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Pricing of Covered Warrants: An Analysis on Borsa İstanbul[1]

Melek AKSU *(https://orcid.org/0000-0003-2906-1117), Department of Business Administration, Balıkesir University, Turkey; e-mail: maksu@balikesir.edu.tr*

Şakir SAKARYA *(https://orcid.org/0000-0003-2510-7384), Department of Business Administration, Balıkesir University, Turkey; e-mail: sakarya@balikesir.edu.tr*

Hisse Senedine Dayalı Yatırım Kuruluşu Varantlarının Fiyatlaması: Borsa İstanbul'da Bir Uygulama[2]

Abstract

This paper examines the pricing of 23 call and 23 put covered warrants based on Eregli Demir Celik Fabrikaları T.A.S. stocks, issued and expired in 2015. Black-Scholes, and Gram-Charlier pricing models are used to price covered warrants. Empirical results show that pricing performance of Black-Scholes model is better for call warrants while pricing performance of Gram-Charlier model is better for put warrants. It is also indicated that observed market prices are irrationally higher than model prices and both of models are not so succesfull for pricing warrants in Turkey.

Keywords : Covered Warrants, Black-Scholes, Gram-Charlier, Pricing.

JEL Classification Codes : G10, G12.

Öz

Bu çalışmada 2015 yılında ihraç edilmiş ve aynı yıl vadesi dolmuş Ereğli Demir Çelik A.Ş. hisse senetlerine dayalı 23 adet alım ve 23 adet satım yatırım kuruluşu varantının piyasada doğru fiyatlanıp fiyatlanmadığı araştırılmıştır. Varantları fiyatlamak için literatürde yer alan Black-Scholes ve Gram-Charlier opsiyon fiyatlama modellerinden yararlanılmıştır. Çalışmanın sonucunda Ereğli Demir Çelik A.Ş. hisselerine dayalı varantların piyasa fiyatlarının, modeller yardımıyla hesaplanan teorik fiyatlara göre yüksek olduğu tespit edilmiştir. Black-Scholes fiyatlama modelinin alım varantlarını Gram-Charlier'e göre daha doğru fiyatladığı ve satım varantlarının fiyatlamasında da Gram-Charlier modelinin tercih edilebileceği ve her iki modelin de Türkiye'de varantları fiyatlama konusunda çok başarılı olmadığı tespit edilmiştir. Bu sonuçlar doğrultusunda bu modellerin Türkiye'deki varantları fiyatlamak için uygun olmadığı yorumu yapılabilmektedir.

Anahtar Sözcükler : Yatırım Kuruluşu Varantı, Black-Scholes, Gram-Charlier, Fiyatlama.

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[1] *This article is the revised version of the master thesis titled as "Pricing Covered Warrants: An Analysis on Borsa Istanbul" which was presented by Melek Aksu in Balıkesir University, on June 28, 2016 under supervision of Prof. Şakir Sakarya.*

[2] *Bu çalışma, Prof.Dr. Şakir Sakarya danışmanlığında, Melek Aksu tarafından hazırlanan, 28.06.2016 tarihinde Balıkesir Üniversitesi Sosyal Bilimler Enstitüsü İşletme Anabilim Dalı'nda savunulan "Hisse Senedine Dayalı Yatırım Kuruluşu Varantlarının Fiyatlaması: BIST'te Bir Uygulama" başlıklı yüksek lisans tezinden türetilmiştir.*

1. Introduction

It is no doubt that most or all kinds of investment involve some forms of risk. In the financial markets, financial derivatives are used by investors to control investment risks. One of the common question of the investors is what the price of the financial derivatives will be (Jiratumpradub & Chavanasporn, 2016). Determining the theoretical price for financial derivatives is regarded as one of the most important issues in financial research. Accurately calculating financial derivatives' current price or forecasting its future price helps investors to make wise decisions in a more effective fashion (Liang & Zhang & Xiao & Chen, 2009: 3055). The forecasting activity should realistically identify the financial derivatives' price in the future without knowing underlying asset price in advance (Liang & Zhang & Li, 2009: 586).

In all over the world, investors are searching for new investment opportunities to get higher returns in emerging markets. However, emerging markets are the most volatile markets with higher risk premiums than developed markets. For this reason, derivatives markets and efficient pricing models are crucial for hedging purposes in emerging markets (Alp, 2016: 70). Policymakers or regulators should care that the pricing of financial derivatives has diverged from their theoretical values; hence the market is very large and the potential systemic risks of a mispricing of such a large market cannot be dismissed. Derivatives prices also have become integral to many regulatory frameworks themselves. Regulators accept derivatives contracts as risk-limiting hedges for banks' asset portfolios. In many jurisdictions, the calculations of insurance company and pension fund liabilities reference swap rates: mispriced derivatives have consequences for real-world pensions and insurance contracts (Mutkin, 2015).

Covered warrants which are securitized options have been traded in Turkey since 2010. The warrants market has a very short history in Turkey. Covered warrants may improve financial depth and width in Turkey. Despite covered warrants' growing market size and significance, there are a few researches on covered warrants market in Turkey. Pricing of covered warrants has not been studied as much as pricing equity warrants on literature. This study contributes to the literature by pricing covered warrants using a method of Gram-Charlier that is used to price options and not used to price warrants before. This study investigates the pricing efficiency of Black-Scholes and Gram-Charlier models on covered warrants in Turkey. The purpose of this paper is to attempt to price covered warrants issued and expired between January, 2015 and December, 2015 and based on Eregli Demir ve Celik Fabrikaları T.A.S. stocks and to determine whether these models are appropriate to price covered warrants in Turkey.

The rest of the study is organized as follows. Following section gives information about covered warrants market of Turkey. Section 3 presents warrant pricing models. Section 4 reviews the relevant literature. Section 5 describes the data and methodology. Section 6 interprets the empirical results, and last section concludes.

