The Performance of Skewness and Kurtosis Adjusted Option Pricing Model in Emerging Markets: A case of Turkish Derivatives Market

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Abstract

In this study, the option pricing performance of the adjusted Black-Scholes model proposed by Corrado and Su (1996) and corrected by Brown and Robinson (2002), is investigated and compared with original Black Scholes pricing model for the Turkish derivatives market. The data consist of the European options written on BIST 30 index extends from January 02, 2015 to April 24, 2015 for given exercise prices with maturity April 30, 2015. In this period, the strike prices are ranging from 86 to 124. To compare the models, the implied parameters are derived by minimizing the sum of squared deviations between the observed and theoretical option prices. The implied distribution of BIST 30 index does not significantly deviate from normal distribution. In addition, pricing performance of Black Scholes model performs better in most of the time.

Key Words: Black Scholes pricing Formula, Carrado-Su pricing Formula, Implied Parameters

JEL classification: G13, G17

Introduction

In recent years, with the globalization of the financial markets, the derivatives market are expanding rapidly. As they are proposed for hedging, they become more subtle and used to get information about the investors’ expectations related to future prices and mainly used for speculative investments.

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.

The Turkish derivative market is a new and developing financial market. Futures markets management was established in Turkey on May 3, 1994. First private derivative exchange, TURKDEX, was established in İzmir in 2001. It started its operations after the company was registered in the Official Bulletin of the Registry of Commerce on July 4, 2001 (Saatçıoğlu and Karagül, 2005). Options are being use in Turkey since 21 December 2012 (Akyapı, 2014).
There are limited studies about option pricing in Turkish market. Demir and Tütek (2004) tested the applicability of Empirical Martingale simulation approach in pricing of options in the Borsa İstanbul. Hypothetically they prepared a set of options that are assumed to be written on the BIST Composite Index. They have concluded that the Martingale Simulation Approach exhibits prices closer to the Black Scholes option prices. Akyapı (2014) analyzed the differences between observed and theoretical prices which are derived by using Black Scholes option pricing formula in BIST 30 index options market. His results showed that Turkey’s option markets may be open for arbitrage opportunities. He find that, in most of the time, observed option prices are not equal to the theoretically calculated option prices.

The aim of this paper, is to evaluate the pricing performances of theoretical option pricing formulas for Turkish derivative market. Turkish derivative market is a new and a developing market for investors trading in Turkish stock exchange. As there are limited studies about this market, the purpose is to fulfill this gap.

This paper is organized as follows. Section 1 introduces the problem and summarizes the studies in the literature. In Section 2, adjusted Black Scholes Formula and Implied Parameter Estimation procedure is presented. The data and results are given in Section 3 and Section 4 concludes the paper.

Literature Review

The Black and Scholes (1973) option pricing model is the most popular pricing model in option pricing models. In Black Scholes option pricing formula, the stock price, the strike price of the option, the continuously compounded risk free interest rate and the time to maturity parameters can be directly observed from market data but the volatility parameter is unobservable. Although, its assumption of constant asset’s volatility and log-normal distribution price are criticized by a number of authors (Mandelbrot, 1963, Fama, 1965 and Bekaert et al., 1998). There are many extensions of the Black Scholes model to solve the non-normality and volatility smile problem. The extension used in this paper is the extension of Corrado and Su (1997) included the skewness and kurtosis parameters in the option-implied distributions of stock returns as the source of volatility smile and corrected by Brown and Robinson (2002).

Referring back again, Black and Scholes (1973) and MacBeth and Merville (1979) derived implied volatility by using the Black-Scholes European call option pricing model. The implied volatilities are estimated by equalizing the market option price and Black Scholes option price formula. If their approach was perfect, then the implied volatility should be same for all option market prices, but empirical observations shows that this is not the case. Their implied volatilities strongly depend on the maturity and the strike of the European option (Heston, 1993). Therefore, one of the problem of Black Scholes approach is to find an implied volatility when there are several options on the same stock for a given day. To solve this problem Latane and Rendleman (1976), Schmalensee and Trippi (1978) and Beckers (1981) tried to use average of implied volatilities of each options.

