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Linear Regression Approach for the Financial Risks of Shipping Industry

D. Yazir & B. Sahin
Karadeniz Technical University, Trabzon, Turkey

ABSTRACT: The aim of this study is to propose a linear regression approach for Black & Scholes model that is used for call option and put option to derive pricing and risk management. In this study, the effects of share prices, exercise prices, volatility and interest rate on put options are observed in an interactive manner. Financial risks of maritime transportation are studied in order to provide a feasible solution for the threats in the global maritime economic system. In conclusion, the unclear behaviors of the Black & Scholes models are revealed by the linear regression model.

1 INTRODUCTION

Due to the financial crisis of the early 1970s seen at the conventional money and capital markets, new financial assets are decided as a requirement in order to protect and control the financial risks. Options as one of these assets are firstly exercised by the Chicago Board Options Exchange in 1973. Developing countries model financial markets and techniques of the developed countries, then the derivative markets are expanded globally (Tural 2008). As a developed financial technique, an option provides a right to buy or sell an asset on or after a pre-defined time at a particular stated price, which depends on the form of the option.

In finance, an option always provides a right to the owner (holder or buyer), but it is not obligatory for the owner of the option. The owner only pays the option premium, but the seller is obligated to fulfill the requirements of the conditions. The financial asset might be exercised by the holder during the favorable conditions. The option contracts are commonly exercised in underlying shares, stock market index, and exchange and interest based tools (Akalın 2006, Alpan 1999, Yazir 2011).

Black & Scholes (B&S) model has widely been used by many scholars. Merton (1976) generates an option pricing formula for the returns of the underlying shares (Merton 1976). Geske (1979) studies composite options. The study of Scott (1987) deals with the pricing of European call options with randomly changing variances. Turnbul and Wakeman (1991) propose a faster algorithm of B&S. Demir (2003) analyses the call options price which the data derived from Borsa Istanbul by using finite difference method. In another study, Polat (2009) investigates quantitative solution techniques particularly for American type of call options. The studies of Easley et al. (1998), Madan et al. (1998) are given to determine the values of options for the interested readers.

In this study, a linear regression model for the call option and put option is proposed to analyze the changes by manipulating the parameters of the B&S model. In order to compare the results, we used the same example in the study of Erol and Dursun (2015) in which they calculate call option premium by using

B&S model. We observe that the proposed model in the study is more suitable than their study of Erol and Dursun (2015). Effects of volatility and risk-free interest rate on options are obviously monitored by this model.

2 PARTICULARS OF THE OPTIONS

The options might be categorized into two types as call option and put option in terms of the intended use. The holder of the call option expects profit meaning that an increase of asset price. The call option conveys the right to the holder after the price is increased under the specified conditions. If the financial asset decreases, the holder loses the premium paid. The seller of the call contracts expects a decreasing trend. The seller sells the call options by obtaining the premium to minimize financial loss or to make profit. Similarly, the holder of the put option expects profit on decreasing trend of asset price. The put option conveys the right to the holder after the price is decreased under the predefined conditions. If the price of financial asset increases, the holder loses the premium paid. In order to take an advantage of the increase, the option is sold for the returns of the premium.

The related concepts should be defined in terms of profitability of the options.

Market (spot) price is the price of the underlying share at that moment. Market price is a significant indicator because it will continuously be compared to the exercise price during the time period. Intrinsic value represents the profit after option exercised. In other words, it is the relationship between the market price and exercise price.

The intrinsic value of the call option = max (market price-exercise price, 0)

The intrinsic value of the put option = max (exercise price-market price, 0)

Option price is the sum of intrinsic value and time value. Time value is obtained by subtracting the spot price from option premium. Since the In the money options indicates profit and out of the money options shows the financial loss, at the money options represent neither profit nor loss (Hull 2006, Wilmot et al. 1995, Yazir 2011).

3 FINANCIAL RISKS FOR THE SHIPPING INDUSTRY

Financial risks are denoted in their study of Erol and Dursun (2015) in detail. Table 1 shows the possible risks in shipping industry and the derivative products corresponding these risks in order to prevent them.