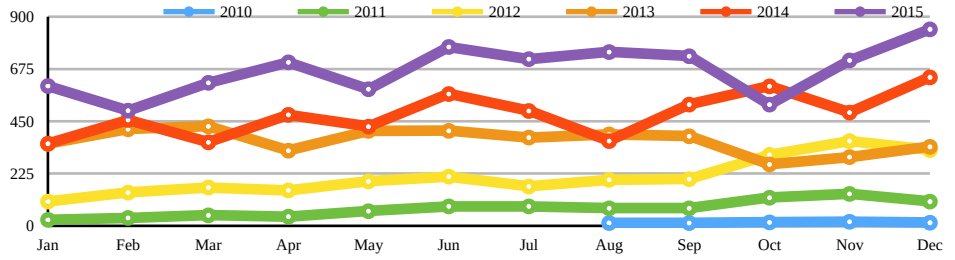
2. Covered Warrants Market in Turkey

Covered warrants are securitized options that give the holder the right, but not the obligation, to either buy or sell an underlying asset like equity (equity of other companies), index, currency and commodities (gold and oil) at a predetermined price (exercise price) on or before a certain date in the future (expiry date) (London Stock Exchange, 2016). Covered warrants and equity warrants have similar definitions, but there are several differences between them. The most significant difference between covered and equity warrants is that covered warrants are issued by banks or financial institutions and based on other companies' stocks, commodities or currencies, while equity warrants are issued by companies and based on own stocks (Ekstrand, 2011: 196; Temple, 2007: 143).

The investors have different cultural bias, psychological modes, life expectations and scarce budget in Turkey and need to a diversified portfolio for investing and hedging. The different types of covered warrants have been emerged to satisfy investors' different needs and expectations in Turkey in 13 August 2010.

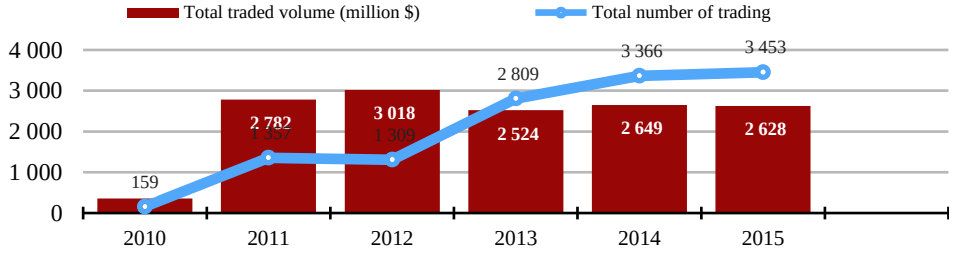
The World Federation of Exchanges categorizes exchange of Turkey (BIST) between Europe-Africa-Middle East exchanges. BIST has been issuing structured products since 2010 according to statistics of The World Federation of Exchanges. It means that Turkey started to issue structured products with covered warrants in 2010. After 2010, the number of issued structured products, number of trading and trading volume have been increasing as shown in Figure 1 and 2. This can be a signal to development of covered warrants.

Figure: 1
The Number of Structured Products in Turkey



**Prepared by the author according to WFE statistics.*

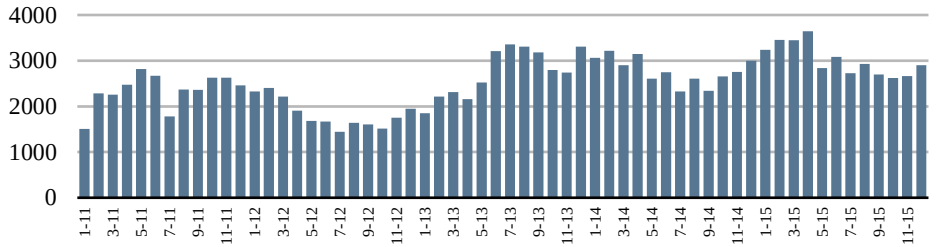
Figure: 2
The Number and Volume of Transactions of Structured Products in Turkey



**Prepared by the author according to WFE statistics.*

According to the statistics of Turkish Capital Markets Association, the number of investors who invest in covered warrants has been increasing as is seen from Figure 3. The number of investors is around 1.500 in 2011, and then increases to 2.500 in 2014.

Figure: 3
The Number of Covered Warrants Investors in Turkey Between 2011-2015



**Prepared by the author according to Turkish Capital Markets Association statistics.*

Three institutions issue covered warrants in Turkey; IS Investment, Deutsche Bank and Garanti Bank. The law allows to issue American or European types of covered warrants based on stocks included in BIST 30 index and a basket of these stocks, convertible exchanges, commodities, stock indexes prepared by BIST, and indexes that are accepted internationally. However, there are only European covered warrants in the market of Turkey. The covered warrants are traded on the Market of Collective Investment and Structured Products under BIST.

Deutsche Bank has been issuing covered warrants based on S&P 500, Dow Jones Industrial Average, NASDAQ 100, EURO STOXX 50, DAX, FTSE 100 and Nikkei 225 indexes, stocks of AKBNK, EKGYO, EREGL, GARAN, HALKB, ISCTR, KCHOL, SAHOL, THYAO, TTKOM, TUPRS, VAKBN and YKBNK stocks (Deutsche Bank, 2016). IS Investment has been issuing covered warrants based on AKBNK, EKGYO, EREGL, GARAN, HALKB, ISCTR, KCHOL, SAHOL, SISE, THYAO, TOASO, TTKOM, TUPRS, VAKBN and YKBNK stocks, BIST 30 and DAX® indexes, ons gold, Brent oil, USD/TL

and EUR/USD exchanges. Also IS Investment has been issuing also flexo exchange, flexo oil, flexo gold and flexo DAX warrants (Is Warrant, 2016). The underlying asset of covered warrants of Garanti Bank that has started to issue covered warrants in 2013 is BIST 30 indexes (Garanti Bank, 2016).

3. Warrant Pricing Models

Option pricing models are used to price warrants. There are several models to predict warrant price, but there is no model to set an exact price for warrants (Boonchuaymetta & Kongtoranin, 2007: 57). Black-Scholes model that is the most popular option pricing model and Gram-Charlier model that allows for skewness and greater kurtosis than the normal distribution are reviewed in this section because these models are used to price covered warrants in this study.