Latane and Rendleman (1976), Schmalensee and Trippi (1978) and Beckers (1981) found that implied volatility is better than historic volatility at predicting actual volatility. Schmanlensee and Trippi (1978) take the simple arithmetic averages of implied volatilities. Beckers (1981) specifically studied the predictive ability of implied volatility, taking into account the dividend problem and the problem of optimal weighting schemes when there are several options on the same stock.Whaled (1982) estimated the implied volatility by using simultaneous equations procedure. In this method, the implied volatility is estimated by minimizing the sum of squared deviations between the observed and theoretical option prices.

Black Scholes option pricing model uses the Geometric Brownian Motion (GBM) dynamic for risky assets. In GBM pricing dynamic, over a finite time interval the returns on a common stock are log normally distributed with constant parameters. Its assumption of constant asset’s volatility and log-normal distribution price are criticized by a number of authors (Mandelbrot, 1963, Fama, 1965 and Bekaert et. al, 1998). Black and Scholes (1973) found that the implied volatilities for out-of-the-money call options are less than implied volatilities obtained from at-the-money call options. As a result by using the implied volatility derived from Black Scholes formula are tend to overprice options with high volatility and underprice options with low volatility estimates. This problem causes the inconsistency in pricing deep in-
the-money and deep out-of-the-money options when Black Scholes Formula is used. This problem is known as the volatility smile (Corrado and Su, 1997).

To solve the constant volatility and volatility smile problem, Hull and White (1987), Wiggins (1987) and Heston (1993) have generalized the Black Scholes option pricing model stochastic volatility case. Another approach is to use Hidden Markov Models in pricing to capture the volatility changes. Duan et. al (2002) and Fuh et. al (2012) tried to price options by using Hidden Markov Models.

In the literature it is stated that the asset price have leptokurtic and asymmetric distributions (Mandelbrot, 1963, Fama, 1965 and Bekaert et al., 1998).

To reflect the asset price dynamics Merton (1976) derived option pricing formula and generated volatility skews and smiles by adding discontinuous Poisson jumps to the GBM dynamics to describe discontinuous changes of asset returns upon arrival of new information. Another extension to the Balck Scholes option pricing formula is the option pricing formula proposed by Kou (1999) and Kou (2002). In this model, the continuous part of asset prices is driven by Brownian Motion and jump part is modeled by logarithm of the jump sizes having a double exponential distribution. As a result the model is successful to reflect the leptokurtic feature and volatility smile of asset returns. Another extension is derived by Jarrow and Rudd (1982). They provided an approximate formula to the option pricing problem which is the Black-Scholes option price plus adjustment terms including the higher moments where the asset price distribution is not lognormal but can be approximated with lognormal distribution.

Corrado and Su (1997) used the approach developed by Jarrow and Rudd (1982) and derived an approximate probability density function by using a Gram–Charlier expansion and used in option pricing. In their model, their approach include skewness and kurtosis parameters in the option-implied distributions of stock returns as the source of volatility smile. Their aim is to derive implied distribution in order to reduce the volatility smile.

Brown and Robinson (2002) provided a correction in Corrado-Su pricing formula for the expression of the skewness coefficient. Navatte and Villa (2000) used the Corrado Su Gram–Charlier series expansion of the normal distribution approach for using long-term CAC 40 option prices contracts. They found that the first moments contain a sufficient information for future moments although this amount decreases with respect to the moment's order. In addition, they concluded that the implied distribution shows consistent results with volatility smile shape. Blancard et.al (2001) investigated the pricing and hedging performances of the Corrado Su model for CAC 40 index European call options. They have concluded that this model does not improve hedging strategy of Black Scholes pricing model.

