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# 1 Introduction

In 1995, plain vanilla warrants, also called covered warrants, was introduced on the Swedish stock market (OMX) and at the Nordic derivative exchange (NDX). Since its introduction, the trade of warrants have steadily increased and in 2009 the sales of warrants totalled 40 million SEK per day at OMX (D'Agostino 2006; The Swedish financial market, 2010). The primary target for the Swedish plain vanilla warrants market, as in any other capital market, is allocation of ownership of the economy's capital stock. Hence prices here should provide accurate signals for resource allocation. In theory this is a market in which the prices of all instruments at any time fully reflect all available information. Thus investors can choose freely among all the instruments on the markets which correspond to ownership of firm activities such as production investments (Fama, 1965). However, recent reports suggest that differences in prices among comparable warrants exist on the market[1] (D'Agostino, 2006). This violates the conditions of prices fully reflecting all information and also rejects the hypothesis of information efficiency (Dimson & Mussavian, 1998). Further the intermediaries on the Swedish warrant market lacked in information to the investors regarding their prospects. For instance the importance of implied volatility (IV)[2], which represents the market makers belief about future movements of the underlying stock, and its effect on warrant prices was poorly described in the prospects of the intermediaries. As a consequence of these findings the Swedish Financial Inspection (FI) announced[3] in 2006 that they would sharpen regulation and the information given to investors of the Swedish plain vanilla warrant market. Factors like IV and it´s affect on the price and bid ask spreads should according to this be put forth much clearer in the prospects of the intermediaries.

Unlike the option market, the regulation of the Swedish plain vanilla warrant market states that only certified issuers called intermediaries are allowed to short calls and puts (Hull, 2006). For this reason, arbitrage opportunities from shorting overly expensive warrants are not possible on this market from the investor´s point of view. And the self adjusting price mechanisms found in the option market is eliminated. Due to the regulation of the warrant market, investors are reliant of accurate bid and ask prices from the market makers who works for the intermediaries (Koorts & Smit, 2002; D´Agostino, 2006). Since the risk free rate, underlying stock and time to maturity are assumed to be fixed, the only unfixed remaining parameter impacting the price of a warrant is the IV. Hence market making to quote accurate bid and ask prices is done by adjusting for this parameter (Yang, 2006).

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[1] Similar to the findings in this thesis, D'Agostino (2006) found differences in IV strategies among the intermediaries when comparing matching pair warrants. For graphical views of the results in this thesis see graph A1 to A11 in appendix.

[2] Up to 30% of the price differences between comparable warrants might be explained by differences in the IV´s (D'Agostino, 2006)

[3] For further information see the document "FI skärper informationskraven för warranter till småsparare"

Due to the increasing trade, the lack of previous academic research and the sharpened regulation of the actual information given to investors on the Swedish plain vanilla warrant market, the purpose of this paper are to investigate the information efficiency of Swedish plain vanilla warrants. Thus enabling to answer the research question; *Are Swedish plain vanilla warrants ideally for capital allocation?* Furthermore this paper will view the IV strategies among the examined warrants, and also the market power among the intermediaries.

The method used in this thesis will be similar to the information efficiency tests proposed by Chan et.al (2010), Majewska & Majewski (2005) and the comparison method used by Korts & Smit (2002). This thesis will test whether past returns adds further information to that already incorporated in the IV obtained from observable warrant market price (Chan et al., 2010). Compare the warrant market price with the theoretical warrant price calculated via the B&S model and compare the IV´s among matching pair warrants (Majewska & Majewski, 2005; Korts & Smit, 2002)

The included warrants in this thesis will be chosen in a similar way as in Claessen & Mittnik (2002). Only warrants 10% in the money (ITM) or out of the money (OTM), with more than 10 days to maturity are included. The time period is limited to 2010-07-09 to 2011-04-01. All information regarding the risk free rate, historical volatility, stock prices for the underlying asset and warrant prices are gathered from databases from Handelsbanken, Avanza and Svenska Riksbanken. The theoretical warrant price and the IV are all calculated via a MAKRO. Moreover statistical software has been used to generate the likelihood ratio (LR) test statistics.

Although warrants are a well researched area within finance, especially when it comes to evaluate different pricing methods, for instance see Veld (2000); Lauterbach & Schultz (1990) and Hauser & Lauterbach (1997), the majority of the literature tends to focus towards methods to price warrants. Only a few articles investigate the markets where warrants are traded (Majewska & Majewski, 2005). The findings from this thesis will contribute to the gap in academic research of the information efficiency of this financial derivative on the Swedish market. It will also show the implication of the sharpened regulation of the market; in terms of information efficiency (Chan et al., 2010).

The analysis showed that none of the performed test in this thesis accepted the null hypothesis of information efficiency. Furthermore this thesis confirms the findings of D'Agostino (2006) and Koorts & Smit (2002), where different strategies among market makers representing the intermediaries, in the IV among comparable warrants were found, see graph A1 to A11 in appendix. Together with regulation of this market, the findings of imperfect information in the prices given to investors and differential strategies among the intermediaries, this thesis conclude that this is an oligopoly market. The findings of non information efficiency are due to the actual market structure. Furthermore this suggests that the included warrants are none ideally for capital allocation.

The remaining parts of this thesis will be structured into six sections. After the introduction part, section two, named characteristics of warrants, will explain the characteristics of a warrant and the Swedish warrant market. The third section will provide previous findings in literature related to the subject and also how these might contribute to this thesis. Section four which is the theoretical framework, will provide relevant theories regarding, information efficiency, market structure, warrant pricing models, IV, and models developed for testing this hypothesis. The fifth section will provide the method, limitations and the data within this paper. In section six the empirical findings and the analysis from the data will be presented. The final section will provide a discussion based on section six and suggestions for further studies.

# 2 Characteristics of warrants

Plain vanilla call warrants, also called covered or derivative call warrants are closely related to regular call options of the European type, but with a longer time to maturity (often measured in years). As in the case of an option, a warrant is a contract who gives the owner the right, but not the obligation to issue the underlying asset at the end of the contract (Beckman et al., 2008). Although additional to the time horizon, warrants are different from options when it comes to the instrument type, contract type, the exchange in which they are traded and the rights to issue the instrument, all these can be seen in Table 1.

*Table 1: Comparison between options and warrants*

| Characteristics | Options | Warrants |
|---|---|---|
| Time to maturity | Months | Years |
| Issuers | Anyone | Only authorized issuers |
| Type of instrument | Pure financial derivative | Synthetic |
| Type of contract | Standardized | Not standardized |
| Trading exchange | Separated option exchange | Stock exchange, or over the counter |

Source: (Chan et al,. 2010)

Since a warrant combines the position of a stock, with the position of an option, warrants are a synthetic[4] type of instrument, unlike options which are regarded as pure financial derivative. Hence the issuers of warrants must securitize (cover) their positions via hedging procedures[5] (Chan et al., 2010; Koorts & Smit, 2002). Due to the synthetic classification of warrants, the only authorized issuers of warrants are companies of which the underlying asset refers to, or financial institutions with large shares of stocks (Hull, 2006). Warrants issued by companies, are widely referred to as equity or corporate warrants (Li & Zhang, 2009; Chan et al., 2010). Warrants are not standardized and rather than being traded at a separate exchange as in the case of options, warrants are traded at the stock exchange or over the counter (Chan et al., 2010).

Trade of warrants was introduced on the Swedish market in 1995 and has increased steadily ever since, although in recent years it increased more rapidly (D´Agostino, 2006). In 2009 the warrant sales totalled 40 million SEK per day on OMX, and together with certificate market the turnover was 25775 billion SEK in this year (Den Svenska warrant och certifikat marknaden, 2009; The Swedish fi-

[4] A synthetic financial instrument is an artificial instrument created to give a new net position, by combining two positions on the market (Greenleaf, 1989).

[5] I.e. the hedging for a covered call is when the writer of a call owns the corresponding underlying asset (Koorts & Smith, 2002).

nancial market, 2010). The major contributions of trade among warrants came from private investors (D´Agostino, 2006). In Sweden the authorized warrant issuers are often referred as intermediaries. In table 2 the intermediaries on the Swedish plain vanilla warrant market can be seen.

*Table 2: intermediaries on the Swedish warrant market*

| **Intermediary** | **Short name** |
|---|---|
| Citigroup Global Markets detschland Ag | CIT |
| Commerzebank Ag | CBK |
| Carnegie | CAR |
| Nordea Securities Bank Ab | NDS |
| E Öhman J:or Fondkommission AB | OHM |
| Svenska Handelsbanken | SHB |
| Swebank | SWE |
| The Royal Bank of Scotland | RBS |
| Société Générale | CSI |

Source: (Derivatinfo.com)

Along with the issuance of certificates, SHB had the largest market share (73,5%) follow by CBK (6%) and CAR (5,4%) of warrant issuance in Sweden 2009 (Den svenska warrant och certifikat marknaden, 2009). The included issuers in this thesis are CIT, CBK, CAR, NDS, OHM, SHB and SWE. Since the liquidity of the warrant market is none continuously, market makers who often represent the intermediary acts as counterparts when trading. By continuously quoting bid and ask prices the market makers keep the market perfectly liquid at all time. Hence unlike the option market, where investors trade with other investors, warrants are traded with market makers and the opportunities of shorting put and calls are eliminated. Combined with the restrictions of short selling in Sweden and the elimination of investor's opportunities of issue puts and calls, the self adjusting price mechanism found on the option market do not exist on the warrant market. Hence investor investors on this market are reliant of accurate bid and ask prices quoted by the market makers (D´Agostino, 2006).

# 3 Literary review

To show the differences and the similarities between option and warrant markets, this section will explain the methods and results from previous research in the area of information efficiency of both these markets.

## 3.1 Information efficiency on option markets

Mittnik & Rieken (2000) research the German Dax index option market. To enabling answering their research question of information efficiency of the German Dax index option market they apply the put-call parity (PCP) theory. Given that the Dax index option market is information efficient, options of the call type should be efficiently priced relative to identical puts. Hence the sum of both portfolios in the PCP test should equal zero, otherwise arbitrage opportunities exist on the market and thus violates the condition for an information efficient market. The results reject the hypothesis of market information efficiency on the Dax index option market. Although potential arbitrage opportunities do exists on the market using the PCP, the authors claims that due to restrictions of short selling in Germany, taking full advantage of these differences is not possible. Due to the short selling restrictions, the German Dax index option market is regarded as market information efficient according to (Mittnik & Rieken, 2000).

When researching the information efficiency of European Options in the S&P 500 market, Kamara & Miller (1995) applies the PCP. This study confirms that deviation from the PCP conditions exists in European Options quoted on S&P 500 market. Although the findings of arbitrage opportunities are consistent, the authors suggest that arbitrageur's faces transactions cost on the market. Only if these are not exciting, or very low, these differences in portfolio returns from the PCP might be used. Due to the transaction costs, Kamara & Miller (1995) confirms that European options quoted on S&P 500 market are information efficient.

Brunetti & Torricelli (2005) applies similar methods as Kamara & Miller (1995) and Mittnik & Rieken (2000). In their research they look at European-style index option contracts based on the Italian Index Mib30. By using the PCP condition, the authors conclude that without frictions such as transactions cost, deviations of the PCP are frequent and positive arbitrage strategies are possible in 57% of the sample.  Although when frictions are included, positive arbitrage opportunities are decreased to only 1.63%. These results are in line with the findings of Kamara & Miller (1995). European-style index option contracts based on the Italian Index Mib30 is information efficient, as frictions exist on the Italian market.

