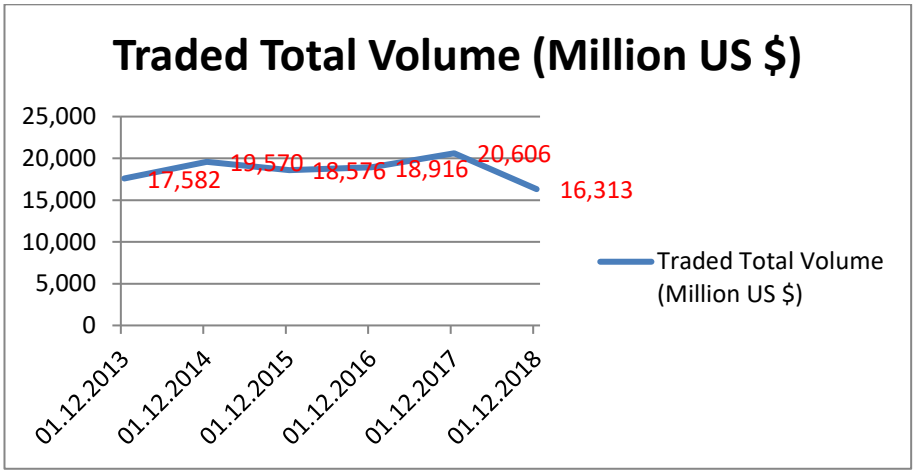
5.2.Exchange Traded Markets

Situation of OTC market in Turkey is considered previous section. An exchange traded market-Futures and Option Market (VİOB)-was opened to enable the use of options by more people in 21st December, 2012. Moreover, there was also VİOP A.Ş. in which futures and some commodities are traded. All of them merged in the name of VİOP and today it is under the framework of Borsa Istanbul A.Ş. (BİST). Both of stocks are going to be explained detailed in following sections. Volume of options, futures market and their sum are at below according to BİST dataset.

Figure 10: Volume of Options, Futures and Their Total Values







5.3.Organization Structure of Exchange Traded Markets and Parties

Parties operating at exchange traded markets can be considered at 5 main groups according to their functions:

- Stock market
- Clearing house
- Intermediary institutions (Members)
- Market participants
- Supervisory institutions

5.3.1. Stock Market

There are two types of stock market such as cooperative stocks and private stocks in the world. Cooperative stocks are founded and managed by members. There is no profit purpose for this type of stock markets. Structure of cooperative stock markets turned to profit aimed private stock markets in recent years. For instance, Chicago Board of Trade (CBOT) and Chicago Mercantile Exchange (CME). Reason for that is to adapt the changed conditions and to compensate the expectations of market effectively.

Moreover, high competition between stock markets caused the merges. For example, German Exchange Traded Market (DTB) and Switzerland Stock SOFEX combined and they founded EUREX.

VİOP was also founded in a status of incorporation company and electronic operating system has been using.

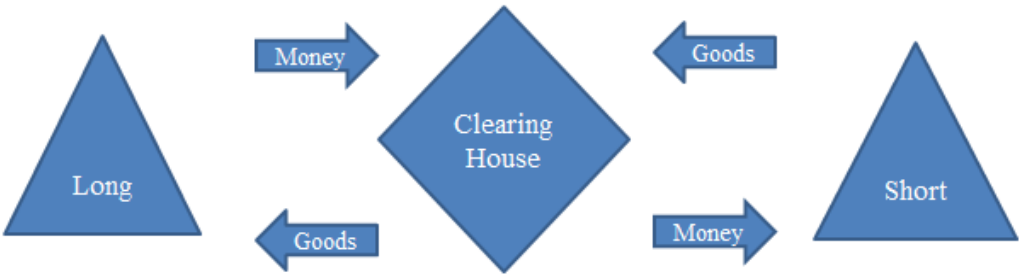
Stock markets guarantee the transactions that are done by members by way of Clearing House. This clearing house can be organized either dependent or independent from stock market.
Stock markets have some functions to enable the efficient market:

- Publishing the updated data of price information and transactions
- Designing the contracts that will be traded
- Determining the brokers that will operate in stock market
- Determining the initial and continuous margin rate or prices in accordance with price movements.
- Making some regulations in accordance with law and general rules
- Taking precaution to provide efficient market and implementing necessary sanctions.

5.3.2. Clearing house

Clearing house is one of the essential key points to transfer the risk. Each contract that is traded in the stock market has two parties, buyer and seller. Position of buyer is “long” and seller is “short”. Commitments are guaranteed by the clearing house which is seller when opposite is buyer, or is buyer when opposite is seller.

Figure 11: Role of Clearing House at the Delivery Process



Clearing house applies a margin system to make its mission. Firstly, investor pays the margin to intermediary institution to position for a futures contract. This margin is paid to clearing house by intermediary institution. The only purpose for the margin is to guarantee that each investor fulfill the contract conditions. Long or short party can also get loss, so two parties must pay the margin that compensates the risk.

Margin system depends on each stock market. For example, VİOP facilitates that some of margin can be compensated by security having the interest revenue. Reason for that is enabling investors to trade with low cost.

5.3.3. Intermediary Institutions (Members)

Intermediary institutions serve to people who want to trade for investment or make hedging in the exchange traded markets. They are compulsory for exchange traded markets as such in other stock markets.

There are two types of membership in exchange traded markets like clearing member and non-clearing members.
Clearing members make other members' transactions with a commission.
Intermediary institutions that are non-clearing member must make an agreement with a clearing member to trade in the stock market.

There are some personnel members that trade just for themselves at some stock exchanges. They also must agree with a clearing member.

These membership types are general, but they can be dependent from stock to stock. Moreover, to become a member of VİOP, intermediary authority document must be got from Capital Markets Board of Turkey (SPK).

5.3.4. Supervisory Institutions

Stock markets, intermediary institutions operating in stock market and transactions in markets are audited to enable efficient exchange traded markets. Supervisory institutions show the side of public.
Basic Purpose of Supervisory Institutions:

- Keeping the investors
- Preventing the artificial prices

SECTION SIX

6. BORSA İSTANBUL A.Ş (BİST)

6.1.Markets

- It is the major market where orders are matched during normal session and regular fixing session. It includes four markets such as equity, debt securities, derivatives (VİOP) and precious metals and diamond markets.

Subject of the thesis is about VİOP, so only attributes of VİOP market will be considered next parts.

6.1.1. Mechanism of VİOP

6.1.1.1.Instruments Trading in VİOP

Contracts trading on VİOP according to derivative types:

- Options
- Futures

6.1.1.2.Account Types of VİOP

Four types of account are determined to trade in the market:

- Customer accounts
- Portfolio accounts
- Market-maker accounts
- Global accounts

All transactions at VİOP buy-sell system are followed by an account. Orders are entered to system with account number and if there is no margin in account, it is not traded. Distinct accounts must be opened for each private people or corporations. More than one customer use just one account in Global account. Sub accounts in global account will be followed by intermediary institutions and it will be committed with Takas Bank in end of days.

6.1.1.3.Transaction Hours of VİOP

Table 8: Transaction Hours

Start	End	Announcement of Settlement / balance Price
09:30	18:15(Equity Derivative market ends 18:10)	Daily settlement prices are calculated by using the trades in the Closing Period, last 10 minutes of session.

6.1.1.4.Size of Contract

Size of contract in market is determined according to types of futures contracts. For example, contracts that will be done on US Dollar, size of contracts are determined like USD 1000.

6.1.1.5.Price Trick

Price trick is the minimum price change for one time for each contract. For instance, price trick in the currency or exchange rate futures contracts is equal to 0.0001 TL.

6.1.1.6.Last Transaction Day

Last trading day all of derivatives traded in VİOP is last business day of each contract month

6.1.1.7.Order Methods

To order in VİOP, one of five price determining methods should be chosen:

- Limit Order (LMT)
- Market Order (PYS)
- Market to Limit Order
- Conditional (SAR)
- Strategy (STJ)

6.1.1.8.Contract Codes

Table 9: Options Contracts

Code	Explanation
O_	Instrument group (Options)
XU030	Underlying asset code
E	Exercise style (A: American-The contractual right can be used on any date until or on expiry date, E: European-The contractual right can be used on expiry date)
0417	Expiration date (Ex. April 2019)
C	Option class (C: Call option P: Put option)
136.000	Strike price

Table 10: Futures Contracts

Code	Explanation
F_	Instrument group (Futures)
XAUTRY	Underlying asset code
M	Contract code regarding the contract size
0419	Expiration date (Ex. April 2019)

6.1.1.9.Underlying Assets

Types of underlying assets are below. Detailed information is at Appendix 3.

- Equity, which includes 30 underlying assets.
- Index, which includes 3 underlying assets.
- Commodity, which includes 3 underlying assets.
- Currency, which includes 6 underlying assets.
- Precious Metals, which includes 2 underlying assets.

- Energy, which includes 1 underlying asset.
- Metal, which includes 1 underlying asset.
- Foreign Indices, which includes 1 underlying asset.
- Overnight Repo Rate, which includes 2 underlying assets.

6.1.2. Pricing Applications in VİOP and Its Optimality

6.1.2.1.Futures Pricing Application in VİOP

It can be said that pricing of futures are not complex, and its pricing method is standard. Consequently, testing optimality of futures is unnecessary. Only optimality analysis of options will be tested.

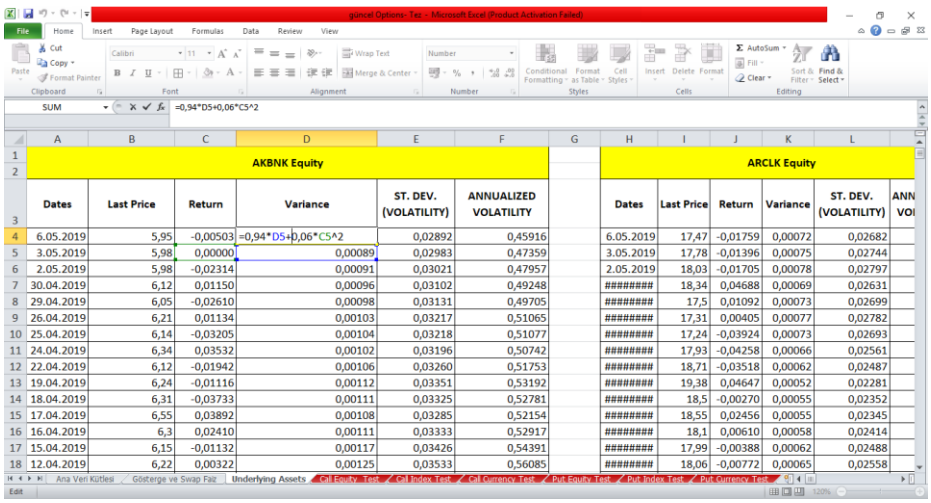
6.1.2.2.Option Pricing Application in VİOP

Detailed information about testing of call&put options in VİOP are stated below.

- Firstly, historical stock prices of all underlying assets of options are downloaded from Bloomberg Channel. Also, TR indicator interest rate, TR monthly swap point interest rate and USA monthly swap point interest rate are downloaded from it.
- Then, daily returns of underlying are calculated.
    - For stock and index underlying assets: Return of Today= LN (Today's price/Last Day's Price)
    - For currency underlying assets: Return of Today= (Today's price-Last Day's Price) / (Last Day's Price) -1
- After that daily variances are calculated with using of daily returns.
    - This is Exponential Weighted Average method: Today's Variance = λ * (Last Day Variance) + (1- λ) * (Last Day's return) ^ 2
    - λ is between 0 and 1. λ is assumed as 0.94 by J.P. Morgan Riskmetrics.

