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A Seminar paper in Analytical Finance I

Option Volatility in Swedish Equity Market

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ABSTRACT

Title: Options Volatility in Swedish Equity Market

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Problem: The Black-Scholes (1973) model on option pricing represents one of the most striking developments in financial economics. Nowadays, both the pricing and hedging of derivative securities is governed by this model to the extent that prices are often quoted in terms of the volatility parameters implied by the model. One of the most important aspects of this model is the volatility of the underlying price which is assumed to be constant. However, empirical analyses of stock volatility have proven otherwise. To add, the prices at which derivatives (and especially call options) are traded are inconsistent with a constant volatility assumption.

Method: This paper compares a 3 month floating volatility with historical data and the implied volatility using Black-Scholes (BS) model. It uses a moving 3-months window on the data and calculates the volatility inside the window. Thereafter, we calculate (by using the BS formula) the implied volatility for an options with (as close as possible) 3 month to maturity. The paper then evaluates the results of the volatilities to see if there exists a smile or a skew. We shall also follow the options a few days and see if the implied volatility changes and how well it changes with the historical data. For us to accomplish this task, we downloaded data for OMXS30 index and Ericsson B. from NasdaqOMX Nordic webpage. This paper then studies the volatility of options, one call and one put. It also calculates and plots the 3 month floating volatility using MS. Excel.

Conclusion: The result of this study shows that there exist differences between the market price and the theoretical prices. Such difference is accounted for as the premium placed on the option's market price by market participants. They are expecting greater volatility than SV currently is signaling, and therefore the imputed volatility, or IV, is telling us what the best guess of the marketplace is for the future volatility of the underlying stock.

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INTRODUCTION

Problem formulation

The Black-Scholes (1973) model on option pricing represents one of the most striking developments in financial economics. Nowadays, both the pricing and hedging of derivative securities is governed by this model to the extent that prices are often quoted in terms of the volatility parameters implied by the model. One of the most important aspects of this model is the volatility of the underlying price which is assumed to be constant. However, empirical analyses of stock volatility have proven otherwise. To add, the prices at which derivatives (and especially call options) are traded are inconsistent with a constant volatility assumption.

Method

This paper compares a 3 month floating volatility with historical data and the implied volatility using Black-Scholes (BS) model. It uses a moving 3-months window on the data and calculates the volatility inside the window. Thereafter, we calculate (by using the BS formula) the implied volatility for an options with (as close as possible) 3 month to maturity. The paper then evaluates the results of the volatilities to see if there exists a smile or a skew. We shall also follow the options a few days and see if the implied volatility changes and how well it changes with the historical data. For us to accomplish this task, we downloaded data for OMXS30 index and Ericsson B. from NasdaqOMX Nordic.[1] This paper then studies the volatility of options, one call and one put. It also calculates and plots the 3 month floating volatility using MS. Excel.

[1] http://www.nasdaqomxnordic.com/

CHARACTERISTICS OF OPTIONS

Stock Option

On NasdaqOMX Nordic, options are named based on the name of the stocks, expiry date and the strike price. For example, using the Swedish stock Ericsson as the underlying, then, ERIC8J45 is a call option with expiry date in October 2008 with strike price 45 SEK (determined by the current market price). It should be noted that the expiry date is on the *third Friday* on the month.

An illustration of the option classification is given on the table below. The letter J signifies a call option with expiry date in October. Likewise, the letter W signifies a put option with expiry date in November.

Month	***J***	***F***	***M***	***A***	***M***	***J***	***J***	***A***	***S***	***O***	***N***	***D***
Call	A	B	C	D	E	F	G	H	I	J	K	L
Put	M	N	O	P	Q	R	S	T	U	V	W	X

Index Option

An option on the OMX30 index is characterized by the following;

- An identity
- An index level
- A strike price, and
- A time to maturity (six months for short and 2 years for long).

There are always at least five strike prices for each time to maturity. On the Swedish derivative exchange (OMX), the maturity is always on the *fourth Friday* in respective month unlike the *third Friday* of every month as in the case of stock options. At most, there are five different maturities, three short and two long.