Researching the French option market (MONEP) by using intraday data of the French stock index CAC 40 index options is Capelle-Blancard & Chaudhury (2001). In this article, the findings are in line with previous studies such as Brunetti & Torricelli (2005) and Kamara & Miller (1995). Similar to Brunetti & Torricelli (2005) the authors applies the PCP condition and integrate frictions such as bid-ask spread, exchange fees, brokerage commissions and short sale constraint in their testing. The results show that without these frictions the PCP condition is violated and arbitrage opportunities exist, thus rejecting the market information efficiency. However, when applying these frictions, arbitrage opportunities decrease and are approximately vanished for retail traders. Hence, as these frictions do exist on MONEP, the authors conclude that this market is information efficient.

In further studies regarding information efficiency of the German Dax index option market, Claessen & Mittnik (2002) uses an alternative way of testing the efficiency. Rather than using the PCP the authors applies a method in which they compare the IV derived from observed option prices via the B&S model, with volatility forecasting models that uses past returns to modelling for the volatility. The authors apply different types of ARCH/GARCH models to forecast for the volatility. The results shows that these models does not yield a better result, or any further information to that already captured by the IV derived from German Dax index option prices. Furthermore the finding rejects the hypothesis of IV being an unbiased estimator of future volatility. But even though the IV is not unbiased, it still remains a highly informative predictor of future volatility. Hence the authors conclude that the German Dax index option market is information efficient.

Lamoureux and Lastrapes (1993) use similar methods as Claessen & Mittnik (2002) to research the hypothesis of informational efficiency of the Chicago Board Option Exchange (CBOE). The authors apply a GARCH (1.1) IV model, with the exogenous variable of IV derived from obtained option price on the market via a stochastic volatility pricing model. By comparing the statistical significance of the included parameters, namely the ARCH, GARCH and IV the authors rejects the hypothesis of historical returns adding no further information to that already incorporated in the IV. Hence the GARCH (1.1) IV model generates a better volatility forecast than the IV in the sample. However, when comparing the results from IV´s solely with the GARCH model, the IV remains a better predictor for future volatility. The result from Lamoureux and Lastrapes (1993) suggest that the CBOE is a non information efficient market.

Day & Lewis (1992) confirms the findings of Lamoureux and Lastrapes (1993). By conducting the GARCH (1.1) IV model, the authors analyze the information included in the IV derived from observed option prices on S&P 100 Index via the dividend adjusted B&S model. In their findings, the authors conclude that neither the forecasted volatility from the IV, nor the forecasted volatility from GARCH/ARCH models captures the realized (actual) volatility of the underlying stocks. Although, the result suggest that both the ARCH and the GARCH term adds further information to that incorporated in the IV. Hence the authors conclude the non information efficiency of the S&P 100 Index

Contrary to the findings of Lamoureux and Lastrapes (1993), Xu and Taylor (1995) supports the hypothesis of historical returns adding no further information to that already incorporated in the IV when researching the informational efficiency of the Philadelphia stock Exchange (PHLX). As in the case of Lamoureux and Lastrapes (1993) the authors adapt the GARCH (1.1) IV model. Although opposite to their research, Xu and Taylor (1995) only look at near ITM options. By implement constraints on the GARCH (1.1) IV model such that the ARCH and the GARCH term equals zero. Xu and Taylor (1995) performs a LR test for the constraint and the unconstraint version of the GARCH (1.1) IV model. The results show that the IV from observed put/call option prices outperforms volatility forecasted from models of the ARCH/GARCH type. Furthermore the volatility forecasted from the GARCH (1.1) IV model adds no further information to that already captured by the IV. Hence the authors conclude that options quoted on PHLX are information efficient.

## 3.2 Information efficiency of warrant markets

Though warrants differ from options in some sense, similar methods can be applied when viewing the efficiencies of the warrant market. For instance Chan et al. (2010) applies a GARCH (1.1) IV model, similar to that of Claessen & Mittnik (2002), to research the information efficiency of the UK covered warrant market. In their study they perform a bootstrap procedure built upon the GARCH (1.1) IV model to test their hypothesis of market informational efficiency. Further they also conduct a Stochastic Dominance Test, where they test whether holding a portfolio of warrants yields more utility than holding a portfolio of the corresponding underlying assets of the warrants. The applied Stochastic Dominance Test suggests that both of the portfolios yield the same amount of utility. Additional, the information efficiency test where the GARCH (1.1) IV model is used, shows that 75% of the examined warrants efficiently reflects the information regarding past returns of the underlying stock price. Thus confirming the first test and further strengthen the findings of informational efficiency at the UK warrant market.

Majewska & Majewski (2005) research the informational efficiency of covered warrants quoted on Warsaw stock exchange. In their study they apply two different tests to research the information efficiency. The first test is a comparison between the B&S theoretical warrant price and the actual market price. Second, they examine the relationship between implied and historical volatility. Here the historical volatility is estimated by using six different methods. The first one is the classical standard deviation method. Second, are four different exponential weight moving average (EWMA) models with the smoothing parameters of 0.5, 0.7, 0.9 and 0.95. The last historical volatility estimation method is the ARCH (q) model. Contrary to the finding of Chan et.al (2010) the results from Majewska & Majewski (2005) rejects the information efficiency hypothesis. Only two warrants out of thirty-eight indicated a weak form of efficiency in the Warsaw stock exchange.

Confirming the findings of non information efficiency of the warrant market is (Koorts and Smit, 2002). This study investigates different strategies in the IV´s calculated via the B&S model among intermediaries quoting warrants on the Johannesburg stock exchange (JSE). By using the closing price of warrants to compute the IV from the B&S model and compare this among matching pair warrants from different issuers. The author’s found that the IV differ as much as 10% from different intermediaries during the chosen time period. From the findings in their research Koorts and Smit (2002) concludes that 3 different strategies among IV´s of the intermediaries on JSE exist, low, medium and premium where premium uses the highest IV. The authors suggest that as in any other retail market, the competition for customers among the intermediary’s results in these differences in IV strategies. Some intermediaries keep a low IV strategy which results in a low price, to attract investors. Other uses a differentiation strategy with a high IV, which results in a high price. This strategy often uses a more aggressive marketing than the low IV strategy. Or sometimes rather than aggressively marketing, this strategy offers special attributes, such as a consistency in the warrants IV throughout the time horizon of the warrant. This is not offered by intermediaries using a low IV, here the IV tends to fluctuate more. Hence from an investor's point of view, knowledge about these strategies will affect the return on an investment. Due to these differences among warrant issuing strategies on the JSE, Koorts and Smit (2002) provides sufficient evidence that the warrant market in South Africa is non information efficient.

## 3.3 Article summary and contributions to the thesis subject

Previous articles tackling the subject of information efficiency on warrant markets, shows that the results are mixed. For instance, the findings from Chan et al. (2010) accepts the hypothesis of warrants being informational efficient, Koorts & Smit (2002) and Majewska & Majewski (2005) rejects this. Although the results among these differ, they all apply the B&S model to research the information efficiency. In line with these articles this thesis will apply the B&S model. Furthermore Chan et al. (2010) and Majewska & Majewski (2005) utilize the null hypothesise of information efficiency. Due to the utter importance of information efficiency and previous research in this area, it´s assumed that the Swedish plain vanilla warrants included in this thesis are ideally for capital allocation. Information efficiency is crucial for factors such as hedging, speculation functions and price discovery (Chan et al. 2010; Capelle-Blancard & Chaudhury, 2001; Brunetti & Torricelli, 2005)

This thesis investigates whether the included Swedish plain vanilla warrants are information efficient and ideally for capital allocation. For this matter, contributing tests from all three articles researching the area of information efficiency of warrant markets are included in this thesis. The method proposed by Majewska & Majewski (2005), of comparing the theoretical B&S price with the actual market price is included to research the information efficiency. As this thesis only focuses on near at the money (ATM) or ATM warrants; price calculated via the B&S model should match with the market price in an information efficient market (Veld, 2000; Green & Figlewski, 1999; Leonard & Solt, 1990; Majewska & Majewski, 2005). Further, evaluating different volatility forecasting methods similar to Claessen & Mittnik (2002) and Chan et al. (2010) is also a method which is included to research the information efficiency of the included warrants. To follow up on the results in first test, this thesis will apply the GARCH (1.1) IV model to test whether the IV derived through the B&S model contains all information regarding past returns. Not only does this test the information efficiency, but also whether this is a perfect competitive market. In information efficient and perfect competitive markets the information given to actors is assumed to be perfect. Hence the findings from this test will explain the findings in the first test and relate it to the market structure (Perloff & Carlton, 2005; Claessen & Mittnik, 2002). Volatility forecasted from models using past returns such as the GARCH (1.1) IV model, should not add any information at all to that included in the IV backed out from the B&S model when focusing on ATM or near ATM warrants (Claessen & Mittnik, 2002). To further investigate the market structure[6] and follow up on previous tests, the competition among different intermediaries will be shown (Koorts & Smit, 2002). The IV strategies among comparable warrants are presented to enable to answering whether the included warrants are information efficient. This test also shows the market power among the intermediaries and the market structure. In a perfect competitive and information efficient market there should be no deviations in price strategies when comparing matching pair warrants and market power is not existing (Koorts & Smit, 2002; Perloff & Carlton, 2005).

[6] There are four ways of market structure. Either the market is perfectly competitive, oligopoly, monopoly or monopolistic competitive (Perloff, 2008).

# 4 Theoretical Framework

## 4.1 Market information efficiency and Market structure

In 1900 the French mathematician Bachelier introduced the concept of market information efficiency. He suggested that the market price reflects events, both in the past, future and present. Hence, arbitrage opportunities in an information efficient market does not exist (Dimson & Mussavian, 1998). The importance of information efficiency in capital markets, such as the Swedish plain vanilla warrant market is crucial, as factors like capital allocation, price discovery and risk management rely on this. In fact none information efficient operating market might even affect the growth rate of the market (Capelle-Blancard & Chaudhury, 2001; Brunetti & Torricelli, 2005).

Closely related to the efficiency of a market, is the market structure (Case & Fair, 2007). There are four types of market structures, perfect competiveness, oligopoly, monopolistic competition and monopoly (Perloff, 2008). In a perfect competitive market, buyers and seller are assumed to be price takers. Hence, nor the customers, or the sellers can influence on the prices. This is solely determined by the market. Furthermore in a perfect competitive market all relevant information regarding the price, quality and the market are assumed to be possessed by sellers and buyers. Hence in this market, the information reflected in the price is assumed to be perfect, and contain all information. There are no barriers to enter this market and no one in the market can be better off without making someone else worse off. The products sold by the different companies in this market are all identical (homogenous) and customers are indifferent between these (Perloff & Carlton, 2005).

Opposite to perfect competition is a monopoly. In a monopoly the monopoly firm sets its own price rather than being a price taker. To prevent other firms from entering the market, significant barriers are created by the monopoly firm (Case & Fair, 2007). In between these pure types of market structures (monopoly and perfect competition) is monopolistic competition and oligopoly.

A special form of oligopoly is monopolistic competition (Varian, 2006). This is a market where a large numbers of firms produce and offers differentiated products. Furthermore there are no barriers to enter this market. Similar to a perfect competitive market, firms in this market are not able to influence on the market price.