3.1. Black - Scholes Pricing Model

Black-Scholes model is hailed as a milestone in derivative trading, and elaborates hedging strategies which provide investors with a safe growth of appropriately composed portfolios of financial assets. The usefulness of the Black-Scholes formula was based on several assumptions (Kleinert & Korbel, 2016: 1). The model assumes ideal conditions in the market (Black & Scholes, 1973: 640):

- The short-term interest rate is known and is constant through time.
- The stock price follows a random walk in continuous time with a variance rate proportional to the square of the stock price. Thus the distribution of possible stock prices at the end of any finite interval is log-normal. The variance rate of the return on the stock is constant.
- The stock pays no dividends or other distributions.
- The option is "European", that is, it can only be exercised at maturity.
- There are no transaction costs in buying or selling the stock or the option.
- It is possible to borrow any fraction of the price of a security to buy it or to hold it, at the short-term interest rate.
- There are no penalties to short selling. A seller who does not own a security will simply accept the price of the security from a buyer, and will agree to settle with the buyer on some future date by paying him an amount equal to the price of the security on that date.

Every aspect of the market cannot be considered in any given model, as every factor affecting the price of a financial security cannot be captured mathematically. Despite of these assumptions, the Black-Scholes formula remains in wide spread use and despite its harshest critics a formula that is still integral to options pricing can hardly be called "dead" or "dying" (Yalincak, 2005: 2-9).

The Black-Scholes model for put and call warrants is demonstrated below (Higham, 2004: 80-81).

Pricing model for call warrants;

$$C = SN(d_1) - Ke^{-rt}N(d_2)$$

Pricing model for put warrants;

$$P = Ke^{-rt}N(-d_2) - SN(-d_1)$$

The variables of Black-Scholes formula are explained below (Higham, 2004: 80; Chambers, 2012: 113).

d_1 $= \frac{1}{\sigma\sqrt{\tau}}\left[\ln\left(\frac{S}{K}\right) + \left(r + \frac{\sigma^2}{2}\right)\tau\right]$

d_2 $= \frac{1}{\sigma\sqrt{\tau}}\left[\ln\left(\frac{S}{K}\right) + \left(r - \frac{\sigma^2}{2}\right)\tau\right] = d_1 - \sigma\sqrt{\tau}$

S = underlying stock price

K = warrant exercise price

R = annual risk free rate of interest

σ = annual standard deviation of logarithmic return of stocks

τ = remaining days to maturity

N(x) = cumulative standard normal distribution function
= N(0,1) cumulative probability distribution function

ln = natural logarithm

e = mathematical constant (2.7183)

3.2. Gram - Charlier Pricing Model

Gram-Charlier model is developed by Backus, Foresi, and Wu (2004) and accounts both skewness and kurtosis of returns of the underlying asset. They use a Gram-Charlier expansion up to the fourth order in the distribution of returns of the underlying asset. This allows for skewness and greater kurtosis than the normal distribution to be introduced into

option pricing. This model, however, assumes that volatility is constant over time (Rouah & Vainberg, 2007: 124).

The pricing formula and variables of Gram-Charlier model are demonstrated below (Straja, 2003: 2; Rouah & Vainberg, 2007: 126).

$$C = S\,e^{-\delta\tau-\sigma^3\tau^2\frac{3}{2}\frac{\gamma_1}{6}-\sigma^4\tau^2\frac{\gamma_2}{24}}N(d) - Ke^{-r\tau}N\left(d-\sigma\sqrt{\tau}\right) + S\,e^{-\delta\tau}\sigma\sqrt{\tau}\varphi(d)\left\{\left(2\sigma\sqrt{\tau}-d\right)\frac{\gamma_1}{6}+\left[3\sigma^2\tau-3\sigma\sqrt{\tau}d+d^2-1\right]\frac{\gamma_2}{24}\right\} + S\,e^{-\delta\tau-\sigma^3\tau^2\frac{3}{2}\frac{\gamma_1}{6}-\sigma^4\tau^2\frac{\gamma_2}{24}}\cdot\left[\sigma^3\tau^2\frac{3}{2}\frac{\gamma_1}{6}+\sigma^4\tau^2\frac{\gamma_2}{24}\right]N(d)$$

$$d = \frac{\left[ln\left(\frac{S}{K}\right)+(r-\delta)\tau+\frac{\sigma^2\tau}{2}-\sigma^3\tau^{3/2}\frac{\gamma_1}{6}-\sigma^4\tau^2\frac{\gamma_2}{24}\right]}{\sigma\sqrt{\tau}}$$

S = underlying stock price

K = warrant exercise price

r = annual risk free rate of interest

σ = annual standard deviation of logarithmic return of stocks

τ = remaining days to maturity

N(x) = cumulative standard normal distribution function
= N(0,1) cumulative probability distribution function

ϕ = normal probability distribution function

δ = dividend yield

γ1 = skewness of underlying stocks' return

γ2 = kurtosis of underlying stocks' return

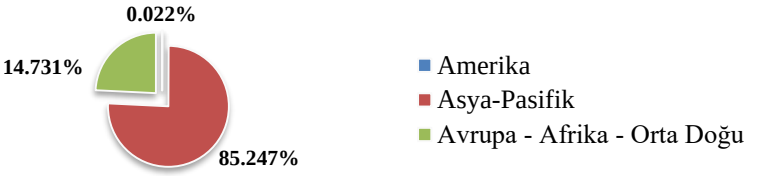
4. Literature Review

The World Federation of Exchanges has divided exchanges of world into three groups; exchanges of Asia and Pacific, Europe, Africa and Middle East, and America. Exchanges' trading volume of warrants is illustrated in Figure 4 and 5. Literature is reviewed

under two categories; Asia-Pasific countries and Europe-Africa and Middle East countries, because there is no more warrants traded in America.

Figure: 4
Transaction Volume of Structured Products in 2014

Figure: 5
Transaction Volume of Structured Products in 2015



4.1. Literature Review of Asia and Pacific Countries on Covered Warrants

Exchanges of Asia and Pacific countries are more familiar with structured products like warrants, as seen from the figures above, so there are more studies about pricing covered warrants in Asia and Pacific literature.

Hong Kong Exchange is the most significant and biggest exchange about warrants trade. Duan and Yan (1999) price covered warrants traded on the Hong Kong Exchange and based on HSBC stocks for before and after of 1997 crisis. The result of their study presents that the models have priced warrants lower than the market. Wu, Ma and Wang (2012) use GARCH diffusion and Black-Scholes model to price Hang Seng Index warrants traded on the Hong Kong Stock Exchange. Empirical results show that the GARCH diffusion model outperforms the Black-Scholes model in terms of the pricing accuracy, indicating that the pricing model incorporated with stochastic volatility can improve the pricing of warrants.