- Literally, there are two types of volatility calculations for option pricing process such as historical and implied volatility. Historical volatility includes three type methods like Simple, Exponentially Weighted Moving Average (EWMA) and GARCH models. According to Riskmetrics of J.P. Morgan, EWMA is preferred because of its simplicity and it is not accurate that either historical or implied volatility is better. Consequently, EWMA method is widely accepted by market agents because of above reasons.
- Thereafter daily standard deviation is found like Daily Stdev= (Variance) ^ (0,5)
- Later, Annualized Volatility for each day is calculated such as Annualized Volatility= Daily Stdev * [252 ^ 0,5]

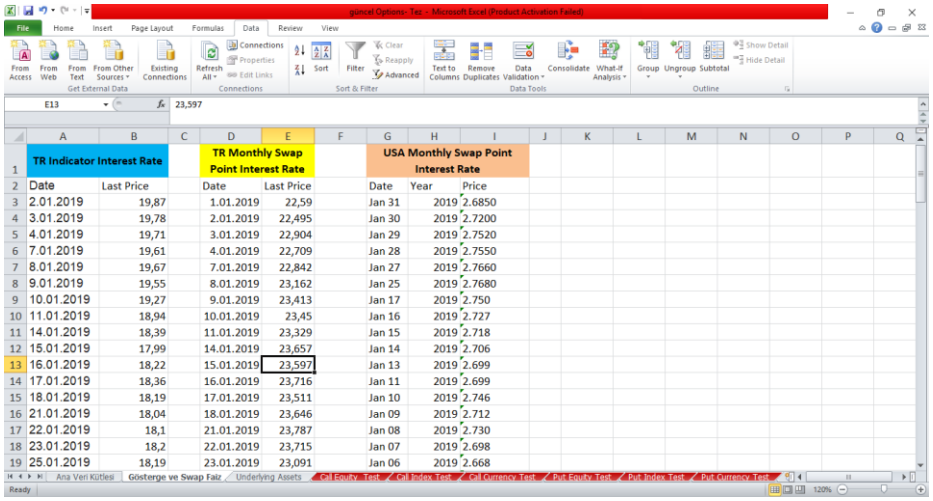
Figure 12: Underlying Asset Sample from Excel



	AKBNK Equity						ARCLK Equity					
	Dates	Last Price	Return	Variance	ST. DEV. (VOLATILITY)	ANNUALIZED VOLATILITY	Dates	Last Price	Return	Variance	ST. DEV. (VOLATILITY)	ANN VOL
4	6.05.2019	5,95	-0,00503	=0,94*D5+0,06*C5^2	0,02892	0,45916	6.05.2019	17,47	-0,01759	0,00072	0,02682	
5	3.05.2019	5,98	0,00000	0,00089	0,02983	0,47359	3.05.2019	17,78	-0,01396	0,00075	0,02744	
6	2.05.2019	5,98	-0,02314	0,00091	0,03021	0,47957	2.05.2019	18,03	-0,01705	0,00078	0,02797	
7	30.04.2019	6,12	0,01150	0,00096	0,03102	0,49248	########	18,34	0,04688	0,00069	0,02631	
8	29.04.2019	6,05	-0,02610	0,00098	0,03131	0,49705	########	17,5	0,01092	0,00073	0,02699	
9	26.04.2019	6,21	0,01134	0,00103	0,03217	0,51065	########	17,31	0,00405	0,00077	0,02782	
10	25.04.2019	6,14	-0,03205	0,00104	0,03218	0,51077	########	17,24	-0,03924	0,00073	0,02693	
11	24.04.2019	6,34	0,03532	0,00102	0,03196	0,50742	########	17,93	-0,04258	0,00066	0,02561	
12	22.04.2019	6,12	-0,01942	0,00106	0,03260	0,51753	########	18,71	-0,03518	0,00062	0,02487	
13	19.04.2019	6,24	-0,01116	0,00112	0,03351	0,53192	########	19,38	0,04647	0,00052	0,02281	
14	18.04.2019	6,31	-0,03733	0,00111	0,03325	0,52781	########	18,5	-0,00270	0,00055	0,02352	
15	17.04.2019	6,55	0,03892	0,00108	0,03285	0,52154	########	18,55	0,02456	0,00055	0,02345	
16	16.04.2019	6,3	0,02410	0,00111	0,03333	0,52917	########	18,1	0,00610	0,00058	0,02414	
17	15.04.2019	6,15	-0,01132	0,00117	0,03426	0,54391	########	17,99	-0,00388	0,00062	0,02488	
18	12.04.2019	6,22	0,00322	0,00125	0,03533	0,56085	########	18,06	-0,00772	0,00065	0,02558	

Moreover, annual compound base interest rate of each day is entered to an excel sheet.

Figure 13: Annual Compound Base Interest Rate per Day



	TR Indicator Interest Rate			TR Monthly Swap Point Interest Rate			USA Monthly Swap Point Interest Rate		
2	Date	Last Price		Date	Last Price		Date	Year	Price
3	2.01.2019	19,87		1.01.2019	22,59		Jan 31	2019	2.6850
4	3.01.2019	19,78		2.01.2019	22,495		Jan 30	2019	2.7200
5	4.01.2019	19,71		3.01.2019	22,904		Jan 29	2019	2.7520
6	7.01.2019	19,61		4.01.2019	22,709		Jan 28	2019	2.7550
7	8.01.2019	19,67		7.01.2019	22,842		Jan 27	2019	2.7660
8	9.01.2019	19,55		8.01.2019	23,162		Jan 25	2019	2.7680
9	10.01.2019	19,27		9.01.2019	23,413		Jan 17	2019	2.750
10	11.01.2019	18,94		10.01.2019	23,45		Jan 16	2019	2.727
11	14.01.2019	18,39		11.01.2019	23,329		Jan 15	2019	2.718
12	15.01.2019	17,99		14.01.2019	23,657		Jan 14	2019	2.706
13	16.01.2019	18,22		15.01.2019	23,597		Jan 13	2019	2.699
14	17.01.2019	18,36		16.01.2019	23,716		Jan 11	2019	2.699
15	18.01.2019	18,19		17.01.2019	23,511		Jan 10	2019	2.746
16	21.01.2019	18,04		18.01.2019	23,646		Jan 09	2019	2.712
17	22.01.2019	18,1		21.01.2019	23,787		Jan 08	2019	2.730
18	23.01.2019	18,2		22.01.2019	23,715		Jan 07	2019	2.698
19	25.01.2019	18,19		23.01.2019	23,091		Jan 06	2019	2.668

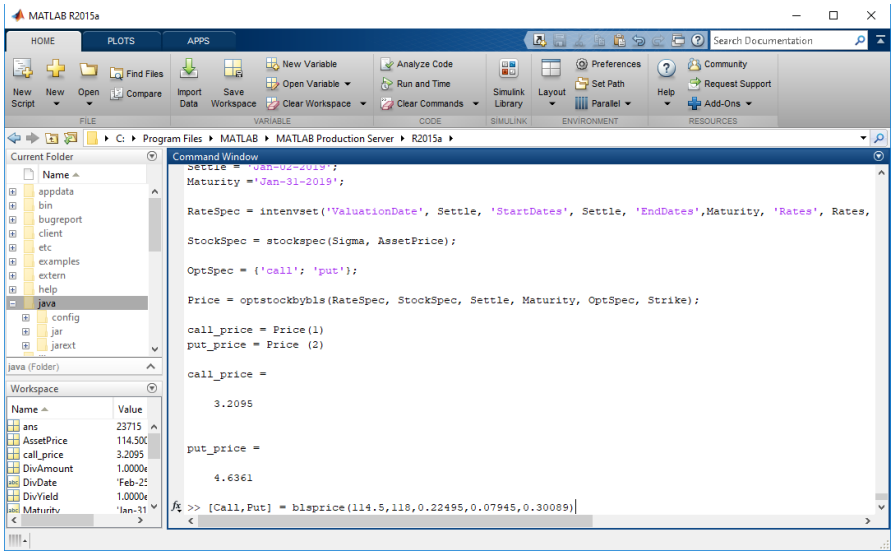
- After those six sheets are formed according to types and underlying assets such as call&put equity, currency and index option sheets. Information about option and models are included in these sheets.
- It is stated before that MATLAB is used to test the optimality; this means prices of options are calculated with using Black&Scholes, Garman-Kohlhagen, Roll-Geske-Whaley and Bjersund-Stensland 2002 models. Codes are like:
    - Codes of Black and Scholes Model

```
>>Strike = 118;
AssetPrice = 114.5;
Sigma = 0.30089;
Rates =0.22495;
Settle = 'Jan-02-2019';
Maturity ='Jan-31-2019';
RateSpec = intenvset('ValuationDate', Settle, 'StartDates',
Settle, 'EndDates',Maturity, 'Rates', Rates, 'Compounding', -1);
StockSpec = stockspec(Sigma, AssetPrice);
OptSpec = {'call'; 'put'};
Price = optstockbybls(RateSpec, StockSpec, Settle, Maturity,
OptSpec, Strike);
call_price = Price(1)
put_price = Price (2)
[Call,Put] = blsprice(Price,Strike,Rate,Time,Volatility)
[Call,Put] = blsprice(__,Yield)
```

OR

```
>> [Call,Put] = blsprice(114.5,118,0.22495,0.07945,0.30089)
```

Figure 14: MATLAB Output Example for Black and Scholes Model



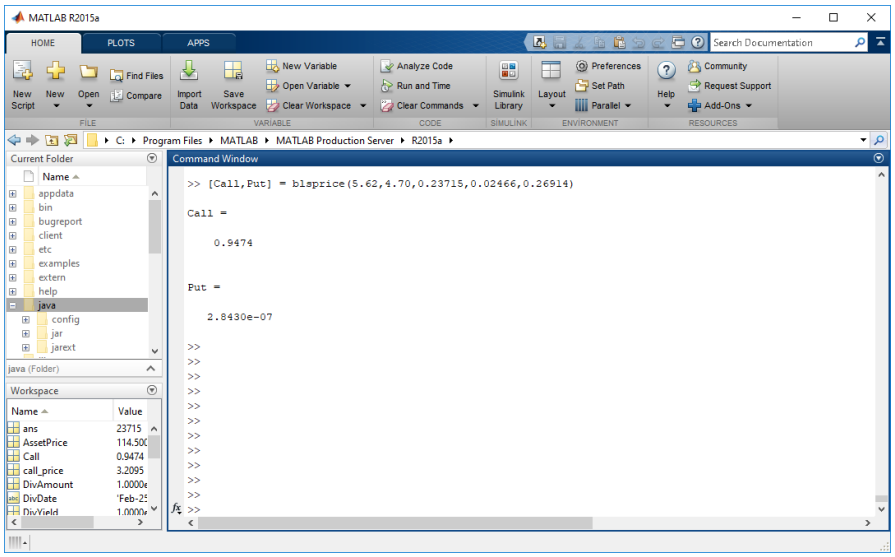
- Codes of Garman-Kohlhagen Model

```
S = 1.6;  % spot exchange rate
X = 1.6;  % strike
T = .3333;
r_d = .08;  % USD interest rate
r_f = .11;  % GBP interest rate
sigma = .2;

Price = blsprice(S,X,r_d,T,sigma,r_f)
```

>> [Call,Put] = blsprice(5.62,4.70,0.23715,0.02466,0.26914)

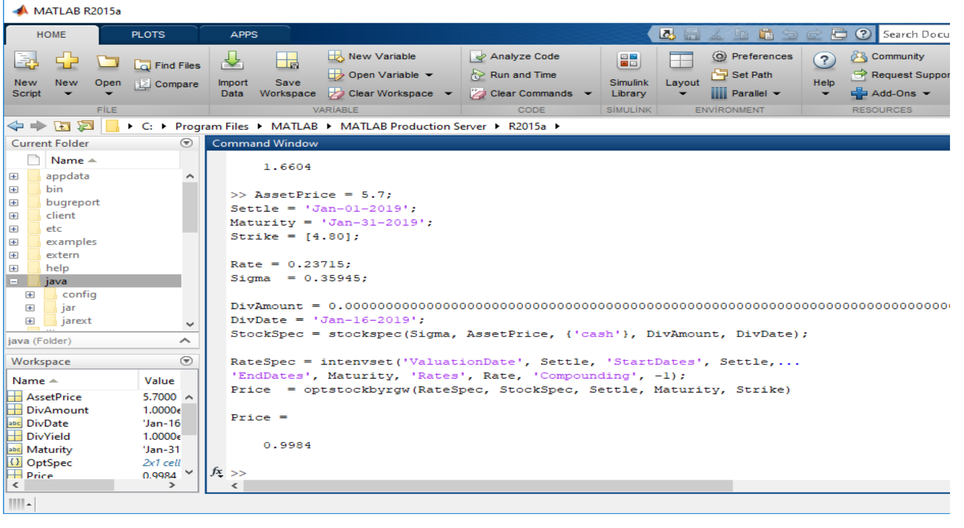
Figure 15: MATLAB Output Example for Garman-Kohlhagen Model