An oligopoly is market structure that exists in many forms. In this type of market there are a few dominating firms with a large market share, acting in a market. Related to their individual company size, they are all more or less able to influence on market price. In some oligopoly the market consist of few actors, which all are able to influence on the market price. Other oligopolies are markets with many actors, but with only few firms that are able to influence on the market price. As in the case of a monopolistic competition, the products offer by the firms are differentiated, although they could be homogenous as well (Case & Fair, 2007).

Monopoly, monopolistic competition and oligopoly are major factors for a non efficient market and market power is exercised in these types of markets (Varian, 2006). In monopolistic competition and oligopolies, firms differentiate their products to gain market power. Different price strategies, special attributes and marketing are common ways to differentiate products on this type of markets. Hence the information contained in prices in this type of market doesn´t always contains all relevant information, since the firms keep different prices levels to attract customers (Case & Fair, 2007).

Due to the importance of information efficiency on capital markets, previous findings in this area and the increase in regulation of the Swedish warrant market. This thesis takes the starting point of Swedish plain vanilla warrants being an ideally market for capital allocation. Thus leading to the hypothesis of:

$H_o$ : Swedish plain vanilla warrants in this thesis are information efficient

$H_1$ : Swedish plain vanilla warrants in this thesis are non information efficient

## 4.2 Warrant pricing models and IV

This thesis will take a similar approach as Chan et al. (2010), Majewska & Majewski (2005) and (Koorts & Smit (2002) and use the B&S as the true model of the included warrants. The B&S model includes the assumption of no arbitrage opportunities, which is assumed in an information efficiency market. In this type of market all information is assumed to be captured in the price. This model has also been used in all previous articles researching this area. In line with previous articles and due to the assumptions within this model, applying it is suitable for this thesis (Majewska & Majewski, 2005). The assumptions in the B&S model are as follow (Black & Scholes, 1973):

1. Constant risk free interest over time. The underlying stock prices continuously follow geometric Brownian motion and the variance rate is assumed to be proportional to the square of the stock price and constant through time. The stock prices are distributed log normal at the end of any finite interval
2. The underlying stock pays no dividend
3. The option is of the European type
4. When buying/selling the stock or option no transaction are involved
5. Borrowing and lending is allowed at the risk free rate
6. No fees involved when short selling
7. No arbitrage opportunities

In line with Claesen & Mittnik (2002) and Chan et al. (2010) this thesis will assume that the actions of all investors on this market are captured within the assumptions of this model. Hence in line with the information efficient hypothesis, it´s assumed that all included issuers in this thesis quote prices which reflects events both in the past, future and present (Claesen & Mittnik, 2002; Majewska & Majewski, 2005).

The assumptions of constant volatility and risk free rate, tends to be continuously violated when applying the B&S models onto warrants. Hence many alternative models have been worked out to compensate for these. Although, the original B&S model is still most widely used model and as a matter a fact its accuracy in predicting ATM or near ATM warrant prices are approximately as good as any other models (Veld, 2000; Green & Figlewski, 1999; Leonard & Solt, 1990; Misra et al., 2006). The B&S model for pricing options and warrants is constructed in the following way (Black & Scholes, 1973):

$$C_0 = S_0 N(d_1) - Xe^{-rT} N(d_2) \quad (1)$$

$$d_1 = \frac{\ln\left(\frac{S_0}{X}\right) + (r + \sigma^2/2)T}{\sigma\sqrt{T}} \quad (2)$$

$$d_2 = d_1 - \sigma\sqrt{T} \quad (3)$$

Where $S_o$ in equation (1) and (2) is the price of the underlying asset at time zero and $c_0$ in equation (1) is the value of the warrant at time zero. In equation (1) $N(d)$ is the probability that a standard normal distributed variable will be less than $d$ and the strike price is denoted as X. Further in equation (1) the base for the natural logarithm is denoted as $e$, $r$ is the risk free rate. The time value is denoted with T in equation (1), (2), (3) and the historical volatility is $\sigma$ in equation (2) and (3) (Hull 2006).

Given that the strike price, risk free rate, market price of the warrant and the price of the underlying stock is already known, one might solve for the volatility in the B&S model. This volatility is referred as the IV. According to Merton (1973) and Hull & White (1987) the IV obtained from an observed warrant market prices is an ex ante forecast of the future average volatility of the underlying asset during the time horizon of the warrant. The power of the IV to predict future movements of the underlying asset is a measure of the information content incorporated in the warrant price (Day & Lewis, 1992). When assuming the warrant market is information efficient and the model used to back out the IV captures the behaviour of all investors in this market. The IV, which represents the market makers beliefs of future volatility, should contain all information regarding events in the past (Claessen & Mittnik, 2002). In the B&S model the IV is assumed to be constant across assorted strike prices and maturities. Although sufficient evidence shows that IV´s varies across different strike prices and maturities. Where the relation between strike price and IV known as the volatility smile and can be seen in figure 1 (Misra, Kannan & Misra, 2006).

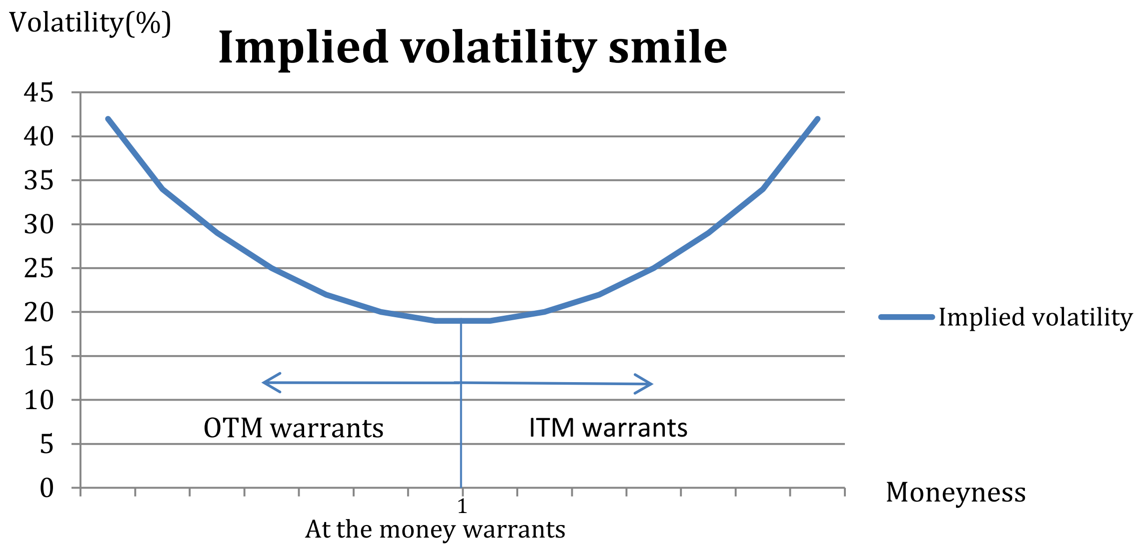


*Figure 1: Implied volatility smile*

Here the moneyness which is the market price divided by the strike price of a warrant, and the IV can be seen. As shown by this picture the further ITM (the strike price is below the market price) or OTM (strike price is above the market price) a warrant is, the higher the IV volatility is. Due to this, limiting the research to only near ATM or ATM warrants is essential when using the B&S model to back out the IV and comparing the theoretical B&S price with the market price. Only the IV derived via the B&S model for an ATM warrant will yield an unbiased estimator of the average volatility of the underlying asset during the remaining time horizon of the warrant (Claessen & Mittnik, 2002).

Even though the B&S model yields a good result for ATM or Near ATM warrants, adjusting the B&S models to make it more suitable for warrants is common among academic research (Majewska & Majewski, 2005). To view the weaknesses of the B&S formula and also the models that could be used to compensate for these. This section will provide a description of the major models developed for this matter. For instance assumptions such as such as constant variance and risk free rate provides major problems when applying it to price warrants. Since warrants have a much longer time to maturity then options, often measured in years, the volatility and the risk free rate are likely to fluctuate during the life time of a warrant (Lauterbach & Schultz, 1990).

The first major alternative model is the Black & Scholes Merton European Call Option Model. To compensate for the assumption of constant risk free rate in the origin B&S model, this model uses the yield to maturity of a random chosen risk free bond with the same exercise date as the warrant at risk free rate. Further to include stochastic interest rates, the Merton model uses the variance of a portfolio containing the risk free bond described above and the stock which is used as the underlying asset of the warrant (Lauterbach, 1990).

The second major model is the Dilution adjusted B&S Merton model which is commonly used when pricing equity warrants. This model takes in to consideration the dilution effect that occurs when warrants are exercised. The exercise of a warrant leads to more shares issued by the company of which the underlying stock refers to. If the exercise price written in the contract is lower than the market price the warrant will be used and the company of which this share refers to must issue additional shares. Hence the pool of shares increases and this dilutes the interest to the existing shareholders (Hull, 2006). To compensate for this, the following adjustments of the B&S are used:

1. Adjustment for stock price S: $S + \frac{M}{N} * W$
2. Adjustment for $\sigma$ : consider $\sigma$ as the volatility of $S + \frac{M}{N} * W$
3. Multiply the result with $\frac{N}{N+M}$

Where N=numbers of outstanding shares, W=warrant price and M=numbers of outstanding warrants (Lauterbach, 1990).

The third type is models allowing for the volatility to be inversely related to the stock price. For instance the constant elasticity of variance (CEV) model where adjustments of the origin B&S model allows for the volatility to be an inverse relation toward the stock price, thus considering the volatility to be stochastic rather than constant (Beckers, 1980; Hsu & Lu, 2005).

## 4.3 Models for testing information efficiency and market structure on warrant markets

Since the warrant market has certain regulations of shorting puts and calls, using the PCP model which is often applied when researching information efficiency on the option market is not applicably (Koorts & Smit, 2002). Hence to test for the information efficiency alternative methods must be adapted. This thesis will first use a similar method as (Majewska & Majewski, 2005). Here the theoretical options/warrant prices generated from a model is compared with the actual market price (Mittnik & Rieken, 2000; Majewska & Majewski, 2005). As the B&S model has been used in all previous articles researching this area and contains the assumption of no arbitrage, which is definition of information efficient markets, applying this model is suitable (Majewska & Majewski, 2005). By limiting the research such that only warrants near ITM or ATM are included, the B&S model should generate the same theoretical prices as the actual market price in an information efficient market (Veld, 2000; Green & Figlewski, 1999; Leonard & Solt, 1990; Majewska & Majewski, 2005).

To follow up on the results from the first test, a second test similar to the ones adapted by Claessen & Mittnik (2002) and Chan et al. (2010) is used. In both articles the authors applies volatility forecasting methods to research the information efficiency. Accordingly to Claessen & Mittnik (2002) there are two ways of generating volatility forecast. The first ways is to use volatility forecasting models which uses past returns such as the ARCH/GARCH model (Claessen & Mittnik, 2002).

Considering two days $t_0$ and $t_1$, the basic idea behind the ARCH model developed by Engle (1982) is that if volatility is high in $t_0$, then the volatility of the following day $t_1$is likely to have a high volatility as well (McDonald, 2006). Further the ARCH/GARCH models assume that the variance of the error term $\epsilon_t$ is assumed to be heteroskedastic.