Table 1. Financial risks of maritime transportation and derivative products (Gilleshammer and Hansen 2010, Erol and Dursun 2015)

Risks	Future	Forward	Swap	Option
Freight Rate Risk				
Bulk Carrier	+			+
Tanker	+			+
Asset price risk				
New ship Price				
Second hand		+		
Demolition		+		
Exchange rate risk	+	+	+	+
Interest rate risk	+	+	+	+
Bunker risk	+	+		+

4 METHODOLOGY

4.1 *Pricing of futures contract*

Alizadeh and Nomikos (2009) describe transport cost model as transport cost until contract time, forward price and spot price. The formula is given below:

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

F_0 : forward price

S_0 : spot price

r : risk free interest rrate

T : time (year)

Forward price is compared with the spot price at expiration date. At this point since one has some profits other gets in loss (Alizadeh & Nomikos 2009).

4.2 *Black & Scholes (B&S) Model*

The price (premium) of the call option is obtained from the following B&S formula (Wilmot et al. 1995):

$$C(S,t) = SN(d_1) - Ee^{-r(T-t)}N(d_2)$$

where,

S : market price of the share.

$Ee^{-r(T-t)}$: discounted value of the using price of the option before the expiry date.

$N(d_j)$: probability derived from the standard normal distribution, j=1,2.

$C(S,t)$: value of the call option.

B&S formula,

$$C(S,t) = SN(d_1) - Ee^{-r(T-t)}N(d_2)$$

$$d_1 = \frac{\ln\left(\frac{S}{E}\right) + \left(r + \frac{1}{2}\sigma^2\right)(T-t)}{\sigma\sqrt{(T-t)}}$$

$$d_2 = d_1 - \sigma\sqrt{T-t}$$

so,

$$d_2 = \frac{\ln(\frac{S}{E}) + \left(r - \frac{1}{2}\sigma^2\right)(T-t)}{\sigma\sqrt{(T-t)}}$$

Parameters of the call option used in B&S formula are given below, which depend on S value of the share;

$N(d_1), N(d_2)$: Cumulative normal probability distribution values for (d_1, d_2)

$N(d_1)$: The rate of the share in the portfolio

$N(d_2)$: The usage probability of the share option

S : Current price of the share

E : Exercise price or striking price of the option

r : The rate of risk free interest

σ : Annual standard deviation for the return rates of the share

T-t : The time remaining the expiry date of the option

$e^{-r(T-t)}$: Rate of discount

$\ln$: Logarithm symbol

4.3 $N(d_j)$, *coefficients of the B&S model*

The average of the values at the standard distribution curve is zero, standard deviation is 1, and standard normal distribution is expressed as $N(0,1)$. The values of d_1, d_2 are the deviation values from the average values of the standard normal distribution.

The value of cumulative standard normal distribution with the probability of $z = d$ on the standard normal distribution curve is found by adding of the probability values until the given value $f(z;0,1) = \frac{1}{\sqrt{2\pi}} e^{-\frac{z^2}{2}}$ of standard normal variable.

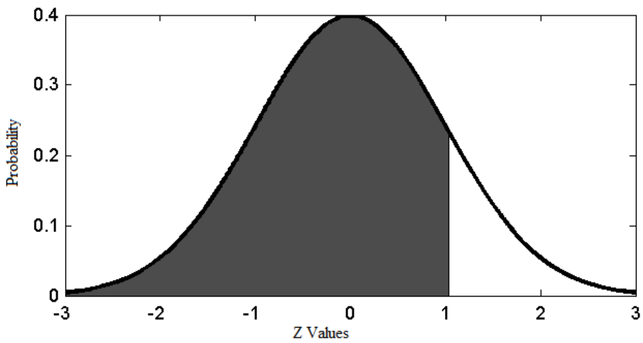

Figure 1. Representation of $N(d_1)$ probability value on standard normal distribution curve

The value in the Figure 1, $d_1 = 1.0318$ means that the value of d_1 deviates from the average zero value as much as 1.0318. $N(1{,}0318)$ is the cumulative probability of standard normal distribution, which means the cumulative addition of the probability values at the shaded area. In the normal distribution curve, the value of the area from the left to average zero becomes 0.5.