Exchanges of Taiwan is also significant for covered warrants. Chen and Huang (2002), and Chen (2003) price covered warrants traded on Exchanges of Taiwan that is one of the significant exchanges of the Asia and Pacific region. Chen and Huang have used Hull-White and Black-Scholes models to price covered warrants and attained similar results with Duan and Yan. Another result of the study of Chen and Huang is that models which include implied or stochastic volatility are more powerful to predict the price of warrants. Chen has priced 23 covered warrants traded in Taiwan by using Black-Scholes and Klein model that

is incorporated with credit risk, and reported that when credit risk included in warrant pricing, price of warrant will be lower than Black-Scholes model price.

Pricing of covered warrants has attracted a great deal of attention in China. Fan and Yuan (2011) price 10 covered and 7 equity warrants traded in warrants market in China and find that the observed market prices are irrationally higher than the Black-Scholes model prices by 80.38% (using 180-day historical volatility) and 140.50% (using EGARCH volatility). The study of Liu and Rangan (2012) examines the pricing covered warrants traded in China and finds that the implied volatility is higher than the realized volatility across maturities, resulting in huge overvaluation across maturities. The results appear to be overvalued covered warrants and inefficient markets.

Bursa Malaysia has a huge variety of financial products. Mansor and Jaffar (2014) price covered warrants traded in Bursa Malaysia by using finite difference approach and central in time and central in space scheme (CTCS). Their study reveals that CTCS scheme gives closed prices to market prices.

4.2. Literature Review of Europe-Africa and Middle East Countries on Covered Warrants

The exchanges of the United Kingdom, Greece, and Turkey are among Europe-Africa and Middle East exchanges.

Klinpratoom (2010) studies on covered warrants pricing in the United Kingdom and uses Black-Scholes model and Klein model that is incorporated with credit risk. She explores that covered warrants are overvalued in the market of the United Kingdom, and Klein model gives lower prices than Black-Scholes model. Siriopoulos and Fassas (2014) attempts to price covered warrants in Exchange of Athens. The results of their study show that covered warrants are undervalued in market. Akmehmet (2012) prices covered warrants based on stocks of several companies and BIST-30 index by using Black-Scholes model and different volatilities and interest rate parameters. The model that is incorporated Central Bank Republic of Turkey's policy interest rate and 90 day volatility data has the highest capacity to forecast market prices. Karakuş and Zor (2014) examines 61 covered warrants based on BIST-30 index by using Black-Scholes, Black-Scholes-Merton, Binomial, and Square Root Constant Elasticity Variance models. As a result of their study, Black- Scholes-Merton model is the most efficient pricing model for in-the-money warrants, but it is not possible to choose any model for at-the-money and out-of-money warrants.

5. Data and Methodology

This study attempts to price 25 call and 25 put covered warrants based on stocks of Eregli Demir ve Celik Fabrikaları T.A.S., issued by IS Investment by using Black-Scholes and Gram-Charlier models. The research group covers covered warrants that are issued and expired between January, 2015 and December, 2015. In line with the study of Chen and Liao

(2010), butterfly warrants[3] are excluded from research group and so final research group consists of 23 call and 23 put warrants. Table 1 provides a complete list of research group. The covered warrants that have codes of ERIDB, ERIDC, ERIVV and ERIVY are excluded research group because of their butterfly character. The covered warrants have the "0" value on some days and warrants that are traded till maturity have no value at the end of the maturity, so "0" days and the last day of maturities are excluded from analysis.

Table: 1
The Research Group

Type of Warrants	Codes of Warrants	Underlying Asset	Issuer	Date of Issuance	Expiry Date	Trading Days
Call	ERIBO	Eregli Stocks	IS Investment	14.01.2015	30.04.2015	75
Call	ERICA	Eregli Stocks	IS Investment	14.01.2015	30.04.2015	72
Call	ERICB	Eregli Stocks	IS Investment	14.01.2015	30.04.2015	67
Call	ERICC	Eregli Stocks	IS Investment	18.03.2015	29.05.2015	48
Call	ERICD	Eregli Stocks	IS Investment	18.03.2015	29.05.2015	46
Call	ERICE	Eregli Stocks	IS Investment	18.03.2015	29.05.2015	47
Call	ERICF	Eregli Stocks	IS Investment	09.04.2015	30.06.2015	51
Call	ERICG	Eregli Stocks	IS Investment	09.04.2015	30.06.2015	52
Call	ERICH	Eregli Stocks	IS Investment	09.04.2015	30.06.2015	54
Call	ERICI	Eregli Stocks	IS Investment	12.05.2015	31.07.2015	49
Call	ERICJ	Eregli Stocks	IS Investment	12.05.2015	31.07.2015	42
Call	ERICK	Eregli Stocks	IS Investment	12.05.2015	31.08.2015	53
Call	ERICL	Eregli Stocks	IS Investment	26.05.2015	31.07.2015	40
Call	ERICM	Eregli Stocks	IS Investment	16.06.2015	31.08.2015	43
Call	ERICN	Eregli Stocks	IS Investment	16.06.2015	31.08.2015	38
Call	ERIDA	Eregli Stocks	IS Investment	16.06.2015	30.09.2015	48
Call	ERIDB	Eregli Stocks	IS Investment	02.07.2015	30.09.2015	butterfly
Call	ERIDC	Eregli Stocks	IS Investment	02.07.2015	30.09.2015	butterfly
Call	ERIDD	Eregli Stocks	IS Investment	02.07.2015	30.10.2015	40
Call	ERIDE	Eregli Stocks	IS Investment	24.08.2015	30.10.2015	46
Call	ERIDF	Eregli Stocks	IS Investment	24.08.2015	30.10.2015	46
Call	ERIDG	Eregli Stocks	IS Investment	24.08.2015	30.10.2015	39
Call	ERIDH	Eregli Stocks	IS Investment	10.09.2015	30.11.2015	54
Call	ERIDI	Eregli Stocks	IS Investment	10.09.2015	30.11.2015	53
Call	ERIDJ	Eregli Stocks	IS Investment	10.09.2015	30.11.2015	49
Put	ERITV	Eregli Stocks	IS Investment	14.01.2015	30.04.2015	73
Put	ERITY	Eregli Stocks	IS Investment	14.01.2015	30.04.2015	73
Put	ERITZ	Eregli Stocks	IS Investment	14.01.2015	30.04.2015	70
Put	ERIUP	Eregli Stocks	IS Investment	18.03.2015	29.05.2015	24
Put	ERIUR	Eregli Stocks	IS Investment	18.03.2015	29.05.2015	16
Put	ERIUS	Eregli Stocks	IS Investment	18.03.2015	29.05.2015	16
Put	ERIUT	Eregli Stocks	IS Investment	09.04.2015	30.06.2015	53
Put	ERIUU	Eregli Stocks	IS Investment	09.04.2015	30.06.2015	46
Put	ERIUV	Eregli Stocks	IS Investment	09.04.2015	30.06.2015	43
Put	ERIUY	Eregli Stocks	IS Investment	12.05.2015	31.07.2015	55
Put	ERIUZ	Eregli Stocks	IS Investment	12.05.2015	31.07.2015	40
Put	ERIVP	Eregli Stocks	IS Investment	12.05.2015	31.08.2015	73
Put	ERIVR	Eregli Stocks	IS Investment	26.05.2015	31.07.2015	45
Put	ERIVS	Eregli Stocks	IS Investment	16.06.2015	31.08.2015	52
Put	ERIVT	Eregli Stocks	IS Investment	16.06.2015	31.08.2015	46
Put	ERIVU	Eregli Stocks	IS Investment	16.06.2015	30.09.2015	71
Put	ERIVV	Eregli Stocks	IS Investment	02.07.2015	30.09.2015	butterfly
Put	ERIVY	Eregli Stocks	IS Investment	02.07.2015	30.09.2015	butterfly
Put	ERIVZ	Eregli Stocks	IS Investment	02.07.2015	30.10.2015	79
Put	ERIYP	Eregli Stocks	IS Investment	24.08.2015	30.10.2015	46
Put	ERIYR	Eregli Stocks	IS Investment	24.08.2015	30.10.2015	36
Put	ERIYS	Eregli Stocks	IS Investment	24.08.2015	30.10.2015	31
Put	ERIYT	Eregli Stocks	IS Investment	10.09.2015	30.11.2015	54