Vähämaa (2003) investigated the delta hedging performance of the corrected Corrado-Su option pricing formula. The study concluded that the hedging errors of the pricing Formula is worse than the Black-Scholes option pricing Formula when applied to the FTSE 100 index options traded at the London International Financial Futures and Options Exchange. Jurczenko et.al (2004) proposed the modified version of corrected Corrado Su option pricing Formula to provide consistency with a martingale restriction. In addition they compared the sensitivities of option prices to shifts in skewness and kurtosis parameters derived from Corrado Su pricing formula, corrected Corrado Su pricing Formula and modified version and market data from the French options market. They concluded that the differences between these pricing formulas are minor. Andreous et. al (2008) compare the performances of Black Scholes model, Corrado Su model, Artificial Neural Network and Black Scholes and Corrado Su based hybrid Artificial Neural Networks to price European call options on the S&P 500 index. They concluded that Black Scholes based hybrid artificial neural network models outperform the others. Åjö (2008) investigated the effects of UK and US macroeconomic news announcements on return distribution of FTSE-100 index option prices whose implied moments were extracted by using the model developed by Corrado and Su (1996) and Brown and Robinson (2002). The results of the paper provided that the implied return distribution are affected by certain macroeconomic news announcements.
The normality of the emerging market returns is argued in studies such as; Harvey (1995), Bekaert and Harvey (1997) and Bekaert et al. (1998). The studies stated that the emerging market asset returns have leptokurtic features.

The results of studies for Turkish stock market is consistent with the literature about emerging market. There are different studies using BIST 30 stock index which have findings about leptokurtic feature. Aydin (2003) has examined the behavior of the Borsa İstanbul Index, BIST 30, which includes 30 leading Turkish companies. In the study, it is observed that there are volatility clusters, negative skewness, large kurtosis, and autocorrelation in index prices series. Tokat (2009) investigated the volatility of BIST 30 index January 1990-April 2007 period. Sudden changes in volatility and leptokurtic distribution with extra kurtosis is also observed. Kayalıdere and Aktaş (2012) has investigated the GARCH effect, risk-return tradeoff, and day of the week effect for the BIST 30 futures for the period of 2006-2011. In their descriptive analysis they have concluded that, the BIST 30 index shows Fat tailed distribution with negative skewness. Gökgöz and Sezgin-Alp (2014) modelled the main Turkish stock market indexes under Arbitrage Pricing Theory with Artificial Neural Networks. In their descriptives studies they have concluded that the BIST 30 index has leptokurtic feature. Demir and Tutek (2004) tested the applicability of empirical Martingale simulation approach in pricing of options in the Borsa İstanbul market. Hypothetically they prepared a set of options that are assumed to be written on the BIST Composite Index. They have concluded that the Martingale Simulation Approach exhibits prices closer to the Black Scholes option prices. Saatçioğlu and Karagül (2005) presented an overview of derivative markets and discussed the applicability of derivative markets in Turkey. Kayalıdere and Aktaş (2012) concluded that the BIST 30 future contract volatility is effected mostly from the negative news compared to positive news, risk-return tradeoff is not rational and even are not weak-form efficient. Ersoy and Bayraktaroğlu (2013) investigated the lead-lag relationship between spot and futures markets using daily closing prices of BIST 30 index and Turkish BIST 30 index future contracts and concluded that there are not lead-lag relationship between spot and futures markets. Akyapi (2014) analyzed the differences between observed and theoretical prices which are derived by using Black Scholes option pricing formula in BIST 30 index options market. His results showed that Turkey’s option markets may be open for arbitrage opportunities. He find that, in most of the time, observed option prices are not equal to the theoretically calculated option prices.

**Research and Methodology**

Jarrow and Rudd (1982) show how a given probability distribution can be approximated by an arbitrary distribution in terms of Edgeworth series expansion involving second and higher moments. They had specialized this expansion to the option pricing problem where the asset price distribution is not lognormal but can be approximated with lognormal distribution. The option price of their approximation leads a formula which is the Black-Scholes option price plus adjustment terms including the higher moments. Their analysis yields several variations (Corrado and Su, 1997).

Corrado and Su (1997) used the approach developed by Jarrow and Rudd (1982) and derived an approximate probability density function by using a Gram-Charlier expansion of the normal density function and used this expression in pricing the S&P 500 index options. They have found that the non-normal skewness and kurtosis in option-implied distributions solves the inconsistent result of Black Scholes option pricing when volatility smile is observed. Their derivation is known as the Corrado-Su option pricing formula and used by several studies such as: Navatte P and Villa (2000), Blancard et.al (2001), Vähämaa (2003), Jurczenko et.al (2004), Androue et. al (2008) and Äijö (2008).

