



NEKM03 Master Thesis
Spring 2008

SCHOOL OF ECONOMICS
AND MANAGEMENT
Lund University

Volatility in covered warrants

- *A comparison between EGARCH-forecasted volatility and implied volatility on the Swedish
warrant market* -

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Summary

Title:	<i>Volatility in covered warrants – a comparison between EGARCH-forecasted volatility and implied volatility on the Swedish warrant market</i>
Seminar date:	2008-06-03
Course:	NEKM03 - Degree Project in Finance
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Key words:	Volatility, Warrants, EGARCH, Black and Scholes
Purpose:	The aim of this thesis is to study the implied volatility on certain warrants on the Nordic Derivatives Exchange and compare it to an EGARCH-forecasted volatility (which throughout the thesis is used as proxy for the true volatility by the authors) in order to see if the difference follows a specific pattern.
Theoretical framework:	The theoretical framework consists of options theory, the structure of volatility, and hedging within option trading.
Method:	A quantitative method is used in order to achieve the forecasted and the implied volatility on a set of warrants.
Empirical platform:	Selected covered warrants traded on the Nordic Derivatives Exchange and issued by Commerzbank AG are included in the study.
Conclusion:	The difference between the forecasted volatility and the implied volatility fluctuates across moneyness and the lifetime of the warrant. A number of patterns are detected across the two parameters, which in turn might be caused by the market maker's behavior towards market uncertainties. In addition to this, a "ratio-smile" trend over time was detected on several warrants. That is, the ratio (implied volatility over forecasted volatility) is higher at the beginning and the end of the lifetime of the warrant compared to the middle of the lifetime (which coincided with an increase in moneyness).

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1 Introduction

This section will give a background to the topic chosen, followed by a discussion of the problem and ending with a formulation of the purpose of the thesis.

1.1 Background

In recent time derivatives have become increasingly important in the world of finance. Futures and options are now traded actively on the biggest stock exchanges throughout the world. Many of these contracts are traded by financial institutions, fund managers and corporate treasurers in the over the counter market (OTC). A derivative is a financial instrument whose value depends (or derives from) on the values of other, more basic, underlying variables. Very often the variables underlying derivatives are the prices of traded assets. A stock option, for example, is a derivative whose value is dependent on the price of a stock (Hull, 2006). A popular form of a financial derivative is a warrant. It has the same properties as a stock option but a big difference is that the issuing bank of the warrant claims to provide perfect liquidity in the market. This perfect liquidity in the warrant market implied by the market maker is difficult to find in the option market, since here, supply and demand has to match for a trade to go through (volume and price). In the warrants market, the market maker guarantees at all time to quote bid and ask prices (if sold out then ask prices are not quoted) on their issued warrants. Another difference is that in the warrant market is not allowed for anyone but the issuer to short sell the warrant (Nordic Derivatives Exchange). In this setting it is easy to see that the market maker faces a certain amount of risk by being in the market. Therefore, when comparing option contracts and warrants with the same underlying asset, time to maturity and strike price, the warrant will be more expensive. The reason why the warrant is more expensive is because the market maker uses a higher volatility, i.e. the market implied volatility, when they quote their prices. This compensates the market maker for the extra risk they take by providing liquidity in the market (Nordic Derivatives Exchange).

There are two ways in which a market maker earns a profit. The first one is the bid-ask spread, in which the market makers earns a profit from buying at the bid price and selling at (a higher) ask price (Campbell, Lo & MacKinlay, 1997). It is widely known, and accepted, that the market maker earns a profit from the bid-ask spread. The second source of profit derives from the market makers' individually set volatility and differs from market maker to market maker, due to the individual preferences of the market maker, what level of risk they are prepared to take and their current position in the market (Yang, 2006). Thus, since the price of the warrant is based on, amongst other

variables, the size of the volatility, the price of a warrant with the same parameters will differ from one market maker to another. The volatility should reflect the market maker's estimations of the likelihood that the underlying asset moves far enough to impose a loss for the market maker. Since the size of the volatility is the only variable that the market maker is able to individually set when pricing a warrant, it is interesting to investigate at what level it is set. The implied volatility (the volatility set by the market maker), which can be backed out from the Black Scholes (BS) formula, can then be compared with a forecasted volatility derived from e.g. a generalized auto regressive heteroskedasticity (GARCH) model, in order to see how much *extra* volatility the market maker adds to that of the volatility forecasted by a volatility forecasting model (e.g. GARCH)¹. Although, according to Figlewski (1997), a market maker might set the volatility *below* the true volatility in order to increase demand of its warrants from which it would earn the bid-ask spread. The amount of previous academic research within this area is limited, whilst it is widely known amongst practitioners. This tendency of a debatable extra volatility set by market makers thus is an interesting subject for academic research, although it limits the thesis' background discussion due to the infinitesimal amount of previous research.

1.2 Specification of the problem

The area subject of interest is, based on the discussion put forward in the previous section, the difference in volatility between the implied and that of an EGARCH-forecasted, on specific warrants on the Nordic Derivatives Exchange (NDX). This occurrence might arise due to a number of reasons, none of which we intend to put much emphasis on in this thesis. Our focus will instead lie on the actual measurement of the volatility difference, and if it is possible to spot certain patterns in this difference across; time, underlying asset, strike price and other not yet specified parameters. By emphasizing this, we hope to add some knowledge to the minuscule research that exists within this area today.

1.3 Purpose

The aim of this thesis is to study the implied volatility on certain warrants on the Nordic Derivatives Exchange and compare it to an EGARCH-forecasted volatility (which throughout the thesis is used as proxy for the true volatility by the authors) in order to see if the difference follows a specific pattern.

¹ This said, the authors are aware of the fact that different market makers might depart from different volatility-forecasting models, with different inputs, thus departing from a different volatility (than that forecasted by the authors) when setting their implied volatility.

1.4 Thesis outline

Chapter two consist of a, for the thesis, relevant theoretical framework. Included are theories dealing with options and warrants, the pricing of such derivatives and the structure and traits of volatility in derivatives. Chapter three explains the methodology used, the econometrics models applied and the data collection procedure, as well as possible downsides related to them. The empirical findings are presented in chapter four followed by an analysis of the results in chapter five. The thesis is summarized and concluded in chapter six.

2 Theoretical framework

This section presents theories surrounding options pricing. The volatility within these theories is scrutinized. Research about efficient markets and its connection with econometric models are touched upon, whilst a presentation of the econometrics models and its theories are analyzed more thoroughly in chapter three. Furthermore, it is assumed that the reader of this thesis has appropriate knowledge within finance and derivatives; hence the level of theory is set thereafter

2.1 Option pricing theory

Since a majority of literature and research regarding derivatives and derivatives pricing focus on that of options, this theory section will depart from options theory and make appropriate remarks about differences between options and warrants when needed, throughout the text. There are two major differences between the warrants this thesis is dealing with, namely *covered warrants*, and options. The first difference is that the issuer of a warrant can be either the company of the underlying asset (Hull, 2006) or a financial institution (e.g. an investment bank as is the case with *covered warrants*) (London Stock Exchange glossary, 2008), whilst the issuer of the option is either an individual investor or the exchange that trades the option (Briys, Bellalah, Mai & De Varenne, 1998). Second, the cover ratio (parity) is the number of warrants you need to buy one share, e.g. if the parity is 10/1 it means that you need 10 warrants to buy one share of the underlying asset. Contrary, the holding of one option generally corresponds to the right to buy/sell one share of the underlying asset. The following table clarifies matters regarding the difference between warrants and options:

Table 2.1 Warrants vs. Options

Characteristics	Warrants	Standardized options
Call or sell	The same rights as options	The same rights as warrants
American or European	Works like the options market	See warrant cell
Black & Scholes	Most commonly used	See warrant cell
Time to maturity	Usually 3-36 months	Mainly shorter time periods than warrants
Special authorization	Only needed for the issuer, not for the investor	Needed for both parties trading with options
Expiration date	Can be any date	The 3 rd Friday in the month
Underlying asset	Ample of warrants with different underlying asset	Fewer options with different underlying asset
Parity	Often more than one warrant is needed for one unit of the underlying asset	One option for one unit of the underlying asset
Issuer	Only authorized companies	Anyone with some collateral
Number outstanding	Mainly predefined	No limit

2.2 Black-Scholes formula

This thesis employs the well-known options pricing model derived by Black and Scholes (1973) to obtain the implied volatility from the price of the warrant. Therefore, only a simple presentation of the model along with its components is given in this section, hence the derivation of the formula is left out. Emphasis is instead put on the volatility, the difficulties surrounding it and how to attain it from the BS formula.

$$c_{option} = SN(d_1) - Ke^{(-rt)}N(d_2)$$

and

$$p_{option} = Ke^{(-rt)}N(-d_2) - SN(-d_1)$$

Where:

S = Current price of the underlying asset

t = Time until option expire

K = Option strike price

r = Risk-free interest rate

N = Cumulative standard normal distribution

e = exponential term

$$d_1 = \frac{\ln(S / K) + (r + \frac{1}{2}\sigma^2)t}{\sigma\sqrt{t}}$$

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

σ = Standard deviation of stock returns

ln = natural logarithm

To explain the model for a call option in short and simple terms, it can be divided into two parts. First, $SN(d_1)$, is the expected benefit from buying the underlying asset direct, i.e. multiplying the stock price by the change in the call premium with respect to a change in the underlying asset price. Second, $Ke^{(-rt)}N(d_2)$, is the present value of paying the exercise price on the maturity day, times the probability of the option finishing in the money, i.e. that $S > K$ for a call at maturity. The second term is then subtracted from the first term in order to achieve the fair value of the call warrant.

In order to attain the *fair value* of the warrant, a number of assumptions must be fulfilled, these are according to Briys, Bellalah et al. (1998):

- The option is European – exercise is allowed only at maturity
- The interest rate over the lifetime of the option is known
- The price of the underlying asset, S_t , follows a geometric Brownian motion with constant drift, μ , and volatility σ :

$$dS_t = \mu S_t dt + \sigma S_t dW_t$$

- The underlying asset pays no dividends or other distributions
- There are no transaction costs, and short selling is allowed
- Trading takes place continuously and the standard form of the capital market model holds at each instant

2.3 Merton's extension of the BS-formula

Merton (1973) extended the original BS- formula to include the dividends paid out by the underlying asset's firm. Assume that the firm pays out an ordinary dividend, where the dividend yield is q and assumed to be continuously compounded. By incorporating q into the original BS-formula, we now account for the annual dividend yield. The pricing of the option is now calculated through the following formula, where the present value of S is used instead of S as in the original formula:

$$c_{option} = S_0 e^{(-qt)} N(d_1) - K e^{(-rt)} N(d_2)$$

and

$$p_{option} = K e^{(-rt)} N(-d_2) - S_0 e^{(-qt)} N(-d_1)$$

$$d_1 = \frac{\ln(S / K) + (r + \frac{1}{2} \sigma^2) t}{\sigma \sqrt{t}}$$

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

2.3.1 The price of a warrant

When pricing a warrant the BS formula is used since the underlying assumptions are the same. The only difference is the parity of the warrant, i.e. the quantity of warrants needed to buy one stock. If the parity is 20 and the BS formula gives a price of 10 then the warrants price is 0.5 (Nordic Derivatives Exchange).

$$c_{warrant} = \frac{c_{option}}{parity}$$

The same relationship holds for a put.

2.4 Criticism of the BS formula

The criticism surrounding BS is mainly something that needs to be taken into account when using it as a pricing model, and not when using it to back out the implied volatility as is our aim. However, in order to make way for the models used to forecast the volatility (which are presented in the method section), a brief discussion about the criticism is dealt with here. First, the underlying asset does not follow a lognormal process. Instead, the distribution of financial time series is leptokurtic, i.e. it has *fat tails* and a high peak² (Brooks, 2002). Furthermore, the stock return distribution is assumed by traders to be skewed to the left and to have heavier left tail, and a less heavy tail to the right (Hull, 2006). In other words, financial time series experience higher probability of extreme events than does data that is normally distributed. Second, Campbell et al. (1997) describes several studies showing that the volatility of the returns of the underlying asset is time varying, i.e. contrary to the constant variance assumed by Black and Scholes. Third, Mandelbrot (1963) talks about the phenomena of *volatility clustering*, or in his own words “...large changes tend to be followed by large changes - of either sign - and small changes tend to be followed by small change...” (Mandelbrot, 1963, p. 418). What this implies is that the squared residuals display a positive, significant, and gradually decaying autocorrelation function, hence the volatility level of the current

² A kurtosis value higher than 3. A distribution with a kurtosis value of 3 is considered normally distributed.

period is positively correlated with the volatility of the period preceding it.

2.5 Sensitivities of options

Traders of derivatives often refer to the “Greeks” of their option position. The most common “Greeks” consist of delta, gamma, Vega, theta and rho, which simply put are different order derivatives of the BS model with respect to different variables. Each “Greek” (except for theta) quantifies the risk in owning an option, and are used by investors to hedge and neutralize the risk in their portfolios. These key ratios can also be seen as a measure of the characteristics of the warrants. The above mentioned key ratios are now scrutinized further, with emphasis on *vega* since it is closely related to the main issue of the thesis, i.e. volatility. The key ratios are in the next section explained in forms of hedging, in order to give the reader an idea about what is meant by hedging within warrant trading and how market makers utilize it to manage their risk exposure. The following definitions follows the reasoning by Hull (2006).

2.5.1 Delta

Delta is a ratio that compares the change in the price of the underlying asset to the corresponding change in the price of a, in our case, warrant. In mathematical terms, it is the derivative of the value of the warrant with respect to the underlying asset’s price:

$$\Delta = \frac{\partial C}{\partial S}$$

or expressed in the form of the previous stated BS model:

$$\Delta = N(d_1)$$

where $N(\cdot)$ is the normal probability density function.

E.g. a call warrant with a delta value of 0.6 means that for every 1 SEK the underlying asset moves, the call warrant will move 0.6 SEK, all else equal.