[3] *Butterfly warrants are warrants that issued several issuers (Deutsche Bank and IS Investment) based on same underlying security and have same maturity.*

Put	ERIYU	Eregli Stocks	IS Investment	10.09.2015	30.11.2015	50
Put	ERIYV	Eregli Stocks	IS Investment	10.09.2015	30.11.2015	35

The data set of this study includes variables of Black-Scholes and Gram-Charlier models; strike prices of covered warrants, daily closing prices of Eregli stocks, risk free rate of interest, dividend yield of stocks, volatility, skewness and kurtosis of logarithmic return of stocks and the maturity of covered warrants. To evaluate the pricing capacity of models, daily closing prices of covered warrants are needed. The sources and programs that are used to obtain data are presented on Table 2.

Table: 2
Sources of Data

Strike prices of covered warrants	CSD
The maturity of covered warrants	CSD
Daily closing prices of covered warrants	Finnet 2000+
Daily closing prices of Eregli stocks (unadjusted prices)	BIST Data Store
The risk free rate of interest	CBRT
The dividend yield of Eregli stocks	Finnet
The daily volatility of logarithmic return of Eregli stocks	Numbers
The skewness and kurtosis of logarithmic return of Eregli stocks	SPSS

**CSD: Central Securities Depository of Turkey; CBRT: Central Bank Republic of Turkey.*

The variables of risk free rate of interest, dividend yield of stocks, and volatility of logarithmic return of stocks are not exactly definite or observable variables so they should be assumed. The interest rate of the treasury bills and government bonds sold by auction is used as the risk free rate of interest. The annual simple average interest rate of the bills and bonds that have the shortest maturity is used, because warrants have no longer maturity in Turkey. The dividend yield of Eregli stocks is calculated as average of 5-year period (2010-2014), because covered warrants have become to issue in 2010 and this study examines covered warrants of 2015. 21-day historical volatility is used to predict the volatility, because the maturity of covered warrants traded on BIST is no longer, and 21-day is one of the period that is used by BIST to gauge volatility. Daily volatility is calculated over the maturity of covered warrants. Morever, the unadjusted daily closing prices of Eregli stocks are used to price warrants. The variables are demonstrated on Table 3.

Table: 3
The Variables of Models

Types of Warrants	Codes of Warrants	Date of Issuance	Expiry Date	Risk Free Interest Rate (%)	Strike Prices (₺)	Skewness	Kurtosis	Dividend Yield
Call	**ERIBO**	14.01.2015	30.04.2015	7.75	4.5	-0.667	0.493	0.0598
Call	**ERICA**	14.01.2015	30.04.2015	7.75	5	-0.667	0.493	0.0598
Call	**ERICB**	14.01.2015	30.04.2015	7.75	5.2	-0.667	0.493	0.0598
Call	**ERICC**	18.03.2015	29.05.2015	8.08	3.75	-3.201	16.189	0.0598
Call	**ERICD**	18.03.2015	29.05.2015	8.08	4	-3.201	16.189	0.0598
Call	**ERICE**	18.03.2015	29.05.2015	8.08	4.2	-3.201	16.189	0.0598
Call	**ERICF**	09.04.2015	30.06.2015	9.1	3.9	-2.579	12.661	0.0598
Call	**ERICG**	09.04.2015	30.06.2015	9.1	4.1	-2.579	12.661	0.0598
Call	**ERICH**	09.04.2015	30.06.2015	9.1	4.4	-2.579	12.661	0.0598
Call	**ERICI**	12.05.2015	31.07.2015	9.69	4.55	-2.021	9.397	0.0598
Call	**ERICJ**	12.05.2015	31.07.2015	9.69	4.75	-2.021	9.397	0.0598
Call	**ERICK**	12.05.2015	31.08.2015	9.69	4.9	-1.366	6.837	0.0598
Call	**ERICL**	26.05.2015	31.07.2015	9.69	4.3	-1.855	7.935	0.0598
Call	**ERICM**	16.06.2015	31.08.2015	9.85	4.4	0.220	-0.091	0.0598
Call	**ERICN**	16.06.2015	31.08.2015	9.85	4.6	0.220	-0.091	0.0598
Call	**ERIDA**	16.06.2015	30.09.2015	9.85	4.75	0.189	-0.264	0.0598
Call	**ERIDD**	02.07.2015	30.10.2015	9.52	5	0.138	-0.111	0.0598

