Option Greeks

- Evaluating Option Price Sensitivity to:

  Price Changes to the Stock

  Time to Expiration

  Alterations in Interest Rates

  Volatility as an indicator of Supply and Demand for the Option

Different Types of Greeks in Terms of Importance

DELTA – The amount by which the price of an option changes as compared to a $1 increase in the price of a stock expressed as a decimal or percentage.

THETA – The amount that the price of an option changes as compared to the passage of time [typically 1 day], which is a negative number because the value of the option decreases with time.

GAMMA- The amount that DELTA changes as compared to a $1 increase in the price of the stock which may be important where the DELTA becomes particularly sensitive to changes in the stock price.

VEGA – is the measure of volatility in the underlying stock, the amount the option price changes with an increase in volatility.

RHO - the amount that the price of an option changes as compared to a unit increase in the risk free rate (i.e., short term US Treasury Bill rate), the least important Greek because most options are short term in nature and so interest costs are a smaller component of the overall change in the option price.

Price vs. Value

The right to buy or sell an underlying security has value because of the supply and demand characteristics associated with ownership of an option. There are **several characteristics which influence supply and demand** – (1) there is more demand for an option that has **longer time to expiration** because of the greater possibility over time to be right on the direction and strength of a movement in the stock price (2) **the rate of change in the underlying price of the stock** on which the option is based (3) **volatility in terms of the volume of trading** in a particular option (4) the relationship of the stock's price to the strike price on the option [out-of-the money, at-the-money, in-the-money options] (5) **changes in the level of interest rates** which impact cash flows relative to the option.

DELTA

Definitions:

1. The rate of change of an option value relative to a change in the underlying stock price

2. The equivalent of the underlying shares represented by an option position

3. An estimate of the likelihood of an option expiring in-the-money

First definition: Δ Option premium/ Δ underlying stock price

A trader may choose to hold the option in lieu of purchasing the stock. Say you buy 1 call to control 100 shares of INTC. If INTC rises by $1 you would expect to gain on the option, but how much? To answer this question you must consider the delta of your option. Delta is stated as a percentage. If your INTC option has a delta of 50, that means that according to the model the option premium should change 50% in relation to the change in the price of the stock. Here's how it works:

INTC Stock Price $20 ============goes to =================➔$21 [$1 gain]

Call Premium $2 ==============.50 DELTA =============➔ $2 + .5[$1] = $2.50

Deltas are always positive, because there is a positive correlation between the price of a stock and the option premium. The option premium price is directly related to the price of the stock [i.e., stock price goes up, option premium goes up, and vice versa].

On the other hand, a put option premium has a negative correlation to the underlying stock price. If the stock price goes up, then the value of the put should decline and vice versa. So, for example,

INTC Stock Price $20 ============goes to =================$21 [$1 gain]

Put Premium $2 ==============.40 DELTA ============= $2 - .4[$1] = $1.60

In reality the changes in option premium values is not linear and so you have to keep in mind that if INTC were to increase in value by $1, the option price might change by more than what is indicated in these examples.

Definition 2.

The delta option varies between 0 and 1,the closer the delta is to 1, the more the option price will move in tandem to the underlying stock price [typical of a deep in-the- money option].

If a stock were to have a delta of 1, the option premium would trade in exact relationship to the stock price. A $1 increase in the stock price would cause a $1 increase in the option premium. For 1 contract that controls 100 shares, this would be a $100 gain. If an option trader purchased a 1 call with a delta of .60, this would be equivalent to controlling .60 x 100 or 60 shares to stock in terms of the movement in the stock price [i.e., a $1 increase in the stock price on a call = $1 x .60 x 100 x shares = $60 or alternatively, you effectively control 100 x .60 = 60 shares, 60 shares x $1 gain = $60]. The delta is the option's equivalent of a position in the underlying shares of stock based on the strength of the correlation between the option premium and the underlying price of the stock.