- Codes of Roll-Geske-Whaley Model

```
AssetPrice = 114.5;
Settle = 'Jan-01-2019';
Maturity = 'Jan-31-2019';
Strike = [118];
Rate = 0.22495;
Sigma  = 0.30089;
DivAmount =
0.00000000000000000000000000000000000000000000000000000000000000000000000
0000000000000000000000000000000000000000000000000000000000000000000000000
00001;
DivDate = 'Jan-16-2019';
StockSpec = stockspec(Sigma, AssetPrice, {'cash'}, DivAmount, DivDate);
RateSpec = intenvset('ValuationDate', Settle, 'StartDates', Settle,...
'EndDates', Maturity, 'Rates', Rate, 'Compounding', -1);
Price  = optstockbyrgw(RateSpec, StockSpec, Settle, Maturity, Strike)
```

Figure 16: MATLAB Output Example for Roll-Geske-Whaley Model

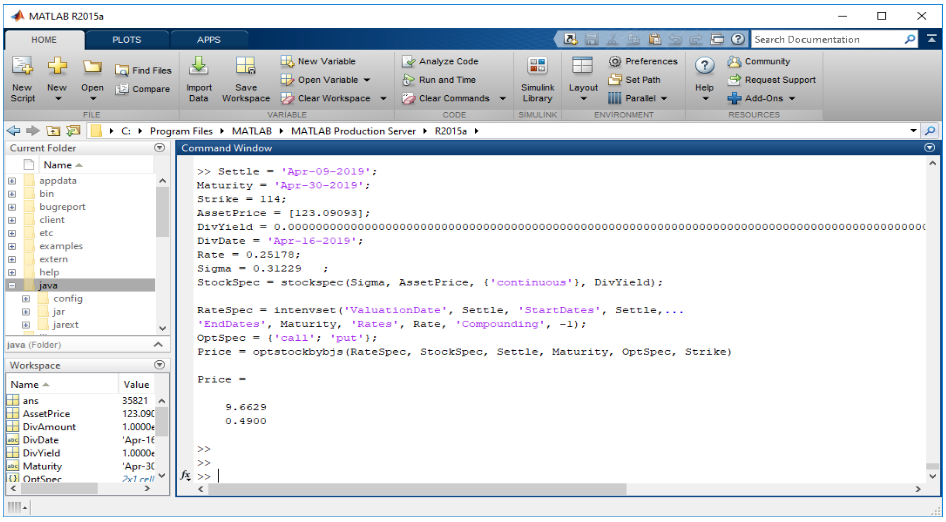


- Codes of Bjersund-Stensland 2002 Model

```
Settle = 'Jan-1-2019';
Maturity = 'Jan-31-2019';
Strike = 118;
AssetPrice = [114.5];
DivYield =
0.00000000000000000000000000000000000000000000000000000000000000000000000
0000000000000000000000000000000000000000000000000000000000000000000000000
000000000000001;
DivDate = 'Jan-16-2019';
Rate = 0.22495;
Sigma = 0.30089;
StockSpec = stockspec(Sigma, AssetPrice, {'continuous'}, DivYield);
RateSpec = intenvset('ValuationDate', Settle, 'StartDates', Settle,...
```

```
'EndDates', Maturity, 'Rates', Rate, 'Compounding', -1);
OptSpec = {'call'; 'put'};
Price = optstockbybjs(RateSpec, StockSpec, Settle, Maturity, OptSpec,
Strike)
```

Figure 17: MATLAB Output Example for Bjersund-Stensland 2002 Model



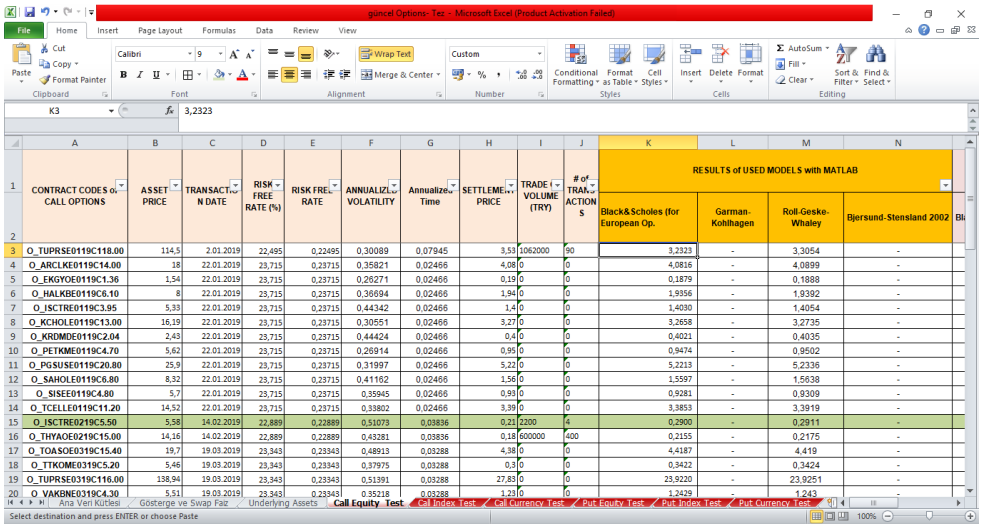
- In these models, Strike price, Asset price, Sigma, Rates, Settle and Maturity dates are entered and then output is taken. Asset price is equal to underlying asset's price on transaction day. Sigma means annualized volatility on transaction day. Rate is annual compound base interest rate on transaction day. Swap interest rates are used in the market applications, so it is used as rate instead of indicator interest rate. Settle day means transaction date. And maturity date is also written on the option's contract.
- In call equity and index option pricing tests, Black&Scholes and Roll-Geske-Whaley models are used.
- In call&put currency option pricing tests, Black&Scholes and Garman-Kohlhagen models are used.
- In put equity and index option pricing tests, Black&Scholes and Bjersund-Stensland 2002 models are used.
- Normally, Black&Scholes model is used for pricing of European call and put options, Roll-Geske-Whaley model is used for pricing of American call options and Bjersund-Stensland 2002 model is used for American call

and put options. However, Roll-Geske-Whaley and Bjersund-Stensland 2002 models are used for European equity&index option tests to compare models with Black&Scholes. According to "Equity Derivatives Using Closed-Form Solutions" of MATLAB website, Roll-Geske-Whaley fits better for call options and performs better than Bjersund-Stensland model. So, Roll-Geske-Whaley is used in call equity&index option pricing and Bjersund-Stensland is used in put equity&index option pricing.

  - Totally, 39 call and 16 put options are analyzed and tested.
  - All the results of options from MATLAB are entered to Excel sheets.
  - Prices which are provided from three models are compared with Settlement prices of Borsa Istanbul.

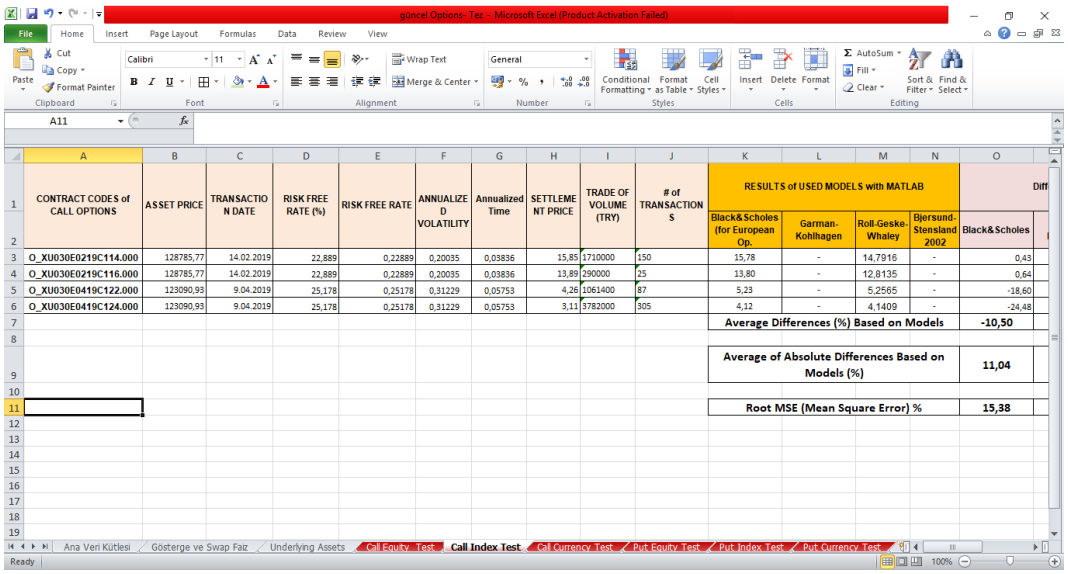
- Three models are also based, means they are assumed like true price. Consequently, differences between models and settlements prices are calculated like:
  - Difference between Model and Settlement Price= (Settlement price of option – True price according to Model Test) / (True price according to Model Test)
- In conclusion, outputs of tested options are on Excel sheets at below.

Figure 18: Call Equity Option Test Output from Excel



- Average Difference of call equity options between Black&Scholes and Roll-Geske-Whaley models is respectively -1.09 % and -1.37 % when outliers data is excluded.
    - It is respectively -3.76 and -3.62 when all data is included.
- Average of Absolute Differences of call equity options between Black&Scholes and Roll-Geske-Whaley model is respectively 3.72 % and 3.59 % when outliers data is excluded.
    - It is respectively 6.16 % and 5.68 % when all data is included.
- Root MSE Differences of call equity options between Black&Scholes and Roll-Geske-Whaley models is respectively 6.59 % and 6.55 % when outliers data is excluded.
    - It is respectively 11.19 % and 10.07 % when all data is included.

Figure 19: Call Index Option Test Output from Excel

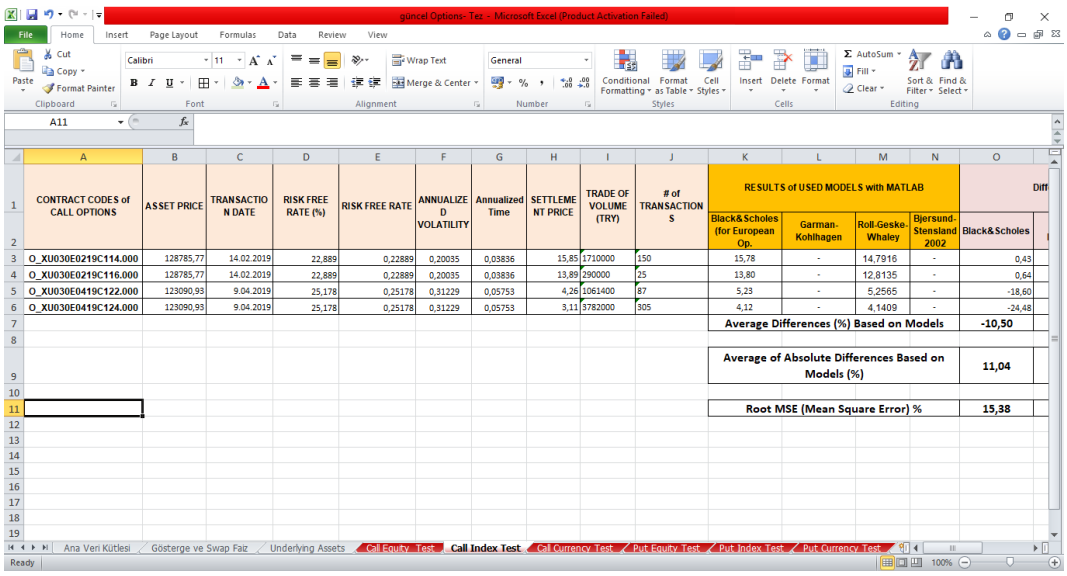


CONTRACT CODES of CALL OPTIONS	ASSET PRICE	TRANSACTION DATE	RISK FREE RATE (%)	RISK FREE RATE	ANNUALIZED VOLATILITY	Annualized Time	SETTLEMENT PRICE	TRADE OF VOLUME (TRY)	# of TRANSACTIONS	RESULTS of USED MODELS with MATLAB				Diff
										Black&Scholes (for European Op.	Garman-Kohlhagen	Roll-Geske Whaley	Bjersund-Stensland 2002	Black&Scholes
O_XU030E0219C114.000	128785,77	14.02.2019	22,889	0,22889	0,20035	0,03836	15,85	1710000	150	15,78	-	14,7916	-	0,43
O_XU030E0219C116.000	128785,77	14.02.2019	22,889	0,22889	0,20035	0,03836	13,89	290000	25	13,80	-	12,8135	-	0,64
O_XU030E0419C122.000	123090,93	9.04.2019	25,178	0,25178	0,31229	0,05753	4,26	1061400	87	5,23	-	5,2565	-	-18,60
O_XU030E0419C124.000	123090,93	9.04.2019	25,178	0,25178	0,31229	0,05753	3,11	3782000	305	4,12	-	4,1409	-	-24,48
										Average Differences (%) Based on Models				-10,50
										Average of Absolute Differences Based on Models (%)				11,04
										Root MSE (Mean Square Error) %				15,38

- Average Difference of call equity options between Black&Scholes and Roll-Geske-Whaley models is respectively -5.84 % and -1.13 % when outliers data is excluded.
    - It is respectively -10.50 and -7.07 when all data is included.