2.5.2 Gamma

Gamma measures the speed of which delta changes with respect to the underlying asset’s price (i.e. the curvature). It is the second partial derivative of the value of the warrant with respect to the underlying asset’s price:

$$\Gamma = \frac{\partial^2 C}{\partial S^2}$$

or

$$\Gamma = \frac{N(d_1)}{S\sigma\sqrt{t}}$$

Gamma is important because it shows how the warrant will respond to relatively large changes in the underlying asset's price. A large gamma in absolute terms corresponds to a delta highly sensitive to changes in the underlying asset's price and is also the characteristics for a warrant that is near the money. The contrary applies for a small gamma, and is characteristic for a warrant deep in- or out of the money.

2.5.3 Theta

Theta measures the rate of change of the value of the warrant with respect to the amount of time to expiry of the warrant, and can be written as:

$$\Theta = \frac{\partial C}{\partial T}$$

or

$$\Theta = -\frac{S\sigma}{2\sigma\sqrt{t}} N(d_1) - Ke^{-rt} N(d_2)$$

In other words, the warrant will lose value as the time to maturity decreases.

2.5.4 Rho

Rho represents the rate of change of the value of the warrant with respect to the interest rate, i.e. it is the derivative of the warrant value with respect to the interest rate:

$$\rho = \frac{\partial C}{\partial r}$$

or

$$\rho = tKe^{-rt} N(d_2)$$

2.5.5 Vega

The Vega of a warrant is the rate of change of the value of the warrant with respect to the volatility of the underlying asset, i.e. it is the second derivative of the warrant's value with respect to the volatility of the underlying asset³:

$$v = \frac{\partial^2 C}{\partial \sigma^2}$$

or

$$v = S\sqrt{t}N'(d_1)$$

If the absolute value of Vega is high, the value of the warrant is very sensitive to small changes in the volatility of the underlying asset. Events, such as the release of earnings reports, might trigger a

³ Since vega is not a letter in the Greek alphabet, instead the letter *nu* is used to denote Vega in the formula below. Although it will be referred to as Vega through out the text.

large change in the underlying assets volatility with a corresponding rapid increase in Vega. Historically, volatility has had a tendency to climb before the earnings report, peak, and then fall after the report (McMahon, 2007). This behavior of volatility before a large event is mainly due to two reasons. First, the demand for these warrants increases before an event because of speculations that the event may cause a rapid change in the underlying assets price, hence an increase in volatility. Second, as a response to the increased demand, the market makers increase the volatility to be able to charge a higher price. Vega can thus be seen as a measurement of how much the value of a call/put could change with respect to the volatility of the underlying asset. In other words, it is a "...tool to measure how expensive the option is relative to the fear factor" (McMahon, 2007, p. 56).

2.3 Hedging

Traders must hedge their positions in the market. There are several ways of doing this and it is up to the trader to decide which way to choose. The most common used form of hedging is done with help of the sensitivities of the options (Greeks).

2.3.1 Delta hedging

Delta hedging departs from making the trader's portfolio delta neutral. It can be achieved by taking an opposite position in the market with respect to the underlying asset. That is, if you sell a call warrant (delta is negative for the trader, i.e. delta is shorted) then he must either buy the underlying asset or buy a call option that has the same strike and maturity as the call warrant he just sold (Hull, 2006). At least one time during the trading day, the trader tries to have a delta-neutral-position. A delta-neutral-position is when the value of trader's portfolio does not fluctuate with respect to the underlying asset's movements, i.e. he has taken two different positions in the market that offset each other as previously described. By trading with options the trader can hedge his position with an instrument that will move in the same way as a warrant in the market with respect to the underlying asset (Hull, 2006). Because of the fact that delta changes, the position in the market will stay delta-neutral only short periods of time therefore the trader needs to rebalance his position in the market. This only applies if delta is hedged through buying the underlying asset directly in the market. If the trader finds an equal option on the market as the warrant he will not have to rebalance to the same extent. Therefore, if there is an underlying options market for the warrants underlying asset, hedging can and will be done by trading the options (Hull, 2006).

2.3.2 Gamma hedging

A delta neutral portfolio needs to be gamma-neutral to account for a possible large move in the underlying asset, between rebalancing. Gamma hedging is used to correct for the delta hedge error

that will arise from the non linear relationship between c and S , therefore the trader needs to hedge for this *curvature*. Gamma hedging for a trader can only be done by buying options or other non linear derivatives with the same characteristics as the warrants sold in the market. This is done in order to offset the positions taken by selling the warrants in the first place and create a gamma-neutral position (Hull, 2006).

2.3.4 Vega hedging

Vega hedging is needed because the volatility of the warrant's underlying asset is not constant. The value of the warrant will change with respect to the change in volatility the passage of time and the change of the underlying assets price. When issuing a warrant you are selling (short-selling) Vega regardless if the warrant is a call or a put. To hedge this volatility risk, i.e. balance the market position so a Vega-neutral position is created you must buy (go long) in Vega. You can easily do this by taking the corresponding long position in the underlying asset. As already discussed, this implies that a portfolio cannot be Vega-neutral and gamma-neutral at the same time if you only use one type of hedge, combining two different hedges will enable the trader to be gamma-neutral and Vega-neutral at the same time. For a trader it is difficult at all times to be delta-neutral, gamma-neutral and Vega neutral. According to Hull (2006), traders can rarely hedge their gamma and Vega exposures at all since that requires an existing underlying option market where the hedge can be made at competitive prices. As a rule of thumb options should be issued to be sold at-the-money, because the relative gamma and Vega is large (Hull, 2006). As time passes, the underlying asset will move, and at maturity (when the trader usually buys them back) Vega and Gamma are low in absolute terms and have very little influence on the price of the warrant. Hull (2006, p.363) states that "The nightmare scenario for an option trader is where written options remain very close to the money as the maturity date is approached". From the discussion postulated at hand above it is possible to see that if you sell Vega when Vega is large, and buy when Vega is low, you will earn the Vega spread (or volatility spread).

2.4 How to interpret the warrant's trading symbols

On the NDX, and the OMX exchange, warrants are quoted using a standardized system. This is done in order to simplify matters for investors when making their investment decisions. The quoted symbols tell the investor which the underlying asset is, expiration date, strike price, if it is a call- or a put warrant and the issuer of the warrant. An example of this is given below:

Quoted symbol: **SEB7F230CBK**

where:

- SEB is the underlying asset. In this case, it is the bank SEB
- 7 is the year of expiration (2007)
- F is the month of expiration and indicates if it is a call or a put, following the reasoning in the table below

Table 2.2 Interpretation of warrants

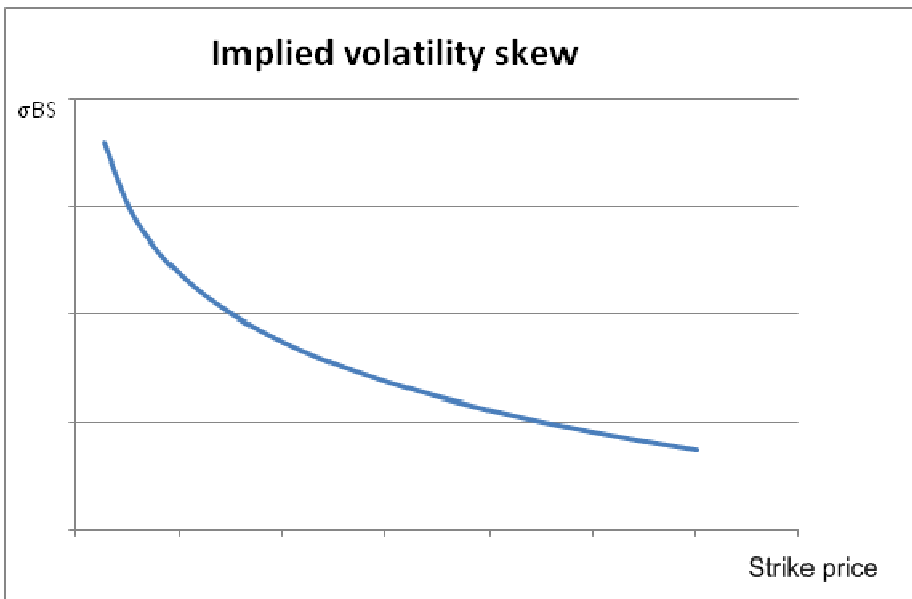
CALL		PUT	
Letter	Month	Letter	Month
A	January	M	January
B	February	N	February
C	March	O	March
D	April	P	April
E	May	Q	May
F	June	R	June
G	July	S	July
H	August	T	August
I	September	U	September
J	October	V	October
K	November	W	November
L	December	X	December

- 230 is the strike price of the warrant
- CBK is the issuer of the warrant, in this case Commerzbank AG

2.5 Volatility smile, volatility skew and volatility surface

A plot of the implied volatility of an option as a function of its strike price gives rise to a curve known as a *volatility smile* (for foreign currency options and equity options before 1987), or a *volatility skew* (for equity options after 1987) (Rubinstein, 1985; Hull, 2006). In other words, the volatility in equity warrants decreases when the strike price increases as can be seen in the figure below.

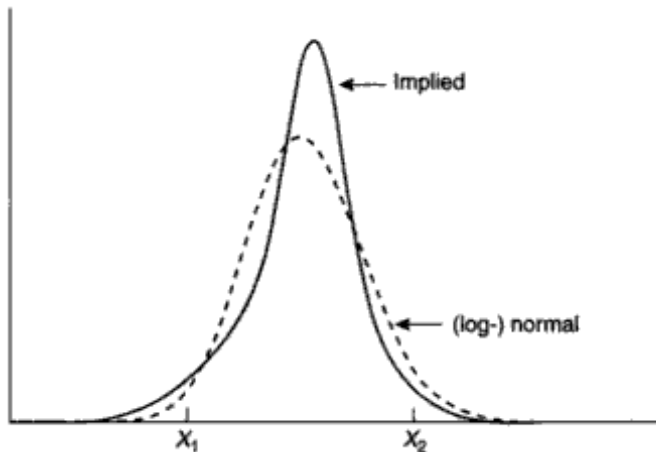
Figure 2.1 Volatility skew



Furthermore, it is also true that, as the stock price moves towards the money or in the money, the implied volatility tends to decrease (Gustafsson & Lindberg, 2005). This tendency is in line with Derman’s (1999) idea about “sticky moneyness”, which says that the volatility of an option only depends on its moneyness (S/K).

The implied probability distribution corresponding to the volatility smile for equities has a heavier left tail and a less heavy right tail than the lognormal distribution (see figure 2.2).

Figure 2.2 Implied/Lognormal Distribution (Los, 2003)

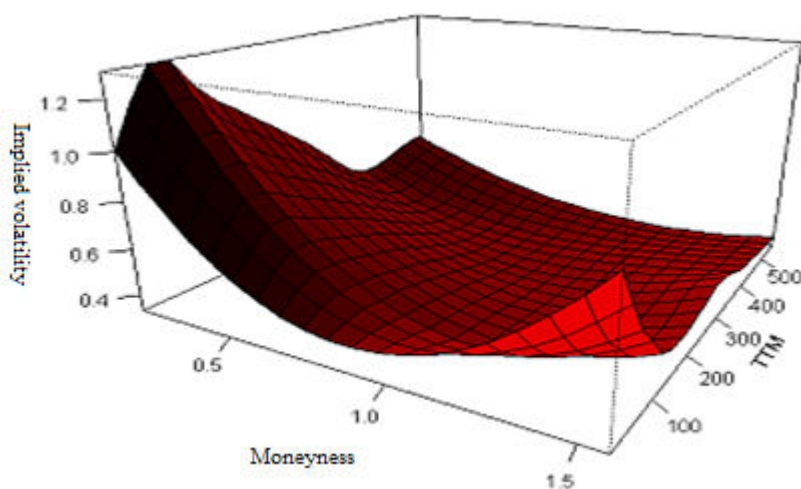


Departing from the above figure, consider a call warrant that is deep out-of-the money with strike price X_2 . This warrant has a lower price when the implied distribution is used than when the lognormal distribution is used because the warrant only pays off if the underlying assets price turns out to be above X_2 . The probability of this event to happen is lower for the implied probability distribution than for the lognormal distribution, leading to a relatively low price of the warrant (Hull, 2006). The relatively low price corresponds to a relatively low implied volatility, as can be

observed in the figure above. The opposite is true for a put warrant that is deep out-of-the-money with strike price X_1 , i.e. the implied distribution is expected to yield a relatively high price, hence a high implied volatility. Hull (2006) argues that one of the reasons behind these occurrences is the relation to a company's leverage. As its equity falls, its leverage increases, i.e. the equity becomes more risky, hence an increased volatility. The opposite, with increased equity and decreased volatility, is also true. Rubinstein (1994) explains "crashophobia" as one of the possible causes for the equity volatility skew. The volatility skew pattern did not occur before the market crash of October 1987 (where a volatility smile pattern was more common), and Rubinstein argues that the post-crash traders behave accordingly, pricing options with a possibility of a new market crash in mind. Yet another explanation is put forward by Passarelli (2005), where he argues that the issuance of "covered calls"⁴ with high strike prices are common in practice, with the intention being to gain the premium. This leads to a higher demand than supply, which in turn leads to an increase in price on options that are out of the money.

By combining the implied volatility as a function over time with the implied volatility as a function of moneyness, one can gain a volatility surface. The assumption by the BS model that volatility is constant over the lifetime of a plain vanilla option is violated by the empirical option price data at hand. The assumption of the volatility being constant over time implies that the implied volatility surface is flat over the options lifetime and over the strikes (or moneyness). Instead by deriving the implied volatility from empirical option price data, the pattern in figure 2.3 will be seen. The surface tells us how the implied volatility has varied over time and strikes (moneyness). The evolution of this surface in time shows the evolution of prices in the option market (Fonseca, 2002).

Figure 2.3 Volatility surface (Keller 2008)



⁴ A covered call is a process in which the investor owns shares of a stock, and writes a corresponding amount of call options.