Assuming an Stationary Autoregressive Moving Average (ARMA) model of $Y_t$ as mean equation[7] in equation (5).

$$Y_t = \alpha_0 + \alpha_1 y_{t-1} + \epsilon_t \tag{5}$$

Here the return of a stock at time t ($Y_t$) is forecasted by a constant ($\alpha_0$), the return of the same stock from the previous day ($\alpha_1 y_{t-1}$) and the residual ($\epsilon_t$) (Enders, 1995). In equation (6) is the variance equation for the residuals ($\epsilon_t$).

$$\epsilon_t = v_t \sqrt{h_t} \tag{6}$$

Where $v_t$ is a white noise process such that $\sigma^2{}_v = 1$. In equation (7) we see the equation for $h_t$ which is the ARCH (q) model (Enders, 1995).

$$h_t = \omega + \alpha \epsilon^2{}_{t-1} \tag{7}$$

Here the volatility is forecasted by using the squared residuals from the previous observation ($\alpha \epsilon^2{}_{t-1}$) which is the ARCH term and a constant ($\omega$). In equation (8) is the GARCH (m,n) model developed by (Bollerslev, 1986).

$$h_t = \alpha_0 + \sum_{i=1}^{m} \alpha_i \epsilon^2{}_{t-i} + \sum_{j=1}^{n} \beta_i h_{t-i} \tag{8}$$

Where the volatility ($h_t$) is forecasted by both an ARCH term (the squared residuals from the previous observation) and a GARCH term. The GARCH term is the forecasted volatility from previous observation ($\beta_i h_{t-1}$) (McDonald, 2006).

The second way to generate volatility forecast, is to back out the IV from observed options or warrant prices via a theoretical Option/ warrant pricing model. If this model captures the behaviour of all inventors on the market, the IV derived from this model should be the best biased predictor of future volatility. Hence it should contain all information regarding events in the past. Thus volatility forecasts based on past returns such as the ARCH/GARCH models should not outperform, or add any further information to that already captured by the IV in an information efficient market (Claessen & Mittnik, 2002). Furthermore this test also gives an implication of the actual market structure (imperfect or perfect competitive). Since in a perfect competitive market, the information given to consumers regarding the price is assumed to be perfect and contain all relevant information there is. Hence if the volatility forecasted from models using past returns adds any further information to the IV, this suggest that information given to customers in this market is not perfect. Further this also shows that the market structure is not perfect, since

[7] The mean equation does not necessarily need to be a stationary model (ARMA models), it could also be and unstationary model (random walk models)

in a perfect competitive market the information given to customers is assumed to be perfect (Perloff & Carlton, 2005).

Following up on the first and the second test, is a third way of testing for market information efficiency of the included warrants. This thesis will apply a test where IV strategies among warrants pairs are compared (Koorts & Smit, 2002). In information efficient markets, prices should contain all information regarding events both in the past future and present. Furthermore arbitrage opportunities should not exist. The IV, which is the only unfixed parameter that can be adjusted by market makers in the warrant market to quote accurate bid and ask prices, should contain all information regarding events, both in the past, future and present if the market is information efficient (Fama, 1965; Yang, 2006). When comparing the IV among warrant pairs, differences among intermediary's strategies in IV should not exist in an information efficient market (Koorts & Smit, 2002). Secondly this test will also show the actual market structure and follow up on the implications from the first and the second test. In this test the pricing strategies will be viewed among the intermediaries. In a perfectly competitive market these strategies should not differ when comparing homogenous products (Perloff & Carlton, 2005). Hence differentiated IV strategies among comparable warrants should not exist in a perfect competitive market. The results from this test will show whether this is a monopoly, monopolistic competition, oligopoly or perfect competitive market. Further it will also show the market power among the intermediaries.

# 5 Method

The first method used (Test 1) to examine the information efficiency will be a comparison between the actual market price and the calculated B&S price. In this approach the B&S model will be used as the true model of the Swedish plain vanilla market (Majewska & Majewski, 2005). Using the regression model in equation (9), where the B&S price is as an explanatory variable of market prices. When assuming the null hypothesis of information efficiency and that the B&S model captures the behaviour of all investors on this market, the regression model should have a $\alpha = 0, \beta_1 = 1$ (Mittnik & Rieken, 2000). By performing a hypothesis test where H0: $\alpha = 0, \beta_1 = 1$ and H1: $\alpha \neq 0, \beta_1 \neq 1$ the null hypothesis will either be accepted or rejected.

$$y = \alpha + \beta_1 x_1 + \varepsilon \quad (9)$$

Where

$x_1 = BS\ price$ and $y = Market\ price * parity$

Following up on the findings in the first test, is a second test (Test 2). Not only will the results from this test show the information efficiency of the included warrants, it will also show the information contained in the prices given to customer in this market. This test will show whether volatility forecasted from a model using past return adds any further information to that captured by the IV backed out from the B&S model. Due to the limitation of ATM or near ATM warrants in this thesis, volatility forecasted from a model using past return should not add any information at all to the IV backed out from the B&S model (Claessen & Mittnik, 2002). Further in a perfect competitive market, the information given to customers is assumed to be perfect (Perloff & Carlton, 2005). Hence the findings from this test will also show the type of market structure (perfect competitive or imperfect competitive). If the GARCH (1.1) IV models adds any information to the IV, this suggest that this is an imperfect competitive market where the information given to customer is not perfect. Since the market structure is a major contributing factor of the efficiency/non efficiency of a market, the findings from this test will explain the findings in the first test (Case & Fair, 2007).

In this test (Test 2) the IV from the B&S formula will be tested against the forecasted volatility from a GARCH (1,1) IV model. This model not only uses the GARCH model as a variance equation, but also includes an exogenous variable consisting of IV (Day & Lewis, 1992). The GARCH (1,1) IV model consist of the following parameters (Chan et al., 2010) :

$$R_t = \alpha_0 + \alpha_1 R_{t-1} + \varepsilon_t \quad (10)$$

$$\varepsilon_t \sim GED(0, {\sigma_t}^2) \quad (11)$$

$${\sigma_t}^2 = \omega + \gamma {\varepsilon_{t-1}}^2 + \delta {\sigma_{t-1}}^2 + \varepsilon {IV_{t-1}}^2 \quad (12)$$

Where $R_t$ = Return at time t for a given share, $GED$= Generalized error distribution see equation (13), $(\omega, \gamma, \delta, \epsilon)$ =constants in equation (12) and ${\sigma_t}^2$is the variance.

In equation (12) the only difference from a standard GARCH (1,1) model such as described in Engle (2001) is the extension $\epsilon {IV_{t-1}}^2$ which is the included exogenous variable of IV from the B&S model (Claessen & Mittnik, 2002). To allow for fat tailed distributions of the underlying stocks this model uses a (GED) distribution rather than a Gaussian distribution. The GED distribution can be seen in equation (13) and has a positive tail parameter of $\nu$. If $\nu = 2$ the GED follows a Gaussian distribution and if it´s bigger than two the tail is fatter (Taylor, 1994).

$$f(z) = \frac{\nu \exp\left(-\frac{1}{2}|\epsilon_t/\lambda|^{\nu}\right)}{\lambda 2^{1+1/\nu}\,\Gamma(1/\nu)},\ \nu > 0 \tag{13}$$

With

$$\lambda = \left(\frac{2^{-\frac{2}{\nu}}\Gamma(1/\nu)}{\Gamma(3/\nu)}\right)^{1/2}, \tag{14}$$

In equation (12) the null hypothesis of information efficiency and the information contained in the prices of the examined warrants will be tested. According to Claessen & Mittnik (2002) volatility forecast methods based on past returns such as the GARCH (1.1) IV model should not generate a better result, or add any further information to the forecast based on IV solely in an information efficient market. Simply by testing for the constraints of $\gamma = 0, \delta = 0$ in equation (12) the information efficiency will be tested.

Since:

$${\sigma_t}^2(\gamma, \delta = 0\,) = \ \omega + \gamma {\varepsilon_{t-1}}^2 + \delta {\sigma_{t-1}}^2\ + \varepsilon {IV_{t-1}}^2 \tag{15}$$

$$\Rightarrow {\sigma_t}^2 = \ \omega + \varepsilon {IV_{t-1}}^2 \tag{16}$$

Hence the only thing determines the volatility today (day t) in equation (16) is the estimated implied volatility from the B&S model from yesterday (t-1) and a constant.

By performing a LR test as proposed by Xu & Taylor (1995), where LR = $2(L_1 - L_o)$, the information efficiency and the information contained in the warrant prices are shown. Here $L_1$= maximum log likelihood for the null hypothesis (H0) namely the constraint equation in (16) and $L_o$= the maximum log likelihood for our alternative hypothesise (H1) the unconstraint equation in (12). Given that the null hypothesis (H0) in equation (16) of $\gamma, \delta = 0$ is not rejected, the LR test between $L_1$ and $L_0$ should have a chi-square distribution. If there is a chi-square distribution between $L_1$ and $L_0$ the warrant is information efficient and the volatility forecasted from the GARCH (1.1) IV model adds no further information to the IV (Xu & Taylor, 1995).

The third test applied (Test 3) in this thesis will view the IV (which is the only unfixed parameter affecting the price of warrants) strategies among the different intermediaries of the examined warrant pairs. Following up on test 1 and test 2 this test will also show the information efficiency of the included warrants. Further it will show the market structure (monopoly, monopolistic competition, oligopoly or perfect competitive) and market power among the included intermediaries. When comparing homogenous products such as warrant pairs, no differences in IV strategies should consist in perfect competitive market (Perloff & Carlton, 2005). According to Fama (1965) all information is assumed to be incorporated into the price in an information efficient market. Hence differences in the IV strategies among intermediaries when comparing matching pair warrants should not exist in an information efficient market either (Koorts & Smit, 2002). Based on this the null hypothesis (H0), which indicates information efficiency is stated as follow: no differences in mean IV among intermediaries in matching pairs warrants exist. The alternative hypothesis (H1), which indicates a non information efficient market, is stated as follow: differences in mean IV among intermediaries in matching pairs warrants do exist. Where the condition for comparable warrants, or also called matching pair warrants, is that the warrants must have the same underlying asset, same parity, identical time to maturity, same exercise price and be of the same type, namely call or put (Loudon & Nguyen, 2006).

## 5.1 Data

The warrants in this thesis are selected in a similar way as in Claessen & Mittnik (2002). Due to the volatility smile which can be seen in figure 1 only near ITM or ATM warrants will be included (Xu & Taylor, 1995). This thesis only includes warrants with an average of 10% in-or out of the money during the examined period. Further the warrants must have a remaining lifetime of more than 10 day to maturity. Since the IV´s in this paper will be derived using the B&S model applying these conditions above will diminish the specification error when assuming the validity of the B&S model. Further it will also decrease the risk of biases induced by using lesser traded warrants (Claessen & Mittnik, 2002).