- Average of Absolute Differences of call equity options between Black&Scholes and Roll-Geske-Whaley models is respectively 6.56 % and 11.50 % when outliers data is excluded.
    - It is respectively 11.04 % and 14.85 % when all data is included.
- Root MSE Differences of call equity options between Black&Scholes and Roll-Geske-Whaley model is respectively 10.75 % and 12.66 % when outliers data is excluded.
    - It is respectively 15.38 % and 16.59 % when all data is included.

Figure 20: Call Currency Option Test Output from Excel

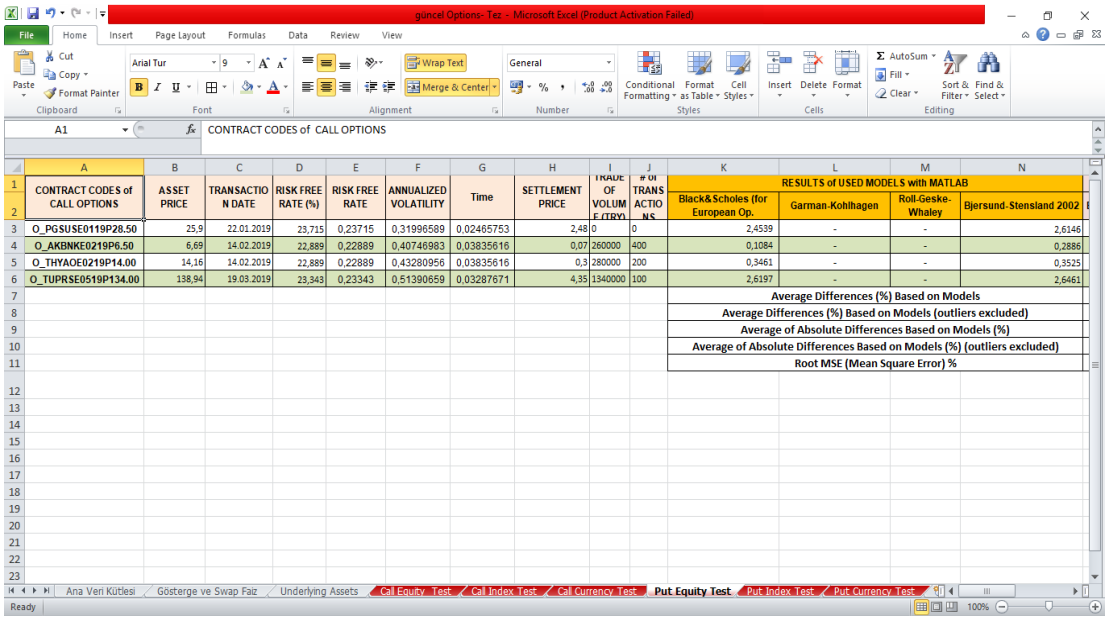


CONTRACT CODES of CALL OPTIONS	ASSET PRICE	TRANSACTION DATE	RISK FREE RATE (%)	RISK FREE RATE	ANNUALIZED VOLATILITY	Annualized Time	SETTLEMENT PRICE	TRADE OF VOLUME (TRY)	# of TRANSACTIONS	RESULTS of USED MODELS with MATLAB				Diff
										Black&Scholes (for European Op.	Garman-Kohlhagen	Roll-Geske Whaley	Bjersund-Stensland 2002	Black&Scholes
O_XU030E0219C114.000	128785,77	14.02.2019	22,889	0,22889	0,20035	0,03836	15,85	1710000	150	15,78	-	14,7916	-	0,43
O_XU030E0219C116.000	128785,77	14.02.2019	22,889	0,22889	0,20035	0,03836	13,89	290000	25	13,80	-	12,8135	-	0,64
O_XU030E0419C122.000	123090,93	9.04.2019	25,178	0,25178	0,31229	0,05753	4,26	1061400	87	5,23	-	5,2565	-	-18,60
O_XU030E0419C124.000	123090,93	9.04.2019	25,178	0,25178	0,31229	0,05753	3,11	3782000	305	4,12	-	4,1409	-	-24,48
										Average Differences (%) Based on Models				-10,50
										Average of Absolute Differences Based on Models (%)				11,04
										Root MSE (Mean Square Error) %				15,38

- Average Difference of call equity options between Black&Scholes and Garman-Kohlhagen models is respectively 17.36 % and -1.52 % when outliers data is excluded. Only results of Garman-Kohlhagen model should be considered, because it is specially used for fx option pricing.
    - It is respectively 42.65% and -16.21% when all data is included. It could be relevant with volatility in last year of USD/TRY FX currency in market.
- Average of Absolute Differences of call equity options between Black&Scholes and Garman-Kohlhagen model is respectively 11.56 % and -1.39 % when outliers' data is excluded.
    - It is respectively 49.83 % and 21.61% when all data is included.

- Root MSE Differences of call equity options between Black&Scholes and Garman-Kohlhagen model is respectively 23.10 % and 11.66 % when outliers' data is excluded.
    - It is respectively 94.84 % and 28.89 % when all data is included.

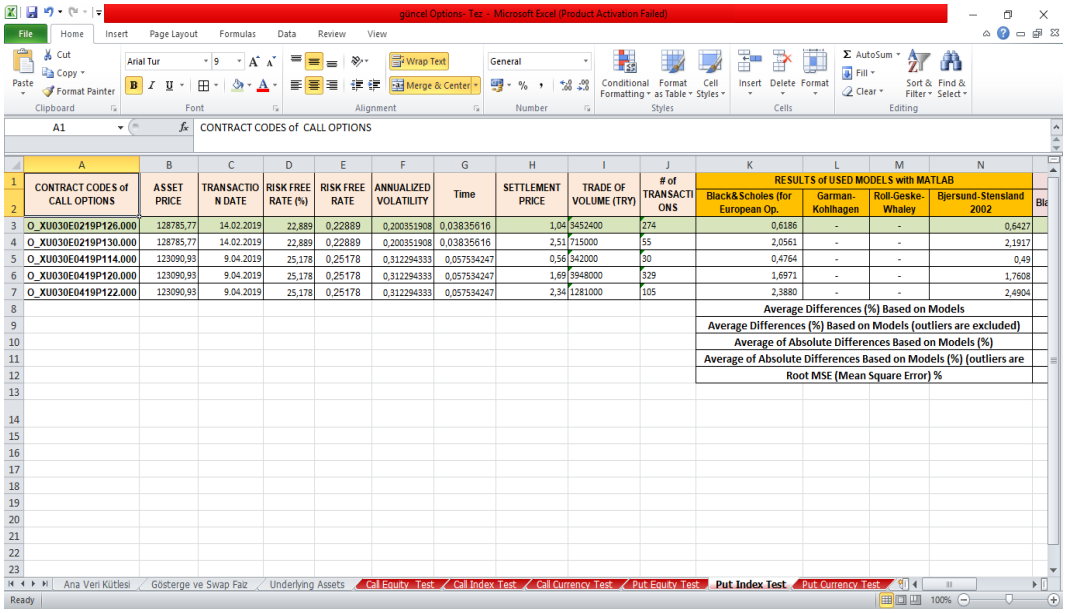
Figure 21: Put Equity Option Test Output from Excel



CONTRACT CODES of CALL OPTIONS	ASSET PRICE	TRANSACTION DATE	RISK FREE RATE (%)	RISK FREE RATE	ANNUALIZED VOLATILITY	Time	SETTLEMENT PRICE	TRADE OF VOLUME (TRY)	# of TRANSACTIONS	RESULTS of USED MODELS with MATLAB: Black&Scholes (for European Op.)	Garman-Kohlhagen	Roll-Geske-Whaley	Bjersund-Stensland 2002
O_PGSUSE0119P28.50	25,9	22.01.2019	23,715	0,23715	0,31996589	0,02465753	2,48	0	0	2,4539	-	-	2,6146
O_AKBNKE0219P6.50	6,69	14.02.2019	22,889	0,22889	0,40746983	0,03835616	0,07	260000	400	0,1084	-	-	0,2886
O_THYAOE0219P14.00	14,16	14.02.2019	22,889	0,22889	0,43280956	0,03835616	0,3	280000	200	0,3461	-	-	0,3525
O_TUPRSE0519P134.00	138,94	19.03.2019	23,343	0,23343	0,51390659	0,03287671	4,35	1340000	100	2,6197	-	-	2,6461
										Average Differences (%) Based on Models			
										Average Differences (%) Based on Models (outliers excluded)			
										Average of Absolute Differences Based on Models (%)			
										Average of Absolute Differences Based on Models (%) (outliers excluded)			
										Root MSE (Mean Square Error) %			

- Average Difference of put equity options between Black&Scholes and Bjersund-Stensland 2002 model is respectively -6.13 % and -10.02 % when outliers' data is excluded.
    - It is respectively 4.59 and -7.85 when all data is included.
- Average of Absolute Differences of put equity options between Black&Scholes and Bjersund-Stensland 2002 models is respectively 7.19 % and 4.87 % when outliers data is excluded.
    - It is respectively 28.96 % and 40.04 % when all data is included.
- Root MSE Differences of put equity options between Black&Scholes and Bjersund-Stensland 2002 models is respectively 9.45 % and 11.14 % when outliers data is excluded.
    - It is respectively 38.07 % and 50.33 % when all data is included.

Figure 22: Put Index Option Test Output from Excel



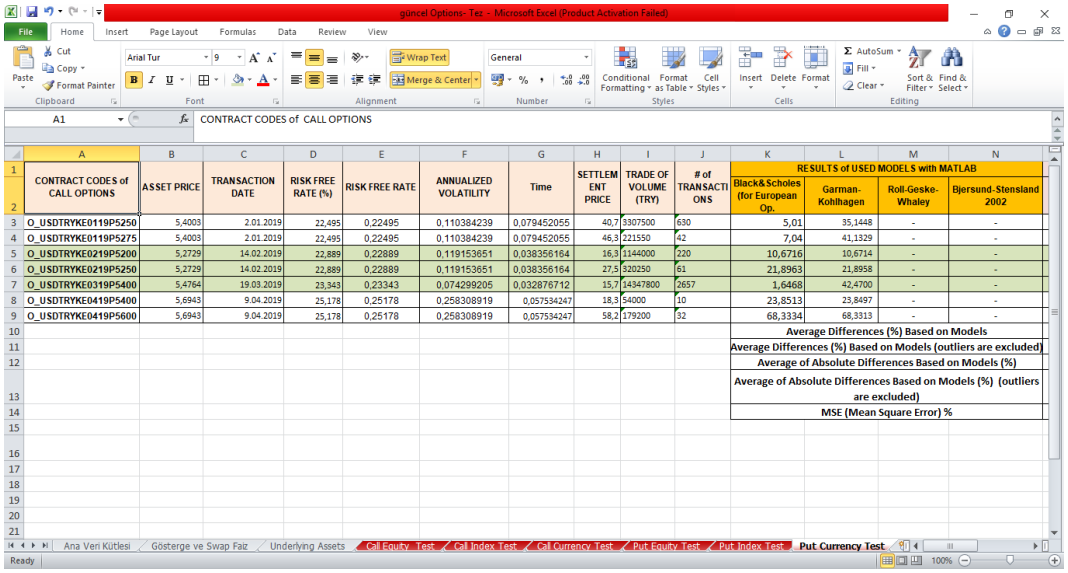
güncel Options- Tez - Microsoft Excel (Product Activation Failed)