2.6 The efficient market hypothesis' influence on GARCH

Since this thesis deals with financial time series and GARCH-forecasted volatility, it is interesting to scrutinize the main ideas behind the efficient market hypothesis (EMH) as developed by Fama (1970). An explanation why it is important will be given after the EMH has been reviewed. The EMH discusses to what extent information is reflected in the price of traded assets, such as stocks and bonds. Fama (1970) developed the EMH to include different levels of the EMH with respect to the information available:

- Weak-form efficiency

It is not possible to use historical information regarding an asset's price movements (returns) to gain excess return. The future price movement of the asset's price is random, and the use of technical analysis will not yield excess return over time.

- Semi-strong form efficiency

This level of efficiency implies that all publicly available information is reflected in an asset's price quickly and thus it is not possible to earn any excess return. Furthermore, neither technical analysis nor fundamental analysis can be used to gain excess return.

- Strong-form efficiency

In addition to publicly available information, insider information is also reflected in the asset's price, which makes it impossible for *anyone* to gain excess return.

GARCH (which will be presented in detail in the next chapter) utilizes historical values to forecast future volatility, which in turn can be used to forecast future asset prices. Hence, the different models within the GARCH-family can be considered to be consistent with the different levels of market efficiencies mentioned above. Furthermore, since GARCH innovations, η_{t-1} , are serially uncorrelated, using GARCH to model volatility does not breach the EMH (MATLAB Tutorial 2008). However, consider the strong-form level where insider information is reflected in the price of the asset. If insiders knew that a major event was about to happen in a company tomorrow, this information would be reflected in the price. This means that the volatility stemming from a GARCH-model conducted today about the volatility tomorrow would yield the same level of volatility as the market's implied volatility tomorrow.

3 Methodology and data collection

This section deals with the research approach and the choice of data, as well as the models used to attain and analyze the empirical data. Problems and weaknesses with chosen method and models are also accounted for.

3.1 Research approach

This thesis departs from specific observations, which are then used to detect certain patterns. We then formulate some form of hypothesis, ending up with the development of general conclusions or theories; hence we use an inductive approach (Bryman & Bell, 2003). The volatility observed and forecasted is retrieved by performing a quantitative study on European plain vanilla warrants issued by CBK on the NDX from January 2007 until June 2007.

3.2 Data collection and excluded observations

Due to the recent turbulence on the financial markets, the chosen warrants for observation are warrants issued no earlier than January 2007 with a maturity date no later than June 2007. Since one of the thesis' most important parameters is the volatility, limiting the time period to pre turbulence, a time period with less unforeseen events, i.e. less fluctuations in the financial market's volatility, can instead be studied. Employing these limits improves the results, since they can be used on a more general financial climate. As opposed to using observations from the recent turbulent period that might have led to results only applicable to periods experiencing turbulence. The observed warrants are European plain vanilla warrants issued by CBK traded on the NDX. The reason why European plain vanilla warrants have been chosen to be included in the analysis and not Asian tail is because of the specific feature of the Asian tail option. A reference price is activated at the end of a warrants life if the underlying should fall below a volume weighted 10-day average before the warrant expires (Hull, 2006). This feature would have caused difficulties when backing out the implied volatility of such warrants. European plain vanilla warrants on the other hand do not include this specific feature, and follows the underlying assets price movement all the way to maturity. Hence, no average of the underlying asset's price during the last 10 days is used when pricing a European plain vanilla warrant. By using European plain vanilla warrants, a more standardized forecasting method can be used, without the need of a Monte Carlo simulation

method⁵. To make the calculations of implied volatility more responsive, certain requirements of the underlying assets needs to be fulfilled for the time period observed. These are; no extraordinary dividend payments, shares repurchased, split of the underlying asset's share or spinoffs. In other words the strike price and the parity of the chosen warrants have not been adjusted for these issues.

The authors' initial intention was to include warrants issued by UBS into the study. This would have been interesting since it would have enabled a comparison between different issuer of warrants. Due to a couple of reasons, it was not possible to retrieve warrants issued by UBS that fulfilled certain requirements. First, the amount of issued warrants by UBS was scarce during the time period chosen. Second, close to all issued warrants by UBS had a maturity date in July, i.e. beyond a priory time period chosen. Third, the authors were not able to retrieve the final terms on several warrants. The final terms contains important information about the warrant in terms of type, legal issues and parity.

3.2.1 Warrants data collection

The closing bid and ask price of the chosen warrants were collected from NDX. If the warrant's closing bid and ask price was missing from any time series due to technical problems in market making from CBK or because of other market implied problems, (market risk increase due to upcoming news or other type of stock price driving events) the quoted day before bid and ask closing price was used. The warrants chosen were issued 2007-01-19, 2007-02-12, 2007-02-13 and 2007-03-02, with maturity date no later than 2007-06-15. The corresponding final terms sheet for the different issues, were downloaded from the web page of Commerzbank AG, in order to collect the ISIN code of the underlying stock and the correct maturities, parities etc. The bid and ask prices were quoted in SEK for warrants with foreign underlying stocks while the strike price was given in US\$, the quoted bid-ask price in SEK was exchanged to US\$ before deriving the implied volatility (since the underlying stock price (S) was also retrieved in US\$). The daily quotes of the exchange rate SEK/US\$ was retrieved from DataStream. The chosen risk-free interest rate used is the daily quotes of the 6-month STIBOR, retrieved from DataStream Since the quoted bid-ask prices of the warrants have been priced with respect to the ordinary dividend payments; the dividend yield of the different stocks were retrieved from DataStream.

3.2.2 Underlying stock data collection

For each warrant, the underlying stocks daily closing price was retrieved from DataStream from on a priory defined time period. The criteria regarding the time period was to gather as much

⁵ A Monte Carlo simulation implies an advanced method of simulating a large number of paths of future stock prices. This would be needed if Asian tail warrants were used since they are priced using the average stock price of the last 10 days before maturity, and not the actual stock price.

observations as possible. Since the time period chosen is different and stock dependent it will be in detail reviewed in the empirical findings section of this thesis. Furthermore, we calculated the log “over the week return” (assuming 5 days per week) of the stock, by applying the following formula:

$$rt_w = \ln\left(\frac{p_w}{p_{w-1}}\right),$$
 where p_w is the Friday closing price of the stock. If Friday was a holiday then the

Thursday closing price was used and so on.

3.2.3 Forecasting

The log “over the week stock return’s” volatility was forecasted by using EGARCH(1,1) since it allows for asymmetric shocks and therefore the model is assumed to make forecasts more in accordance to the market conditions. When making forecasts there exists several applicable methods. They are all independent of which model you are using and it is up to the researcher to choose which one he regards as the most suited one, depending on the characteristics of the data. We intend to forecast out-of-sample i.e. a multi-step-period ahead forecast (Brooks, 2002). Because of the nature of GARCH-type models, they tend to make unreliable forecasts over longer horizons. The reason for this is that when you forecast out-of-sample, the model parameters estimated for $t-1$, will be used for $t+s$ forecasts, where s is forecast horizon. This implies that as s increases ($t+2$ forecasts will be based on $t+1$ and so on) forecasts will be based on new forecasts which will make the out-of-sample forecast less reliable. GARCH-type model generally make adequate $t+1$ forecast (Ederington & Guan, 2007).

The longest forecast horizon in our research is 18 weeks. In order to reduce the forecast horizon, to find a good solution to this trade-off, we have used the return over the week instead of daily return or intraday return. Nevertheless, there is an approach developed by Ederington et al. (2007) called ARLS, which according to their results, makes better forecasts on out-of-sample basis than GARCH-type models. We choose not to use this approach in our thesis since ARLS hypothesize that the stock returns are log-normally distributed. For us, Nelson’s EGARCH fulfills our requirements for a decent modeling of the market, which is that asymmetry is allowed for, and that we can choose the distribution of the residuals ourselves. Since we know that stock price return series depart from normality, we have employed the Generalized Error Distribution (GED) in our forecast. The computer software Eviews in which we have modeled the volatility allows to choose GED and calculates the parameter needed for it (r) (Eviews 5.0 manual, 2008). The resulting forecasted variance from Eviews (which is given as weekly variance) is then annualized by multiplying it with 52 (i.e. the number of weeks per year). In order to reach the standard deviation (volatility), the square root is taken on the forecasted variance.

3.3 Deriving the implied volatility

To back out the implied volatility from the BS – formula it is necessary to apply an iterative method of bisections. The reason for this is that the BS – formula cannot be reformulated so that the volatility (σ) can be written as a function of the warrants price. We therefore need to derive a linear relationship in terms of C , S , K , r and t , to be able to calculate the implied volatility from the BS formula. Here, C_w is calculated as the observed average bid-ask price for a call, i.e. $(\text{bid}+\text{ask})/2$. The same logic is used for a put warrant.

First define:

$$\mathbf{A} = C_{\text{option}}/S \quad \mathbf{B} = K/S \quad \mathbf{R} = rt$$

$$y = \sigma\sqrt{t} = IV\sqrt{t}$$

$$1. A = N(d_1) - Be^{-R}N(d_2)$$

$$\text{where: } d_1 = \frac{(-\log(B) + R(1/2)y^2)}{y}$$

$$\text{and } d_2 = d_1 - y$$

Our task is to find y in terms of \mathbf{A} , \mathbf{B} and \mathbf{R} .

We rewrite (1) so:

$$\text{Error} = N(d_1) - Be^{-R}N(d_2) - A$$

When Error is 0, then for any given number of A , B and R , an y -value makes Error = 0, $IV = \frac{y}{\sqrt{t}}$.

This approach has limitations. One known issue to the authors of this thesis is when $S \gg K$ for a call i.e. a deep-in-the-money call, the implied volatility tends to go to 0. Hence, if we have a deep-in the money option $\rightarrow S \gg K$ then d_2 and $d_1 \rightarrow \infty \rightarrow N(d_1)$ and $N(d_2)$ both = 1.

The price of a call will then be $c = S - Ke^{-rt}$, in the limit as the implied volatility becomes 0. The interesting thing is that there is no implied volatility that can be derived from the actual warrants price, since the intrinsic value rule has been violated i.e. $c \geq S - Ke^{-rt}$. Whether this condition is violated or not is solely determined by the risk-free interest rate that you use (r) (Ponzo, 2008).

The authors have used an MS Excel VBA-script that uses the principle exposed above to derive the daily implied volatility from the BS formula. The script assumes 252 trading days as a base for calculating the implied volatility. The script is an open source code retrieved online from www.powerxl.com. To present this script in detail in this thesis would violate one of the terms of utilizing the script. (For interested readers please go to the webpage and look for IVOL).

3.4 Econometric models

This section will introduce two econometric models that can be used to forecast volatility.

3.4.1 Generalized Auto Regressive Conditional Heteroskedasticity (GARCH)

Following the reasoning in the theory section that the variance is time varying, the underlying asset is non-normally distributed and the occurrence of *volatility clustering*, we now introduce a model that properly manages these features, i.e. "...treats the heteroskedasticity as a variance to be modeled..." (Engle, 2001, p.157). The model is denoted GARCH (Bollerslev, 1986), and is subsequently used to forecast the volatility. GARCH is in turn a development of Engle's (1982) ARCH model. In a GARCH model, the conditional variance, σ_t^2 , depends on past values of the squared errors (η_{t-1}^2) and on past conditional variances σ_{t-1}^2 . The following model is a GARCH(1,1):

$$\sigma_t^2 = \omega + \beta\sigma_{t-1}^2 + \alpha\eta_{t-1}^2$$

with mean equation:

$$y_t = \mu + \phi y_{t-1} + \eta_t \quad \eta_t \sim N(0, \sigma_t^2)$$

In a GARCH(1,1), only one lagged squared error and one lagged variance is used, this is said to be enough to capture the volatility dynamics. The term η_t in the model above has mean zero and is conditional on time t-1 information. Campbell et al. (1997) describes it as the shock to the volatility, and the coefficient α as the measurement of the degree of which a volatility shock today affects the volatility of the next period. Whilst $(\alpha+\beta)$ measures the pace at which this effect dies out over time. Departing from the GARCH(1,1) we can now construct a model that lets us forecast the volatility. Letting $\alpha+\beta < 1$, the *unconditional* variance is equal to:

$$\sigma^2 = \frac{\omega}{1-\alpha-\beta}$$

By recursive substitution and the law of iterated expectations the conditional expectation of volatility j periods ahead is:

$$E_t[\sigma_{t+j}^2] = (\alpha + \beta)^j \left(\sigma_t^2 - \frac{\omega}{1-\alpha-\beta} \right) + \frac{\omega}{1-\alpha-\beta}$$

where the volatility forecast reverts to its unconditional mean, at rate $(\alpha+\beta)$.

In order to estimate a GARCH model, the *maximum likelihood* technique is utilized. The basic intuition behind the maximum likelihood approach is to find the most likely values of the parameters given the actual data. More specifically, a log-likelihood function is formed and the values of the parameters that maximize it are sought (Brooks, 2002). For a GARCH(1,1) with a mean equation defined as:

$$r_t = \gamma + \eta_t$$

$$Var[\eta_t | \Omega_{t-1}] = \sigma_t^2$$

and normally distributed residuals, the conditional log-likelihood function is:

$$LnL_t = -0,5 \ln(2\pi \times \sigma_t^2) - 0,5 \frac{\eta_t^2}{\sigma_t^2}$$

the next step is to maximize the above function with respect to α , β , ω , i.e.:

$$\max \ln L = \sum_t^N \ln L_t \text{ w.r.t. } (\omega, \alpha, \beta)$$

with the additional constraint that α , β , $\omega \geq 0$, in order to guarantee a resulting positive volatility.

Ederington et al. (2007) hypothesizes that because volatility in standard GARCH is a linear function of squared residuals, the model tends to overestimate the volatility, so when a high volatility day occurs a *high* volatility forecast results, which implies *biased* forecasts.