The value of $d_2 = 0.9516$ is similar for the standard normal distribution. $N(0.9516)$ represents the deviation from the average of standard normal distribution as much as 0.9516.

Since d_1 and d_2 values are positive, probability of the values are calculated as given below where $N(d_j)$ (j=1,2), are the probability values of d_j.

$N(d_j)$ = (The value for the area under the left side of the normal distribution curve=0.5) + (d_j value, the probability value of the deviation from the average zero=table value of the normal distribution)

Since d_1 and d_2 values are negative, the probability of these values are calculated as $N(-d_j)$=1-$N(d_j)$, (j=1,2).

In this paper, we investigate which shares are linear in case of change in call options based on increasing share prices for the changing risk free interest rates and volatility values (Wilmot et al. 1995). Yazir (2011) indicates that if share price is at the neighborhood of exercise price, $C(r,\sigma)$ behaves as linear. In this study, we propose to reveal the unclear behaviors $C(r,\sigma)$ of the B&S models. By the linear regression model,

$$C_L = \alpha r + \beta\sigma + c$$

the effects of the α, β, c coefficients, related interest rate and volatility on call option value are analyzed.

The value of call option based on B&S model is calculated as,

$$C_{B\&S} = SN(d_1) - Ee^{-r(T-t)}N(d_2)$$

However, due to it is too hard to calculate semi-infinite integrals, regression method based on changes in r and σ values are used. After finding the acceptable α, β and c values, C_L linear equation is transformed when the share prices are at the neighborhood values for the exercise prices. Here, $C(r,\sigma)$ represents the price of call option, r is the risk free interest rate, σ is volatility and c is a constant (Yazir 2011).

4.4 *Linear regression approach for* $C(r,\sigma)$

Yazir (2011) finds $C_L = \alpha r + \beta\sigma + c$ as a convenient approach. Therefore, let find the α, β ve c values by the least squares method, which minimizes the following equation (Yazir 2011):

$$E = \sum_{i=1}^{N}(\alpha r_i + \beta\sigma_i + c - C(r_i, \sigma_i))^2$$

from the equations of

$$\frac{\partial E}{\partial \alpha} = 0, \ \frac{\partial E}{\partial \beta} = 0, \ \frac{\partial E}{\partial c} = 0$$

$$\frac{\partial E}{\partial \alpha} = 2\sum_{i=1}^{N}\left(\alpha r_i + \beta\sigma_i + c - C(r_i, \sigma_i)\right) r_i = 0,$$

$$\frac{\partial E}{\partial \beta} = 2\sum_{i=1}^{N}(\alpha r_i + \beta\sigma_i + c - C(r_i,\sigma_i))\sigma_i = 0,$$

$$\frac{\partial E}{\partial c} = 2\sum_{i=1}^{N}(\alpha r_i + \beta\sigma_i + c - C(r_i,\sigma_i)) = 0$$

are obtained. After conducting the required modifications

$$\sum_{i=1}^{N}(c + \alpha r_i + \beta\sigma_i) = \sum_{i=1}^{N} C_i$$

$$\sum_{i=1}^{N}(c r_i + \alpha r_i^2 + \beta\sigma_i r_i) = \sum_{i=1}^{N} C_i r_i$$

$$\sum_{i=1}^{N}(c\sigma_i + \alpha r_i\sigma_i + \beta\sigma_i^2) = \sum_{i=1}^{N} C_i\sigma_i$$

are found. Here, in order to select the most acceptable α, β, c coefficients, the following system is obtained by minimizing sum of error squares.

$$\begin{bmatrix} N & \sum r_i & \sum \sigma_i \\ \sum r_i & \sum r_i^2 & \sum r_i\sigma_i \\ \sum \sigma_i & \sum r_i\sigma_i & \sum \sigma_i^2 \end{bmatrix} \begin{bmatrix} c \\ \alpha \\ \beta \end{bmatrix} = \begin{bmatrix} \sum C_i \\ \sum C_i r_i \\ \sum C_i\sigma_i \end{bmatrix}$$

5 APPLICATION

Erol and Dursun (2015) calculate call option premium by using B&S model. In this study, we obtain the data of their study, and compute again to check, and compare our results of linear regression model. It is important to say here that this approach is not only suitable for this particular case study but also it is convenient for all other pricing call and put options.