Call	**ERIDE**	24.08.2015	30.10.2015	11.02	3.6	-0.107	-0.331	0.0598
Call	**ERIDF**	24.08.2015	30.10.2015	11.02	4	-0.107	-0.331	0.0598
Call	**ERIDG**	24.08.2015	30.10.2015	11.02	4.4	-0.107	-0.331	0.0598
Call	**ERIDH**	10.09.2015	30.11.2015	11.03	3.5	-0.634	0.667	0.0598
Call	**ERIDI**	10.09.2015	30.11.2015	11.03	3.9	-0.634	0.667	0.0598
Call	**ERIDJ**	10.09.2015	30.11.2015	11.03	4.1	-0.634	0.667	0.0598
Put	**ERITV**	14.01.2015	30.04.2015	7.75	5	-0.667	0.493	0.0598
Put	**ERITY**	14.01.2015	30.04.2015	7.75	4.5	-0.667	0.493	0.0598
Put	**ERITZ**	14.01.2015	30.04.2015	7.75	4.2	-0.667	0.493	0.0598
Put	**ERIUP**	18.03.2015	29.05.2015	8.08	3.4	-3.201	16.189	0.0598
Put	**ERIUR**	18.03.2015	29.05.2015	808	3.2	-3.201	16.189	0.0598
Put	**ERIUS**	18.03.2015	29.05.2015	8.08	3	-3.201	16.189	0.0598
Put	**ERIUT**	09.04.2015	30.06.2015	9.1	4.1	-2.579	12.661	0.0598
Put	**ERIUU**	09.04.2015	30.06.2015	9.1	3.9	-2.579	12.661	0.0598
Put	**ERIUV**	09.04.2015	30.06.2015	9.1	3.7	-2.579	12.661	0.0598
Put	**ERIUY**	12.05.2015	31.07.2015	9.69	4.3	-2.021	9.397	0.0598
Put	**ERIUZ**	12.05.2015	31.07.2015	9.69	4.1	-2.021	9.397	0.0598
Put	**ERIVP**	12.05.2015	31.08.2015	9.69	4	-1.366	6.837	0.0598
Put	**ERIVR**	26.05.2015	31.07.2015	9.69	4.6	-1.855	7.935	0.0598
Put	**ERIVS**	16.06.2015	31.08.2015	9.85	4.4	0.220	-0.091	0.0598
Put	**ERIVT**	16.06.2015	31.08.2015	9.85	4.2	0.220	-0.091	0.0598
Put	**ERIVU**	16.06.2015	30.09.2015	9.85	4	0.189	-0.264	0.0598
Put	**ERIVZ**	02.07.2015	30.10.2015	9.52	4	0.138	-0.111	0.0598
Put	**ERIYP**	24.08.2015	30.10.2015	11.02	4.2	-0.107	-0.331	0.0598
Put	**ERIYR**	24.08.2015	30.10.2015	11.02	3.6	-0.107	-0.331	0.0598
Put	**ERIYS**	24.08.2015	30.10.2015	11.02	3.4	-0.107	-0.331	0.0598
Put	**ERIYT**	10.09.2015	30.11.2015	11.03	3.9	-0.634	0.667	0.0598
Put	**ERIYU**	10.09.2015	30.11.2015	11.03	3.5	-0.634	0.667	0.0598
Put	**ERIYV**	10.09.2015	30.11.2015	11.03	3.3	-0.634	0.667	0.0598

6. Empirical Results

Table 4 reveals average market, Black-Scholes and Gram-Charlier model prices of covered warrants.

Table: 4
Average Market, Black-Scholes and Gram-Charlier Prices of Covered Warrants

Codes of Warrants	Type of Warrants	Market	Black-Scholes	Gram-Charlier
ERIBO	**Call**	0.1932	**0.1573**	0.1275
ERICA	**Call**	0.1549	**0.0560**	0.0298
ERICB	**Call**	0.1157	**0.0406**	0.0156
ERICC	**Call**	11.528	0.7526	0.9214
ERICD	**Call**	0.8004	0.5393	0.6275
ERICE	**Call**	0.5548	0.3684	0.3859
ERICF	**Call**	10.342	0.6698	0.8064
ERICG	**Call**	0.7114	0.4917	0.5286
ERICH	**Call**	0.3581	**0.2698**	0.1656
ERICI	**Call**	0.1654	**0.1978**	0.1066
ERICJ	**Call**	0.1063	**0.1465**	0.0417
ERICK	**Call**	0.1009	**0.1384**	0.0680
ERICL	**Call**	0.2169	**0.2213**	0.1216
ERICM	**Call**	0.1463	**0.1249**	0.1182
ERICN	**Call**	0.0947	**0.0883**	0.0862
ERIDA	**Call**	0.0873	**0.0830**	0.0808
ERIDD	**Call**	0.0435	0.0256	0.0372
ERIDE	**Call**	0.3671	**0.3616**	0.3466
ERIDF	**Call**	0.1089	**0.1117**	0.1037
ERIDG	**Call**	0.0264	**0.0276**	0.0151
ERIDH	**Call**	0.4860	0.4687	0.4721
ERIDI	**Call**	0.2055	**0.1860**	0.1655
ERIDJ	**Call**	0.1298	**0.1133**	0.0859
ERITV	**Put**	13.892	0.6762	0.6891
ERITY	**Put**	0.6476	0.2846	0.2925
ERITZ	**Put**	0.3626	0.1356	0.1481
ERIUP	**Put**	0.0582	0.0029	0.5267
ERIUR	**Put**	0.0331	0.0009	10.199
ERIUS	**Put**	0.0238	0.0002	12.544
ERIUT	**Put**	0.1891	0.0448	0.1077