3.4.2 EGARCH

One of the developed versions of GARCH is the exponential GARCH (EGARCH), and was first proposed by Nelson (1991).

$$\ln(\sigma_t^2) = \omega + \beta \ln(\sigma_{t-1}^2) + \gamma \frac{\eta_{t-1}}{\sqrt{\sigma_{t-1}^2}} + \alpha \left[\frac{|\eta_{t-1}|}{\sqrt{\sigma_{t-1}^2}} - \sqrt{\frac{2}{\pi}} \right]$$

It has mainly two advantages over GARCH. First, the underlying assumption in GARCH is that positive and negative error terms have the same effect on the volatility, i.e. good and bad news have the same effect on volatility. By log-transforming the volatility, it ensures its non-negativity even if the parameters are negative, hence it does not artificially impose non-negativity on the parameters, as GARCH does (Brooks, 2002). In other words, EGARCH allows for different treatment of good

and bad news. Second, it allows for asymmetry, i.e. positive and negative shocks can render asymmetric reactions. This can be seen through the relationship between volatility and returns, e.g. if this relationship is negative, then γ will be negative. In general EGARCH, GARCH and GJR tend to overestimate the standard deviation of stock price returns. For GARCH(1,1) and GJR, but not EGARCH this bias is particularly strong when very high volatility is predicted (Ederington et al. 2007).

The problem with EGARCH is that, since we do not know the traits of the future distribution of the residuals from the mean equation we need to somehow estimate it. In other words, the skewness and the kurtosis need to be estimated in order to gain a good estimate of the forecasted volatility. By maximizing the log likelihood function in Eviews, we find the parameters that should maximize the sum of log-likelihood function with respect to the chosen distribution, β , γ and α :

$$\ln L_t = -\frac{1}{2} \log \left(\frac{\Gamma(1/r)^3}{\Gamma(3/r)(r/2)^2} \right) - \frac{1}{2} \log \sigma_t^2 - \left(\frac{\Gamma(3/r)(y_t - X_t' \Theta)^2}{\sigma_t^2 \Gamma(1/r)} \right)^{r/2}$$

Eviews finds for us, the estimates of the parameters of the variance equation. Second, it automatically generates the distribution that best fits the data, i.e. it solves the problem mentioned above about the estimation of the future distribution and calculates the GED-parameter. The GED-parameter in turn tells us whether the GED is normally distributed ($r=2$), or if it is fat-tailed ($r<2$).

3.5 Reliability

The basic intuition behind the concept of reliability is, according to Bryman & Bell (2003) that a study conducted can be repeated yielding similar results as it did during the first occasion. Hence, the correlation between the two tests will be high. To be able to assess if this study is reliable we need to turn to the pillars on which the thesis is built upon, namely the data. The data in this thesis is collected from sources such as DataStream and NDX. DataStream can be considered reliable since it gets its data from the companies themselves and from different countries' regulated marketplaces. NDX provides a platform for trading of derivatives and other instruments, and is supervised and monitored by Finansinspektionen (the Swedish Financial Supervisory Authority), which makes NDX a reliable source of information.

3.6 Validity

Bryman and Bell (2003) argues that validity is one of the most important measures within research. A measurement, in our case the implied- and forecasted volatility, is valid when it measures what it is suppose to measure. Since the intention of the thesis is not to use the calculated volatilities as a

measure of risk (as it normally is), but instead as a comparison with each other, a validity problem does not exist under these presumptions. However, an accuracy problem might instead lie within the parameters and assumptions behind the implied volatility (as mentioned in 3.3). This in turn might lead to faulty conclusions when comparing the implied volatility with the EGARCH-forecasted volatility. This said, the difficulties that exist when calculating the implied volatility are known and accounted for in the best way possible.

4 Empirical findings

In this chapter, the findings from our observations are presented, both verbally and graphically. The warrants' and stocks' statistics are also exhibited and commented upon.

4.1 The underlying stocks descriptive statistics

In our sample we have the following stocks, LM Ericsson AB B share (ERIC B), Svenska Enskilda Banken AB C share (SEB C), Autoliv Inc SDB (ALIV-SDB), Lundin Petroleum (LUPE), Stora Enso R (STE-R), Tele 2 AB B share (TEL2 B), Trelleborg AB B share (TREL B), Gazprom SP ADR (GAZP), Yahoo! Inc. (YHOO), Svenska Handelsbanken AB A share (SHB A) and Nordea Bank AB (NDA-SEK).

Table 4.1 Underlying stock description 1

	<i>ERIC B</i>	<i>TEL2 B</i>	<i>TREL B</i>	<i>SHB A</i>	<i>NDA-SEK</i>	<i>SEB C</i>
ISIN	SE0000108656	SE0000314312	SE0000114837	SE0000193120	SE0000427361	SE0000148884
Time period	5/01/1998 – 6/15/2007	5/01/1998 – 5/18/2007	5/01/1998 – 5/18/2007	5/01/1998 – 6/15/2007	5/01/1998 – 6/15/2007	5/01/1998 – 6/15/2007
Nr. of 'return over the week'	476	472	472	476	476	476
Mean	-0.000693	0.000615	0.001676	0.001158	0.001377	0.001538
Kurtosis	6.344901	5.930062	5.192023	6.242070	6.202706	10.71855
Skewness	-0.339837	-0.316872	0.249431	0.133321	-0.077516	0.213066
Jarque	231.0646*	176.7423*	99.39200*	209.8786*	203.9136*	1185.191*
Bera	(0.00000)	(0.00000)	(0.00000)	(0.00000)	(0.00000)	(0.00000)
ARCH LM Test	59.98770* (0.00000)	43.78628* (0.00000)	11.61593** (0.040447)	39.53084* (0.00000)	8.547273 (0.128543)	42.25545* (0.00000)

(*) statistically significant at the 99% confidence level

(**) statistically significant at the 95 % confidence level

(***) statistically significant at the 90 % confidence level

p-values within parenthesis

Table 4.2 Underlying stock description 2

	<i>GAZP</i>	<i>STE-R</i>	<i>YHOO</i>	<i>LUPE</i>	<i>ALIV-SDB</i>
ISIN	US3682872078	FI0009007611	US9843321061	SE0000825820	SE0000382335
Time Period	5/01/1998 – 4/20/2007	12/29/1998 – 5/18/2007	5/01/1998 – 4/20/2007	9/06/2001 – 5/18/2007	5/01/1998 – 5/18/2007
Nr. of 'return over the week'	468	437	468	297	472
Mean	0.003644	0.001200	0.002798	0.009629	0.001071
Kurtosis	4.815784	4.850835	5.221447	6.986917	13.21283
Skewness	0.027757	0.090113	0.152467	-0.339487	-1.246994
Jarque	64.35302*	62.96574*	98.04235*	202.4118*	2173.599*
Bera	(0.00000)	(0.00000)	(0.00000)	(0.00000)	(0.00000)
ARCH LM Test	25.95490* (0.00091)	33.40891* (0.00003)	22.04748* (0.000513)	10.13715*** (0.071441)	1.487917 (0.914460)

(*) statistically significant at the 99% confidence level

(**) statistically significant at the 95 % confidence level

(***) statistically significant at the 90 % confidence level

p-values within parenthesis.

The warrants' underlying assets are presented in the table above, and the characteristics of the stocks will now be presented in order to highlight certain matters that are of importance to the study. It should be noted that the calculated returns are made on a weekly basis, hence the same characteristics might not exist if the study would have been made on daily returns.

According to the Jarque Bera (JB) tests performed, it can be seen that none of the observed stocks are normally distributed, i.e. it is statistically significant that the null hypothesis of the stocks being normally distributed can be rejected. Furthermore, it can be seen that all stocks have fat tails (Kurtosis value larger than 3 (Brooks, 2002)) and experience skewness. However, some stocks experience negative skewness, whilst some experience positive skewness. Moreover, all stocks show ARCH-structure except for ALIV-SDB and NDA-SEK. This implies that the time series observed in each stock experiences volatility clustering.

4.2 The warrants chosen

In order to make the upcoming graphs over the warrants easier to understand, a table containing the different warrants and its respective characteristics can be seen below:

Table 4.3 Warrant description

Call			Put	
D-Warrants – maturity 04/20/07	E-warrants – maturity 05/18/07	F-warrants – maturity 06/15/07	Q-warrants – maturity 05/18/2007	R-warrants – maturity 06/15/07
GAZ7D45CBK	ALI7E460CBK	ERI7F27CBK	ALI7Q415CBK	ERI7R25CBK
GAZ7D50CBK	LUP7E80CBK	ERI7F29CBK	TEL7Q95CBK	NDA7R100CBK
YHOO7D30CBK	TEL7E115CBK	ERI7F31CBK	TRE7Q150CBK	
YHOO7D35CBK	TEL7E130CBK	SEB7F250CBK	STE7Q110CBK	
	TRE7E170CBK	SEB7F230CBK		
		SHB7F230CBK		

Observe that the bid and ask price for YHOO- and GAZP warrants are quoted in SEK, but the *strike price* of the underlying asset is given in US\$.

4.3 Forecast periods & estimated parameters used for the forecast

In the following two tables the results of the EGARCH modeling are presented.

Table 4.4 Forecast periods and EGARCH estimated parameters 1

	<i>ERIC B</i>	<i>TEL2 B</i>	<i>TREL B</i>	<i>SHB A¹</i>	<i>NDA-SEK²</i>	<i>SEB C</i>
ISIN	SE0000108656	SE0000314312	SE0000114837	SE0000193120	SE0000427361	SE0000148884
Forecasted time period	2/12/2007 – 6/15/2007	2/13/2007 – 5/18/2007	2/13/2007 – 5/18/2007	2/13/2007 – 6/15/2007	2/12/2007 – 6/15/2007	2/13/2007 – 6/15/2007
Nr. of forecasted weeks (σ_w^2)	18	14	14	18	18	18
Time period used for parameter estimation	5/08/1998 – 2/09/2007	5/08/1998 – 2/09/2007	05/08/1998 – 2/09/2007	5/08/1998 – 2/09/2007	5/08/1998 – 2/09/2007	5/08/1998 – 2/09/2007
Nr. of weeks	458	458	458	458	458	458
β	0.972892(*)	0.978653(*)	0.884410(*)	0.954787(*)	0.970737(*)	0.963951(*)
α	0.227347(*)	0.207857(*)	0.119185	0.209865(*)	0.172840(*)	0.069740(***)
γ	-0.054340(***)	0.002146	-0.096543(**)	-0.034363	-0.093631(**)	-0.151944(*)
GED parameter (r)	1.484490(*)	1.367255(*)	1.491465(*)	1.552484(*)	1.479327(*)	1.461222(*)
Log likelihood	595.0200	674.0899	854.7935	930.6203	859.9438	804.9724

(*) statistically significant at the 99% confidence level

(**) statistically significant at the 95 % confidence level

(***) statistically significant at the 90 % confidence level

1 – did not converge

Table 4.5 Forecast periods and EGARCH estimated parameters 2

	<i>GAZP</i>	<i>STE R</i>	<i>YHOO</i>	<i>LUPE</i>	<i>ALIV-SDB³</i>	<i>SEB C⁴</i>
ISIN	US3682872078	FI0009007611	US9843321061	SE0000825820	SE0000382335	SE0000148884
Forecasted time period	1/19/2007 – 4/20/2007	2/13/2007 – 5/18/2007	1/19/2007 – 4/20/2007	2/12/2007 – 5/18/2007	2/12/2007 – 5/18/2007	2/23/2007 – 6/15/2007
Nr. of forecasted weeks (σ_w^2)	13	13	13	14	14	16
Time period used for parameter estimation	5/08/1998 – 1/12/2007	1/05/1999 – 2/09/2007	5/08/1998 – 1/12/2007	9/13/2001 – 2/08/2007	5/08/1998 – 2/09/2007	5/08/1998 – 3/02/2007
Nr. of weeks	455	424	455	283	458	460
β	0.970290(*)	0.989326(*)	0.968005(*)	0.877283(*)	0.978915(*)	0.961518(*)
α	0.252990(*)	0.166190(*)	0.253787(*)	0.138272(***)	0.118959(**)	0.071593(***)
γ	0.070000(***)	-0.039625	-0.029254	0.164413(**)	-0.078551(**)	-0.155166(*)
GED parameter (r)	1.704890(*)	1.550286(*)	1.476277(*)	1.215256(*)	1.303142(*)	1.463644(*)
Log likelihood	570.5182	730.6881	517.3665	413.4721	850.4194	810.0085

(*) statistically significant at the 99% confidence level

(**) statistically significant at the 95 % confidence level

(***) statistically significant at the 90 % confidence level

2,3 – Recall that the arch structure not found is shown in table 4.1 and 4.2

4 – Due to shorter time to maturity the parameters had to be re-estimated to match SEB7F230CBK

Departing from the time period from which the forecast starts (forecast time period), the warrant's time to maturity corresponds to the time period forecasted. E.g. the GAZP warrant had a life time stretching from 1/19/2007 to 4/20/2007, which corresponds to the forecast of 13 weeks (Nr. of forecasted weeks, σ_w^2 , where w is the number of the week forecasted $1 \leq w \leq 13$). The time period used for parameter estimation begins 5/8/1998 on all stocks, except for STE R (1/05/1999) and LUPE (9/13/2001), and ends one week before the warrants are issued.

The estimated EGARCH parameters β , α and γ are now presented:

- β is statistically significant with a 99% confidence interval for all stocks. All observed β :s are less than 1, which implies that the variance process is stationary (Pederzoli, 2006) i.e. the variance will not increase with the forecast period chosen.
- α is statistically significant with a level of significance stretching from 90% to 99% on all stocks, except for TREL B where α is not statistically significant different from zero. α tells us the size of the effect that shocks have on the time-varying variance.
- γ varies between being statistically significant and not being statistically significant (see table 4.4-4.5 for details). γ captures the asymmetry in the innovations, i.e. negative shocks have larger impact on the variance than equally big positive shocks.