The assets in the index are weighted in such a way that the most traded have more impact on the index level. Ericsson is the dominating asset in the index.

It should be noted that index options can be used to:

- Hedge a complex portfolio provided it is diversified and has a beta value similar to the OMX30 index.
- Speculate the entire market. Since European options cannot be exercised during their life-time, a holder of an index option can sell the option at any time or buy the opposite position and in such a way net his position.

VOLATILITY

The volatility of an option measures the spread of the price movements of the underlying instrument. The more volatile the underlying instrument, the greater the time value of the option will be. This implies a linear relationship between the option price and its volatility. Option prices increase as volatility rises and decrease as volatility falls. This paper uses the time adjusted volatility ($\sigma\sqrt{T}$), that is, the volatility of the return on the underlying asset between now and maturity as we read from page 147 of the lecture note.[2]
Volatility can be a very important factor in deciding what kind of options to buy or sell. It shows the investor the range at which the stock prices have fluctuated in a certain period.[3] There are two types of volatility: Statistical volatility and Implied volatility.

Statistical Volatility

The Black-Scholes pricing formula for stock options assumes that the price $(P_t)_{t \leq T}$ of a stock is the solution to a stochastic differential equation (SDE)[4]

$$dP_t = P_t\left(\sigma dB_t + \mu dt\right) \tag{1}$$

where σ is a known and constant volatility parameter and B is a Brownian motion. Given the widespread use of the Black-Scholes formula, concern has been expressed about some of the assumptions necessary for the derivation of the formula. The most criticized of these assumptions is the imposition of a constant Volatility. This critique involves the use of Statistical Volatility (SV). This measures the actual asset price changes over a specific period of time using historical data. Once you have a measure of statistical volatility for any underlying, you can plug the value into a standard options pricing model and calculate the fair market value of an option.

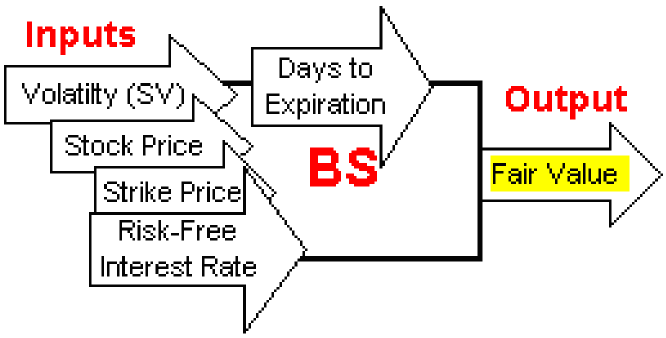

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Figure 1: Black-Scholes options pricing model reversed [5]

However, this fair value of the underlying is not often consistent with the actual market value thus the need for Implied Volatility.

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[2] http://janroman.dhis.org/index_eng2.html
[3] http://www.optionseducation.org/advanced/volatility_greeks.jsp
[4] http://janroman.dhis.org/finance/Volatility%20Models/stoch.%20vola.pdf
[5] http://www.investopedia.com/university/optionvolatility/volatility3.asp

Implied Volatility

Implied volatility (IV) measures the market's expected best guess of future volatility of the underlying. It measures of how much the "market place" expects asset price to move, for an option price. It is calculated using the market price of an option, along with other inputs used in price models (BS), and then solving for volatility, in effect by working backwards to solve the price equation.[6]
In Black-Scholes model, volatility is defined as the annual standard deviation of the stock price. Whereas the 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.

Figure 2: Source [7]

The figure below explains the fact that option prices in the marketplace tend to deviate from theoretical prices. This fact is captured in the reverse flow model in figure 1 above, which shows that the price output is now an input and the volatility input is now an output. The model is solved for volatility when market price is used as an input. For this reason, if market price is greater than it was the day before, the explanation for that difference is attributed to IV.