ERIUU	**Put**	0.0381	0.0218	0.1847
ERIUV	**Put**	0.0108	0.0085	0.2968
ERIUY	**Put**	0.1581	**0.1771**	0.1365
ERIUZ	**Put**	0.0713	**0.1009**	0.0371
ERIVP	**Put**	0.1240	**0.1241**	0.0834
ERIVR	**Put**	0.3585	**0.4087**	0.4012
ERIVS	**Put**	0.3631	0.3520	0.3714
ERIVT	**Put**	0.2333	0.2230	0.2370
ERIVU	**Put**	0.1880	0.1735	0.1889
ERIVZ	**Put**	0.2154	0.1858	0.2057
ERIYP	**Put**	0.3378	0.3307	0.3427
ERIYR	**Put**	0.0692	0.0579	0.0678
ERIYS	**Put**	0.0377	0.0272	0.0356
ERIYT	**Put**	0.1530	0.1339	0.1388
ERIYU	**Put**	0.0408	0.0226	0.0534
ERIYV	**Put**	0.0306	0.0109	0.0628

Black-Scholes model gives higher prices than Gram-Charlier model for 16 call warrants (bold), and Gram-Charlier provides higher prices than Black-Scholes for put warrants. Table 5 compares average market prices and model prices and presents that Black-Scholes underprices 17 call and 19 put warrants while overprices only 6 call and 4 put warrants and Gram-Charlier underprices all call and 11 put warrants while overprices only 12 put warrants. The result is that these models show a tendency to underprice covered warrants, only Gram-Charlier model has a tendency to overprice put warrants.

Table: 5
Numbers of Warrants Accurately Priced By Models

For Call Warrants	Warrants	For Put Warrants	Warrants
BS<Market	17	BS<Market	19
BS>Market	6	BS>Market	4
GC<Market	23	GC<Market	11
GC>Market	0	GC>Market	12

The price deviations of models from the market prices are presented on Table 6. Table 6 shows that Black-Scholes model underprices average 21.82% call warrants while Gram-Charlier underprices 36.53%. Black-Scholes still underprices average 31.88% put warrants and Gram-Charlier overprices 22.71%.

Table: 6
Average Model Pricing Error of Warrants

		BS-Market	GC-Market			BS-Market	GC-Market
Codes of Warrants	**Types of Warrants**	**μ**	**μ**	**Codes of Warrants**	**Types of Warrants**	**μ**	**μ**
ERIBO	Call	-0.6654	-0.7555	**ERITV**	Put	-0.5158	-0.5049
ERICA	Call	-0.7931	-1.2600	**ERITY**	Put	-0.5870	-0.5731
ERICB	Call	-0.8079	-1.3958	**ERITZ**	Put	-0.6671	-0.6201
ERICC	Call	-0.3161	-0.2019	**ERIUP**	Put	-0.9726	**28.5897***
ERICD	Call	-0.2979	-0.2320	**ERIUR**	Put	-0.9852	**71.6176***
ERICE	Call	-0.3273	-0.3586	**ERIUS**	Put	-0.9956	**100.4754***
ERICF	Call	-0.3481	-0.2311	**ERIUT**	Put	-0.4243	0.7498
ERICG	Call	-0.3051	-0.2788	**ERIUU**	Put	-0.4045	2.1812
ERICH	Call	-0.2541	-0.6195	**ERIUV**	Put	-0.5171	**7.9013***
ERICI	Call	-0.0437	-0.5404	**ERIUY**	Put	0.1900	-0.1203
ERICJ	Call	0.1683	-0.6758	**ERIUZ**	Put	0.5642	-0.4393
ERICK	Call	0.0933	-0.1564	**ERIVP**	Put	0.0772	-0.3292
ERICL	Call	-0.1543	-0.5818	**ERIVR**	Put	0.1850	0.1431
ERICM	Call	-0.1839	-0.1568	**ERIVS**	Put	-0.0262	0.0389
ERICN	Call	-0.2767	-0.1805	**ERIVT**	Put	-0.0360	0.0380
ERIDA	Call	-0.0612	0.0871	**ERIVU**	Put	-0.0938	-0.0038
ERIDD	Call	0.0097	0.7632	**ERIVZ**	Put	-0.1694	-0.0812
ERIDE	Call	-0.0236	-0.0668	**ERIYP**	Put	-0.0304	0.0037
ERIDF	Call	0.0053	-0.0699	**ERIYR**	Put	-0.2603	-0.1214

ERIDG	Call	-0.0399	-0.7447	**ERIYS**	Put	-0.3606	-0.1424
ERIDH	Call	-0.0400	-0.0323	**ERIYT**	Put	-0.1371	-0.0862
ERIDI	Call	-0.1730	-0.2810	**ERIYU**	Put	-0.4859	1.1682
ERIDJ	Call	-0.1845	-0.4325	**ERIYV**	Put	-0.6789	3.0142
Average	*Call*	*-0.2182*	*-0.3653*	***Average***	*Put*	*-0.3188*	*0.2271*

**These price differences are ignored because of probable misleading effect on average price differences.*

This study is to explore whether Black-Scholes and Gram-Charlier models provide accurate price for days which in warrants are in-the-money or out-of-the-money. Price differences of models from the market are seperated according to warrants moneyness. There are several formulas to calculate moneyness factor in literature, but in this study moneyness is determined by comparing underlying stocks' prices and strike prices of warrants.

Table: 7
The Pricing Differences of Models from the Market According to Moneyness of Call Warrants