5.1 *Case 1*

The relevant data are given as S=F0=778.65 USD, T=14, r=%0.25, K=E=778.19USD, σ = %10.78.

The GUI of proposed algorithm is simulated as follows:

In their study, call option premium is found as 9.6268 USD. In this study, we find the result as 9.6252 with the 9.5555e-10 error rate (Figure 2).

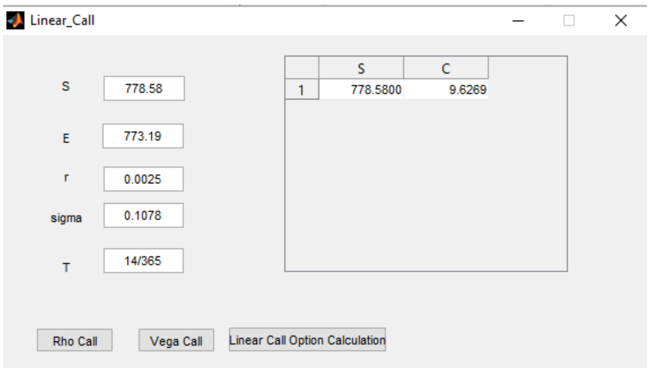

Figure 2. Linear regression model interface

As it seen, the error rate is negligibly low. Additionally, effects of risk-free interest rate and volatility on option premium are explicitly analyzed in our model. For instance, rho and vega are the coefficients of risk free interest rate and volatility, respectively. Figure 3a and Figure 3b show that the values of vega and rho coefficients with the values of 18.5830 and 57.3341 respectively.

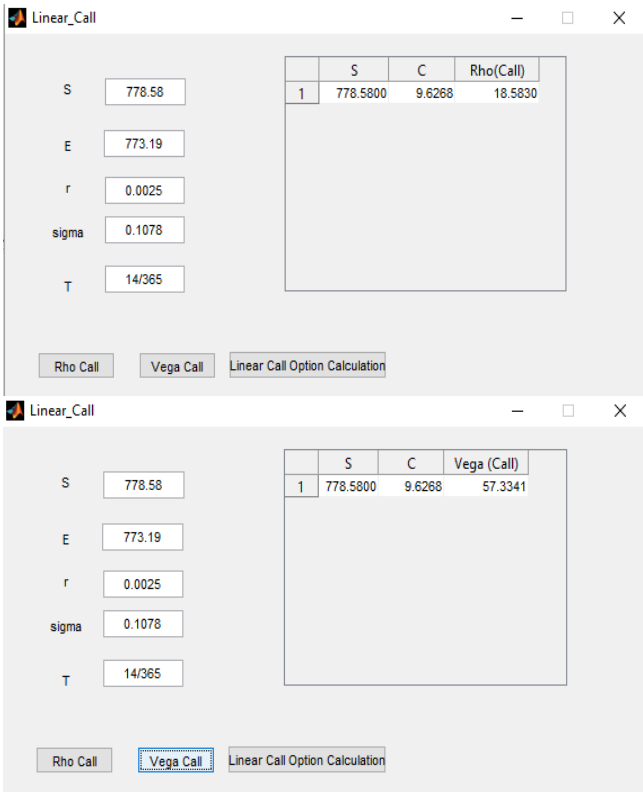

Figure 3. Coefficients of linear options (a - Rho coefficient, b - Vega coefficient)

The simulated results are provided in the Figure 4.