Brown and Robinson (2002) provided a correction in Corrado-Su pricing formula for the expression of the skewness coefficient and they illustrated the effect on call option prices. The corrected Corrado-Su call option pricing formula is given in Equation 1.

$$C_{cs} = C_{bs} + \mu_3 Q_3 + (\mu_4 - 3)Q_4$$  \hspace{1cm} (1)
\[ Q_3 = \frac{1}{3!} S_0 \sigma \sqrt{t} \left[ (2 \sigma \sqrt{t} - d) n(d) + \sigma^2 t N(d) \right] \]  

(2)

\[ Q_4 = \frac{1}{4!} S_0 \sigma \sqrt{t} \left[ (d^2 - 1 - 3 \sigma \sqrt{t} (d - \sigma \sqrt{t})) n(d) + \sigma^3 t^{3/2} N(d) \right] \]  

(3)

\[ d = \frac{\ln \left( \frac{S_0}{K} \right) + \left( r + \frac{\sigma^2}{2} \right) t}{\sigma \sqrt{t}} \]  

(4)

Where,
- \( S_0 \) is the stock price at time 0,
- \( K \) is the strike price of the option,
- \( r \) is the continuously compounded risk free interest rate,
- \( \sigma \) is the volatility of the stock,
- \( t \) is the time to maturity,
- \( \hat{C}_{BS} \) is the corrected Carrado-Su approach European call option price,
- \( C_{BS} \) is the Black-Scholes call option price,
- \( \mu_i \) is the skewness,
- \( \kappa_i \) is the kurtosis,
- \( n(\cdot) \) Standard normal density function and
- \( N(\cdot) \) the cumulative standard normal distribution function.

In Black-Scholes and corrected Corrado-Su option pricing formula the, stock price, the strike price, risk free interest rate and time to maturity parameters can be observed from market data but the volatility parameter for Black-Scholes option formula and volatility, skewness and kurtosis parameters for the corrected Corrado-Su pricing formula are not observable. In one day, there are different contracts for a single index with a given maturity with different strike prices. However, we need to use one implied volatility, implied skewnesses and implied kurtosis for one day for a specific index option with same maturity. For this purpose, in this paper as used in Corrado-Su (1997) and Vähämaa (2003) the implied version of unobservable parameters are the estimated with Whaley’s (1982) simultaneous equations procedure. In this method, the vector of unobservable parameters is estimated by minimizing the sum of squared deviations between the observed market prices and theoretical option prices (Vähämaa, 2003). This procedure yields implied volatility for the Black-Scholes option prices and implied volatility, implied skewness and implied kurtosis for the corrected Corrado-Su option price. When we denote the unknown parameter vector as, then the minimization problem will be as given in Equation 5.

\[ \min_{\Phi} \sum_{i=1}^{N} \left[ C_i - \hat{C}_i(\Phi) \right]^2 \]  

(5)

In the problem given in Equation 2.5, \( N \) is the number of options traded in a specific day with a given maturity for the same index, \( C_i \) is the observed option price and \( \hat{C}_i(\Phi) \) is the theoretical option price with unobservable parameters to be estimated. After, minimizing the the sum of squared deviation the estimated implied parameters are used in pricing formulas.

**Empirical Data and Analysis**

In this paper, the data contain the European options written on BIST 30 index traded at the Turkish Derivatives Market (VIOP). The data include the day end settlement prices of options extends from January 02, 2015 to April 24, 2015 for given exercise prices with maturity April 30, 2015. In this period, the strike prices are ranging from 86 to 124. The pricing period is chosen to avoid any expiration-related unusual price fluctuations and to minimize the liquidity as preffered in Vähämaa (2003).
To calculate the theoretical prices by Black-Scholes model and adjusted Black Scholes model, the strike prices, BIST 30 prices, time to maturity, risk free interest rate, implied volatility, implied skewness and implied kurtosis are needed. The strike prices and index prices can be directly observed from Equity Market and Derivatives Market in Borsa İstanbul. The time to maturity is taken as the day left April 30, 2015 divided by 365. The compounded interest rate of Government bond with maturity of May 13, 2015 which is closest to the maturity of option contract from Debt Securities Market in Borsa İstanbul.