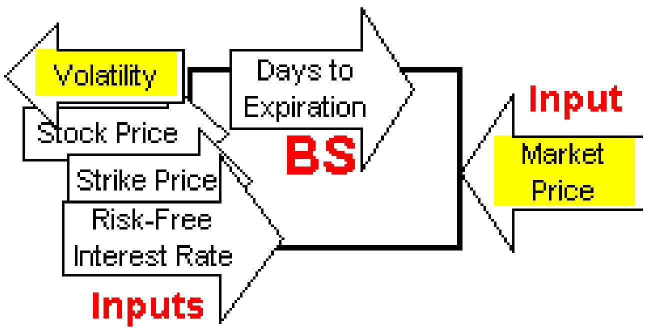

Figure 3: Black-Scholes options pricing model reversed

Empirically, if market price is above theoretical prices, then the difference is simply the premium placed on an option's market price by market participants.[8] They are expecting greater volatility than SV currently is signaling, and therefore the imputed volatility, or IV, is telling us what the best guess of the marketplace is for the future volatility of the underlying stock. Black-Scholes' formulas for this computation are given in the appendix.

[6] http://www.investopedia.com/university/optionvolatility/volatility3.asp
[7] http://www.optiontradingtips.com/options101/volatility.html
[8] http://www.investopedia.com/university/optionvolatility/volatility3.asp

Volatility Curves

Volatility curve is a plot of the strike price against the implied volatility of a group of options with the same expiration. The graphical shape could either take the form of a smile or skew as shown below.

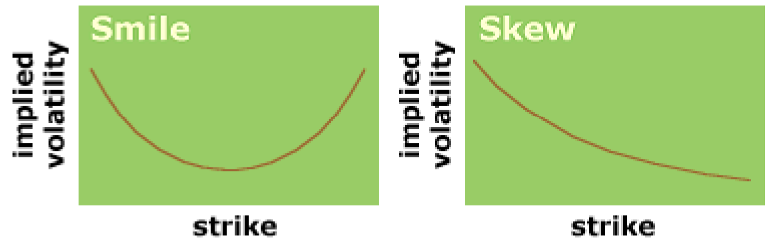

Figure 4: Volatility curve

Volatility skew or smile refers to the fact that implied volatility for strike prices below the current price of an underlying asset are higher than the implied volatility for strike prices above the current price of the underlying asset. [9]

For Call options, the Implied Volatility (IV) typically displays a Volatility Skew pattern, whereby *IV is the highest for deep ITM* options and then is decreasing as it moves towards OTM options. In contrast, for Put options, the IVs also display a Volatility Skew pattern, whereby *IV is the highest for deep OTM options* and then is decreasing as it moves towards ITM options.[10]

EMPIRICAL ANALYSIS

Data Selection

For the purpose of this paper, we downloaded the adjusted closing prices for both the OMXS30 index and Ericsson B. The data spans from the 3rd March 2008 to the 30th of July 2010. This data was used to compute the historical or statistical volatility. We also collected data for a call option and a put option with the same strike and expiration for both the stock and the index. This data was used to compute the implied volatility using Black-Scholes

[9] http://www.wikinvest.com/wiki/Volatility_Skew
[10] http://www.istockanalyst.com/article/viewarticle/articleid/1941708

formulas. The Treasury bill interest rate was used as the risk free interest rate. This data was downloaded from the Riksbank webpage.[11]

Results for Historical Versus Implied Volatility

This paper uses Ms Excel to compute the statistical or historical volatility. As mentioned above, this involves a 3 month floating volatility. It uses a moving 3-months window on the data and calculates the volatility inside the window. The first step involves the computing the logarithmic return or continuous compounded return =LN (C5/C4). The Excel function for variance is given as =VAR(D5:D64,E5)*100. The graph below shows the result of the 3–months floating historical volatility.