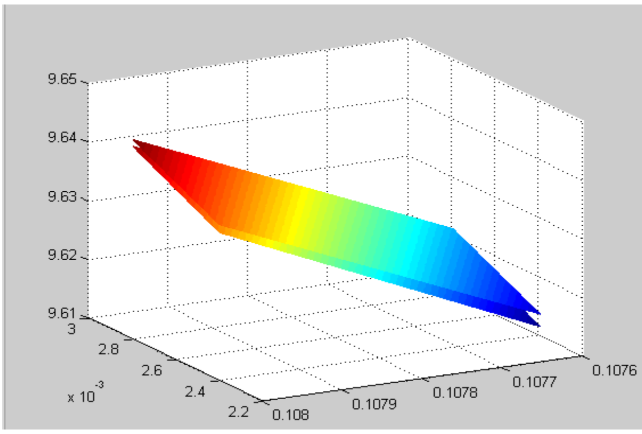

Figure 4. Comparison of B&S model and linear regression model

5.2 *Case 2*

If risk free interest rate is taken as 0.0029 with all other parameters are assumed constant, rho and vega values are changed to 18.5908 and 57.3197 respectively. Call option price is found 9.6343. As it is seen, when risk free interest rate increases, the value of rho increases, but vega decreases. It means that, volatility and call option premium are inversely proportional, and risk free interest rate and call option premium are directly proportional.

5.3 *Case 3*

If volatility is taken as 0.1080 with all other parameters are assumed constant, rho and vega values are changed to 18.5758 and 57.3459 respectively. Call option price is found 9.6383. As it is seen, when volatility increases, both values of rho and vega decreases.

5.4 *Case 4*

If share price is taken as 780 USD with all other parameters are assumed constant, call option price is found 9.6269. As it is easily seen in this model, when share price increases, call option premium increases too.

5.5 *Case 5*

If time is taken as 30 days with all other parameters are assumed constant, rho and vega values are changed to 37.2006 and 86.3758 respectively. Call option price is found 9.6269. It is seen that if time days to expiry date increases, volatility, risk free interest rate and call option premium increase.

In conventional B&S model, it is hardly possible to observe these results because of hard calculations such as semi infinitive integrals. Linear regression model explicitly gives these inferences easier and faster.

6 CONCLUSIONS

The major aim of this study is to provide an alternative model for B&S model in which the effects of interest rate and volatility are analyzed easily and rapidly. In our approach, it is observed that since there exists a positive relationship between price of the call options and price of underlying share, risk-free interest rate, volatility and time, there is a negative relationship between the price of call options and exercise price. In this study, linear regression model is obtained for option price when the share price is at the neighborhood of exercise price.

Coefficients of the volatility in the linear regression model increase as much as the increase in share prices. However, if the share price becomes equal to exercise price, the increase at the coefficients of volatility stops. Then, the coefficients of the volatility decrease when share price soon after exceeds the exercise price. Coefficients of risk-free interest continuously increase with the increasing share price.

Linear regression models are more advantageous than the B&S models for calculation of put and call options. Linear regression model is time efficient, and the effects of changing parameters (i.e. risk free interest rate and volatility) on option premium can easily be analyzed. The coefficients of c, α, β in the linear regression model, and the spot price of underlying share can also be calculated in a short time easily. Proposed linear regression model and B&S are implemented by using a MATLAB GUI application, and overlapping figures are generated for the comparison. The error rates are found then.

For the further studies, B&S model might be analyzed for the time, dependent volatility and interest rate. Free boundary conditions of the problems that require applications before the expiry date should be applied in a not defined boundary. This method can be applied for American option by the proper numerical approaches.