Results and Discussion

The implied volatility for the Black-Scholes option prices and implied volatility, implied skewness and implied kurtosis for the corrected Corrado-Su option prices are calculated with Whaley’s (1982) simultaneous equations procedure by minimizing the sum of squared deviations between the observed market prices and theoretical option prices.

At a day, there are 20 different options with maturity April 30, 2015 with different strike prices range from 86 to 124. Sum of squared deviations between the observed market prices and theoretical option prices are minimized according to the unobservable volatility, skewness and kurtosis parameters for each day. As a result, implied parameters which are same for all options on same index with a given maturity are estimated for each day.

Table 1 presents the summary statistics of the estimated model parameters. These parameters are estimated bu Whaley’s (1982) simultaneous equations procedure. The implied parameters are derived by minimizing the sum of squared deviations between the observed and theoretical option prices. Implied volatilities for both models are nearly the same. The mean of implied skewness and implied kurtosis parameters indicate that the distribution of Turkish stock index BIST 30 has leptokurtic distribution with averagely -0,0718 negative skewness and 3,06331 kurtosis. Although, from the literature we know that the normality of the emerging market returns is argued, the implied distribution is not significantly deviated from normal distribution.

Table 1: Summary of implied parameters

|                   | Black Scholes | Adjusted Black Scholes |
|-------------------|---------------|------------------------|
|                   | Implied Volatility | Implied Volatility | Implied Skewness | Implied Kurtosis |
| Mean              | 0,2330        | 0,2340                 | -0,0718          | 3,0633         |
| Maximum           | 0,3246        | 0,3252                 | 0,7875           | 4,2228         |
| Minimum           | 0,1793        | 0,1785                 | 0,6115           | 1,7712         |
| Std Deviation     | 0,0256        | 0,0262                 | 0,1836           | 0,3152         |

The figures from Figure A.1 to Figure A.17 given in Appendix show the differences between observed and theoretical option prices with different strike prices between 86 and 118 during the period. From the figures it is seen that there are not much deviations for both models from the observed prices. However, surprisingly the Black Scholes model give better results than the adjusted Black Scholes model.

Table 2 summarize the pricing performances of both models according to the mean square deviations (MSD) and mean absolute deviations (MAD) from the observed option prices. The MSD and MAD values are very small that means both models are succesfully pricing the options. Again, surprisingly the deviations are smaller for Black Scholes except the strike prices 90,92 and 94. This result support the results seen by graphs.

In the literature before our study, Akyapi (2014) analyzed the difference between observed and theoretical prices which are derived by using Black Scholes option pricing formula in BIST 30 index options market in Turkey. He find that observed option prices are not equal to the theoretically calculated option prices most of the time. Our results are in contradiction with his result because he used historical volatility estimation for the option prices instead of using implied volatilities. When using implied parameters, the theoretical model option prices for a given day are based on a prior-day, out-of sample implied parameter estimates.
Our results support the other studies using adjusted Black Scholes model. Blancard et.al (2001) concluded that adjusted Black Scholes model does not improve hedging strategy of Black Scholes pricing model. Vähämäa (2003) concluded that the hedging errors of the adjusted Black Scholes model is worse than the Black-Scholes option pricing formula when applied to the FTSE 100 index options traded at the London International Financial Futures and Options Exchange. Andreous et.al (2008) compare the performances of Black Scholes model, Corrado Su model, Artificial Neural Network and Black Scholes and Corrado Su based hybrid Artificial Neural Networks to price European call options on the S&P 500 index. They concluded that Black Scholes based hybrid artificial neural network models outperform the others. As we mentioned, the implied distribution of BIST 30 is not significantly deviated from normal distribution. Therefore, Black Scholes model can be used in option pricing for Turkish stock market.