As an addition, due to the limited time of this thesis, this paper will only examine warrants of ABB LTD, Ericsson B, Sandvik and SSAB A. ABB LTD is a world leading Swedish company in the power and automation technology sector, listed on the stock exchange for the 30 biggest companies in Sweden, OMXS 30. ABB LTD has over 9000 employees in Sweden. Listed on OMXS 30 is also Ericsson. Ericsson is a global operating Swedish telecom company with over 10000 employees in Sweden. Sandvik is a Swedish high technology engineering company, with 10000 employees in Sweden listed on OMXS30. Operating in the steel industry is SSAB. SSAB is multinational Swedish company listed on OMXS 30, with approximately 8000 employees. The stock and warrant prices for these companies was collected between the time periods of 2010-07-09 to 2011-04-01, all gathered from the database of Handelsbanken. The historic volatility is gathered from database of Avanza bank and the risk free rate is a Swedish 10 year government bond (SE GVB 10Y) collected from the Svenska Riksbanken. The B&S price and IV´s are all calculated via programming in Visual Basic, further statistical software has been used to generate LR statistics and hypothesis testing. Altogether this thesis examine theoretical prices and IV´s for 45 warrants with prices varying from 189 to 35 observations with the underlying assets of ABB LTD, Ericsson b, Sandvik and Ssab a. Further if the sample lack in warrant price at some date within the chosen period due to technical problems or other unforeseen events, previous observations warrants price will be used.

# 6 Data and Analysis

## 6.1 Descriptive statistics for underlying stock

Table 3 presents the descriptive statistics for the underlying stocks of all examined warrants during the time period of 2011-04-01 to 2010-07-09.

*Table 3: Descriptive statistics for underlying stocks*

| Underlying Stocks | ABB LTD | Ericsson b | Sandvik | Ssab a |
|---|---|---|---|---|
| Augmented Dickey-Fuller test statistic | 0,102 | 0,554 | 0,704 | 0,447 |
| Mean | 0,007 | 0,007 | 0,010 | 0,014 |
| Kurtosis | 3,92 | 4,99 | 3,74 | 6,83 |
| Skewness | 0,18 | 0,14 | 0,37 | -0,92 |
| Jarque-Bera | 7,70** | 31,70* | 8,54** | 141,52* |
| Arch-LM test | 0,25* | 0,17** | 0,14*** | 0,13*** |
| Numbers of observations | 189 | 189 | 189 | 189 |

NOTE: (*) statistical significant at 99 % confidence level
(**)statistical significant at 95 % confidence level
(***)statistical significant at 90 % confidence level

In table 3 none of the p values of the Dickey-Fuller test statistic are significant. All stocks have a unit root during the chosen time period, hence using a mean equation of the ARMA type is not possible. Due to the appearance of a unit root in the sample, this thesis applied the Elder & Kennedy (2001) strategy[8]. The findings from this strategies suggested that using the mean equation of a pure random walk model fits the sample best. Further the Jarque-Bera statistics suggest that all stocks are non Gaussian distributed at a 95% confidence level, thus confirming that the residuals in the sample follow a heteroskedastic pattern which is essential when applying an ARCH/GARCH model. Table 3 also shows that all stocks are fat tailed, i.e. all stocks has a Kurtosis larger than 3 (Brooks, 2002). Also all stocks are skewed, whereas some negative and some positive. Both of these findings of fat tailed distributions and skewed distributions might involve problems when applying the B&S model as the true model capturing the behavior of all investors on the market. Since the B&S model assumes that the underlying stock of a warrant follows a log normal distribution. Finally the Arch-LM test shows that all stocks experience ARCH structure at a 90% confidence level, which suggests that an ARCH/GARCH model is applicable for the sample.

[8] Elder & Kenedy (2001) provides a simple strategy to estimate the best fitting model when the sample observations experience a unit-root.

## 6.2 Efficiency tests

Since all stock in the sample had insignificant GARCH terms[9]during the chosen time period, an ARCH (1) IV model rather than the GARCH (1.1) IV model as the unconstrained equation in equation (12) will be used in this thesis for all underlying stocks. By assuming that the GARCH term in equation (12) is zero, the ARCH (1) IV model is shown.

Table 4 to table 7 presents the results from the the $\alpha$ and $\beta$ values from Test 1 in equation (9), where an $\alpha = 0$ and $\beta = 1$ indicates information efficiency. Secondly the LR p-value from information efficiency Test 2 is presented. In this test, the critical p-value for a chi-square distribution between the unconstraint and the constraint equation is 0.01, due to the one constraint on the ARCH term. Further the result from information efficiency Test 3 where the mean IV for all warrants during the date in the parentis from can be seen.

[9]I.e. the GARCH term for all underlying stocks did not converge at a 90% confidence interval.

## 6.3 Information efficiency test for ABB LTD warrants

In this section all the results from the three information efficiency tests for ABB LTD warrants will be presented.

*Table 4: Output for market efficiency tests on ABB warrants*

| **Information efficiency tests** | **Test 1** | | **Test 2** | **Test 3** |
|---|---|---|---|---|
| Warrant | $\alpha$ | $\beta$ | LR p-value | Mean IV (Date) |
| ABB1D145SHB | 0.776* | 1.145* | 0.1 | 0.23(110330-110221) |
| ABB1D150NDS | 2.011* | 1.116* | 0.03 | 0.23(110330-110221) |
| ABB1D150OHM | 3.463* | 1.211* | 0.005 | 0.30(110330-110221) |
| ABB1D155NDS | 0.591* | 1.305* | 0,00001 | 0.23(110330-110221) |
| ABB1D155CBK | 0.926* | 1.354* | 0.003 | 0.24(110330-110221) |
| ABB1D160NDS | 1.099* | 1.709* | 0.009 | 0,26(110330-101116) |
| ABB1D160SHB | 1.012* | 1.734* | 0.3 | 0.26(110330-101116) |
| ABB1E150CAR | 2.000* | 1.166* | 0.003 | 0,23(110331-101203) |
| ABB1E150NDS | 0.502 | 1.256* | 0.34 | 0,23(110331-101203) |
| ABB1E150OHM | 2.470* | 1.360* | 0.007 | 0,30(110331-101203) |
| ABB1E150SHB | 0.930** | 0.520* | - | 0,25(110331-101203) |
| ABB1E150SWE | 2.732* | 0.987* | 0.003 | 0,23(110331-101203) |
| ABB1E155CAR | 0.573** | 1.197* | 0.001 | 0,21(110331-110221) |
| ABB1E155NDS | 0.848* | 0.948* | 0.00001 | 0,19(110331-110221) |
| ABB1E160CAR | 0.566* | 1.460* | 0.003 | 0,23(110331-110216) |
| ABB1E160NDS | 0.631** | 1.655* | 0.36 | 0,20(110331-110216) |
| ABB1E160OHM | 1.470* | 2.071* | 0.02 | 0,28(110331-110216) |
| ABB1E160SHB | 0.415 | 1.661* | 0.0001 | 0.23(110331-110216) |

NOTE: (*) statistical significant at 99 % confidence level
(**)statistical significant at 95 % confidence level
(***)statistical significant at 90 % confidence level
LR p-value is significant if p<0,01

From table 4 we can see that according to first information efficiency test proposed in the method section (test 1), none of the significant alpha and beta values for any warrant indicates market information efficiency. Further the LR p-value suggests that only 12 out of 18 warrants are information efficient. As shown by the mean

IV´s there are differences among the IV strategies of the intermediaries when comparing matching pair warrants, hence supporting the findings of none information efficiency from the first two tests.

## 6.4 Information efficiency tests for Ericsson b warrants

Table 5 present all the results for the three information efficiency tests for the included Ericsson b warrants.

*Table 5: Output for market efficiency tests on Ericsson b warrants*

| **Information efficiency tests** | **Test 1** | | **Test 2** | **Test 3** |
|---|---|---|---|---|
| Warrant | $\alpha$ | $\beta$ | LR p-value | Mean IV (Date) |
| ERI1D75CAR | 0.867** | 0.989* | 0.06 | 0.30(110329-101214) |
| ERI1D80CAR | 0.411*** | 1.219* | 0.03 | 0.28(110330-110201) |
| ERI1D80CBK | 0.330* | 0.993* | 0.03 | 0.27(110330-110201) |
| ERI1D80NDS | 0.617** | 0.965* | 0.005 | 0.23(110330-110201) |
| ERI1D85CBK | 0.171* | 1.086* | 0.01 | 0.27(110330-110201) |
| ERI1D85NDS | 0.309* | 1.292* | 0.00001 | 0.25(110330-110201) |
| ERI1E75SHB | 0.0479 | 0.899* | 0.0003 | 0,08(110325-110209) |
| ERI1E77NDS | 0.858* | 0.886* | 0.030 | 0,24(110329-101203) |
| ERI1E78CIT | 0.285** | 0.790* | 0.54 | 0,18(110330-110121) |
| ERI1E80CAR | 0.105 | 0.898* | 0.005 | 0,22(110330-110218) |
| ERI1E80SHB | 2.240* | 0.623* | 0.000006 | 0,23(110330-110218) |
| ERI1E80SWE | 5.804* | 0.089* | 0.01 | 0,36(110330-110218) |

NOTE: (*) statistical significant at 99 % confidence level
(**)statistical significant at 95 % confidence level
(***)statistical significant at 90 % confidence level
LR p-value is significant if p<0,01

From table 5 the first information efficiency test shows none of the significant alpha and beta values indicates market information efficiency of examined warrants. The result of the LR p-value which has a critical value of 0.01, shows that in only 7 out of 12 warrants are information efficient. Hence past returns adds further information to that already captured by the IV among these. The third information efficiency test confirms the findings of the first two, accordingly to the Mean IV, differences among intermediaries in IV exist when comparing matching pair warrants.

## 6.5 Information efficiency tests for Sandvik warrants

Table 6 present will present the findings from the three information efficiency tests for all included Sandvik warrants.

*Table 6: Output for market efficiency tests on Sandvik warrants*

| **Information efficiency tests** | **Test 1** | | **Test 2** | **Test 3** |
|---|---|---|---|---|
| Warrant | $\alpha$ | $\beta$ | LR p-value | Mean IV (Date) |
| SAN1D120NDS | 0.750* | 1.070* | 0.003 | 0.31(110330-110223) |
| SAN1D125CIT | 0.863* | 1.330* | 0.04 | 0.33(110331-110223) |
| SAN1D125SHB | 0.205 | 1.730* | 0.0009 | 0.32(110331-110223) |
| SAN1D125CBK | 0.833* | 1.314* | 0.0002 | 0.35(110331-110223) |
| SAN1E120OHM | 1.683* | 1.119* | 0.04 | 0,35(110330-101222) |
| SAN1E120SWE | 2.225* | 0.859* | 0.000000007 | 0,31(101015-100709) |
| SAN1E122NDS | 0.771* | 0.942* | 0.0004 | 0,26(110330-110204) |
| SAN1E125CAR | 0.555* | 1.097* | 0.002 | 0,28(110330-110216) |
| SAN1E125SHB | 0.470* | 1.199* | 0.09 | 0,27(110330-110216) |

NOTE: (*) statistical significant at 99 % confidence level
(**)statistical significant at 95 % confidence level
(***)statistical significant at 90 % confidence level
LR p-value is significant if p<0,01

From table 6 the results show that the significant alpha and beta values from the first efficiency test, states that none of the examined warrant is information efficient. As shown by the Lr p-value, only 6 out of 9 warrants are information efficient according to the second efficiency test. The third information efficiency test confirms the findings of the first two, the mean IV among warrant pairs differs among different intermediaries.

## 6.6 Information efficiency tests for SSAB warrants

Table 7 shows the results for all three information efficiency test performed on the included SSAB a warrants.