CONTRACT CODES of CALL OPTIONS	ASSET PRICE	TRANSACTION DATE	RISK FREE RATE (%)	RISK FREE RATE	ANNUALIZED VOLATILITY	Time	SETTLEMENT PRICE	TRADE OF VOLUME (TRY)	# of TRANSACTIONS	RESULTS of USED MODELS with MATLAB			
										Black&Scholes (for European Op.	Garman-Kohlhagen	Roll-Geske-Whaley	Bjersund-Stensland 2002
O_XU030E0219P126.000	128785,77	14.02.2019	22,889	0,22889	0,200351908	0,03835616	1,04	3452400	274	0,6186	-	-	0,6427
O_XU030E0219P130.000	128785,77	14.02.2019	22,889	0,22889	0,200351908	0,03835616	2,51	715000	55	2,0561	-	-	2,1917
O_XU030E0419P114.000	123090,93	9.04.2019	25,178	0,25178	0,312294333	0,057534247	0,56	342000	30	0,4764	-	-	0,49
O_XU030E0419P120.000	123090,93	9.04.2019	25,178	0,25178	0,312294333	0,057534247	1,69	3948000	329	1,6971	-	-	1,7608
O_XU030E0419P122.000	123090,93	9.04.2019	25,178	0,25178	0,312294333	0,057534247	2,34	1281000	105	2,3880	-	-	2,4904

Average Differences (%) Based on Models
Average Differences (%) Based on Models (outliers are excluded)
Average of Absolute Differences Based on Models (%)
Average of Absolute Differences Based on Models (%) (outliers are
Root MSE (Mean Square Error) %

- Average Difference of put index options between Black&Scholes and Bjersund-Stensland 2002 model is respectively 9.30% and 4.69% when outliers data is excluded.
    - It is respectively 21.06 % and 16.11% when all data is included.
- Average of Absolute Differences of put index options between Black&Scholes and Bjersund-Stensland 2002 model is respectively 10.51 % and 9.72 % when outliers' data is excluded.
    - It is respectively 22.03 % and 20.14 % when all data is included.
- Root MSE Differences of put index options between Black&Scholes and Bjersund-Stensland 2002 model is respectively 22.03 % and 20.14% when outliers' data is excluded.

Figure 23: Put Currency Option Test Output from Excel



CONTRACT CODES of CALL OPTIONS	ASSET PRICE	TRANSACTION DATE	RISK FREE RATE (%)	RISK FREE RATE	ANNUALIZED VOLATILITY	Time	SETTLEMENT PRICE	TRADE OF VOLUME (TRY)	# of TRANSACTIONS	RESULTS of USED MODELS with MATLAB			
										Black&Scholes (for European Op.	Garman-Kohlhagen	Roll-Geske-Whaley	Bjersund-Stensland 2002
O_USDTRYKE0119P5250	5,4003	2.01.2019	22,495	0,22495	0,110384239	0,079452055	40,7	3307500	630	5,01	35,1448	-	-
O_USDTRYKE0119P5275	5,4003	2.01.2019	22,495	0,22495	0,110384239	0,079452055	46,3	221550	42	7,04	41,1329	-	-
O_USDTRYKE0219P5200	5,2729	14.02.2019	22,889	0,22889	0,119153651	0,038356164	16,3	1144000	220	10,6716	10,6714	-	-
O_USDTRYKE0219P5250	5,2729	14.02.2019	22,889	0,22889	0,119153651	0,038356164	27,5	320250	61	21,8963	21,8958	-	-
O_USDTRYKE0319P5400	5,4764	19.03.2019	23,343	0,23343	0,074299205	0,032876712	15,7	14347800	2657	1,6468	42,4700	-	-
O_USDTRYKE0419P5400	5,6943	9.04.2019	25,178	0,25178	0,258308919	0,057534247	18,3	54000	10	23,8513	23,8497	-	-
O_USDTRYKE0419P5600	5,6943	9.04.2019	25,178	0,25178	0,258308919	0,057534247	58,2	179200	32	68,3334	68,3313	-	-
										Average Differences (%) Based on Models			
										Average Differences (%) Based on Models (outliers are excluded)			
										Average of Absolute Differences Based on Models (%)			
										Average of Absolute Differences Based on Models (%) (outliers are excluded)			
										MSE (Mean Square Error) %			

- Average Difference of put currency options between Black&Scholes and Garman-Kohlhagen models is respectively 307.99% and -2.43% when outliers data is excluded. Only results of Garman-Kohlhagen model should be considered, because it is specially used for fx option pricing.
    - It is respectively 307.99 % and 0.80 % when all data is included.
- Average of Absolute Differences of put currency options between Black&Scholes and Garman-Kohlhagen model is respectively 327.04 % and 16.62 % when outliers' data is excluded.
    - It is respectively 319.98 % and 29.69 % when all data is included.
- Root MSE Differences of put currency options between Black&Scholes and Garman-Kohlhagen model is respectively 452.56% and 17.09% when outliers' data is excluded.
    - It is respectively 470.70 % and 35.01 % when all data is included.

CONCLUSION

General and historical information, which includes definitions, market types and historical development of market, about derivatives and financial derivatives are included. Analysis and research of different financial derivatives such as forward, futures, options, and swaps are also explained intensively. They are compared in different examples to understand the differences between them. Furthermore, types of traders which make transactions on derivative market are demonstrated and compared according to use of which instruments. Moreover, new generation derivatives are considered. Then different financial derivative pricing models are showed.

Derivative products just in exchange traded markets in Turkey is explained detailed. Because, there is no sufficient information about pricing applications of OTC market as before stated over-the-counter market products are not standardized and so trying to find optimal pricing of them is not plausible. Moreover, optimality test of futures prices is not applied. Because, it can be said that pricing of futures are not complex, and its pricing method is standard. Furthermore, optimality test of warrants are not implemented since the technique of warrants is same with options. They are just different from options juristically. Options are contracts while warrants are securities. So, it is not also necessary to analyze warrant pricing models privately.

Options are analyzed and tested in detail using MATLAB. All the needed data is gathered in Excel and then results are gained from MATLAB test and then combined in Excel. According to results, average differences based on two models are -1.09 % and -1.37 % respectively for call equity options when outliers' data is omitted. Average of them is -1.23 %. So, call equity settlement prices of options on Borsa Istanbul should be higher. Also, it can be said that put equity settlement prices of options on Borsa Istanbul are lower than theoretical models when outliers' data is omitted. Average differences based on two models are -6.13 % and -10.2 % respectively. Average of them is -8.07 %. Put equity settlement prices of options on Borsa Istanbul should be higher. Moreover, average differences

based on two models are -5.84 % and -1.13 % respectively for call index options when outliers' data is omitted. Average of them is -3.49 %. Call index equity settlement prices of options on Borsa Istanbul should be higher. Furthermore, average differences based on two models are 9.30 % and 4.69 % respectively for put index options when outliers' data is omitted. Average of them is 6.99 %. Put index equity settlement prices of options on Borsa Istanbul should be lower. Furthermore, only Garman-Kohlhagen model is considered although two models tested with settlement prices of call and put currency options. Because, the model is just specialized model for FX currency option pricing process. Average difference based on the model for call and put currency options are -1.52 % and -2.43 % respectively. Shortly, settlement prices of put&call currency options should be higher. Moreover, there are too much difference between the model and settlement price at outlier examples of call&put currency options. In addition, when Average of Absolute Differences and MSE of differences are considered, it absolutely means that options, except call equity ones, are traded with higher errors compared to prices based theoretical models, even outliers data is omitted. Errors of call equity options are relatively lower than other ones.

In conclusion, some inferences can be done to comprehend the reasons for this discordant. Firstly, many option transactions should be done on Borsa Istanbul to get more confidential test results, but number of them is limited now. Secondly, liquidity of market is low and market is not well developed. Moreover, volatility in USD/TRY currency especially in last one year, active trading of Central Bank of Turkey Republic on VİOP and London TRY swap interest rate hike in recent months could disrupt currency option prices.

REFERENCES

Bennett, C., & Gil, M. A. (2012). Measuring historical volatility: Close-to-close, exponentially weighted, Parkinson, Garman-Klass, Rogers-Satchell and Yang-Zhang volatility. *Santander Investment Bolsa, Sociedad de Valores, SA*.

Bjerksund, P., & Stensland, G. (2002). Closed form valuation of American options.

Black, F. (1975). Fact and fantasy in the use of options. *Financial Analysts Journal*, *31*(4), 36-41.

Black, F. (1989). How we came up with the option formula. *Journal of Portfolio Management*, *15*(2), 4-8.

Black, F., & Scholes, M. (1973). The pricing of options and corporate liabilities. *Journal of political economy*, *81*(3), 637-654.

BIS Quarterly Review. (2018). *International banking and financial market developments.* Date: March 1, 2019.

Cerrato, M. (2012). *The mathematics of derivatives securities with applications in MATLAB*. John Wiley & Sons.

Chen, Z. (1998). *Currency options and exchange rate economics*. World Scientific.

Cohen, J. B., Black, F., & Scholes, M. (1972). The valuation of option contracts and a test of market efficiency. *The journal of finance*, *27*(2), 399-417.

DeRosa, D. F. (Ed.). (1998). *Currency derivatives: Pricing theory, exotic options, and hedging applications* (Vol. 12). John Wiley & Sons.

Figlewski, S., Silber, W. L., & Subrahmanyam, M. G. (Eds.). (1990). *Financial Options: From theory to practice*. Irwin Professional Pub.

Gupta, S. L. (2017). *Financial Derivatives: Theory, concepts and problems*. PHI Learning Pvt. Ltd..

Galati, G., & Tsatsaronis, K. (1996). The information content of implied volatility from currency options. *Bank of International Settlements*.

Gu, C. (2011). Option Pricing Using MATLAB.

Hull, J. (2010). OTC derivatives and central clearing: can all transactions be cleared?. *Financial Stability Review*, *14*, 71-78.

Dontwi, I. K., Dedu, V. K., & Biney, F. (2010). Pricing of foreign currency options in a developing financial market. *European Journal of Scientific Research*, *45*(4), 608-619.

Jabbour, G., & Budwick, P. H. (2010). *The option trader handbook: strategies and trade adjustments* (Vol. 440). John Wiley & Sons.

Jacque, L. L. (2010). *Global derivative debacles: From theory to malpractice*.

Jarešová, L. (2010). EWMA historical volatility estimators. *Acta Universitatis Carolinae. Mathematica et Physica*, *51*(2), 17-28.

Kolb, R. W., & Overdahl, J. A. (2010). *Financial derivatives: pricing and risk management* (Vol. 5). John Wiley & Sons.

Kwok, Y. K. (2008). *Mathematical models of financial derivatives*. Springer.

MacBeth, J. D., & Merville, L. J. (1979). An empirical examination of the Black-Scholes call option pricing model. *The journal of finance*, *34*(5), 1173-1186.

Merton, R. C. (1973). Theory of rational option pricing. *Theory of Valuation*, 229-288.

Poitras, G. (2009). From Antwerp to Chicago: The history of exchange traded derivative security contracts. *Revue d'Histoire des Sciences Humaines*, (1), 11-50.

Qin, Z., & Li, X. (2008). Option pricing formula for fuzzy financial market. *Journal of uncertain Systems*, *2*(1), 17-21.

Reuters, J. M. (1996). *RiskMetrics-technical document*. Technical report, JP Morgan-Reuters.