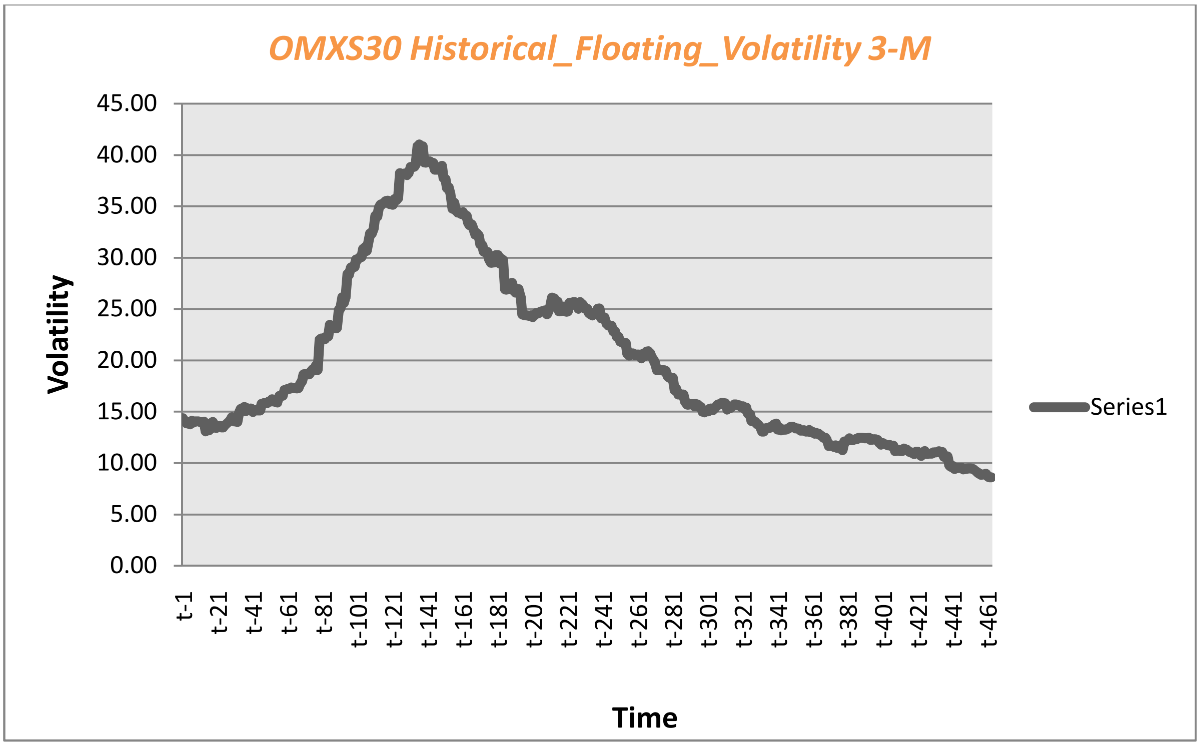

Figure 5: OMXS30 Historical Floating Vol.

From the graph above, we notice that the statistical volatility (SV) ranges from8.2462 to 41.0301. Whereas the call option of the index falls within this range, there are some differences between theses values and that of the implied volatility (IV) for the index put option. We noticed that the later ranges from 0% to 50% which is greater than the former (SV).