| Table 2: MSD and MAD criteria for pricing performances of models |
|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|
|                 | 86              | 88              | 90              | 92              | 94              | 96              | 98              | 100             | 102             |
| MSD             | 0.0046          | 0.0068          | 0.0086          | 0.0126          | 0.0092          | 0.0068          | 0.0052          | 0.0025          | 0.0018          |
| MAD             | 0.0484          | 0.0599          | 0.0691          | 0.0790          | 0.0660          | 0.0552          | 0.0465          | 0.0326          | 0.0274          |
|                 | 104             | 106             | 108             | 110             | 112             | 114             | 116             | 118             |                 |
| MSD             | 0.0013          | 0.0010          | 0.0009          | 0.0009          | 0.0010          | 0.0013          | 0.0016          | 0.0020          |                 |
| MAD             | 0.0223          | 0.0186          | 0.0172          | 0.0174          | 0.0186          | 0.0246          | 0.0298          | 0.0506          |                 |
| Adjusted Black Scholes |                 |                 |                 |                 |                 |                 |                 |                 |                 |
| 86              | 0.0118          | 0.0070          | 0.0047          | 0.0057          | 0.0058          | 0.0073          | 0.0115          | 0.0656          | 0.0731          |
| MSD             | 0.0635          | 0.0486          | 0.0407          | 0.0422          | 0.0438          | 0.0535          | 0.0716          | 0.1857          | 0.1679          |
| MAD             | 0.0428          | 0.0393          | 0.0477          | 0.0899          | 0.0391          | 0.0411          | 0.0320          | 0.0310          |                 |
| 104             | 106             | 108             | 110             | 112             | 114             | 116             | 118             |                 |                 |
| MSD             | 0.1472          | 0.1371          | 0.1400          | 0.1786          | 0.1254          | 0.1240          | 0.1019          | 0.0922          |                 |
| MAD             | 0.1786          | 0.1254          | 0.1240          | 0.1019          | 0.0922          |                 |                 |                 |                 |

Conclusion

The Turkish derivative market is new and developing financial market. As an emerging market, the efficient pricing in derivatives market is very crucial for the investors trading at Turkish stock market. For this purpose, the pricing performances of Black Scholes option pricing Formula and adjusted Black Scholes option pricing formula are compared for the options written on BIST 30 Turkish stock index. As well, for theoretical pricing the implied model parameters are derived.

In this study the implied parameters show that the distribution of BIST 30 is not significantly deviated from normal distribution. In addition, both figures showing the theoretical and observed option prices and the mean square deviations (MSD) and mean absolute deviations (MAD) from the observed option prices results show us that Black Scholes option pricing formula performs better in Turkish stock market. As mentioned before, studies on different stock and derivatives markets also concluded that the skewness and kurtosis adjusted Black Scholes pricing formula give no better results than Black Scholes formula when implied volatility is used instead of using historical volatility. However, the most important contribution of the model is the consistent pricing with volatility smile feature. Least but not last, we can not conclude that the model is useless.

As a future work, the performance of the model should be compared for different types of options and for different periods. In addition, we know that the Turkish stock market is an emerging market and non normal features of stock market is found in studies, and Kou (1999)'s option pricing model should also be investigated for Turkish stock market as well.
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Appendix

A.1. Option prices for Strike Price X=86

A.2. Option prices for Strike Price X=88

A.3. Option prices for Strike Price X=90
A.4. Option prices for Strike Price X=92

A.5. Option prices for Strike Price X=96

A.6. Option prices for Strike Price X=94
A.7. Option prices for Strike Price X=98

A.8. Option prices for Strike Price X=100

A.9. Option prices for Strike Price X=102
A.10. Option prices for Strike Price X=104

A.11. Option prices for Strike Price X=106

A.12. Option prices for Strike Price X=108
A.13. Option prices for Strike Price X=110

A.14. Option prices for Strike Price X=112

A.15. Option prices for Strike Price X=114
A.16. Option prices for Strike Price X=116

A.17. Option prices for Strike Price X=118