Sterk, W. E. (1983). Comparative performance of the Black-Scholes and Roll-Geske-Whaley option pricing models. *Journal of Financial and Quantitative Analysis*, *18*(3), 345-354.
Sermaye Piyasası Lisanslama Sicil ve Eğitim Kuruluşu. (2017). *Türev araçlar, piyasalar ve risk yönetimi.* Date: January 4, 2019.
Wilmott, P. (1998). The theory and practice of financial engineering. *John Wiley&Sons Inc, Chichester*.
Zumbach, G. O. (2007). The riskmetrics 2006 methodology. *Available at SSRN 1420185*.
https://www.tcmb.gov.tr/wps/wcm/connect/EN/TCMB+EN/Main+Menu/Statistics/Balance+of+Payments+and+Related+Statistics/Triennial+Central+Bank+Survey+of+Foreign+Exchange+and+Derivatives+Market+Activityy/Data/

APPENDIX

Appendix 1: Detailed and Updated Information about the Size of OTC Derivative Market

BANK FOR INTERNATIONAL SETTLEMENTS

Table D5.1

Global OTC derivatives market

In billions of US dollars

	Notional amounts outstanding				Gross market value			
	H2 2016	H1 2017	H2 2017	H1 2018	H2 2016	H1 2017	H2 2017	H1 2018
All contracts	**482,421**	**542,439**	**531,911**	**594,833**	**14,948**	**12,683**	**10,956**	**10,326**
Foreign exchange contracts	**78,780**	**88,429**	**87,117**	**95,798**	**3,324**	**2,626**	**2,293**	**2,620**
By instrument								
Outright forwards and forex swaps	44,226	51,754	50,847	56,416	1,515	1,259	1,111	1,249
Currency swaps	22,971	24,532	25,535	26,012	1,510	1,160	989	1,155
Options	11,533	12,088	10,679	13,307	299	208	192	216
Other products	50	55	56	64				
By counterparty								
Reporting dealers	33,027	36,521	36,128	40,609	1,426	1,112	936	1,146
Other financial institutions	35,290	40,258	39,084	43,308	1,304	1,036	918	1,042
Central Counterparties	1,754	2,119	2,100	2,907	70	68	65	71
Non-financial customers	10,413	11,594	11,849	11,817	594	479	439	431
By maturity								
Up to 1 year	60,146	69,461	68,083	76,145				
Between 1 and 5 years	12,997	13,346	13,474	13,879				
Over 5 years	5,587	5,566	5,504	5,709				
By currency								
US dollar	70,550	77,043	74,756	84,448	2,947	2,299	1,974	2,336
Euro	24,334	27,826	28,280	31,368	871	929	782	825
Yen	14,146	14,904	14,838	15,629	714	405	300	363
Pound (sterling)	9,080	11,070	12,257	11,719	367	346	305	357
Swiss franc	3,541	4,120	4,257	4,196	112	113	91	94
Canadian dollar	3,350	4,068	4,088	4,484	111	140	107	117
Swedish krona	1,812	2,038	2,268	2,131	46	55	47	59
Other currencies	30,747	35,788	33,490	37,621	1,479	964	979	1,089
Interest rate contracts	**385,513**	**435,205**	**426,648**	**481,085**	**10,636**	**9,045**	**7,579**	**6,644**
By instrument								
FRAs	63,183	75,414	68,334	84,131	243	129	112	107
Swaps	289,103	321,812	318,870	349,761	9,444	8,131	6,747	5,914
Options	32,823	37,641	39,112	46,833	949	786	719	623
Other products	404	338	332	361				
By counterparty								
Reporting dealers	43,556	42,682	40,720	40,116	2,497	2,122	1,963	1,704
Other financial institutions	329,892	379,504	371,868	426,168	7,450	6,290	5,002	4,326
Central Counterparties	287,219	329,766	320,218	366,665	5,029	4,388	3,217	2,702
Non-financial customers	11,660	12,681	13,729	14,441	688	633	614	614
By maturity								
Up to 1 year	165,888	199,179	191,445	231,284				
Between 1 and 5 years	128,978	141,852	140,035	155,344				
Over 5 years	90,243	93,835	94,836	94,097				
By currency								
US dollar	143,290	159,034	156,506	192,510	2,356	1,850	1,434	1,326
Euro	105,594	126,553	121,890	129,417	4,815	4,155	3,561	3,140
Yen	41,800	40,975	38,772	37,215	753	630	491	443
Pound (sterling)	34,033	36,684	37,570	44,522	1,701	1,490	1,292	1,067
Swiss franc	4,168	4,299	4,107	4,398	102	84	62	52
Canadian dollar	8,471	9,849	10,944	12,494	129	128	135	104
Swedish krona	4,652	6,156	5,985	6,052	96	87	65	60
Other currencies	43,506	51,655	50,874	54,478	683	622	539	452
Equity-linked contracts	**6,253**	**6,964**	**6,569**	**7,071**	**477**	**524**	**575**	**608**
By instrument								
Forwards and swaps	2,574	2,903	3,210	3,299	160	184	197	228
Options	3,678	4,061	3,360	3,772	317	340	378	380
By counterparty								
Reporting dealers	2,120	2,297	1,685	1,770	147	160	163	153

	Notional amounts outstanding				Gross market value			
	H2 2016	H1 2017	H2 2017	H1 2018	H2 2016	H1 2017	H2 2017	H1 2018
Other financial institutions	3,489	3,991	4,161	4,498	255	287	321	337
Central Counterparties	57	70	13	20	1	3	0	0
Non-financial customers	644	676	723	803	76	77	91	117
By maturity								
Up to 1 year	4,016	4,555	4,087	4,435				
Between 1 and 5 years	1,922	2,086	2,121	2,296				
Over 5 years	315	323	361	340				
By market								
US equities	2,782	2,767	2,823	3,027	198	217	239	260
European equities	2,082	2,668	2,227	2,317	134	149	159	170
Japanese equities	251	305	309	309	28	28	33	36
Other Asian equities	255	297	333	366	18	19	20	22
Latin American equities	221	199	244	284	14	11	12	14
Other equities	663	727	634	768	85	99	112	106

Global OTC derivatives market (continued)

In billions of US dollars

Table D5

	Notional amounts outstanding				Gross market value			
	H2 2016	H1 2017	H2 2017	H1 2018	H2 2016	H1 2017	H2 2017	H1 2018
Commodity contracts	**1,671**	**1,762**	**1,862**	**2,133**	**204**	**171**	**189**	**207**
By commodity								
Gold	495	535	520	568	34	23	21	23
Other precious metal	59	75	53	70	5	4	3	4
Other commodities	1,117	1,152	1,288	1,495	166	144	164	180
By instrument and commodity								
Forwards and swaps	1,249	1,352	1,414	1,627				
Gold	351	395	381	419				
Other precious metal	40	58	40	54				
Other commodities	859	900	993	1,153				
Total options	422	410	447	506				
Gold	145	141	139	149				
Other precious metal	19	17	14	15				
Other commodities	259	253	294	342				
Options sold (gross basis)	257	254	275	313				
Gold	88	83	85	87				
Other precious metal	12	11	8	9				
Other commodities	157	160	182	218				
Options bought (gross basis)	259	248	272	305				
Gold	89	89	85	95				
Other precious metal	11	10	9	10				
Other commodities	159	149	178	200				
Credit derivatives	**10,103**	**9,967**	**9,578**	**8,582**	**301**	**307**	**313**	**238**
Credit default swaps	9,931	9,727	9,354	8,346	295	300	304	232
By instrument								
Single-name instruments	5,635	5,101	4,570	4,148	168	152	130	118
Multi-name instruments	4,295	4,626	4,784	4,199	127	148	174	115
Index products	3,840	4,229	4,442	4,004				
By counterparty								
Reporting dealers	3,760	2,971	2,321	1,998	114	89	68	57
Other financial institutions	6,018	6,597	6,817	6,112	175	206	227	171
Central counterparties	4,339	4,912	5,136	4,519	110	142	164	118
Banks and securities firms	452	426	487	408	13	12	14	11
Insurance firms	165	143	124	125	7	6	6	5
SPVs, SPCs and SPEs	96	90	76	56	5	4	4	3
Hedge funds	440	435	375	381	23	21	19	17
Other financial customers	525	590	618	624	18	20	21	18
Non-financial customers	153	159	216	236	5	6	9	5
By rating category								
Investment grade	6,467	6,260	6,008	5,321				
Non-investment grade	2,026	2,156	2,049	1,858				
Non-rated	1,364	1,229	1,216	1,078				
By maturity								
Up to one year	2,672	2,513	1,882	1,404				
Between one and five years	6,455	6,404	6,629	6,077				
Over five years	731	727	763	775				
By sector								
Sovereigns	1,746	1,673	1,530	1,458				
Financial firms	1,804	1,674	1,544	1,435				
Non-financial firms	3,181	2,660	2,406	2,104				
Securitised products	305	293	371	382				
Multiple sectors	2,852	3,380	3,456	2,915				
By location of counterparty								
Home country	2,517	2,380	2,222	2,064				
Abroad	7,340	7,265	7,051	6,192				
United States	2,166	2,205	2,187	1,737				
European developed	4,372	4,278	4,131	3,701				
Japan	100	95	79	75				
Other Asian countries	83	81	75	78				

Latin America	344	323	313	327				
All other countries	276	282	267	273				
Other derivatives	**100**	**112**	**137**	**164**	**6**	**9**	**8**	**9**
Gross credit exposure					**3,296**	**2,770**	**2,683**	**2,570**

Source: BIS Statistics Explorer (http://stats.bis.org/statx/)

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Appendix 2: Detailed and Updated Information about the Size of Exchange Traded Derivative Market

Exchange-traded futures and options, by location of exchange

Notional principal, in billions of US dollars — Table D1

Instrument / location of exchange / market risk category / maturity	Open interest			Daily average turnover						
	Dec 2017	Jun 2018	Sep 2018	2016	2017	May 2018	Jun 2018	Jul 2018	Aug 2018	Sep 2018
Futures										
All markets	**33,669**	**38,697**	**37,855**	**5,152**	**5,877**	**8,270**	**7,176**	**4,306**	**5,234**	**6,644**
Interest rate	33,381	38,418	37,584	5,046	5,762	8,119	7,011	4,191	5,101	6,409
Short-term	31,008	35,874	34,818	4,421	5,065	7,043	6,165	3,681	4,237	5,611
Long-term	2,373	2,543	2,766	625	697	1,076	846	510	864	798
Foreign exchange	289	279	271	106	115	151	164	115	134	235
North America	**22,222**	**26,635**	**25,903**	**3,633**	**3,952**	**5,433**	**4,506**	**2,782**	**3,392**	**4,310**
Interest rate	22,029	26,463	25,733	3,559	3,871	5,333	4,393	2,709	3,311	4,210
Short-term	20,759	25,062	24,116	3,234	3,501	4,679	4,028	2,428	2,767	3,862
Long-term	1,270	1,401	1,617	325	370	653	365	281	545	348
Foreign exchange	194	172	170	73	81	100	113	73	81	101
Europe	**8,700**	**9,422**	**9,362**	**1,236**	**1,636**	**2,479**	**2,290**	**1,264**	**1,554**	**1,910**
Interest rate	8,694	9,418	9,358	1,231	1,633	2,476	2,287	1,262	1,551	1,907
Short-term	7,891	8,597	8,538	1,006	1,388	2,129	1,919	1,100	1,308	1,584
Long-term	802	821	819	226	245	347	368	162	243	323
Foreign exchange	6	4	5	4	3	3	3	2	3	3
Asia and Pacific	**1,749**	**1,730**	**1,724**	**216**	**208**	**227**	**268**	**192**	**204**	**260**
Interest rate	1,725	1,707	1,699	208	199	213	253	178	189	243
Short-term	1,433	1,392	1,375	134	118	137	140	112	113	117
Long-term	292	315	324	74	81	76	113	66	76	127
Foreign exchange	24	24	25	8	9	13	15	14	15	16
Other markets	**998**	**909**	**866**	**68**	**81**	**131**	**112**	**68**	**84**	**163**
Interest rate	933	830	794	48	58	97	79	42	50	48
Short-term	925	823	788	48	58	96	79	41	49	48
Long-term	8	7	6	0	0	0	0	1	0	0
Foreign exchange	65	80	71	20	23	34	33	26	34	115
Options										
All markets	**47,315**	**54,631**	**57,685**	**1,502**	**1,696**	**1,807**	**1,720**	**1,135**	**1,354**	**1,597**
Interest rate	47,191	54,490	57,539	1,489	1,682	1,790	1,704	1,122	1,337	1,580
Short-term	46,438	53,549	56,553	1,403	1,571	1,636	1,568	1,034	1,215	1,457
Long-term	753	941	986	86	110	154	137	88	123	123
Foreign exchange	124	141	146	13	14	17	16	13	16	16
North America	**36,156**	**39,751**	**43,533**	**1,256**	**1,413**	**1,297**	**1,336**	**949**	**1,121**	**1,366**
Interest rate	36,079	39,667	43,453	1,248	1,405	1,287	1,327	942	1,113	1,358
Short-term	35,626	39,085	42,857	1,192	1,330	1,184	1,231	879	1,025	1,270
Long-term	453	583	596	56	74	103	96	63	88	89
Foreign exchange	77	84	80	8	9	10	9	7	8	7
Europe	**10,262**	**14,142**	**13,497**	**230**	**260**	**488**	**354**	**173**	**215**	**214**
Interest rate	10,260	14,141	13,497	230	259	488	354	172	214	214
Short-term	9,979	13,795	13,122	205	227	438	315	151	183	182
Long-term	281	346	375	26	33	49	39	21	31	32
Foreign exchange	2	1	1	0	0	0	0	0	0	0
Asia and Pacific	**22**	**14**	**18**	**6**	**6**	**7**	**7**	**8**	**9**	**9**
Interest rate	19	11	15	4	3	2	2	4	3	3
Short-term	0	0	0	0	0	0	0	0	0	0
Long-term	19	11	15	4	3	2	2	4	3	3
Foreign exchange	3	3	3	2	3	5	5	4	5	6
Other markets	**875**	**724**	**636**	**9**	**17**	**16**	**24**	**5**	**9**	**8**
Interest rate	834	670	574	6	14	13	21	3	7	6
Short-term	833	670	574	6	14	13	21	3	7	6
Long-term	1	1	1	0	0	0	0	0	0	0
Foreign exchange	41	53	62	2	3	2	3	2	3	3