[11] http://www.riksbank.com/templates/stat.aspx?id=17187

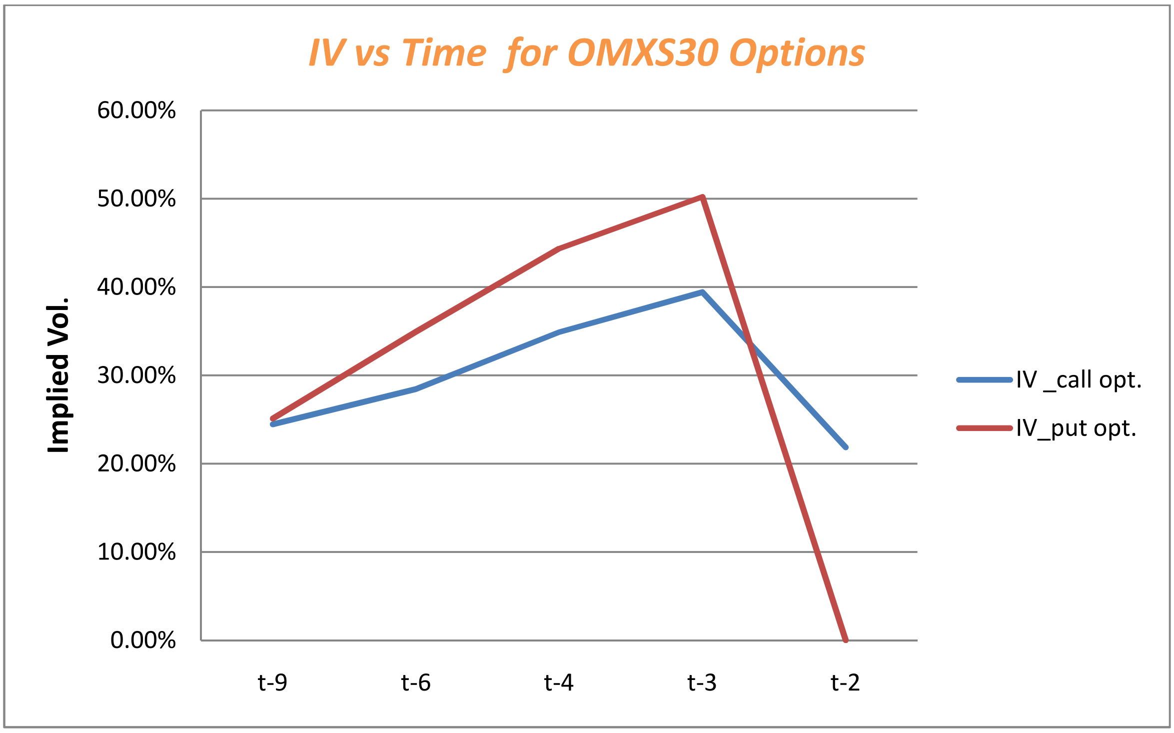

Figure 6 Implied Volatility with BS model.

A similar graph for Ericsson B. volatility is given below. Here the range is from 0.1144% to 2.0623% for the SV of the stock and from 0.22% to 0.66% for the IV of the call option.