Codes of Warrants	Moneyness	Days	BS-Market	GC-Market
ERIBO	in-the money	16	-0.5720	-0.6062
	out-of-the-money	58	-0.6912	-0.7967
ERICA	out-of-the-money	72	-0.7931	-1.2600
ERICB	out-of-the-money	67	-0.8079	-1.3958
ERICC	in-the money	47	-0.3161	-0.2019
ERICD	in-the money	44	-0.3007	-0.2281
	at-the-money	1	-0.1768	-0.4032
ERICE	in-the money	38	-0.3259	-0.2976
	out-of-the-money	8	-0.3340	-0.6485
ERICF	in-the money	50	-0.3481	-0.2311
ERICG	in-the money	51	-0.3051	-0.2788
ERICH	in-the money	35	-0.2045	-0.4569
	at-the-money	1	-0.4590	-0.9176
	out-of-the-money	18	-0.3393	-0.9191
ERICI	in-the money	9	0.4206	0.2270
	out-of-the-money	39	-0.1508	-0.7175
ERICJ	in-the money	8	0.3924	0.0434
	out-of-the-money	33	0.1140	-0.8501
ERICK	in-the money	1	0.2653	-0.0917
	at-the-money	1	0.3078	-0.0769
	out-of-the-money	51	0.0858	-0.1592
ERICL	in-the money	15	0.0814	-0.2883
	out-of-the-money	24	-0.3017	-0.7652
ERICM	in-the money	6	0.1003	0.0182
	out-of-the-money	37	-0.2999	-0.1852
ERICN	out-of-the-money	38	-0.2767	-0.1805
ERIDA	out-of-the-money	48	-0.0612	0.0871
ERIDD	out-of-the-money	40	0.0097	0.7632
ERIDE	in-the money	45	-0.0236	-0.0668
ERIDF	in-the money	9	0.1018	0.0750
	at-the-money	1	0.0010	-0.0261
	out-of-the-money	35	-0.0194	-0.1084
ERIDG	out-of-the-money	39	-0.0399	-0.7447
ERIDH	in-the money	53	-0.0400	-0.0323
ERIDI	in-the money	26	-0.0437	-0.1146
	at-the-money	1	-0.0023	-0.1044
	out-of-the-money	26	-0.3087	-0.4542
ERIDJ	in-the money	5	-0.0580	-0.1286
	at-the-money	3	-0.0216	-0.1333
	out-of-the-money	41	-0.2119	-0.4914

** If stock price>strike price warrant is said to be **in the money (ITM)**, if the S<K the warrant is **out of the money (OTM)** and if S=K the warrant is **at the money (ATM)**, (Lund University, 2016).*

Table: 8
The Pricing Differences of Models from the Market According to Moneyness of Put Warrants

Codes of Warrants	Moneyness	Day	BS-Market	GC-Market
ERITV	in-the money	72	-0.5158	-0.5049
ERITY	in-the money	**57**	-0.5577	-0.5508
	out-of-the-money	**15**	-0.6986	-0.6578
ERITZ	in-the money	**21**	-0.6088	-0.5927
	out-of-the-money	**48**	-0.6926	-0.6322
ERIUP	out-of-the-money	**23**	-0.9726	28.5897
ERIUR	out-of-the-money	**16**	-0.98520	71.6176
ERIUS	out-of-the-money	**16**	-0.9956	100.4754
ERIUT	out-of-the-money	**53**	-0.4243	0.7498
ERIUU	out-of-the-money	**46**	-0.4045	2.1812
ERIUV	out-of-the-money	**43**	-0.5171	7.9013
ERIUY	in-the money	**30**	0.195	-0.0841
	out-of-the-money	**24**	0.1837	-0.1655
ERIUZ	in-the money	**6**	0.1249	0.0147
	out-of-the-money	**33**	0.644	-0.5218
ERIVP	in-the money	**17**	-0.0531	-0.1714
	out-of-the-money	55	0.1175	-0.3779
ERIVR	in-the money	44	0.185	0.1431
ERIVS	in-the money	45	-0.0525	0.0069
	out-of-the-money	6	0.1713	0.2785
ERIVT	in-the money	28	-0.0559	-0.0025
	at-the-money	1	-0.3174	-0.2212
	out-of-the-money	16	0.0164	0.1250
ERIVU	in-the money	36	0.0061	0.0707
	out-of-the-money	34	-0.1996	-0.0827
ERIVZ	in-the money	47	-0.058	0.0270
	at-the-money	1	-0.0819	-0.0198
	out-of-the-money	31	-0.3412	-0.2471
ERIYP	in-the money	45	-0.0304	0.0037
ERIYR	out-of-the-money	36	-0.2603	-0.1214
ERIYS	out-of-the-money	31	-0.3606	-0.1424
ERIYT	in-the money	26	-0.1042	-0.0944
	at-the-money	1	-0.0416	-0.0491
	out-of-the-money	26	-0.1737	-0.0796
ERIYU	out-of-the-money	50	-0.4859	1.1682
ERIYV	out-of-the-money	35	-0.6789	3.0142

** If stock price>strike price warrant is said to be **in the money (ITM)**, if the S<K the warrant is **out of the money (OTM)** and if S=K the warrant is **at the money (ATM)**, (Lund University, 2016).*

Results of Table 7 and 8 are summarized on Table 9. Table 9 concludes that Black-Scholes model is more appropriate to price call warrants and in-the-money days and out-of-the-money days of put warrants. Gram-Charlier model can produce more accurate prices for put warrants at-the-money days than Black-Scholes model.

Table: 9
Average Price Deviations

	Call warrants		Put warrants	
	BS	**GC**	**BS**	**GC**
in-the money days	-0.06917	-0.15643	-0.117338	-0.13344
out-of-the-money days	-0.26036	-1.9252	-0.35289	2.107927
at-the-money days	-0.05848	-0.27692	-0.146967	-0.0967

7. Conclusion

Investors face several risk factors in financial markets due globalization and indefinite future of financial systems. Investors need an effective risk management and various financial derivatives to overcome these risk factors. The covered warrants were

issued in 2010 in Turkey to widen the variety of financial derivatives and strengthen investors against several financial risks. Determining accurate price of financial derivatives helps investors to control several financial risks.

This study is conducted to price covered warrants by Black-Scholes and Gram-Charlier pricing models and determine which model is more robust in reflecting the market price of warrants in Turkey. This study analyzes 23 call and 23 put covered warrants based on Eregli Demir Celik Fabrikaları T.A.S. stocks, issued and expired in 2015.

The results show that Black-Scholes model produces closer prices to the market for call option than Gram-Charlier model. However, Gram-Charlier model is more preferable to price put warrants in Turkey. Another result shows that prices of both Black-Scholes and Gram-Charlier model are not so close to observable market prices. Therefore, both of the models are not appropriate for pricing warrants traded in financial markets of Turkey. Another result shows that pricing performance of Black-Scholes for in-the-money, out-of-the-money and at-the-money days of call warrants and in-the-money and out-of-the-money days of put warrants is better than Gram-Charlier model. On the other hand, Gram-Charlier model produces more accurate prices for at-the-money days of put warrants.

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