Appendix 3: Types of Underlying Assets at VİOP

Equity	
Akbank T.A.Ş.	AKBNK
Arçelik A.Ş.	ARCLK
Aselsan A.Ş.	ASELS
BİM Birleşik Mağazalar A.Ş.	BIMAS
Doğan Holding A.Ş.	DOHOL
Emlak Konut Gayrimenkul Yatırım Ortaklığı A.Ş.	EKGYO
Enerjisa Enerji A.Ş.	ENJSA
Ereğli Demir ve Çelik Fabrikaları T.A.Ş.	EREGL
H.Ö. Sabancı Holding A.Ş.	SAHOL
Kardemir Karabük Demir Çelik Sanayi ve Ticaret A.Ş.	KRDMD
Koç Holding A.Ş.	KCHOL
Koza Anadolu Metal Madencilik A.Ş.	KOZAA
Koza Altın İşletmeleri A.Ş.	KOZAL
Pegasus Hava Taşımacılığı A.Ş.	PGSUS
Petkim Petrokimya Holding A.Ş.	PETKM
T. Garanti Bankası A.Ş	GARAN
T. İş Bankası A.Ş	ISCTR
Tofaş Türk Otomobil Fabrikası A.Ş.	TOASO
Tüpraş Türkiye Petrol Rafinerileri A.Ş.	TUPRS
Türk Hava Yolları A.O.	THYAO
Türk Telekomünikasyon A.Ş.	TTKOM
Turkcell İletişim Hizmetleri A.Ş.	TCELL
Türkiye Halk Bankası A.Ş.	HALKB
Türkiye Şişe ve Cam Fabrikaları A.Ş.	SISE

Soda Sanayii A.Ş.	SODA
Şok Marketler Ticaret A.Ş.	SOKM
TAV Havalimanları A.Ş.	TAVHL
Tekfen Holding A.Ş.	TKFEN
Türkiye Vakıflar Bankası T.A.O.	VAKBN
Yapı ve Kredi Bankası A.Ş.	YKBNK
Index	
BIST 30 Price Index	XU030D
BIST Bank Index	XBANKD
BIST Industrial Index	XUSIND
Currency	
USD / Turkish Lira	USDTRY
Euro / Turkish Lira	EURTRY
Euro/USD	EURUSD
Russian Ruble/ Turkish Lira	RUB/TRY
Offshore Chinese Yuan/ Turkish Lira	CNH/TRY
GBP/USD	GBP/USD
Commodity	
Aegean Color 41 Cotton	COTEGE
The Second Degree Anatolian Hard Red Wheat	WHTANR
The Third Degree Durum Wheat	WHTDRM
Precious Metals	
Pure Gold (TRY/gram)	XAUTRY
Pure Gold (USD/ounce)	XAUUSD
Energy	
Base Load Electricity	ELCBAS
Foreign Indices	

The Sarajevo Stock Exchange Index 10	SASX 10
Metal	
HMS 1&2 80:20 CFR Iskenderun Steel Scrap Index	HMSTR
Overnight Repo Rate	
Aylık Gecelik Repo Oranı	ONREPOM
Üç Aylık Gecelik Repo Oranı	ONREPOQ

Appendix 4: Call Equity Options Test Results

CONTRACT CODES of CALL OPTIONS	ASSET PRICE	TRANSACTION DATE	RISK FREE RATE (%)	RISK FREE RATE	ANNUALIZED VOLATILITY	Annualized Time	SETTLEMENT PRICE	TRADE OF VOLUME (TRY)	# of TRANSACTIONS	RESULTS of USED MODELS with MATLAB				Difference btw Models and Settlement Price (%)			
										Black&Scholes (for European Op.	Garman-Kohlhagen	Roll-Geske-Whaley	Bjersund-Stensland 2002	Black&Scholes	Garman-Kohlhagen	Roll-Geske-Whaley	Bjersund-Stensland 2002
O_TUPRSE0119C118.00	114,5	2.01.2019	22,495	0,22495	0,30089	0,07945	3,53	1062000	90	3,2323	-	3,3054	-	9,21	-	6,79	-
O_ARCLKE0119C14.00	18	22.01.2019	23,715	0,23715	0,35821	0,02466	4,08	0	0	4,0816	-	4,0899	-	-0,04	-	-0,24	-
O_EKGYOE0119C1.36	1,54	22.01.2019	23,715	0,23715	0,26271	0,02466	0,19	0	0	0,1879	-	0,1888	-	1,12	-	0,64	-
O_HALKBE0119C6.10	8	22.01.2019	23,715	0,23715	0,36694	0,02466	1,94	0	0	1,9356	-	1,9392	-	0,23	-	0,04	-
O_ISCTRE0119C3.95	5,33	22.01.2019	23,715	0,23715	0,44342	0,02466	1,4	0	0	1,4030	-	1,4054	-	-0,21	-	-0,38	-
O_KCHOLE0119C13.00	16,19	22.01.2019	23,715	0,23715	0,30551	0,02466	3,27	0	0	3,2658	-	3,2735	-	0,13	-	-0,11	-
O_KRDMDE0119C2.04	2,43	22.01.2019	23,715	0,23715	0,44424	0,02466	0,4	0	0	0,4021	-	0,4035	-	-0,52	-	-0,87	-
O_PETKME0119C4.70	5,62	22.01.2019	23,715	0,23715	0,26914	0,02466	0,95	0	0	0,9474	-	0,9502	-	0,27	-	-0,02	-
O_PGSUSE0119C20.80	25,9	22.01.2019	23,715	0,23715	0,31997	0,02466	5,22	0	0	5,2213	-	5,2336	-	-0,02	-	-0,26	-
O_SAHOLE0119C6.80	8,32	22.01.2019	23,715	0,23715	0,41162	0,02466	1,56	0	0	1,5597	-	1,5638	-	0,02	-	-0,24	-
O_SISEE0119C4.80	5,7	22.01.2019	23,715	0,23715	0,35945	0,02466	0,93	0	0	0,9281	-	0,9309	-	0,20	-	-0,10	-
O_TCELLE0119C11.20	14,52	22.01.2019	23,715	0,23715	0,33802	0,02466	3,39	0	0	3,3853	-	3,3919	-	0,14	-	-0,06	-
O_ISCTRE0219C5.50	5,58	14.02.2019	22,889	0,22889	0,51073	0,03836	0,21	2200	4	0,2900	-	0,2911	-	-27,59	-	-27,86	-
O_THYAOE0219C15.00	14,16	14.02.2019	22,889	0,22889	0,43281	0,03836	0,18	600000	400	0,2155	-	0,2175	-	-16,47	-	-17,24	-
O_TOASOE0319C15.40	19,7	19.03.2019	23,343	0,23343	0,48913	0,03288	4,38	0	0	4,4187	-	4,419	-	-0,88	-	-0,88	-
O_TTKOME0319C5.20	5,46	19.03.2019	23,343	0,23343	0,37975	0,03288	0,3	0	0	0,3422	-	0,3424	-	-12,33	-	-12,38	-
O_TUPRSE0319C116.00	138,94	19.03.2019	23,343	0,23343	0,51391	0,03288	27,83	0	0	23,9220	-	23,9251	-	16,34	-	16,32	-

O_VAKBNE0319C4.30	5,51	19.03.2019	23,343	0,23343	0,35218	0,03288	1,23	0	0	1,2429	-	1,243	-	-1,04	-	-1,05	-
O_YKBNKE0319C1.60	2,33	19.03.2019	23,343	0,23343	0,37476	0,03288	0,74	0	0	0,7422	-	0,7423	-	-0,30	-	-0,31	-
O_ARCLKE0419C16.40	18,65	9.04.2019	25,178	0,25178	0,42038	0,05753	2,45	424760	259	2,5474	-	2,5323	-	-3,82	-	-3,25	-
O_ISCTRE0419C5.30	5,88	9.04.2019	25,178	0,25178	0,45288	0,05753	0,66	219950	415	0,6984	-	0,6995	-	-5,50	-	-5,65	-
O_THYAOE0419C14.60	14,46	9.04.2019	25,178	0,25178	0,50436	0,05753	0,54	1460	1	0,8438	-	0,735	-	-36,00	-	-26,53	-
O_THYAOE0319C13.40	12,96	11.03.2019	23,557	0,23557	0,38859	0,05479	0,32	67000	50	0,3529	-	0,3537	-	-9,32	-	-9,53	-
										Average Differences (%) Based on Models				**-3,76**	-	**-3,62**	-
										Average Differences (%) Based on Models(outliers excluded)				**-1,09**		**-1,37**	
										Average of Absolute Differences Based on Models (%)				**6,16**	-	**5,68**	-
										Average of Absolute Differences Based on Models (%)(outliers excluded)				**3,72**	-	**3,59**	-
										Root MSE (Mean Square Error) %				**11,19**	-	**10,07**	

Appendix 5: Call Index Options Test Results

CONTRACT CODES of CALL OPTIONS	ASSET PRICE	TRANSACTION DATE	RISK FREE RATE (%)	RISK FREE RATE	ANNUALIZED VOLATILITY	Annualized Time	SETTLEMENT PRICE	TRADE OF VOLUME (TRY)	# of TRANSACTIONS	RESULTS of USED MODELS with MATLAB				Difference btw Models and Settlement Price (%)			
										Black&Scholes (for European Op.	Garman-Kohlhagen	Roll-Geske-Whaley	Bjersund-Stensland 2002	Black&Scholes	Garman-Kohlhagen	Roll-Geske-Whaley	Bjersund-Stensland 2002
O_XU030E0219C114.000	128785,77	14.02.2019	22,889	0,22889	0,20035	0,03836	15,85	1710000	150	15,78	-	14,7916	-	0,43	-	7,16	-
O_XU030E0219C116.000	128785,77	14.02.2019	22,889	0,22889	0,20035	0,03836	13,89	290000	25	13,80	-	12,8135	-	0,64	-	8,40	-
O_XU030E0419C122.000	123090,93	9.04.2019	25,178	0,25178	0,31229	0,05753	4,26	1061400	87	5,23	-	5,2565	-	-18,60	-	-18,96	-
O_XU030E0419C124.000	123090,93	9.04.2019	25,178	0,25178	0,31229	0,05753	3,11	3782000	305	4,12	-	4,1409	-	-24,48	-	-24,90	-
										Average Differences (%) Based on Models				-10,50	-	-7,07	-
										Average Differences (%) Based on Models (outliers excluded)				-5,84	-	-1,13	-
										Average of Absolute Differences Based on Models (%)				11,04	-	14,85	-
										Average of Absolute Differences Based on Models (%) (outliers excluded)				6,56	-	11,50	-
										Root MSE (Mean Square Error) %				15,38	-	16,59	-