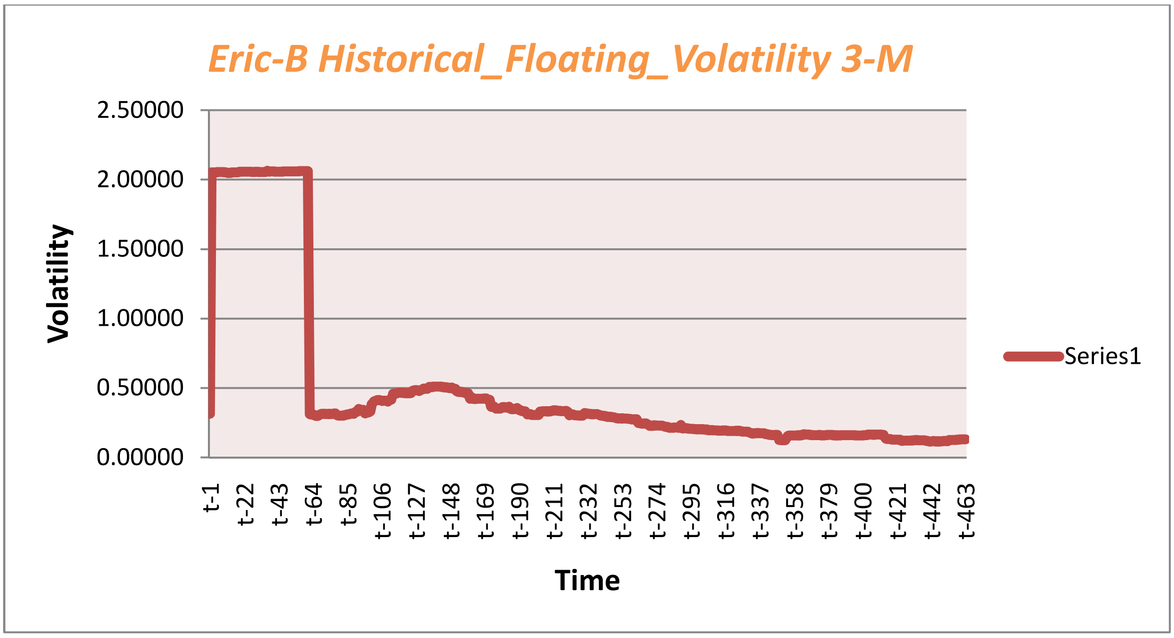

Figure 6 Eric-B Historical Floating Vol.

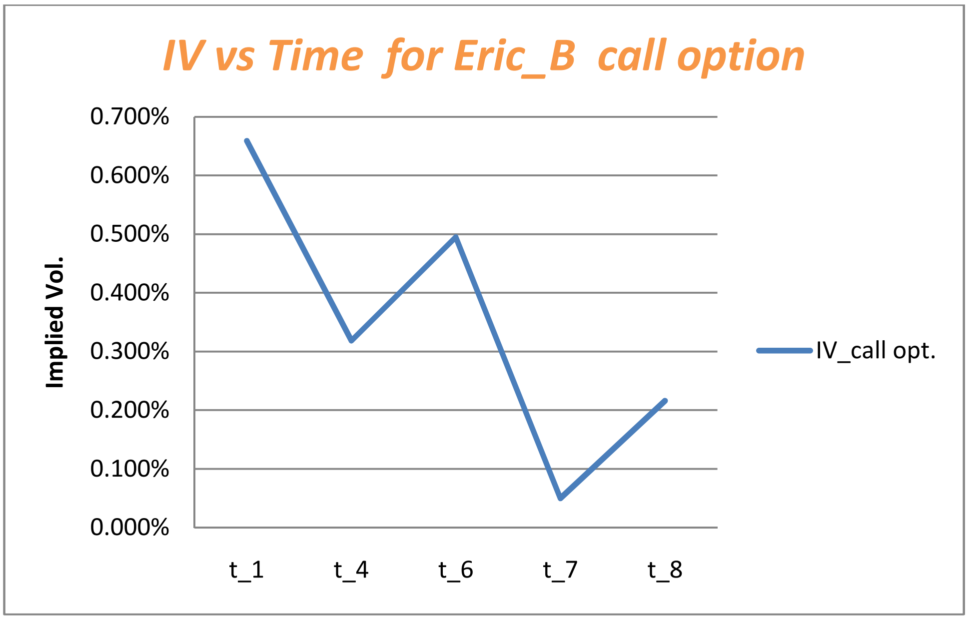

Figure 7: Implied Volatility with BS model for Eric_B call option.

Notice that the figure above ignores the implied volatility for the Eric_B put option because of some difficulties using excel solver. By and large, the statistical volatility for both the stock and index falls within the ranges of the call options of the stock and index respectively.

Results for volatility curve

We earlier on stated that with Call options, the Implied Volatility (IV) typically displays a Volatility Skew pattern, whereby *IV is the highest for deep ITM* options and then is decreasing as it moves towards OTM options. In contrast, for Put options, the IVs also display a Volatility Skew pattern, whereby *IV is the highest for deep OTM options* and then is decreasing as it moves towards ITM options.[12]

This hypothesis is supported by Figure 8 as shown below. However, figure 9 presents contrary result to this theory. It is possible that such result could be due unrealistic results obtained from Excel Solver as shown in the figure.