The GED-parameter, r , is below 2 in all cases, implying a distribution with fat tails.

4.4 Presentation of the implied volatility and the EGARCH forecasted volatility

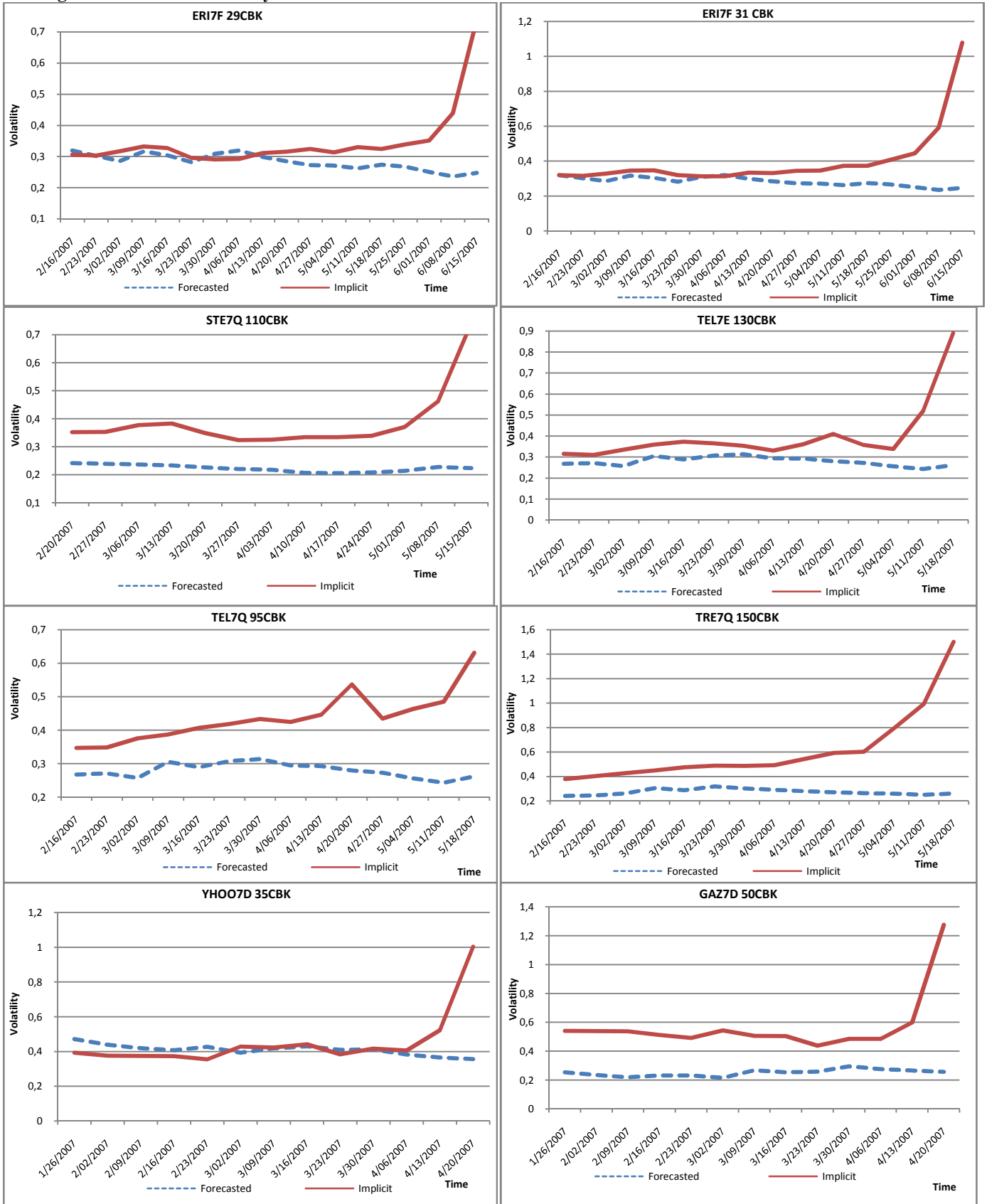
Tables containing the warrants and the numbers of its respective EGARCH- and implied volatility outputs can be found in the appendix. In addition to this, graphs containing the ratio (i.e. the implied volatility divided by the forecasted volatility) over the moneyness and the lifetime of the warrant respectively are also presented in the appendix⁶. The authors will now display graphically, and to some extent verbally the difference between the implied- and the EGARCH-forecasted volatility for the different warrants. They will be presented according to their “moneyness”, i.e. if they are in- at- or out of the money. “Moneyness” is calculated by dividing the stock price with the strike price:

- Out-of-the-money: $S/K < 1$ for a call and K/S for a put
- At-the-money: $S/K \approx 1$
- In-the-money : $S/K > 1$ and for a call and K/S for a put

⁶ The authors would like to stress that the graphs containing the ratio are presented in the appendix due to the large amount of space they require, but should nevertheless be noticed and looked at by the reader since they will be analyzed in the next chapter without any further presentation in this section.

4.4.1 Out-of-the-money warrants

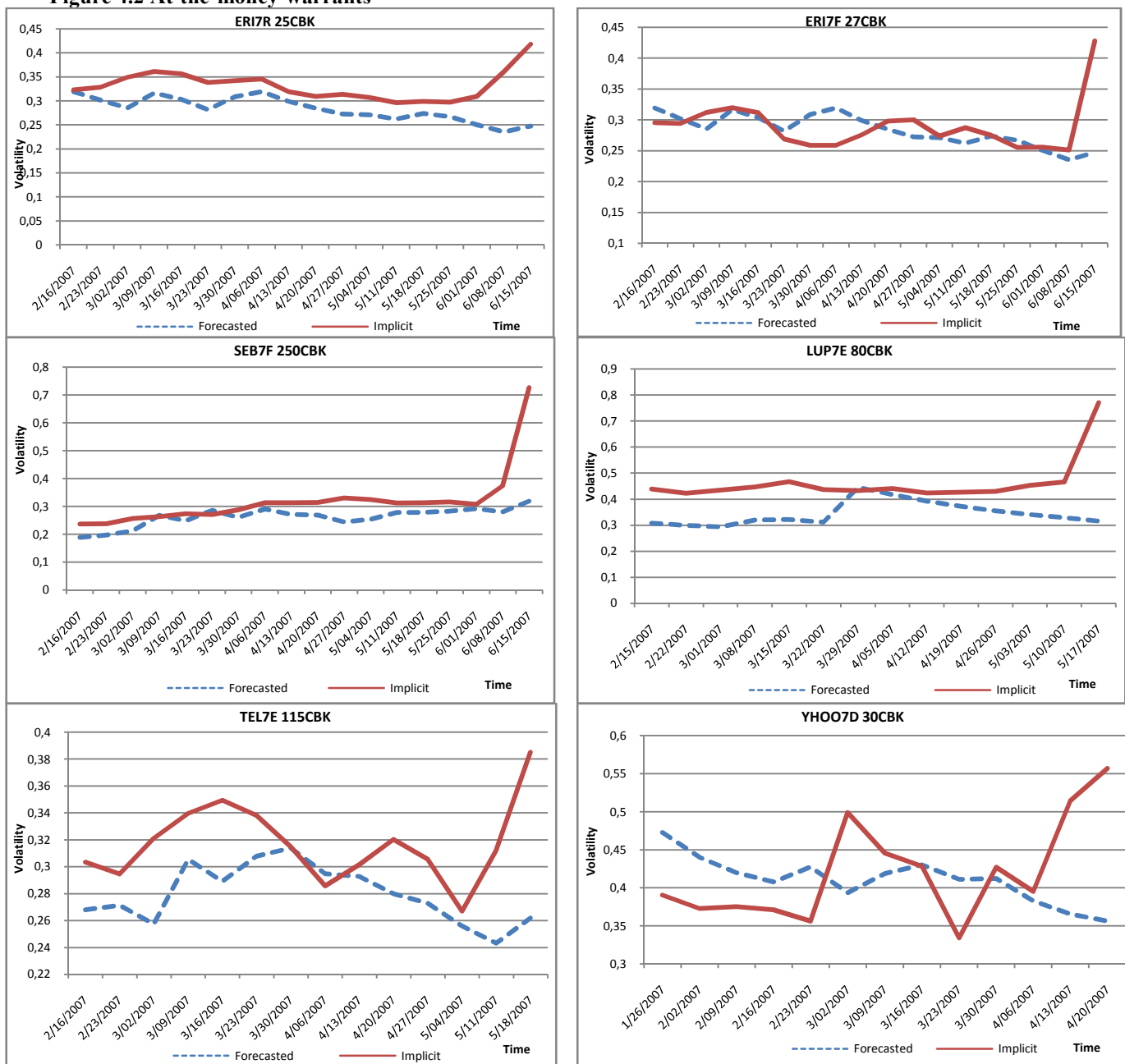
Figure 4.1 Out-of-the-money warrants

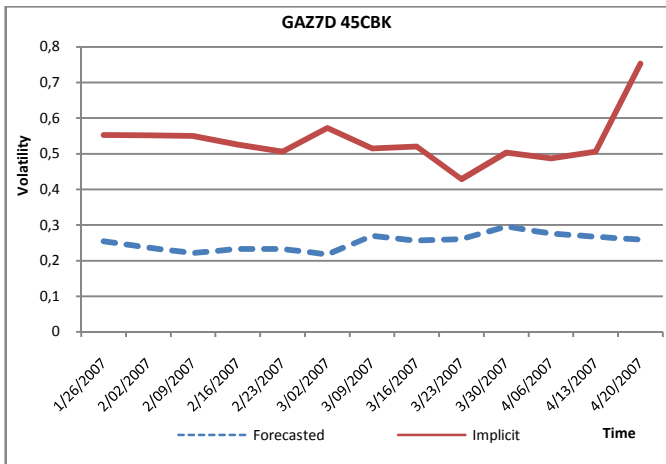


As can be seen in the above graphs there exist two different patterns amongst the warrants. First, ERIF 29CBK, ERIF7F 31CBK, TEL7E 130CBK and YHOO7D 35CBK all exhibit a fairly low spread between the forecasted and the implied volatility (from now on the difference between the implied volatility and the forecasted volatility will be denoted spread). Second, STE7Q 110CBK, TEL7Q 95CBK, TRE7Q 150CBK and GAZ7D 50CBK exhibit a greater spread. In addition to this, there is a characteristic that apply for the entire set, namely a great surge in implied volatility starting two to one week before maturity. Finally, YHOO7D 35CBK is the only out-of-the-money warrant that has a higher forecasted than implied volatility during its entire lifetime.

4.4.2 At-the-money warrants

Figure 4.2 At-the-money-warrants

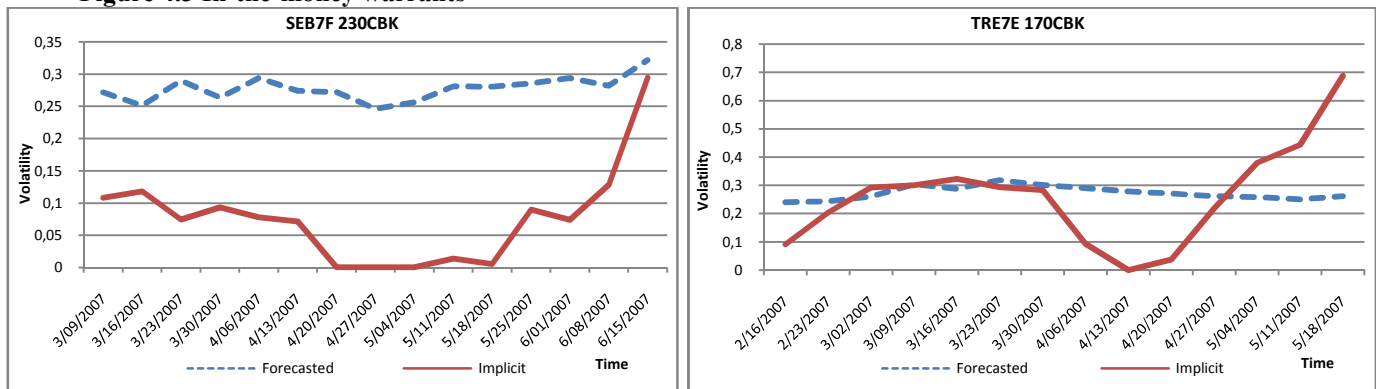




A minor spread can be observed in the warrants of SEB, i.e. SEB7F 250CBK. YHOO7D 30CBK experience a rather big fluctuation in the spread over time, and has the same characteristic in its initial life time as the YHOO7D 35CBK which was out-of-the-money, i.e. the forecasted volatility is larger than the implied. Furthermore, GAZ7D 45CBK show a big spread during its entire lifetime.

4.4.3 In-the-money warrants

Figure 4.3 In-the-money warrants



As mentioned in section 3.3, it is not possible to derive a correct implied volatility for warrants that are deep in-the-money by using the method applied in this thesis. As a result, TRE7E170CBK that is in-the-money during its entire lifetime and SEB7F230CBK that is in-the-money during the majority of its lifetime (0.98-1.06) show a faulty implied volatility (as can be seen in the graph above) with periods with zero implied volatility. Hence, these two warrants will not be used in the analysis.

5 Analysis

In this section the empirical findings are analyzed and scrutinized based on the theory discussed in previous sections.

Since the changes in the different parameters depend on each other, the analysis must be made with this relationship in mind. In other words, the ratio between the implied volatility and the forecasted volatility (from now on called “the ratio”) depends on the change in the underlying asset, which in turn is changing over time. Due to the insufficient amount of observations, a surface of the ratio as a function of time to maturity and moneyness is not possible to attain⁷. Instead the analysis of the findings will be approached from two angles:

- The change in ratio over the lifetime of the warrant
- The change in ratio over the moneyness of the warrant

Due to the unattainable graph of the ratio surface, a verbal reasoning will instead be made based on a combination of the above two bullet points.

