

VOLATILITY EVALUATION IN OPTION PRICING

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Abstract. The volatility of asset returns tends to change over time. Changing volatility is apparent in bond and foreign currency markets, but is perhaps the most evident in stock markets. Analysis of the essential factors influencing prices of option contracts showed that the volatility of stock price showing the riskiness of the stock is one of the main and the most difficult factors to determine, because this parameter is the only one that isn't known exactly at the moment of contract conclusion. So there is need to analyze this factor in detail. The research showed that volatility is random variable that has its own riskiness and possible fluctuations. These fluctuations have to be taken into consideration, because volatility often plays the most important role in actual trading situations. Changes in assumptions about volatility can have huge effect on an option's price and value.

Keywords: Option contract, volatility, standard deviation, mean, investor.

1. Introduction

Within the last decade trading options all over the world has increased at an explosive rate. Not only traditional market participants, such as speculators, hedgers and arbitrageurs have become actively involved in option markets, but the number of individual traders willing to risk their own capital in these markets has grown dramatically. In order to trade successfully investors have to know not only the rules of the market and trade, they have to understand the usual characteristics of option contracts and most importantly the pricing techniques of these contracts.

Analysis of the essential factors influencing prices of option contracts enabled the author of the article to make the conclusion that the volatility of stock price showing the riskiness of the stock is one of the main and most difficult factors to determine, because this parameter is the only one that isn't known exactly at the moment of contract conclusion. There is need to analyze this factor in detail.

The analysis of various authors' works [1 – 4] proved the importance of the riskiness of stock price in options evaluation. The main problem has already emerged choosing which volatility to use for option price calculation. This concept can have three meanings: historical volatility, implied volatility and forecasted volatility. Usually volatility of the stock or other underlying is described as standard deviation of the price.

In many models of option pricing the assumption is made that volatility of analyzed underlying asset is constant [1], but it is not true under the circumstances

of the real market. Volatility itself is random variable with its own possible fluctuations and riskiness. The purpose of the article is to evaluate the factor of stock price volatility as a random number fluctuating under changing conditions of the market.

The tasks of the article are:

- 1) to describe theoretical meaning of the volatility;
- 2) to present the significance of the volatility in option pricing;
- 3) to evaluate volatility as a random number.

The object of the research is volatility used in option pricing models. Systemic, comparative, logical, graphical analysis of scientific literature and empirical calculations were used for the research.

2. Basic facts of option pricing process

2.1. Essence of option contracts

All kinds of derivatives have long been used for the effective mitigation of price and supply risks of various commodities. In fact, for more than 100 years the numerous futures exchanges have been hedging risks associated with currencies, commodities, and interest rates. And since the 1970s, derivatives have become a financial mainstay of most corporate treasury departments [1].

A derivative is an instrument whose value depends on the values of other more basic underlying variables. Derivative securities can be made on the basis of stocks, bonds, currencies, indexes or interest rates. Derivatives consist of options, futures, forwards and swaps. These are main constructing blocks for many investment strategies suitable for different

situations in the market. A futures contract is an agreement to buy or sell an asset at a certain time in the future for a certain price. Forward contracts are similar to futures except that they trade in the over-the-counter markets. A swap is an agreement between two companies to exchange cash flows in the future. The agreement defines the dates when the cash flows are to be paid and the way that they are going to be calculated [5]. An option is an instrument giving its owner the right but not the obligation to buy or sell something at in advance fixed price. Options are available on a wide range of products, beginning from raw materials and ending in financial assets, gold or real estate. A call option is an option to buy a certain asset by a certain date for a certain price (the strike price). A put option is an option to sell a certain asset by a certain date for a certain price (the strike price).

The ways derivative securities may be used are [1, 2]:

- to hedge risks;
- to speculate (take a view on the future direction of the market);
- to lock in an arbitrage profit;
- to change the nature of a liability;
- to change the nature of an investment without incurring the costs of selling one portfolio and buying another

As it can be seen the main aspect of the use of derivatives is to manage and hedge risk. Nowadays in many cases economical and financial factors are kept as the basic factors of risk origin. Enterprises of all types are risking to receive loses because of the changes in exchange or interest rates. Unfavorable changes of these and other factors are the part of financial risk that mostly influences financial results of enterprise.

For the first time exchange listed options were traded in 1973. Since then, the volumes of their trade had risen sharply all over the world. This growing was determined by the special features that options include. Options can be used in many imaginative ways to create various attractive investment opportunities. Empirical researches presented in financial literature [1, 3] illustrated that options incorporate an insurance element not available in any other security and because of that they can be used by investors to create return distributions unobtainable with the strategy of allocating funds between a stock portfolios and fixed income securities. Options can be used to speculate for profit, earn income to enhance investment returns, protect against a temporary decline in the value of a stock or other commodity both financial and material.