[12]http://www.istockanalyst.com/article/viewarticle/articleid/1941708

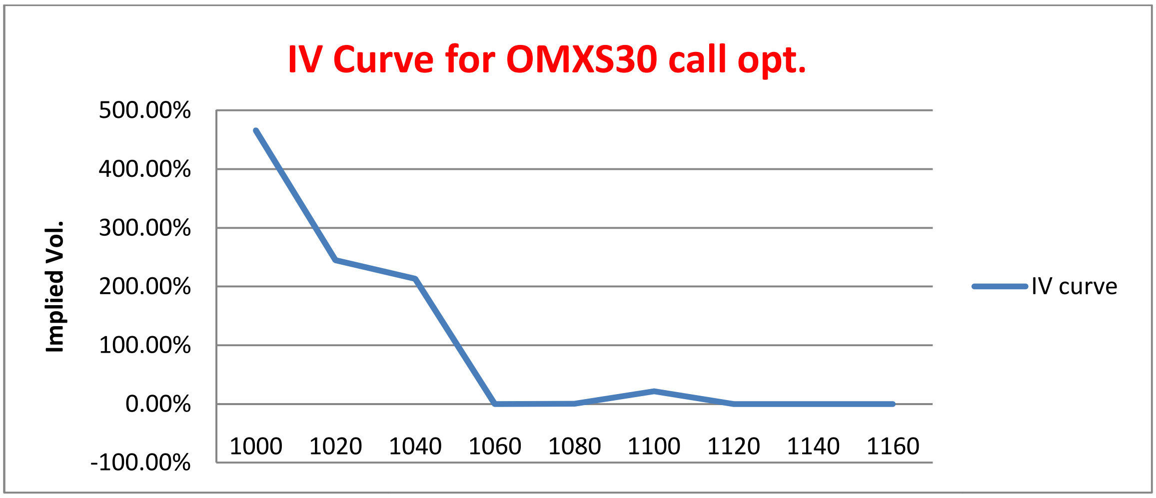

Figure 8: Vol. Curve for OMXS30 Call option.

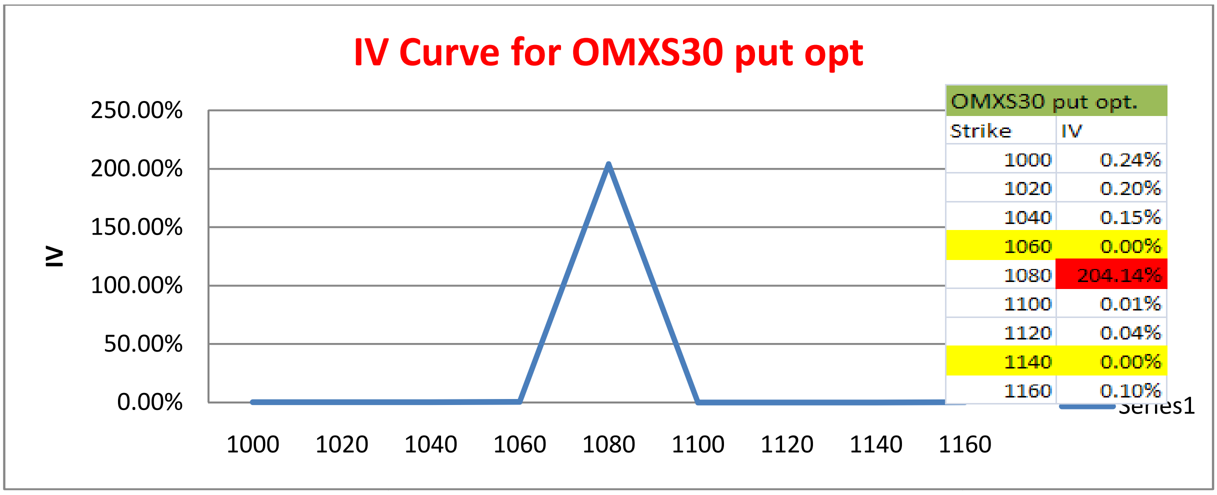

Figure 9: Vol. curve for OMXS30 Put option.