A trader who buys 5 call contracts on INTC with a delta of .45 has a position that is effectively long,

5 x 100 shares x .45 = 225 shares. In the parlance of the options market, we would say this trader is long 225 Deltas.

Conversely, the same idea applies to puts. Being long 10 .60-delta puts makes the trader short a total of: 100 x 10 x .60 or 600 Deltas.

Definition 3

This is sometimes referred to as the trader's definition of delta which provides a practical understanding of delta in regards to trading options. A trader would say that delta is a statistical approximation of the chance of an option expiring in-the-money. An option with a .80 delta would have a 80% likelihood of being in-the-money at expiration.

Because of changing options market conditions, deltas do not remain constant over time. Deltas are calculated from dynamic inputs – stock price, time to expiration, volatility, current interest rate, and strike price. When any of these inputs change it will have an impact on delta.

Some observations about delta:

(1) call and put deltas are close related. Consider the following Option Chain with Deltas on INTC when the stock was trading at $21.40

Call Market	Call Delta	Strike	Put Market	Put Delta
4.80-5.00	.80	18	.90-1.00	-.20
3.30-3.50	.66	20	1.90 – 2.00	-.34
2.35-2.40	.49	22.5	3.20-3.40	-.51

When looking at this listing note that the Put Delta = Call Delta – 1. This relationship between deltas takes into the account the mirror image value of the put option against that of the call. An in-the-money call represents an out-of-the money put at the same strike price. This relationship is sometimes called the put-call parity. Although in this example there is a 100% put-call parity, sometimes the Call Delta + |Put Delta| does not add up to exactly 1, due to rounding or the possibility of early exercise on equity options [ie. American options]. Also dividend paying stocks may have higher deltas on some in-the-money calls so you might get something that looks like this:

Call Market	Call Delta	Strike	Put Market	Put Delta
5.50-6.00	.90	16	.25-.75	-.15

In this instance the deep in-the-money option at a strike of 16 when INTC is trading at $21.40 has a delta greater than .85 which is what the number should be in terms of the counter put delta of -.15.

(2) Moneyness or the degree to which the option is in or out-of-the money also has an effect on deltas. As a rule of thumb, options that are in-the-money (ITM) have deltas greater than .50. On the other hand, out-of-the money(OTM) options generally have deltas that are less than .50. The more in-the-money the option, the closer the delta will be to 1. The more the option is out-of-the-money (OTM) the closer the delta will be to 0. For options that are at-the-money(ATM), the delta should be fairly close to .50 in which case the trading value is about the same for either a put or a call. However, this is a theoretical result not often seen in practice --- there are still some differences between the deltas even when you are at-the-money. The more time until the expiration, the greater the difference between put and call theoretical values. In most cases, the call will have a higher premium and delta than the corresponding put values when ATM largely due to the interest rate and the time to expiration.

(3) Impact of Time on Delta

In athletic events such as basketball, European football [a.k.a. soccer], or American football as time winds down, the elements that impact the ending of the game take on ever greater importance in terms of outcome. The reason why some coaches get exorbitant salaries [notwithstanding the Iowa college coaches] may be due to their abilities to manage risk or take advantage of opportunities in the last seconds of a game. The same phenomenon holds true for an options trader holding a position that may be close to expiration.

The more time an option has to expire, the less certainty there is about whether the option will be ITM or OTM at expiration. The deltas of both the put and call options will reflect that uncertainty. The more time left in the option, the closer the deltas tend to hover around .50. A delta of .50 represents the greatest uncertainty --- a 50 -50chance of ending ITM. At expiration, the delta of the option is theoretically at 1.00 or 0 depending on whether you have a ITM or OTM situation.

(4) Effect of Volatility on Delta

Consider the following estimated delta of a 50-Strike call in terms of volatility for an option on Conoco Phillips stock [COP] trading between $50 and $60 over the last six months. The call has 90 days to expiration.