*Table 7: Output for market efficiency tests on Sandvik warrants*

| **Information efficiency tests** | **Test 1** | | **Test 2** | **Test 3** |
|---|---|---|---|---|
| Warrant | $\boldsymbol{\alpha}$ | $\boldsymbol{\beta}$ | LR p-value | Mean IV (Date) |
| SSA1D110CIT | 1.504* | -0.047 | 0.03 | 0.13(110321-110215) |
| SSA1D110NDS | 1.085* | -0.168** | 0.006 | 0.14(110321-110215) |
| SSA1D110SHB | 0.148 | 1.176* | - | 0.16(110321-110215) |
| SSA1D115CBK | 0.617** | 0.263 | 0.0001 | 0.20(110330-110201) |
| SSA1E110SWE | 4.735* | 0.701* | 0.03 | 0,34(110401-100906) |
| SSA1E115CAR | -0.192 | 1.487* | - | 0,27(110330-101214) |

NOTE: (*) statistical significant at 99 % confidence level
(**)statistical significant at 95 % confidence level
(***)statistical significant at 90 % confidence level
LR p-value is significant if p<0,01

As shown in table 7 none of the significant alpha and beta values from the first information efficiency test suggest that the included warrants are information efficient. Further the result from LR p-value confirms that 2 out of 6 Sandvik warrants are information efficient accordingly to the second efficiency test. Last the third information efficiency test shows that the mean IV´s differs among intermediaries in the warrant pairs, hence confirming the findings of the two first information efficiency tests.

## 6.7 Analysis

In line with the findings of Majewska & Majewski (2005), the results from the test 1 shows that none of the significant alpha and beta values indicates that the B&S model theoretical price matches the market price. The result from this test might be interpreted in two ways. The first possible scenario is that the market makers on the Swedish plain vanilla warrant market doesn't quote accurate bid and ask prices. Since this thesis is limited to near ATM or ATM warrants, the specification errors of the B&S model are minimized. Hence in theory, the theoretical B&S price should match with the market price in an information efficient market (Claessen & Mittnik, 2002). Thereby, which is assumed in this thesis, the included plain vanilla warrants in this thesis are not information efficient. The second way to interpret the result is that the B&S model is a non applicable model for the warrants in this sample. Rather than the market makers quoting inaccurate bid and ask prices, the theoretical B&S price differs from the market price due to miss specifications in the model (Xu & Taylor, 1995). For instance the descriptive statistic of the underlying stocks section in this thesis shows that the underlying stocks are fat tailed and skewed, where the B&S model assumes that the underlying stock follows a log-normal distribution. Hence this assumption might be violated. Secondly Yang (2006) and Huimin et al. (2002) suggest that all market makers uses unique individual pricing models to generate bid and ask prices, and thereby the differences between the theoretical and the market price. According to Yang (2006) the B&S model still is the basic tool when market makers generates bid and ask prices, but rather than using just one input parameter for the volatility, market makers uses a matrix of implied volatilities, one for each strike price and maturity.

Following up on the results of the first test, test 2 shows that only 26 out of 45 (58%) of the examined warrants are information efficient. For 42% of the warrants include in this thesis, historical returns add further information to that already incorporated in the IV derived from the B&S model. The findings from this test are in line with results of Day &Lewis (1992), Lamoureux & Lastrapes (1993), where the null hypothesis of historical information adding no further information to that incorporated in the IV is rejected. Although as in the case of the first test, the result from this test might be interpreted in two ways (Xu & Taylor, 1995). The first scenario, which is assumed in this thesis, is that market makers on the Swedish plain vanilla warrant market don't use all available information when quoting the market price of a warrant. As information regarding past returns adds further information to that already captured by the IV, the null hypothesis in this thesis is rejected. Hence the quoted prices are inaccurate and this market is not ideally for capital allocation. Furthermore this impose that the information contained in the prices given to investors in this market is not perfect. Hence this is a imperfect market and the findings of non information efficiency in test 1 is due to the actual structure of this market (Perloff & Carlton, 2005). The second scenario is that the model used to back out the IV is incorrectly specified. Since this thesis applies the B&S model to back out the IV, the investors on the warrant are automatically assumed to behave in line with the assumptions of this model (Xu & Taylor, 1995). Although this might not be the case since the descriptive statistics of the underlying stocks part in this thesis suggest that the distributions of the underlying asset are skewed and fat tailed.

Similar to the results of Koorts & Smit (2002) and D´Agostino (2006), the comparison of IV´s among matching pair warrants in table 6 and graphs 1-11 in appendix from test three, confirms that differences in IV´s between different intermediaries exist. As in the case of the first and the second test, this test shows the non information efficiency of the included warrants. In table A2, in appendix ,the results from this test shows that the intermediaries CBK and OHM uses a premium IV strategy among all comparable warrants in which they are included. Additional NDS frequently use a low strategy in all comparable warrants except one. Other intermediaries using low strategies in the sample are SWE, CIT and SHB, although SHB and CIT use a medium strategy as well. The results from this test, confirms that knowledge about the different strategies among the intermediaries on the Swedish plain vanilla warrant market will have a sufficient effect on the returns of the investments. Since accordingly to D´Agostino (2006) 30% of the price differences among comparable warrants might be explained in differences in IV´s. Furthermore these differences of IV strategies, impose that actors on this market are able to some extent have control over the prices of their output, by adjusting for the IV. Implication from this suggests that this is an imperfect competitiveness market. Hence market power is exercised, and prices can be raised without the risk of losing all of the quantity demanded for the intermediary's product. As the regulation of the Swedish plain vanilla warrant market works as barrier to enter the market and differential strategies in prices are clearly visible in graph A1 to A11 in appendix. Clearly this is a sign of an oligopoly market structure. Oligopoly competition among the intermediaries leads to differentiation of their issued products. Where some uses a high price strategy with unique attributes, or aggressive marketing connected to their instrument to extend their market share. Other uses low price strategies to attract customers (Koorts & Smit, 2002; Case & Fair, 2007). As imperfect competition and market power are contributing sources of the inefficiency of a market, this explains the reasons behind the findings of non information efficiency in test 1 and 2 (Case & Fair, 2007).

# 7 Conclusion and further research

Even though FI sharpened the regulation of the Swedish plain vanilla warrant market in 2006, all three tests conducted in this thesis reject the null hypothesis of informational efficiency of the included warrants. Oligopoly competition among the intermediaries leads to differential strategies and contributes to the non efficiency of this market. If the B&S model captures the behaviour of all investors in this market, the results imply that this is not an ideally market for capital allocation. Furthermore as the findings from this thesis reject the null hypothesis of information efficiency, this is a market where arbitrage opportunities of the warrants included in this sample are possible.

To follow up on the findings in this thesis of non information efficiency of the included warrants, an interesting extension would be to compare the warrant market with the option market. As previous research suggests that the option market is information efficient, comparing the prices of identical options and warrants to see whether investors are better off trading options rather than warrants is an interesting subject.

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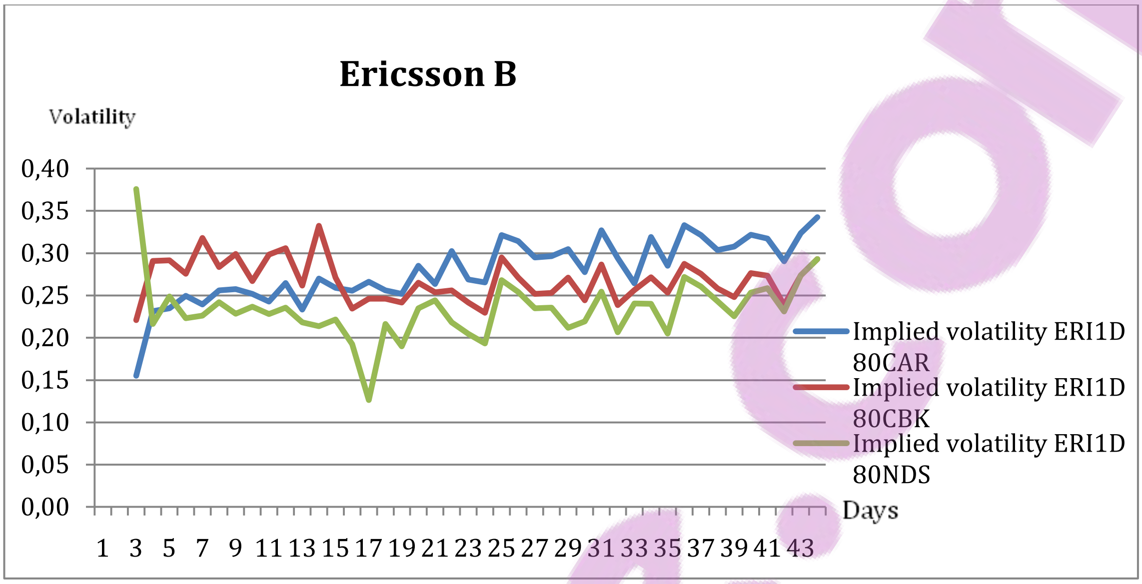
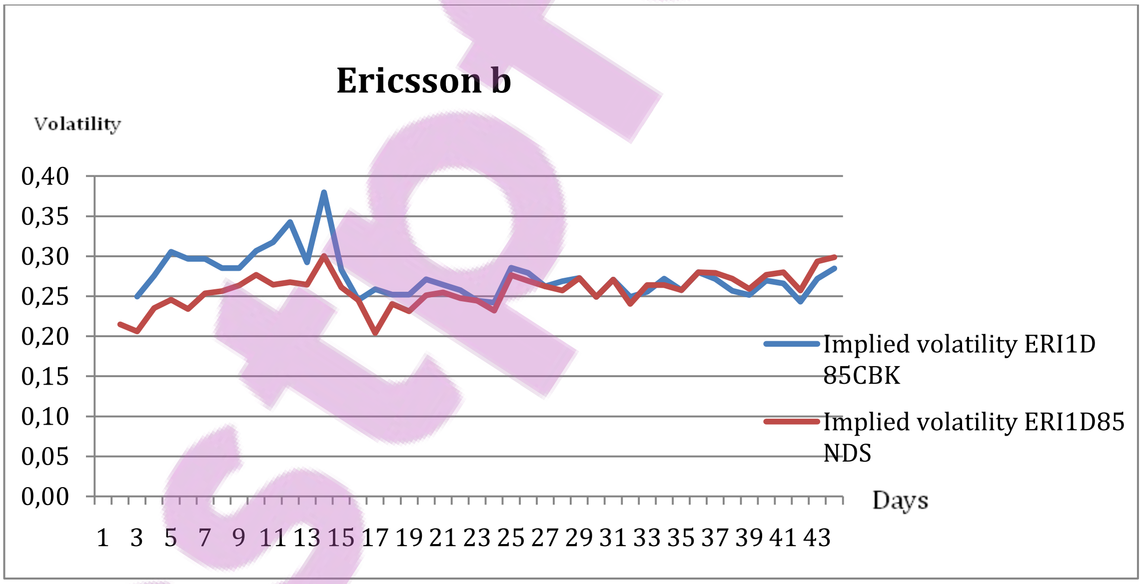
## Appendix:

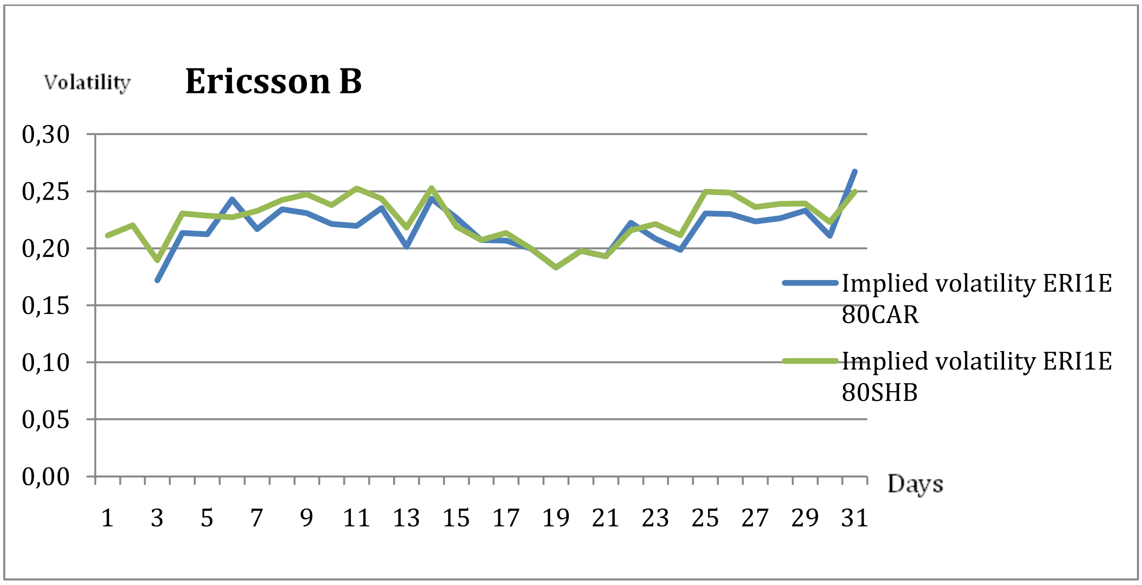
*Graph A1: ERIID80 Implied Volatility comparison*



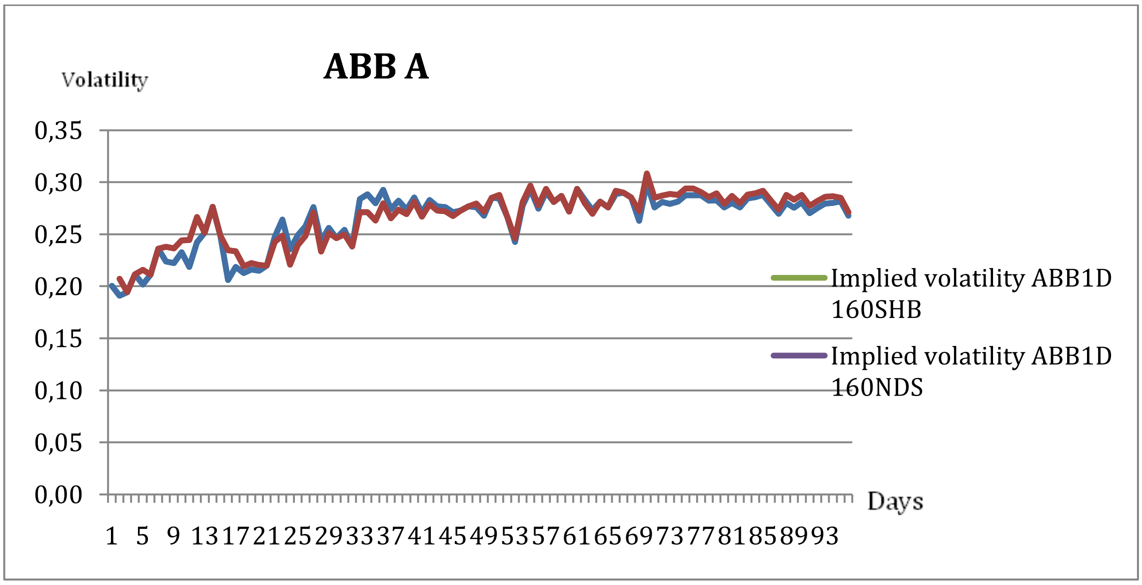

*Graph A2: ERI1D85 Implied Volatility comparison*



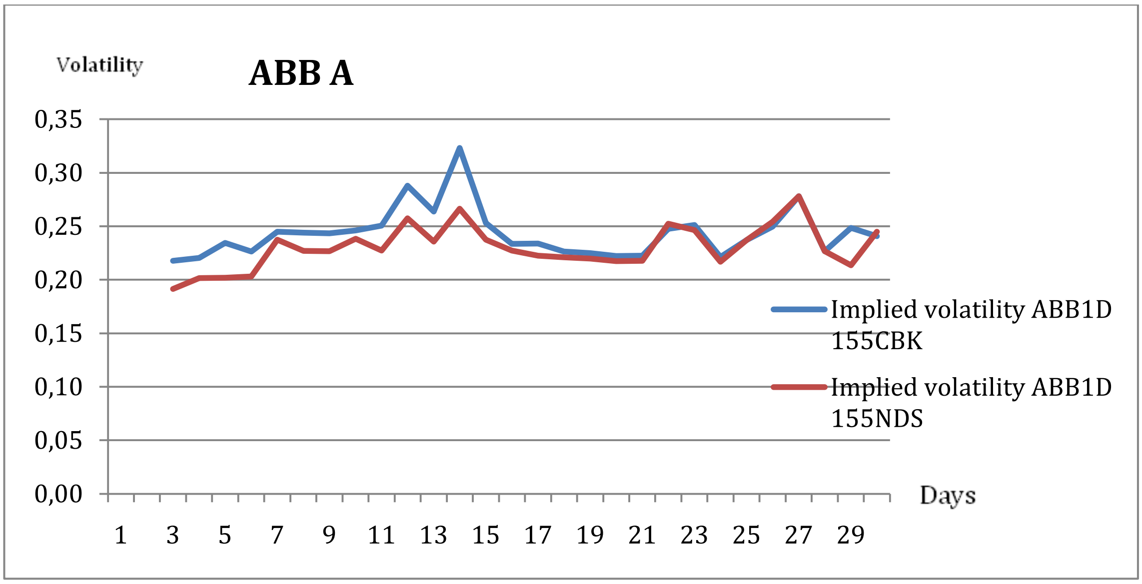
*Graph A3: ERI1E80 Implied Volatility comparison*



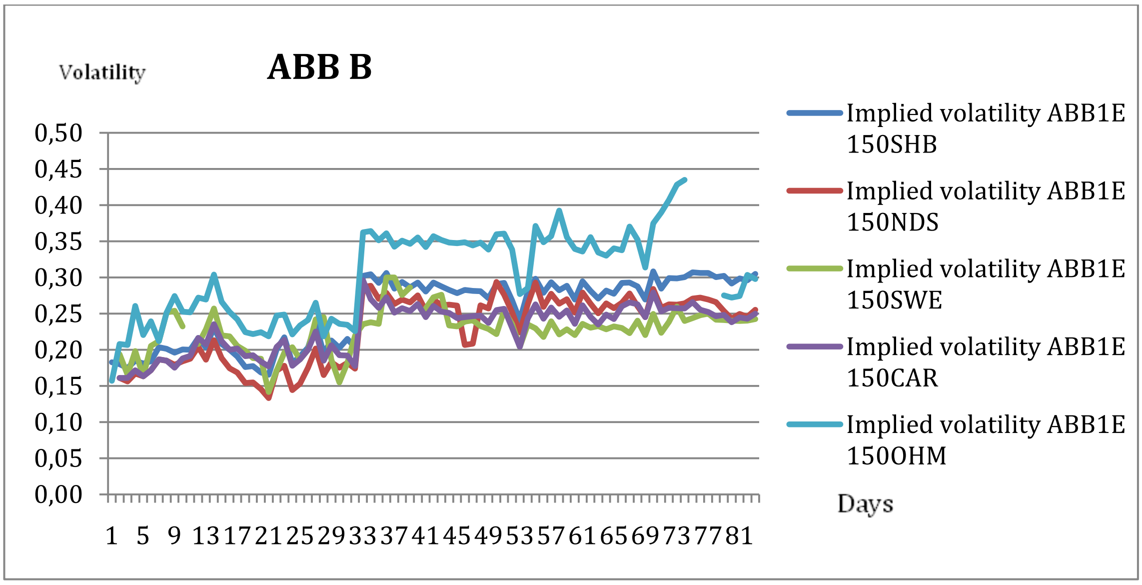

*Graph A4: ABB1D160 Implied Volatility comparison*



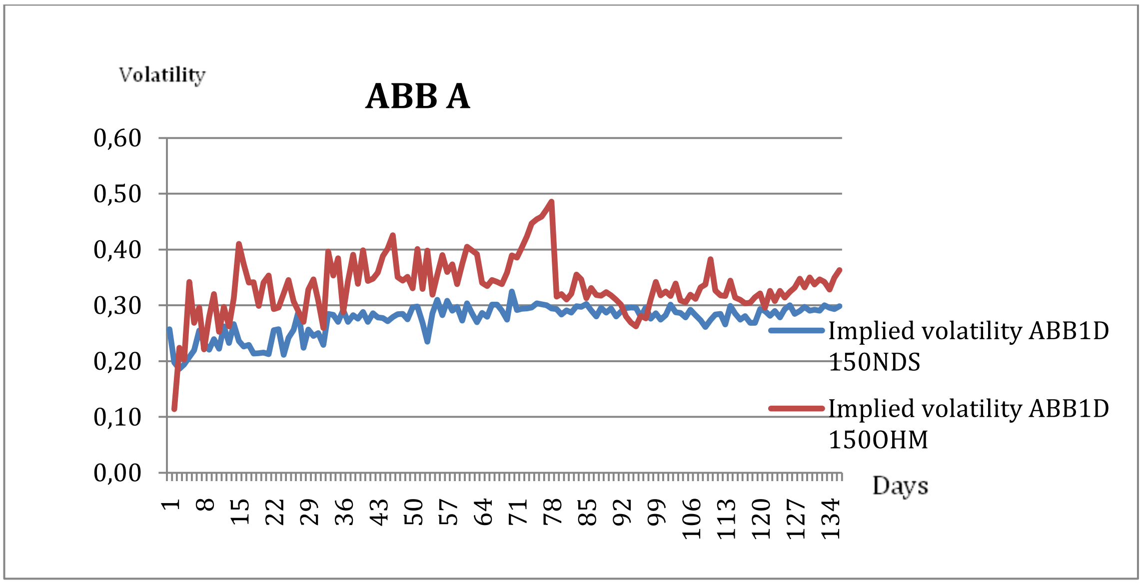
*Graph A5: ABB1D155 Implied Volatility comparisons*