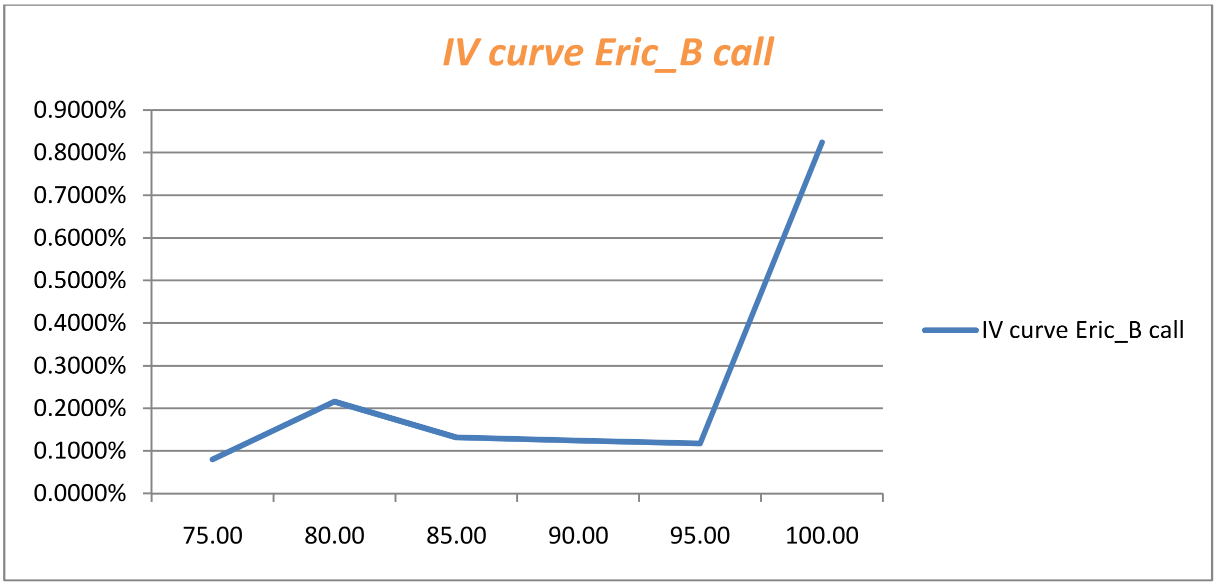

Figure 10: Vol. curve for Eric_B Call option.

Conclusion

From this empirical study, there exist differences between the market price and the theoretical prices. Given the linear relationship between the option price and its volatility, and mindful of the fact that the ranges of the IVs for both call options is greater than that of the SVs for both the stock and the index, then we expect the market price to be higher than that of the fair value. Such difference is accounted for as the premium placed on the option's market price by market participants. They are expecting greater volatility than SV currently is signaling, and therefore the imputed volatility, or IV, is telling us what the best guess of the marketplace is for the future volatility of the underlying stock.

References

http://www.nasdaqomxnordic.com/
http://janroman.dhis.org/index_eng2.html
http://www.optionseducation.org/advanced/volatility_greeks.jsp
http://janroman.dhis.org/finance/Volatility%20Models/stoch.%20vola.pdf
http://www.investopedia.com/university/optionvolatility/volatility3.asp
http://www.wikinvest.com/wiki/Volatility_Skew 2010-10-13
http://www.istockanalyst.com/article/viewarticle/articleid/1941708 2010-10-13
http://www.riksbank.com/templates/stat.aspx?id=17187

Appendix : Formulas

The **logarithmic return** or continuously compounded return, also known as force of interest, is defined as:

$$r_{\log} = \ln\left({p_t}/{p_{t-1}} \right)$$

Variance $$\sigma_i^2 = \sum_{j=1}^{M} \left[P_{ij} \left(R_{ij} - \overline{R_i} \right)^2 \right]$$

Standard deviation $$\sigma_i = \sqrt{\sigma_i^2}$$

The Put-Call parity is given as:

$$P = C - S + Xe^{-rt}$$

The Black-Scholes Formula for Put option is given as:

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

C = price of call option

S= price of the underlying

X= option exercise price

R= risk free interest rate

N ( ) = area under the normal distribution curve

The Black-Scholes Formula for call option is given as:

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

$$d_1 = \frac{\ln(s/x) + \left(r + {\sigma^2}/{2}\right)T}{\sigma\sqrt{T}}$$

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