In Lithuania option contracts are not so many used by investors or other market participants as in USA or big European countries. At the beginning of the year 2007 the turnover of options was 1,6 m. Litas, in the middle of the year it rose to 2,3 m. Litas at the end the turnover dropped to 2,0 m. Litas. These numbers are quite small comparing them with the

turnover of other derivatives such as forwards and swaps, but the level of turnover in options generally remains lower than of forwards, futures and swaps. On the one hand the main reasons for such inactivity are poor liquidity and activity of Lithuanian stock market, the lack of financial instruments and financial innovations, and conservative manner and the lack of special knowledge of our financial market participants. But on the other hand growing numbers show increasing interest and that these contracts are going to find their place in Lithuanian financial market in the future.

Before option pricing can be properly examined, still few important terms must be introduced. There are three different terms for describing where an option is trading in relation to the price of the underlying asset. These terms are “at-the-money”, “in-the-money”, and “out-of-the money”. At the money means that the current market value of the underlying stock is the same as the exercise price of the option. A call option is said to be in the money if the current market value of the underlying stock is above the exercise of the option. In the case of a put option current market value should be below the exercise price of the option. If the exercise price is above the current market value in the case of a call option and below in the case of a put option, the option is said to be out of the money. These options can be executed only at a lost [3].

2.2. Pricing elements of option contracts

The main options pricing models contain five factors that are used to determine a theoretical value for an option [6]:

- 1) current price of the underlying interest;
- 2) strike price;
- 3) time to expiration;
- 4) interest rates;
- 5) dividends expecting during the life of the option;
- 6) volatility of the underlying.

Stock price and strike price. The payoff from a call option will be the amount by which the stock price exceeds the strike price. Call options therefore become more valuable as the stock price increases and less valuable as the strike price increases. For a put option, the payoff on exercise is the amount by which the strike price exceeds the stock price [1, 6]. So the put option becomes less valuable as the stock price increases and more valuable as the strike price increases.

Time to expiration. Both put and call American options become more valuable as the time to expiration increases. European put and call options do not necessarily become more valuable as the time to expiration increases. This is because it is not true that the owner of a long-life European option has all the exercise opportunities open to the owner of a short-life European option.

Volatility. The volatility of a stock price is a measure of how uncertain we are about future stock price movements. As volatility increases, the chance that the stock will do very well or very poorly increases as well. The value of both calls and puts therefore increase as volatility increases [1, 6].

Risk-free interest rate. The risk-free interest rate affects the price of an option in a less clear-cut way. Without additional assumptions it is difficult to gauge the effect of increasing interest rates. Since increasing interest rates decrease the present value of the exercise price, there is a tendency for call values to increase and put values to decrease. It should be emphasized that these results assume that all variables remain fixed. In practice, when interest rates fall (rise), stock prices tend to rise (fall). The net effect of an interest rate change and the accompanying stock price change therefore may be different from that just given [1].

Dividends. Dividends have the effect of reducing the stock price on the ex-dividend date. The values of call options are negatively related to the size of any anticipated dividend, and the value of a put option is positively related to the size of any anticipated dividend.

Investor, having obtained a stock or other security should have in mind three possible events: the value of the stock may rise, it may decrease or it may stay stable. This is the main reason for investor to learn how to manage the volatility of stock value and to make profit from these changes, using special means, helping to achieve mentioned goals.

3. Characteristics of options volatility and its estimation

One well known conclusion of empirical studies pertaining to security markets is that the volatility of asset returns tends to change over time. Changing volatility is apparent in bond and foreign currency markets, but is perhaps most evident in stock markets.

The analysis of the researches of various authors [1, 7, 8] confirmed that riskiness of the stock price is quite significant and mostly difficult to evaluate factor in option pricing. Of all the inputs required for option evaluation, volatility is the most difficult for traders to understand. At the same time, volatility often plays the most important role in actual trading situations. Changes in investors assumptions about volatility can have a dramatic effect on an option's value, and the manner in which the marketplace assesses volatility can have an equally dramatic effect on an option's price [7]. The main problem has already emerged choosing which volatility to use for option price calculation. This concept can have three meanings, that is historical volatility, implied volatility and forecasted volatility.

Volatility is simply a measure of the degree of price movement in a stock, futures contract or any other market.