5.1 Proof and reasons why implied- is higher than forecasted volatility

First and foremost, the authors would like to stress that, looking at the graphs in the empirical findings we see that a majority of the warrants have a higher implied volatility than forecasted volatility during a majority of their lifetime. This result was quite expected and shows that:

1. The warrant market is not driven by supply and demand. Instead it is the market makers that quote bid- and ask prices, leading to an individually set volatility, deriving from expectations by the market.
2. EGARCH only considers historical volatility, i.e. it does not incorporate any form of market speculations when forecasting the volatility.

5.2 The change in ratio over the lifetime of the warrant

This section refers to exhibit one in the appendix where graphs are displayed showing how the ratio changes over time for each warrant. Several findings have been made and will now be presented and analyzed below. Starting off by looking at the time closest to maturity for each warrant, the authors can observe a rapid increase in the ratio for the entire set of warrants. This can be interpreted as if the EGARCH do not account for the rapid surge in volatility during the last couple of weeks when forecasting volatility. This volatility surge probably stems from that the chosen warrants do not have Asian tail. The non-existence of an Asian tail implies that the risk of being in

⁷ This would have rendered a surface of the ratio, as a function of moneyness and time to maturity, much like the idea behind a volatility surface.

the market for the market maker during the last couple of weeks increases tremendously, and he therefore needs to rise the volatility to compensate him for the risk of being in the market. The points put forward in the ex ante discussion about Vega regarding that Vega is large at the end of the lifetime of the warrant makes it even more difficult for the trader to hedge his position. Another explanation for the surge in the ratio is that the strength of the volatility forecast is weaker in the end of the forecasting period. The intuition behind this is that the conditional variance depends on the conditional variance from $t-1$, which in turn depends on $t-2$. Hence, the forecast from the end of the forecasting period is less reliable than the forecasts from the beginning of the period.

Moving on with the analysis of the ratio as a function of the lifetime of the warrant, an interesting trend can be seen. The authors argue that a “smile” in the ratio over time can be observed, i.e. the forecasted volatility tends to be more accurate in the middle of the lifetime of certain warrants than in the beginning and at the end. Polynomial trend lines of third order have been added to the graphs in exhibit one in order to strengthen the above argument. By adding the trend lines it becomes clear that the majority of the warrants experience an increase in the ratio in the beginning of their lifetime, followed by a decrease and finally a rapid surge close to maturity. The authors have not found any theories supporting these findings, and it might be necessary to scrutinize the market maker’s trading behavior in order to explain the results.

As two underlying assets (YHOO and GAZP with four corresponding warrants) are not traded in Sweden it is interesting to see if they exhibit certain characteristics. Looking at exhibit one in the appendix it can be seen that the warrants with GAZP as underlying have a ratio of around 2 during their entire lifetime, whilst warrants with YHOO as underlying have a ratio of around 1 during their entire lifetime. This rather large difference in ratio might occur because of the risk associated with each underlying asset respectively. The risk we are talking about here is the risk of not being able to hedge your position due to the non-existence of an option market in the underlying asset (as mentioned in the hedging section of the theory chapter). In this case, the GAZP stock is traded over-the-counter (OTC), and no options exist on it. Hence, since the market maker who quotes bid and ask prices for warrants with GAZP as the underlying asset is not able to hedge his position, he faces a higher risk, leading to that he takes a higher volatility than the proxy volatility in order to compensate for the risk he faces. On the contrary we have the warrants with YHOO as the underlying asset which is traded on Nasdaq and has a liquid options market, making it easier to hedge. Thus, it can be concluded that the higher volatility set by the market maker derives only from the amount of risk he takes in the market. Furthermore, the ratio of YHOO warrants is under 1 during the initial month of the warrants’ lifetime. This is in line with Figlewski’s theory about market maker’s intention to increase demand by lowering the volatility below the true volatility.

Since the warrants with YHOO as the underlying asset are the only ones that have a ratio lower than one in the beginning of their lifetime, it might be argued that this is done in order to increase the interest for the warrants. Reasons for this might be that YHOO is a foreign traded stock, and therefore is more difficult to sell to investors on the Swedish market, hence a lower price (lower volatility) might induce increased outstanding volume for the market maker. Finally it can be said that the forecasting model used is rather accurate, implying that the true volatility should lie on this rather large distance away from the implied volatility (in the case with GAZP). A forecasting model that would have rendered volatility close to the implied volatility would not have reflected the true expectations of the market or the difficulties in hedging GAZP.

Turning now to the warrants with underlying assets traded on OMX Stockholm, it can be seen that they all experience ratios between 1 and 2 during the majority of their lifetime. Moving on to warrants with the same underlying asset it can be seen that three out of four warrants with ERIC B as underlying asset experience a ratio close to one during a majority of its lifetime. This can in turn be compared to the warrants with STE-R and TREL B as underlying assets, where a ratio above 1.5 can be observed nearly their entire life time. The reasoning surrounding that of YHOO and GAZP can be applied here, with ERIC B being a very liquid stock with a well-developed options market and STE-R and TREL B being less liquid with a less developed options market.

McMahon (2007) argues that there exists an increase in the volatility before an earnings report or other major events, which in turn is followed by a decrease in the volatility. This is not captured by the EGARCH model and results in minor peaks in the ratio around the date for an earnings release. This can be seen in exhibit one for the warrants with the underlying assets TEL2 B (Tele2, 2008) and SEB C (SEB, 2008).

5.3 The change in ratio over the moneyness of the warrant

This section refers to exhibit two in the appendix, where graphs of the ratio over the moneyness for all warrants can be seen. The authors have combined warrants that have the same underlying asset, in order to get the largest span of moneyness as possible for each underlying asset.

The authors have identified an interesting common characteristic amongst the warrants with ERIC B, TEL2 B, STE-R and SEB C as their underlying asset. The trend is that the ratio tends to stabilize as the moneyness increases, i.e. the fluctuations in the ratio decreases as the stock moves further towards the money or further in the money. This can be explained by previous research that states that implied volatility decreases as moneyness increases. Hence, a convergence between the forecasted and implied volatility occurs as the warrants moves towards or in-to-the money.

When isolating the warrants that move in-to-the money during their lifetime and have Swedish traded stocks as underlying assets (TEL2 B and LUPE), an interesting observation can be made. That is that the ratio moves towards one as the moneyness approaches one.

STE7Q110CBK, TRE7Q150CBK and the two warrants with GAZP as the underlying asset, exhibit one similar characteristic according to the authors. That is, they all have sort of a “lower bound ratio” in which they never break through. This “lower bound ratio” is reached four times for GAZP warrants, never breaking through 1.65 (with an average value of 1.67). For STE7Q110CBK it is also reached four times, never breaking through 1.46 (with an average value of 1.48). TRE7Q150CBK reaches its lower bound ratio three times, never breaking through 1.48 (with an average value of 1.55). This lower bound might be viewed upon as the lowest possible volatility that the market maker is prepared to set for a certain warrant. Hence, it can be seen as a measure of how much risk the market maker is willing to take in a certain warrant.

5.4 Combination of the two angles

As mentioned in the beginning of this chapter, it was not possible to plot a ratio surface, so the analysis needs to be taken verbally. By combining the two sections above, one can conclude two things. First, the size of the ratio at the end of the warrant’s lifetime can be divided into two categories – out-of-the-money warrants and at-the-money warrants. Out-of-the-money warrants (presented in figure 4.1, but analyzed in conjunction with the corresponding warrants in exhibit 1) have a ratio in the span of 1.43-5.74 with an average of 3 during the last two weeks of their lifetime. Whilst at-the-money warrants (presented in figure 4.2, but analyzed in conjunction with the corresponding warrants in exhibit 1) have a ratio in the span of 1.06-3.67 with an average of 1.85 during the last two weeks of their lifetime. The simple explanation to this is that, since BS assumes that stock returns are log-normally distributed the probability of a downside tail-event to happen is lower compared to the negative skewness that is visible in the financial markets. Since the market is aware of the negative skewness in financial markets out-of-the-money warrants experience a higher demand, and therefore the price is higher. To account for this, the market maker sets the volatility at a higher level for out-of-the-money warrants compared to at-the-money warrants. The above observed phenomena can be explained by Rubinstein’s (1994) and Passarelli’s (2005) theories regarding the pricing behavior of traders when the warrant moves out-of-the-money.

Second, when combining the “ratio-smile” analyzed in section 5.2 with the change in moneyness, one can see that the lowest point in the “ratio-smile” occurs as the warrants moves closer to the money. Again, this is in line with the theories regarding volatility skew. The authors’ observation

that the difference between the forecasted volatility and the implied volatility is lower mainly in the middle of a warrant's lifetime should not be regarded as a general behavior but should be considered as a mere coincidence as the sample in the thesis is somewhat scarce. However it is an interesting finding and might raise interest for further research.

6 Conclusion

The goal set out by the authors was to compare and analyze the difference between an EGARCH forecasted volatility and the implied volatility on warrants traded on the Nordic Derivatives Exchange. This ratio (difference between the implied volatility and the forecasted volatility) was then analyzed across warrants, moneyness and over the lifetime of the warrant. The intention was to detect and distinguish any form of visible trends as the ratio changed over the previous mentioned parameters.

We find a number of interesting patterns in the ratio's behaviour as the parameters changes. First, a "smile" can be seen in the graphs with the ratio as a function of the warrant's lifetime. The ratio tends to decrease during the midst of the warrant's lifetime (as the warrant moves closer to the money), and increase in the end as well as in the beginning of the lifetime. Second, numerous warrants display a stabilization in the ratio as they move towards- or in to the money, i.e. the fluctuations in the ratio decreases over the moneyness. Third, in a couple of cases the EGARCH-forecasted volatility turned out to coincide with the implied volatility fairly well, implying that the ability of the EGARCH as a model to forecast volatility can be considered rather good.

Furthermore, two findings can be related to the amount of risk the market maker face by providing bid- and ask prices in the warrant market, and if he is able to hedge his position or not. First, the ratio for warrants with an underlying asset that does not have a corresponding option market is high, implying that the market maker sets a higher level of volatility (i.e. higher price) since he is not able to hedge himself in an option market with the same underlying asset. Second, several warrants exhibit a "lower ratio bound", i.e. a level of ratio that is never broken through during its entire lifetime. This might imply that the market maker has a predetermined lower level of volatility (compared to the "true" volatility, i.e. EGARCH-forecasted) which he never lowers since it might impose a too high risk on him.

Some of the observed movements in implied volatility can be anchored in theories dealing with volatility, namely that implied volatility tends to increase before an earnings report and that it increases rapidly close to maturity due to the type of warrant (in this case a European plain vanilla).

The limited amount of previous research limits the ability to connect the findings to general theory, hence the analysis might appear somewhat far-fetched in some cases. Nevertheless, the authors believe that the findings are interesting, and based on them and the progress of this thesis, the authors have three suggestions for further research within this area. First, an increased sample of warrants with the same underlying asset would yield a "ratio surface", much like the well-known

volatility surface but instead of a surface of volatility it would be constructed of different ratios. Second, as different market makers individually set the volatility, it would be interesting to conduct a qualitative study amongst market makers in order to attain a behavioural view on the matter. Finally, it would be interesting to investigate the difference in volatility between options and warrants (trading on the same market) that have the exact same characteristics, i.e. same underlying asset, time to maturity, strike price etc. in order to capture how big the margin is in this specific market. This margin (in combination with other parameters) could then be used by potential new actors in a market when deciding if entering the market will be profitable or not.