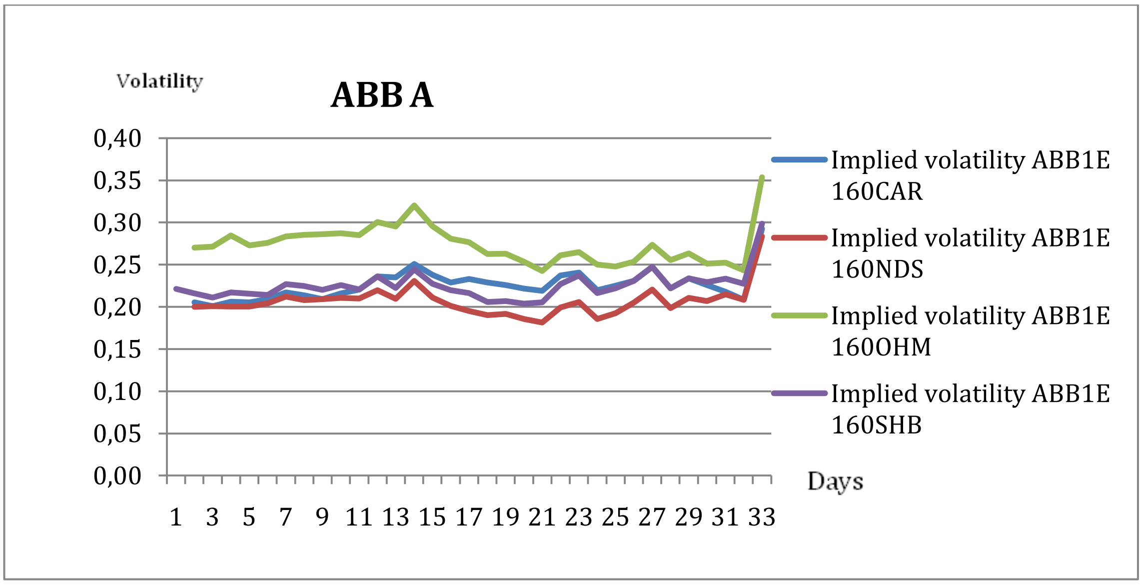

*Graph A6: ABB1E150 Implied Volatility comparison*



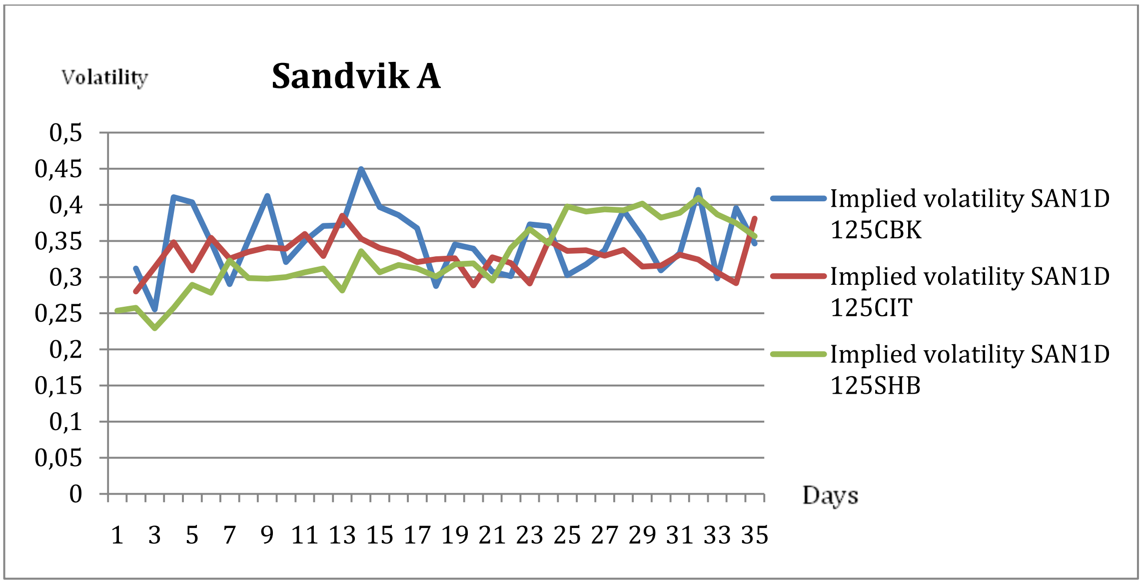
*Graph A7: ABB1D150 Implied Volatility comparison*



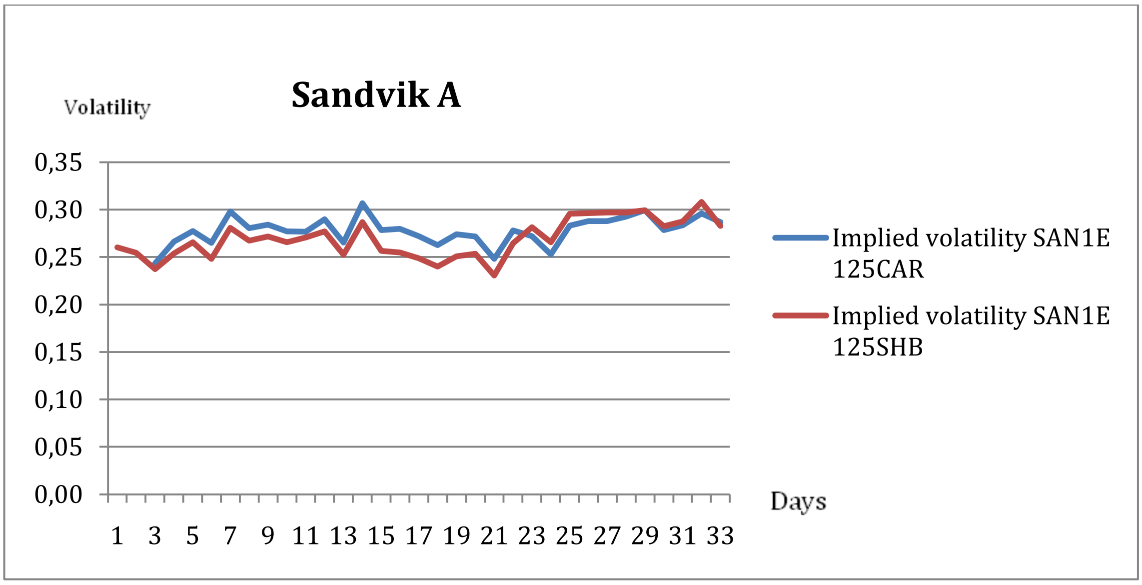

*Graph A8: ABB1E160 Implied Volatility comparison*



*Graph A9: SAN1D125 Implied Volatility comparison*




*Graph A10: SAN1E125 Implied Volatility comparison*



*Graph A11: SSA1D110 Implied Volatility comparison*

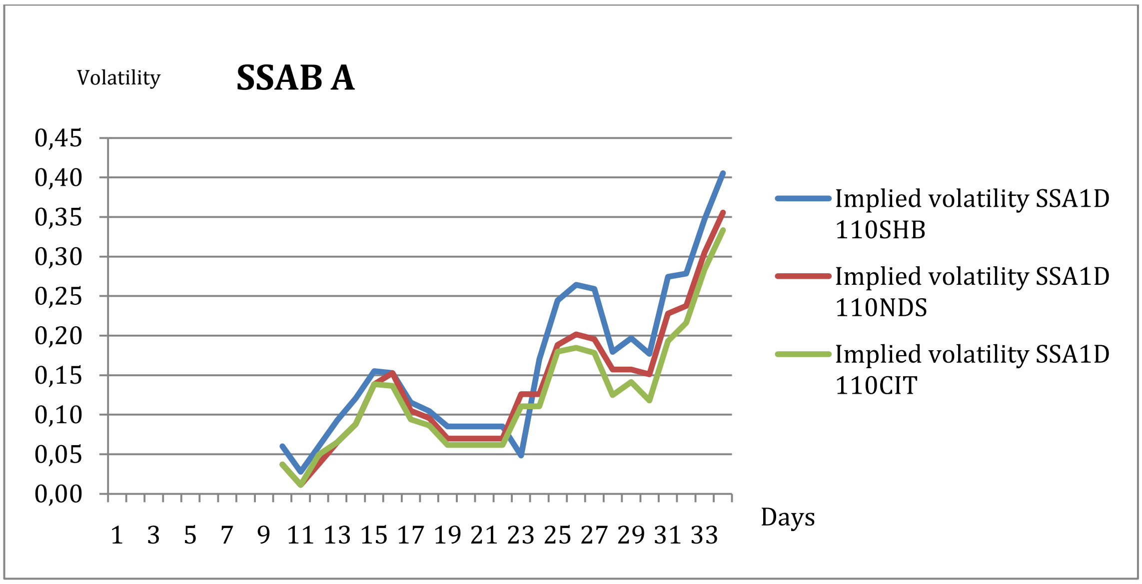



*Table A1: expiration date and warrant type*

| Call | Month | Put |
|---|---|---|
| A | January | M |
| B | February | N |
| C | Mars | O |
| D | April | P |
| E | May | Q |
| F | June | R |
| G | July | S |
| H | August | T |
| I | September | U |
| J | October | V |
| K | November | W |
| L | December | X |

At the NDX and OMX warrant names are built in the following way ABB1C150SHB. This name contains information regarding the underlying stock, date of maturity, strike price, type of warrant and who the issuer is. The first three to five letters in the warrant name gives information about the underlying asset, in this case the warrant uses ABB stocks as underlying asset. Next the first digit shows what year the warrant matures, for instance 1 means 2011, 2 2012 and so on. In table 9 appendix the letter followed after the exercise year is shown (i.e. C), this tells you what type of warrant it is, also it shows the month in which the warrant matures. After this the strike price of the warrants is shown, followed by the issuer of the warrant, see table 2 (D´Agostino, 2006).

*Table A2: Implied volatility strategies among comparable warrants*

| Warrant | Mean impvol (Date) | Strategies |
|---|---|---|
| ABB1D150NDS | 0.23(110330-110221) | Low |
| ABB1D150OHM | 0.30(110330-110221) | Premium |
| ABB1D155NDS | 0.23(110330-110221) | Low |
| ABB1D155CBK | 0.24(110330-110221) | Premium |
| ABB1D160NDS | 0,26(110330-101116) | Same |
| ABB1D160SHB | 0.26(110330-101116) | Same |
| ABB1E150CAR | 0,23(110331-101203) | Low |
| ABB1E150NDS | 0,23(110331-101203) | Low |
| ABB1E150SWE | 0,23(110331-101203) | Low |
| ABB1E150SHB | 0,25(110331-101203) | Medium |
| ABB1E150OHM | 0,30(110331-101203) | Premium |
| ABB1E155NDS | 0,19(110331-110221) | Low |
| ABB1E155CAR | 0,21(110331-110221) | Premium |
| ABB1E160NDS | 0,20(110331-110216) | Low |
| ABB1E160CAR | 0,23(110331-110216) | Medium |
| ABB1E160SHB | 0.23(110331-110216) | Medium |
| ABB1E160OHM | 0,28(110331-110216) | Premium |
| ERI1D80NDS | 0.23(110330-110201) | Low |

| | | |
|---|---|---|
| ERI1D80CBK | 0.27(110330-110201) | Premium |
| ERI1D85NDS | 0.25(110330-110201) | Low |
| ERI1D85CBK | 0.27(110330-110201) | Premium |
| ERI1E80CAR | 0,22(110330-110218) | Low |
| ERI1E80SHB | 0,23(110330-110218) | Premium |
| SAN1D125SHB | 0.32(110331-110223) | Low |
| SAN1D125CIT | 0.33(110331-110223) | Medium |
| SAN1D125CBK | 0.35(110331-110223) | Premium |
| SAN1E120SWE | 0,31(101015-100709) | Low |
| SAN1E120OHM | 0,35(110330-101222) | Premium |
| SAN1E125SHB | 0,27(110330-110216) | Low |
| SAN1E125CAR | 0,28(110330-110216) | Premium |
| SSA1D110CIT | 0.13(110321-110215) | Low |
| SSA1D110NDS | 0.14(110321-110215) | Premium |