Historical volatility is the measure of a stock's price movement based on historical prices. It measures how active a stock price typically is over a certain period of time. Usually, historical volatility is measured by taking the daily percentage price changes in a stock and calculating the average over a given time period. The higher the historical volatility, the more movement the stock has experienced and the more it can move in the future, although this does not provide insight into either direction or trend. Historical volatility is often referred to as actual volatility or realized volatility [8].

In order to calculate historical volatility investor has to do the following steps:

1. Measure the day-to-day price changes in a market.

Calculate the natural log of the ratio (R_t) of a stock's price (S) from the current day (t) to the previous day ($t-1$) [8]:

$$R_t = LN\left(\frac{S_t}{S_{t-1}}\right), \quad (1)$$

The result corresponds closely to the percentage price change of the stock.

2. Calculate the average day-to-day changes over a certain period. Add together all the changes for a given period (n) and calculate an average for them (R_m) [8]:

$$R_m = \frac{\sum R_t}{n}, \quad (2)$$

3. Find out how far prices vary from the average calculated in Step 2. The historical volatility (HV) is the "average variance" from the mean (the "standard deviation"), and is estimated as [8]:

$$HV = \sqrt{\frac{\sum (R_t - R_m)^2}{n-1}}, \quad (3)$$

4. Express volatility as an annual percentage. To annualize the historical volatility, the above result is multiplied by the square root of 252 (the average number of trading days in a year).

Implied volatility is the current volatility of a stock, as estimated by its option price. As it was mentioned, an option's value consists of several components – the strike price, expiration date, the current stock price, dividends paid by the stock (if any), the implied volatility of the stock and interest rates. If investor knows the price of an option and all the above inputs, except volatility, then he can modify the option-pricing model to calculate the implied volatility. Because there are many options on a stock, with different strike prices and expiration dates, each option can, and typically will, have a different implied volatility. Even within the same expiration, options with different strike prices will have different implied volatilities.

Generally, the implied volatilities of calls and puts show a distinct pattern, called the skew of implied volatility. Implied volatility tends to be higher for out-of-the-money (OTM) options compared to at-

the-money (ATM) options. This is because OTM options present more risk on very large moves; to compensate for this risk, they tend to be priced higher. But equally OTM calls and puts do not necessarily have the same implied volatility, and this difference represents the bias or skew of the market. The skew can be caused by a strong directional bias in the stock or the market, or by very large demand for either calls or puts, which pushes implied volatility higher [9].

To use implied volatility in volatility analysis, it is necessary to calculate a representative implied volatility for a stock. This is merely an average of the implied volatilities of the different options on that stock. However, there is no accepted standard for which representative implied volatility to use. Many people simply use the average implied volatility of the at-the-money options for the next few expirations, while some take a more sophisticated approach by factoring in several at-the-money and out-of-the-money options.

Implied volatility acts as a proxy for option value. It is the only parameter in option pricing that is not directly observable from the market, and cannot be “hedged” or offset with some other trading instrument. Because all other factors can be “locked in,” the price of the option becomes entirely dependent on the implied volatility. This is an important fact to consider when looking for relative value in options; to compare the relative value of two options you need only look at their implied volatilities.

Implied volatility represents the market’s expectation of a stock’s future price moves. High implied volatility means the market expects the stock to continue to be volatile — i.e., make large moves, either in the same direction or up and down [7, 8].

Conversely, low implied volatility means the market believes the stock’s price moves will be rather conservative. However, studying implied volatility reveals much more information. Because implied volatility is a surrogate for option value, a change in implied volatility means there is a change in the option value.

Forecasted volatility is an estimate of the future volatility in an underlying stock. Forecasts may be for any period, but most commonly cover periods identical to the remaining life of options on the underlying contract.

It is clear that volatility is a very important factor in deciding what kind of options to buy or to sell. Volatility shows the range that stock price has fluctuated in a certain period. The price of an option is linked to the expected future distribution of the underlying asset price. As expectations of volatility change, so will the option premium. The Greek letter used to describe the sensitivity of the option premium to volatility is vega.

The vega of the option is usually given in point change in theoretical value for each one percentage point change in volatility. “At the money” options have the greatest vega. The further an option goes “in-

the-money” or “out of the money”, the smaller is the vega. As time passes, vega decreases. Time reinforces the effect of volatility changes. As a result, vega is greater for long-dated options than for short dated options [10].

Bought options have positive vega and sold options have negative vega. For example, if option has a vega of +6,8657, that implies that a 1 % rise in volatility will increase the option premium by 6,87 cents.