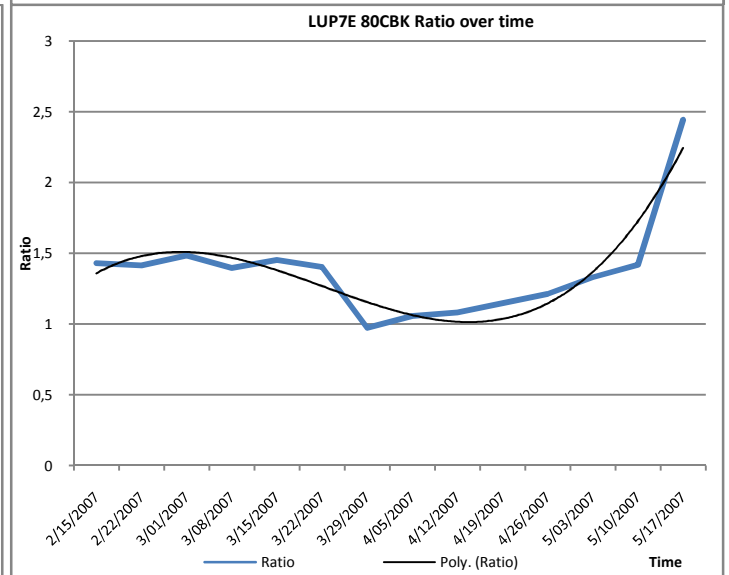
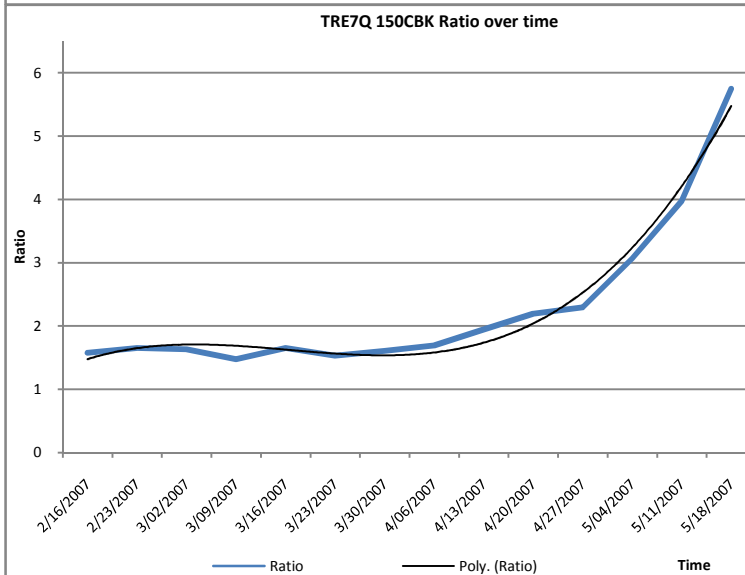
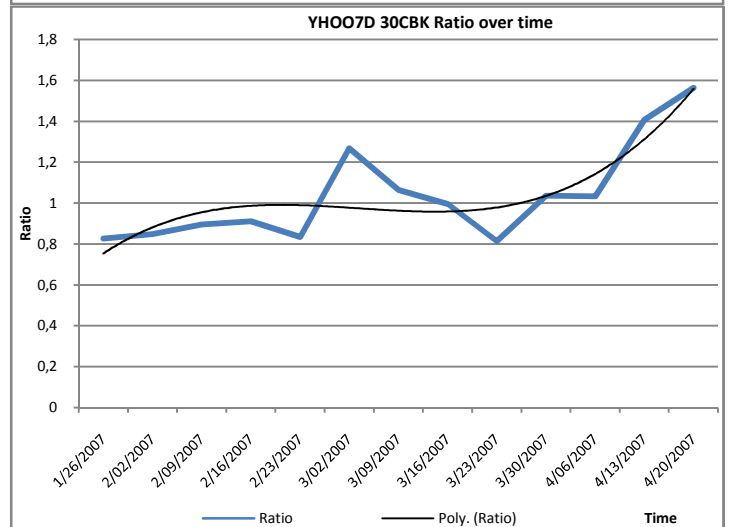
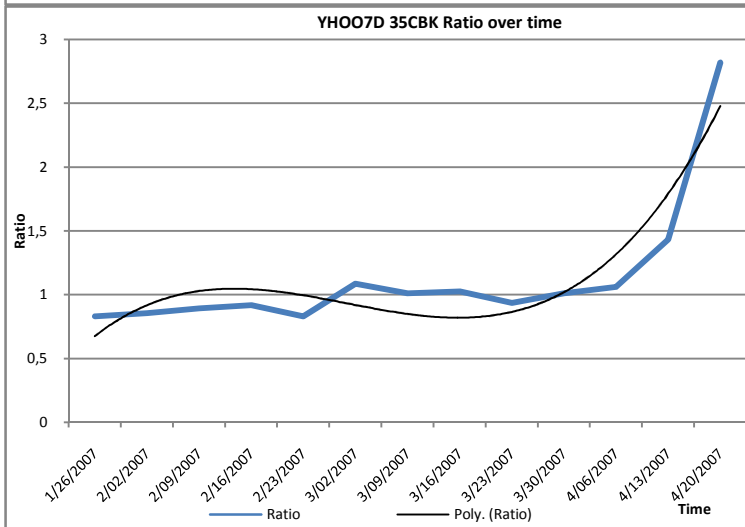
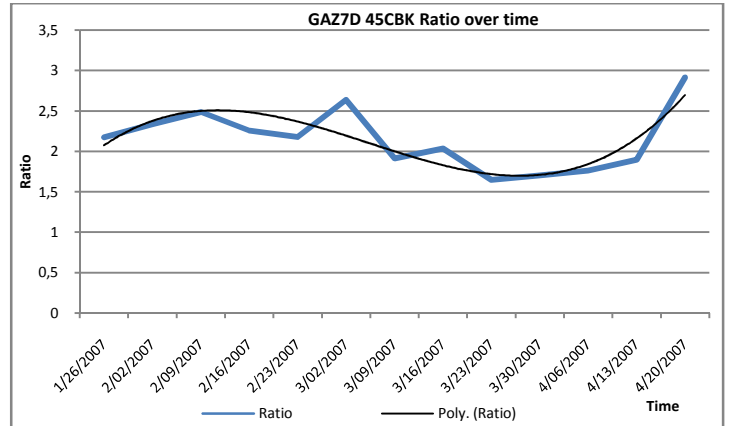
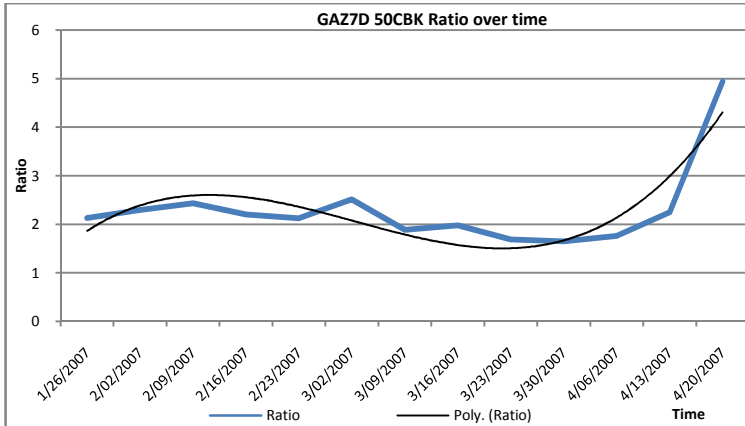
7 References

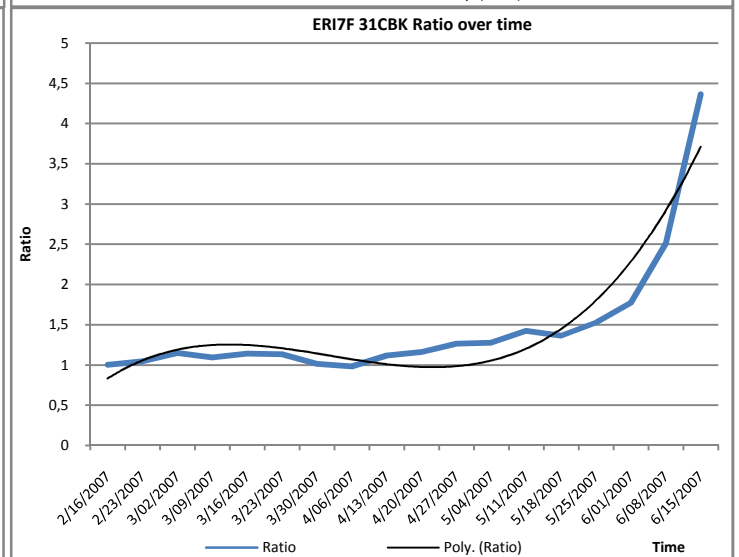
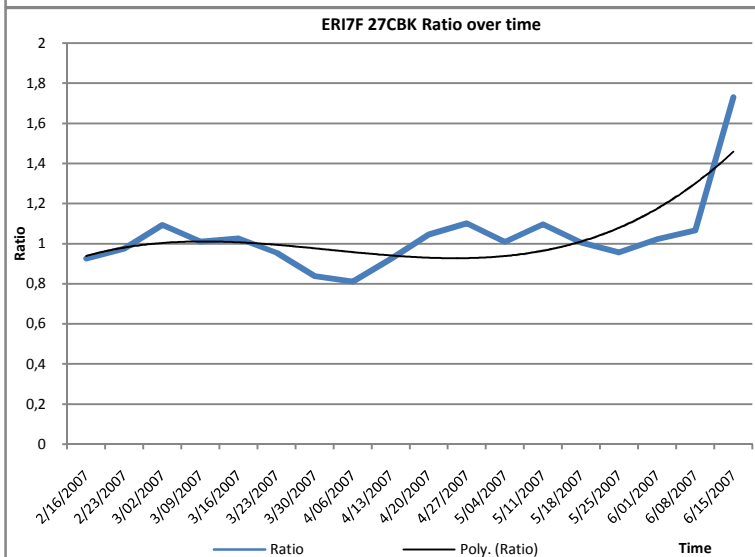
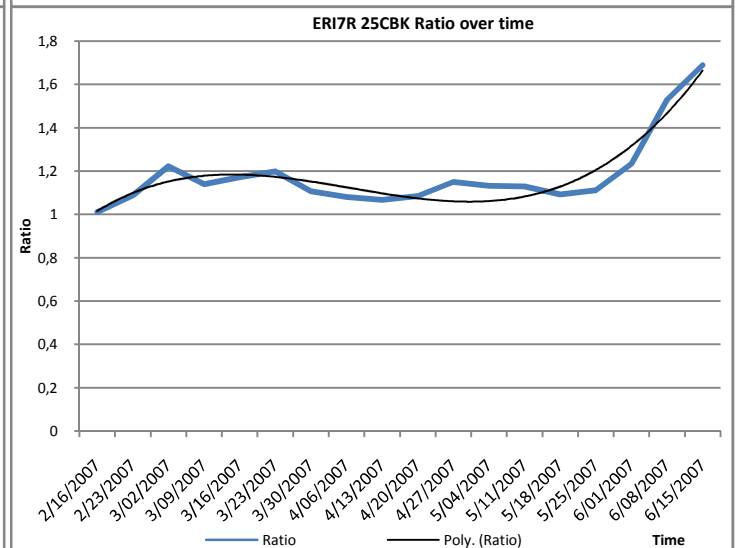
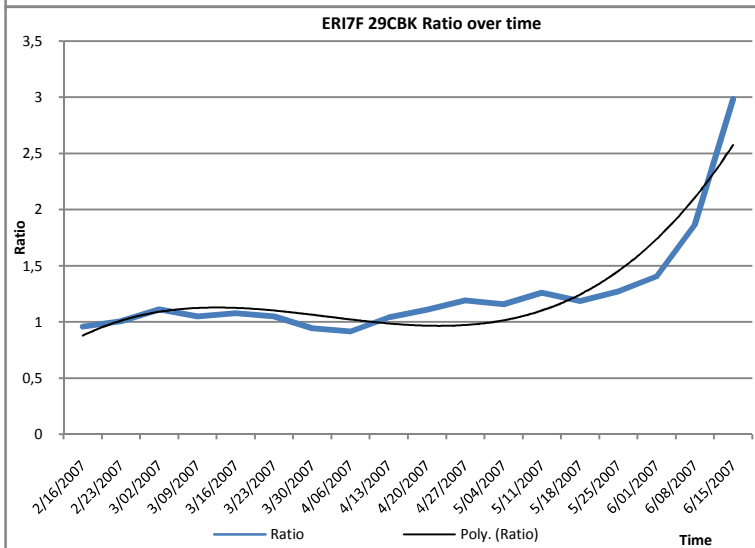
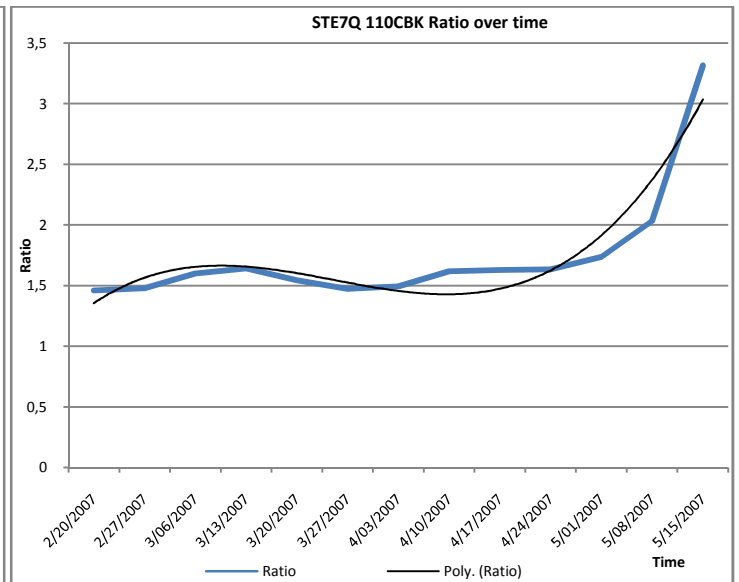
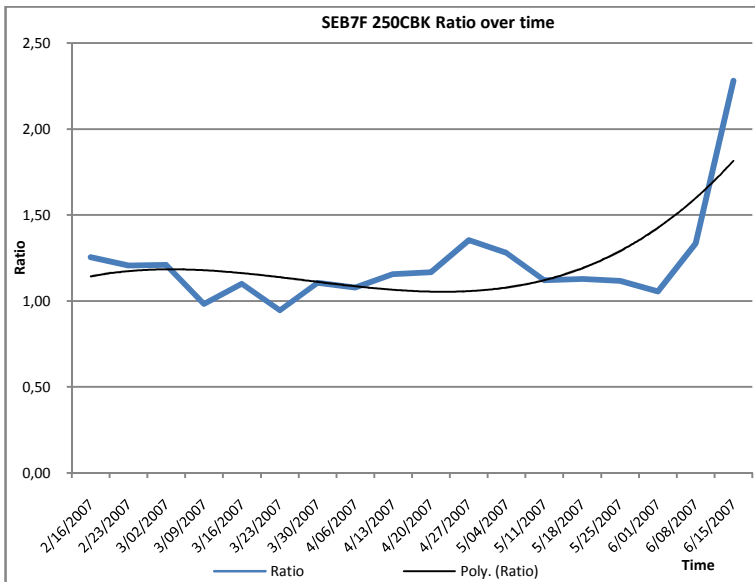
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8 Appendix