Stock Price	10% Vol	15% Vol	20% Vol	25% Vol	30% Vol	35% Vol	40% Vol	45% Vol
42	0	.02	.06	.11	.16	.21	.25	.30
48	.28	.36	.40	.43	.45	.47	.48	.50
52	.84	.75	.70	.67	.66	.64	.64	.63
58	1.00	.98	.94	.90	.87	.83	.81	.79

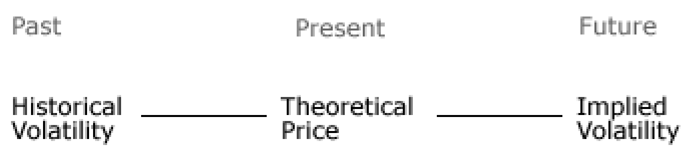
At a 10% volatility [little fluctuation in the underlying stock] the option delta is 1.00 [deeply ITM]. At that same volatility with the stock priced at $42, the option delta is 0 [OTM]. As volatility rises from 10 to 45%, delta increases for an OTM call. [e.g. at $42, delta goes from 0 to .3]. On the other hand, for ITM option, more volatility actually lowers delta [i.e., the option premium may not trade in tandem with the underlying stock price], for example when the stock price is deep in the money at $58/share, delta goes from 1 down to .79 when volatility moves from 10% to 45%.

There are two main ways of measuring volatility in the underlying stock: (1) historical volatility [based on past stock prices] and (2) implied volatility [a byproduct of the Black Scholes Pricing Model]

Why is volatility so important to option traders? Volatility is significant to an options trader or stock purchaser, because volatility measures the possible price changes of the asset in the future. Assets that have high volatility can be expected to have large price changes in the future. As a result, options that are based on assets with high volatility can be expected to have higher prices. For example, someone who is long a call would find more volatility attractive, whereas, the seller of the call would like to have low volatility.

Implied volatility is the markets view of where volatility will be in the future. To determine an option's implied volatility, the trader must use a pricing model.

But for now, take a look at the following illustration;



Historical Volatility tells us how volatile as asset has been in the past. Implied Volatility is the markets view on how volatile as asset will be in the future.

We can tell how high/low implied volatility is by comparing the market price of an option to the options theoretical fair value. This is why we need to use an option pricing model - to determine the fair value of an option and hence know if the market price for the option is over/under valued.

When the market price of an option is higher than its theoretical value (based off past information) it is considered expensive and so to if the market price of the option is less than the theoretical price, it is considered cheap.

THETA

Option prices can be divided into two parts: (1) intrinsic value and (2) time value

Intrinsic value is the market price of the stock less the strike price for the ITM option. Time value is what is left over in terms of the premium paid on the option. The loss in the value of an option due to the passage of time is called decay or price erosion.   Theta (Θ) is the rate of change in an option’s price given a unit change in the time to expiration.   Some models will show thetas that represent one day’s worth of time decay, others show thetas giving 7 days’ worth of decay.   There may be differences on when decay is being experienced – for example, decay may be greater on a Friday because you will lose 2 more days over the weekend when there is not trading in the option.   In some cases, the decay may occur in the day rather than at the end of the day, as the market anticipates a loss in value to the option due to the passage of time.

There are two distinct perspectives on Theta depending on the type of investor trading in the option. For those who hold long options, theta hurts their positions because it reduces the value of the option. Take a 90-strike call with a theoretical value of $3.16 on a stock at $92 a share. The 32-day 90 call has a theta of .05. If a trader owns this position, $.03 would be lost going from 32 to 31 days and so this trader would be negative theta. However, in the case of put there is a similar effect of time. Say the trader has a 32-day 90 strike put with a theta of .04. A put holder would theoretically lose $.04 a day, while the put writer would theoretically make $.04. Consequently, long options carry negative theta, while short positions have positive theta.

The Impact Moneyness has on Theta

Theta is not constant, and the impact of time on options pricing may be more non-linear in nature. On variable that influence's changes to theta is whether the option is ATM. An at-the-money [ATM] option may have higher time value than one that is ITM or OTM. Therefore, with more time premium to lose, an ATM will have a higher decay rate than one that is either ITM or OTM. So, as the stock price changes there may be a revision in theta to reflect changes in moneyness.