4. Empirical research on volatility evaluation

According to the nature of the market, a presumption can be made that all operating market factors are non-determinates. In order to evaluate the riskiness of the stock as a random variable, real market data and conception of historical volatility was used. For that purpose the certain situation have been modeled: it was supposed that at the end of option contract the price of underlying stock would be random variable that under the settled practice should submit to the laws of normal distribution with known mean (μ) and standard deviation (σ) parameters $N(\mu=120 \text{ Lt}; \sigma=12 \text{ Lt})$. Using imitative modelling and fixed parameters a set of possible stock price at the end of option contract had been modelled. The stochastic distribution of the stock price is given in the Fig 1.

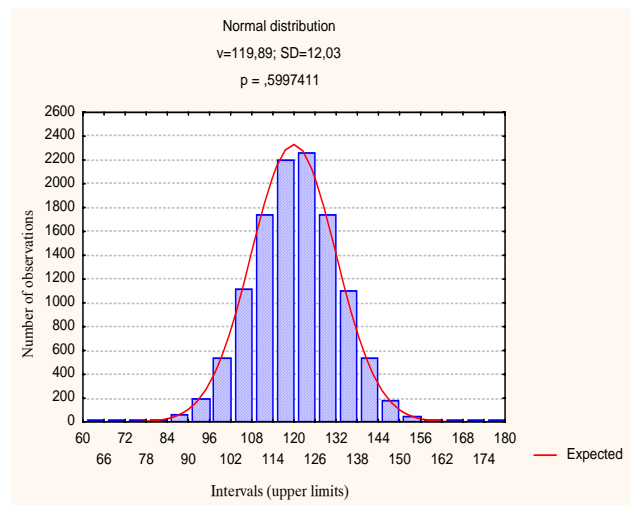


Fig 1. Stochastic distribution of the stock price

Based on the distribution of stock price and the main parameters of mean and standard deviation, the factor of stock price volatility has been calculated, necessary in determining the size of option premium. The problem is this stage of calculation arisen that main parameters of the stock price were denominated in monetary unit and price volatility has to be expressed in percents. For the elimination of this inadequacy variation coefficient was used, because this measure gives possibility to compare fluctuations of feature expressed in different units.

Mathematical expression of variation coefficient is [4]:

$$K_v = \frac{\pm sd}{v} \times 100 \%, \quad (4)$$

Here K_v is variation coefficient, sd is standard deviation and v is average value.

Using Formula 4 and acquainted values of stock price distribution, the result of stock price volatility was calculated equal to 10 %.

In the most models of option evaluation the presumption is made that the above mentioned volatility factor doesn't change, but this is not true in the point of view of real market conditions. Volatility is random variable that has its own riskiness and possible fluctuations.

So the condition have been raised, that stock price volatility will be treated as random variable with the mean equal to obtained volatility meaning and certain little meaning of standard deviation, equal to 0,1 %. The histogram of the stock price volatility is given in the Fig 2.

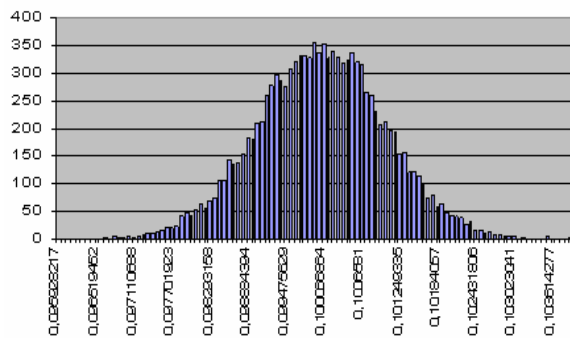


Fig 2. The histogram of the stock price volatility as the random number

It can be concluded that the fluctuations or volatility of the stock price in the market shows its riskiness and becomes one of the main factors of riskiness of option contract, determining price fluctuations of the contract. Volatility is random variable that possible fluctuations in corresponding period should be evaluated.

5. Conclusions

The main variables influencing the price of option contract are current market price of underlying asset, the volatility of the price of underlying asset, exercise price, struck in the contract, time to expiration and interest rate.

Analysis of the essential factors influencing prices of option contracts enabled to make the conclusion that the volatility of stock price showing the riskiness of the stock is one of the main and most difficult factors to determine, because this parameter is the only one that isn't known exactly at the moment of contract conclusion.

Volatility is random variable that has its own riskiness and possible fluctuations.

Inappropriate evaluation of the volatility of a stock price can be one of the main reasons of options investment strategies ineffectiveness.

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