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APPENDIX

MATLAB SOURCE CODE OF LINEAR REGRESSION MODEL

```
clear,clc
close all
S=778.58;
T=14/365;
E=773.19;
r=[0.0023 0.0025 0.0025 0.0425 0.002 0.001
0.0027 0.0525 0.0035 0.0025];
s=[0.2078  0.1076  0.1047  0.1078  0.1059
0.30111 0.1078 0.1066 0.10781 0.1078];
d1=(log(S/E)+(r+0.5*s.^2)*T)./(s*sqrt(T));
d2=d1-s*sqrt(T);
Nd1=normcdf(d1);
Nd2=normcdf(d2);
C=S.*Nd1-E*exp(-r*T).*Nd2;
A=[length(C) sum(r) sum(s);sum(r) sum(r.^2)
sum(r.*s);sum(s) sum(r.*s) sum(s.^2)];
B=[sum(C);sum(C.*r);sum(C.*s)];
C,alpha,beta=inv(A)*B
r=0.0025;
s=0.1078;
linear_regression=xx(2)*r+xx(3)*s+xx(1)
S=778.58;
T=14/365;
E=773.19;
r=0.0025;
s=0.1078;
d11=(log(S/E)+(r+0.5*s^2)*T)/(s*sqrt(T));
d22=d11-s*sqrt(T);
Nd11=normcdf(d11);
Nd22=normcdf(d22);
C=S*Nd11-E*exp(-r*T)*Nd22;
Black_Scholes=C
x=0.0024:0.0001:0.0028;
y=0.1076:0.0001:0.1080;
[r s]=meshgrid(x,y);
d1=(log(S/E)+(r+0.5*s.^2)*T)./(s*sqrt(T));
d2=d1-s*sqrt(T);
Nd1=normcdf(d1);
Nd2=normcdf(d2);
```

```
C=S.*Nd1-E*exp(-r*T).*Nd2;
ff=xx(2)*r+xx(3)*s+xx(1);
Error=sum((sum((xx(2)*r+xx(3)*s+xx(1)-
C).^2)).^2)
mesh(x,y,ff)
hold on
mesh(x,y,C)
hold off
```

REFERENCES

Akalın, O. İ. 2006. Hisse senedi Üzerine Opsiyon Sözleşmeleri ve Türkiye Uygulaması, Yüksek Lisans Tezi, Marmara Üniversitesi, Bankacılık ve Sigortacılık Enstitüsü, İstanbul, 2006.

Alizadeh, A. H. and N. K. Nomikos. 2009. Shipping Derivatives and Risk Management. Faculty of Finance, Cass Business School, City University, London.

Alpan, F. 1999. Örneklerle Futures Anlaşmalar ve Opsiyonlar, 1. Baskı, Literatür Yayıncılık, İstanbul.

Demir, S. 2003. Sonlu Fark Modellerinin Opsiyon Sözleşmelerinin Fiyatlandırılmasında Kullanımı ve Diğer Sayısal Modeller ile Ampirik Bir Karşılaştırma, *Dokuz Eylül Üniversitesi İşletme Fakültesi Dergisi*, 4,1 102-115.

Easley, D., O'Hara, M. and Srinivas, P. S. 1998. Option Volume and Stock Prices, *The Journal of Finance*, 53,2,431-465.

Erol. S. and A. Dursun. 2015. Financial Risks and Hedging in Maritime Transportation. *Dokuz Eylul University Maritime Faculty Journal*, 7(2). 172-201.

Geske, R. 1979. The Valuation of Compound Options. *Journal of Financial Economics*, 7 (1). 63-81.

Gilleshammer, P. K. & Hansen, J. Ø. 2010. Hedging risks in shipping using futures contracts traded on Imarex. (Published Master Thesis). Norwegian. Norges Handelshøyskole.

Hull, J. C. 2006. Options, futures, and other derivatives. Pearson Education India.

Madan, D. B., Carr, P. P. and Chang, E. C. 1998. The Variance Gamma Process and Option Pricing, *Oxford Jounals*, 2,1,79-105.

Merton, R. C. 1976. Option Pricing When Underlying Stock Returns Are Discontinuous. *Journal of Financial Economics*, 3 (1-2). 125-144.

Polat, R., A. 2009. Comparative Study of Black&Scholes Equation, *Selçuk Journal of Applied Mathematics*, 10,1,135-140.

Scott, L. O. 1987. Option Pricing When the Variance Changes Randomly. *Journal of Financial and Quantitative Analysis*, 22. 419-438

Tural, Ö. 2008. Applications of Option Pricing Models for Hedging. Master Thesis, Marmara University, Institute of Banking and Insurance, Istanbul.

Turnbull, S. M. and L. M. Wakeman. 1991. A Quick Algorithm for Pricing European Average Options. Journal of Financial and Quantitative Analysis, 26. 377-389.

Wilmot, P., S. Howison, and J. Dewynne. 1995. The Mathematics of Financial Derivatives. New York.

Yazir, D. 2011. The Linear Regression Approach for the Black & Scholes Option Model. Master's Thesis, Karadeniz Technical University, Institute of Science, Trabzon.