Volatility's Impact on Theta

The greater volatility in the underlying stock price, the higher the value of the option which offers larger decay at a faster rate. Cateris paribus, the higher the volatility, the higher theta.

VEGA

An options trader looking at various call premium prices on same price stocks, say trading at $35 a share, with a strike of $35 [trading at-the-money] will find significant differences in pricing despite these options having the same expiration date. What factor explains these differences? The price difference can be explained by volatility, the way the option price may change due to the volatility tied up in the underlying stock.

Implied Volatility[IM] and VEGA

IV is a percentage change in the stock price based on the way an option is priced in the market. An estimate of IV, along with the other five variables is inputted into the BSOP model to render a theoretical value of the option. The theoretical value of the option may then be compared to the market value to determine whether the option is under or overpriced and by how much. IV levels can and do change over time. When IV rises or falls, the option price moves up or down in direct relation to volatility. Vega is the rate of change of an option's theoretical value in relation to changes in implied volatility. If the IV rises or declines by 1%, then the theoretical value of the option will rise or fall by the option's VEGA. E.G. A call with a theoretical value $2.0 has a VEGA of .05 and IV rises by 1% from 17 to 18%, then the new theoretical value of the call will be $2 + .05 or $2.05. If iV declines 1%, then the theoretical value of the option would be $ 2 - .05 or $1.95.

A put with the same expiration month and same strike on the same underlying stock will have the same VEGA value as its corresponding call. So, raising or lowering the IV by 1% would increase or decrease the theoretical value of the put by the VEGA amount.

Impact of Moneyness on VEGA

The stock price's relationship to the strike price is a major determinant of an option's VEGA. IV affects only the time value portion of an option. Because ATM options have the greatest amount of time value, they have higher VEGAs. ITM or OTM options have lower VEGAs.

How IV May Influence VEGA

As long as an option remains ATM the VEGA will stay a constant amount. However, once the stock price moves and the option is either ITM or OTM the Vega will be altered. Lower IV tends to reduce ITM and OTM VEGAS, while higher IV may cause VEGAS to go up for ITM or OTM options.

The Impact Time Has on VEGA

As time moves forward there will be less time premium in an option that can be impacted by IV. Therefore, VEGA gets smaller as expiration draws near. The reduction of VEGA for an ATM option may occur in a nonlinear fashion the closer you get to expiration.

RHO

RHO, is the amount that the price of an option changes as compared to a unit increase in the risk free rate of interest.

PUT-CALL PARITY

Puts and calls are mathematically bound together in an equation called put-call parity. However, this relationship is based on a set of simplifying assumptions that need to be considered when evaluating put or call premiums through put-call parity. First, put-call parity assumes that options may not be exercised prior to expiration [i.e., the options are European]. Second, interest rates and dividends are considered to be known at the time the put-call relationships are calculated. Third, the relationship is developed when the options under consideration are at-the-money [ATM]

In order to derive the put-call parity equation, one needs to consider two alternative investments:

(1) purchase of a call at a given strike at the money [ATM]

(2) purchase of the stock, as well as, an [ATM] put at the same strike price as in (1)

These two alternative investments are exactly equivalent to each other based on their respective at expiration diagrams.

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|                    /    ITM
|--------------------/--------------------------------------- Stock Price
____________/
                     OTM
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Under these circumstances taking into account the cost of money, the purchase of the options ATM, and the fact that they are European Options leads to the following relationship:

Call Premium = Stock Price – Strike Price + Put Premium –Interest on the Strike + Dividends

In general, when the stock is moving up, the call premium will trade close to intrinsic value based on the difference between the current stock price less the strike. However in buying the stock, as opposed to the option, there is the opportunity cost of tying up the strike value when purchasing the underlying stock . However, this is offset somewhat by the ability to receive dividends while owning the stock [something that the call premium does not offer]. The put premium is the cost associated with placing a floor of your investment similar to what you have when purchasing the call option.