Appendix 6: Call Currency Options Test Results

CONTRACT CODES of CALL OPTIONS	ASSET PRICE	TRANSACTION DATE	RISK FREE RATE (%)	RISK FREE RATE	ANNUALIZED VOLATILITY	Annualized Time	SETTLEMENT PRICE	TRADE OF VOLUME (TRY)	# of TRANSACTIONS	RESULTS of USED MODELS with MATLAB				Difference btw Models and Settlement Price (%)			
										Black&Scholes (for European Op.	Garman-Kohlhagen	Roll-Geske-Whaley	Bjersund-Stensland 2002	Black&Scholes	Garman-Kohlhagen	Roll-Geske-Whaley	Bjersund-Stensland 2002
O_USDTRYKE0119C 5250	5,4003	2.01.2019	22,495	0,22495	0,11038	0,07945	268,3	52500	10	248,3121	238,6786	-	-	8,049507052	12,41	-	-
O_USDTRYKE0119C 5300	5,4003	2.01.2019	22,495	0,22495	0,11038	0,07945	231,1	530000	100	203,881	194,7808	-	-	13,35043481	18,65	-	-
O_USDTRYKE0219C 5200	5,2729	14.02.2019	22,889	0,22889	0,11915	0,03836	161,6	338000	65	129,0287	166,1056	-	-	25,24345359	-2,71	-	-
O_USDTRYKE0219C 5250	5,2729	14.02.2019	22,889	0,22889	0,11915	0,03836	123,2	136500	26	90,6902	137,8300	-	-	35,84709263	-10,61	-	-
O_USDTRYKE0319C 5400	5,4764	19.03.2019	23,343	0,23343	0,07430	0,03288	123,4	1463400	2710	119,4794	126,4817	-	-	3,281402484	-2,44	-	-
O_USDTRYKE0319C 5450	5,4764	19.03.2019	23,343	0,23343	0,07430	0,03288	86,7	10900	2	78,1855	96,0891	-	-	10,89012669	-9,77	-	-
O_USDTRYKE0319C 5500	5,4764	19.03.2019	23,343	0,23343	0,07430	0,03288	57,2	27500	5	39,6212	70,6655	-	-	44,36715698	-19,06	-	-
O_USDTRYKE0319C 5550	5,4764	19.03.2019	23,343	0,23343	0,07430	0,03288	35,5	555000	100	16,5685	50,2058	-	-	114,2620032	-29,29	-	-
O_USDTRYKE0319C 5600	5,4764	19.03.2019	23,343	0,23343	0,07430	0,03288	21	1232000	220	5,2553	34,4000	-	-	299,5965977	-38,95	-	-
O_USDTRYKE0419C 5700	5,6943	9.04.2019	25,178	0,25178	0,25831	0,05753	148,7	3534000	620	182,2163	311,5772	-	-	-18,39368926	-52,28	-	-
O_USDTRYKE0419C 5800	5,6943	9.04.2019	25,178	0,25178	0,25831	0,05753	101,4	580000	100	130,9566	265,3510	-	-	-22,56976739	-61,79	-	-
O_USDTRYKE0319C 5300	5,4455	11.03.2019	23,557	0,23557	0,087758496	0,054795	209,9	5300	1	214,5451	207,0650	-	-	-2,165092561	1,37	-	-
										Average Differences (%) Based on Models				42,65	-16,21	-	-
										Average Differences (%) Based on Models (outliers excluded)				17,36	-1,52		
										Average of Absolute Differences Based on Models (%)				49,83	21,61	-	-

Average of Absolute Differences Based on Models (%) (outliers excluded)	**11,56**	**-1,39**	-	-
Root MSE (Mean Square Error) %	**94,84**	**28,89**	-	-

Appendix 7: Put Equity Options Test Results

CONTRACT CODES of CALL OPTIONS	ASSET PRICE	TRANSACTION DATE	RISK FREE RATE (%)	RISK FREE RATE	ANNUALIZED VOLATILITY	Time	SETTLEMENT PRICE	TRADE OF VOLUME (TRY)	# of TRANSACTIONS	RESULTS of USED MODELS with MATLAB				Difference btw Models and Settlement Price (%)			
										Black&Scholes (for European Op.	Garman-Kohlhagen	Roll-Geske-Whaley	Bjersund-Stensland 2002	Black&Scholes	Garman-Kohlhagen	Roll-Geske-Whaley	Bjersund-Stensland 2002
O_PGSUSE0119P28.50	25,9	22.01.2019	23,715	0,23715	0,31996589	0,02465753	2,48	0	0	2,4539	-	-	2,6146	1,06	-	-	-5,15
O_AKBNKE0219P6.50	6,69	14.02.2019	22,889	0,22889	0,40746983	0,03835616	0,07	260000	400	0,1084	-	-	0,2886	-35,42	-	-	-75,74
O_THYAOE0219P14.00	14,16	14.02.2019	22,889	0,22889	0,43280956	0,03835616	0,3	280000	200	0,3461	-	-	0,3525	-13,32	-	-	-14,89
O_TUPRSE0519P134.00	138,94	19.03.2019	23,343	0,23343	0,51390659	0,03287671	4,35	1340000	100	2,6197	-	-	2,6461	66,05	-	-	64,39
										Average Differences (%) Based on Models				4,59	-	-	-7,85
										Average Differences (%) Based on Models (outliers excluded)				-6,13			-10,02
										Average of Absolute Differences Based on Models (%)				28,96	-	-	40,04
										Average of Absolute Differences Based on Models (%) (outliers excluded)				7,19			4,87
										Root MSE (Mean Square Error) %				38,07	-	-	50,33

Appendix 8: Put Index Options Test Results

CONTRACT CODES of CALL OPTIONS	ASSET PRICE	TRANSACTION DATE	RISK FREE RATE (%)	RISK FREE RATE	ANNUALIZED VOLATILITY	Time	SETTLEMENT PRICE	TRADE OF VOLUME (TRY)	# of TRANSACTIONS	RESULTS of USED MODELS with MATLAB				Difference btw Models and Settlement Price (%)			
										Black&Scholes (for European Op.	Garman-Kohlhagen	Roll-Geske-Whaley	Bjersund-Stensland 2002	Black&Scholes	Garman-Kohlhagen	Roll-Geske-Whaley	Bjersund-Stensland 2002
O_XU030E0219P126.000	128785,77	14.02.2019	22,889	0,22889	0,200351908	0,03835616	1,04	3452400	274	0,6186	-	-	0,6427	68,12	-	-	61,81733313
O_XU030E0219P130.000	128785,77	14.02.2019	22,889	0,22889	0,200351908	0,03835616	2,51	715000	55	2,0561	-	-	2,1917	22,08	-	-	14,52297303
O_XU030E0419P114.000	123090,93	9.04.2019	25,178	0,25178	0,312294333	0,057534247	0,56	342000	30	0,4764	-	-	0,49	17,55	-	-	14,28571429
O_XU030E0419P120.000	123090,93	9.04.2019	25,178	0,25178	0,312294333	0,057534247	1,69	3948000	329	1,6971	-	-	1,7608	-0,42	-	-	-4,020899591
O_XU030E0419P122.000	123090,93	9.04.2019	25,178	0,25178	0,312294333	0,057534247	2,34	1281000	105	2,3880	-	-	2,4904	-2,01	-	-	-6,039190491
										Average Differences (%) Based on Models				21,06	-	-	16,11
										Average Differences (%) Based on Models (outliers are excluded)				9,30	-	-	4,69
										Average of Absolute Differences Based on Models (%)				22,03	-	-	20,14
										Average of Absolute Differences Based on Models (%) (outliers are excluded)				10,51			9,72
										Root MSE (Mean Square Error) %				32,98	-	-	29,29

Appendix 9: Put Currency Options Test Results

CONTRACT CODES of CALL OPTIONS	ASSET PRICE	TRANSACTION DATE	RISK FREE RATE (%)	RISK FREE RATE	ANNUALIZED VOLATILITY	Time	SETTLEMENT PRICE	TRADE OF VOLUME (TRY)	# of TRANSACTIONS	RESULTS of USED MODELS with MATLAB				Difference btw Models and Settlement Price (%)			
										Black&Scholes (for European Op.	Garman-Kohlhagen	Roll-Geske-Whaley	Bjersund-Stensland 2002	Black&Scholes	Garman-Kohlhagen	Roll-Geske-Whaley	Bjersund-Stensland 2002
O_USDTRYKE011 9P5250	5,4003	2.01.2019	22,495	0,22495	0,110384239	0,079452055	40,7	3307500	630	5,01	35,1448	-	-	712,3752495	15,81	-	-
O_USDTRYKE011 9P5275	5,4003	2.01.2019	22,495	0,22495	0,110384239	0,079452055	46,3	221550	42	7,04	41,1329	-	-	557,6704545	12,56	-	-
O_USDTRYKE021 9P5200	5,2729	14.02.2019	22,889	0,22889	0,119153651	0,038356164	16,3	1144000	220	10,6716	10,6714	-	-	52,74185689	52,74	-	-
O_USDTRYKE021 9P5250	5,2729	14.02.2019	22,889	0,22889	0,119153651	0,038356164	27,5	320250	61	21,8963	21,8958	-	-	25,59199499	25,59	-	-
O_USDTRYKE031 9P5400	5,4764	19.03.2019	23,343	0,23343	0,074299205	0,032876712	15,7	14347800	2657	1,6468	42,4700	-	-	853,3641001	-63,03	-	-
O_USDTRYKE041 9P5400	5,6943	9.04.2019	25,178	0,25178	0,258308919	0,057534247	18,3	54000	10	23,8513	23,8497	-	-	-23,27462235	-23,27	-	-
O_USDTRYKE041 9P5600	5,6943	9.04.2019	25,178	0,25178	0,258308919	0,057534247	58,2	179200	32	68,3334	68,3313	-	-	-14,82935139	-14,83	-	-
										Average Differences (%) Based on Models				309,09	0,80	-	-
										Average Differences (%) Based on Models (outliers are excluded)				307,99	-2,43		
										Average of Absolute Differences Based on Models (%)				319,98	29,69	-	-
										Average of Absolute Differences Based on Models (%) (outliers are excluded)				327,04	16,62	-	-
										Root MSE (Mean Square Error) %				470,70	35,01	-	-

Appendix 10: MATLAB Codes for Models

Black and Scholes Formula

[Call,Put] = blsprice(Price,Strike,Rate,Time,Volatility)
[Call,Put] = blsprice(___,Yield)

- Price — Current price of underlying asset
- Strike — Exercise price of the option
- Rate — Annualized continuously compounded risk-free rate of return over life of the option
- Time — Time to expiration of option
- Volatility — Annualized asset price volatility
- Yield — Annualized continuously compounded yield of underlying asset over life of the option

Garman-Kohlhagen Model

Price = blsprice(S,X,r_d,T,sigma,r_f)

- Price an FX option on buying GBP with USD.
- S = 1.6; % spot exchange rate
- X = 1.6; % strike
- T = .3333;
- r_d = .08; % USD interest rate
- r_f = .11; % GBP interest rate
- sigma = .2;

Bjerksund-Stensland Model-2002

StockSpec = stockspec(Sigma, AssetPrice, {'continuous'}, DivYield);
RateSpec = intenvset('ValuationDate', Settle, 'StartDates', Settle,...
'EndDates', Maturity, 'Rates', Rate, 'Compounding', -1);
OptSpec = {'call'; 'put'};
Price = optstockbybjs(RateSpec, StockSpec, Settle, Maturity, OptSpec, Strike)

- Settle = 'Jan-1-2019';
- Maturity = 'Jan-31-2019';
- Strike = 118;
- AssetPrice = [114.5];
- DivYield = 0.000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000001;
- DivDate = 'Jan-16-2019';
- Rate = 0.22495;
- Sigma = 0.30089;

Roll-Geske-Whaley Model

```
StockSpec = stockspec(Sigma, AssetPrice, {'cash'}, DivAmount, DivDate);
RateSpec = intenvset('ValuationDate', Settle, 'StartDates', Settle,...
'EndDates', Maturity, 'Rates', Rate, 'Compounding', -1);
Price  = optstockbyrgw(RateSpec, StockSpec, Settle, Maturity, Strike)
```

- AssetPrice = 114.5;
- Settle = 'Jan-01-2019';
- Maturity = 'Jan-31-2019';
- Strike = [118];
- Rate = 0.22495;
- Sigma = 0.30089;
- DivAmount = 0.0000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000001;
- DivDate = 'Jan-16-2019';