Exhibit 1 Ratio over time





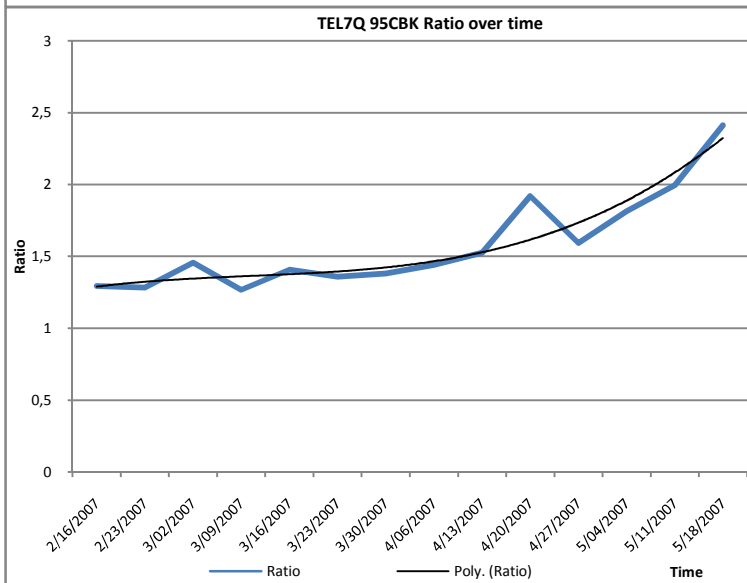
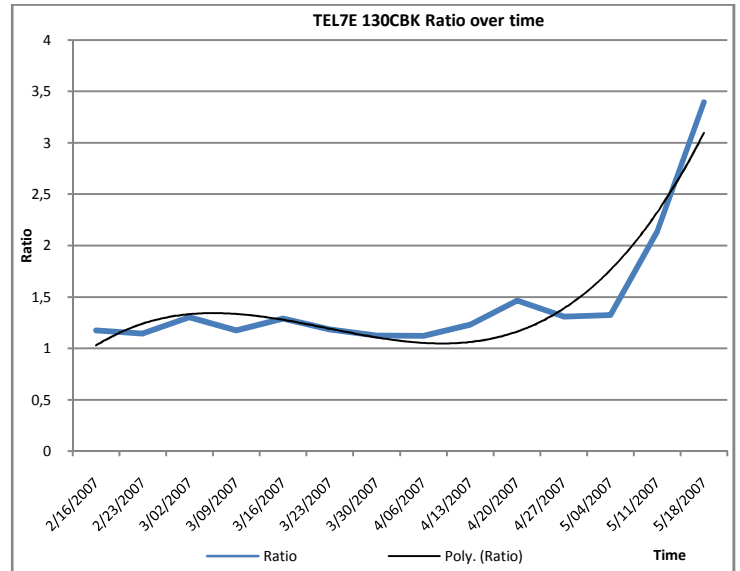
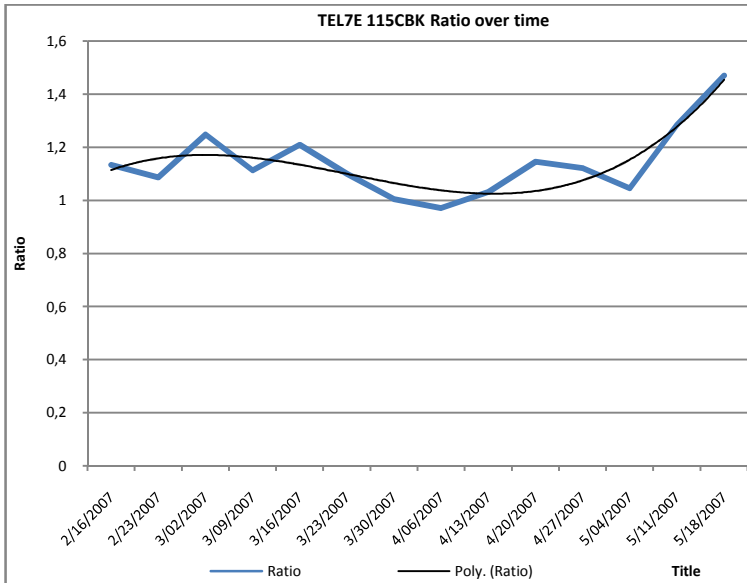
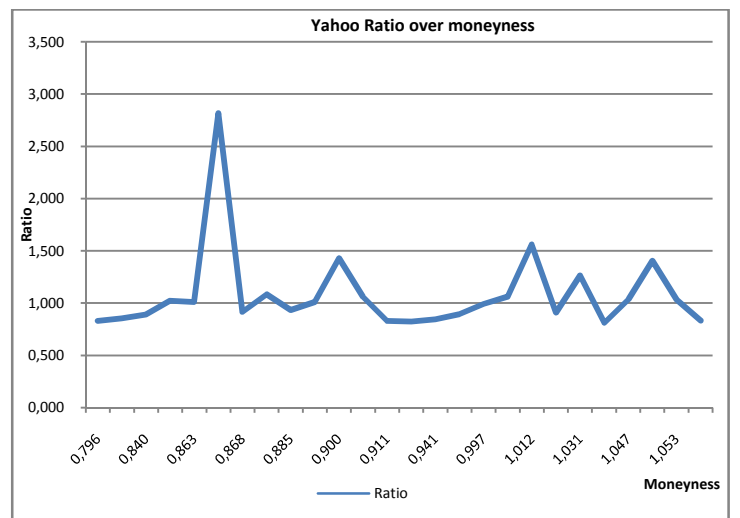
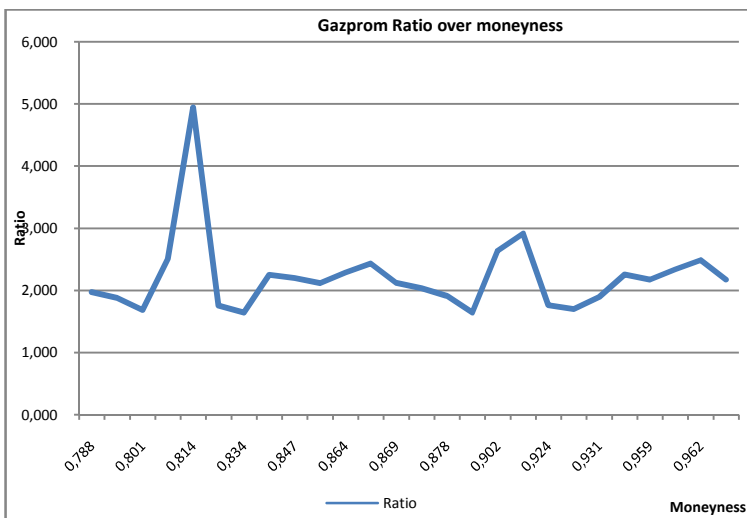


Exhibit 2 Ratio over moneyness



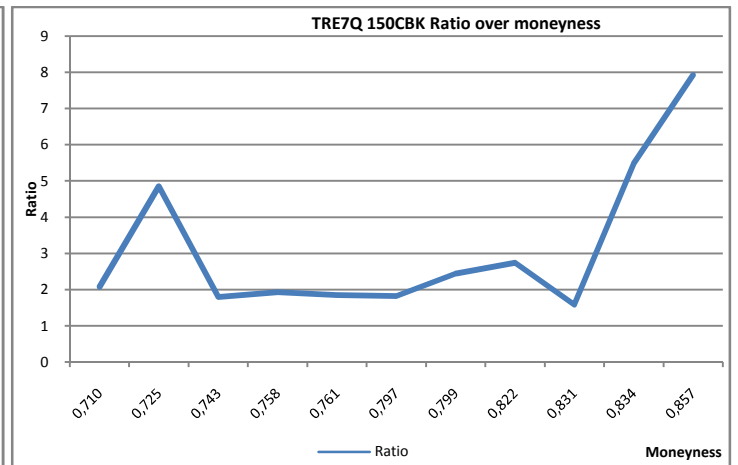
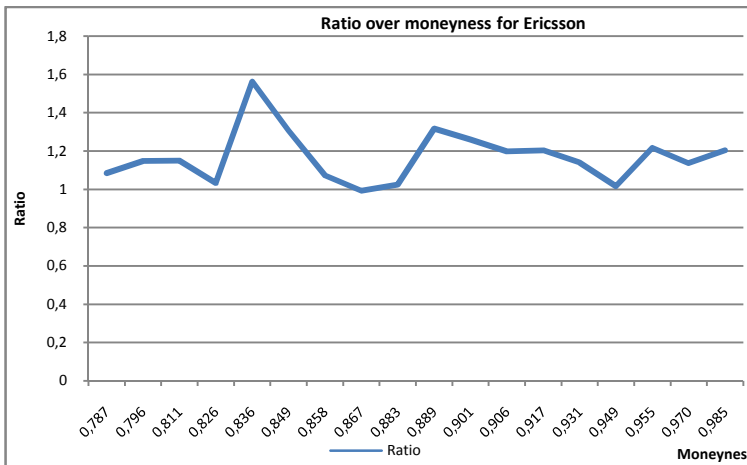
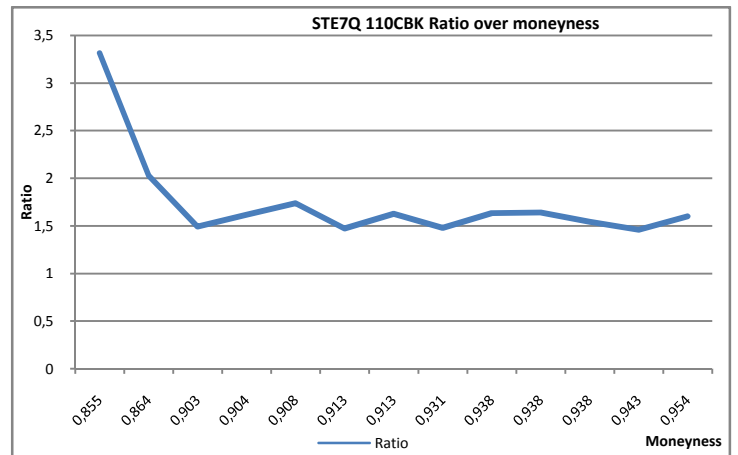
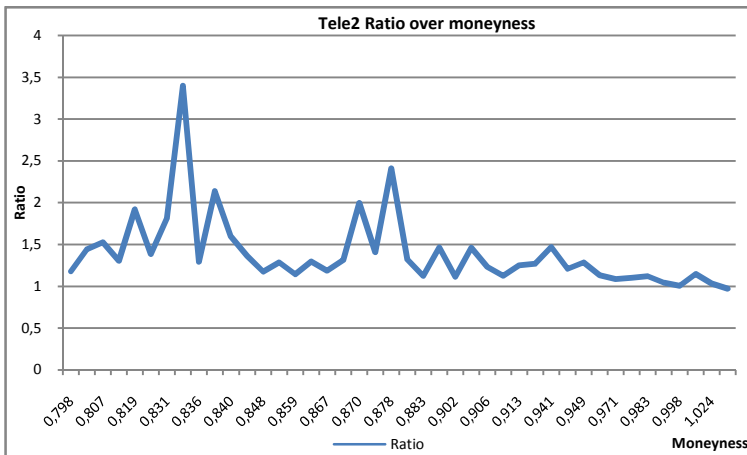
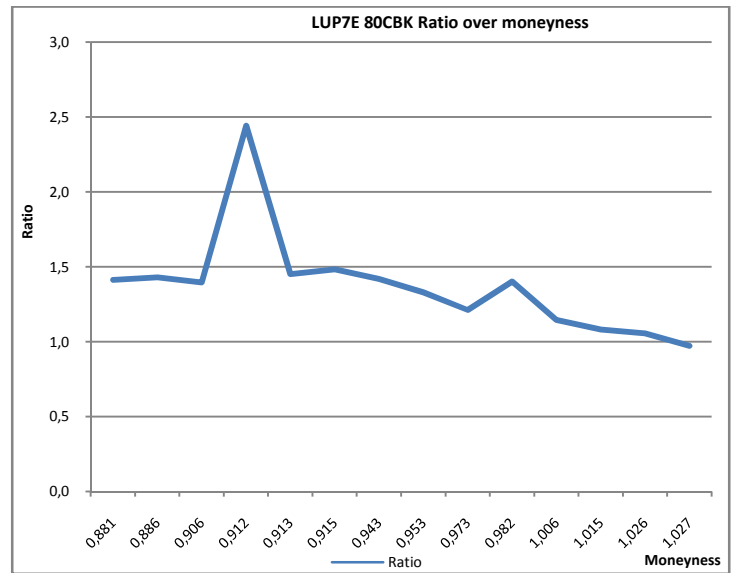
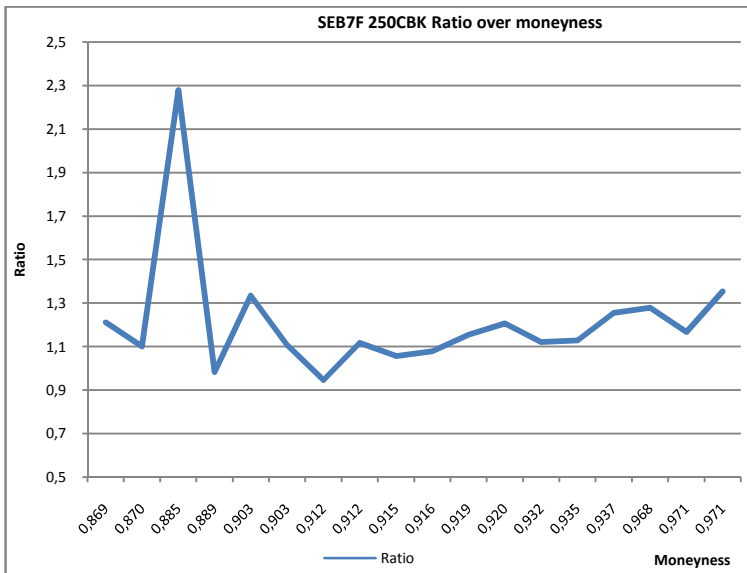


Table 8.1 Implied- and forecasted volatility

ER17R 25CBK										ER17F 27CBK										ER17F 29CBK									
Forecasted	Implied	K/S	Ratio	Forecasted	Implied	S/K	Ratio	Forecasted	Implied	S/K	Ratio	Forecasted	Implied	S/K	Ratio	Forecasted	Implied	S/K	Ratio										
2/16/2007	0.32	0.98	1.01	2/16/2007	0.32	0.95	0.93	2/16/2007	0.32	0.95	0.93	2/16/2007	0.32	0.95	0.93	2/16/2007	0.31	0.88	0.96										
2/23/2007	0.30	0.97	1.09	2/23/2007	0.30	0.96	0.97	2/23/2007	0.30	0.96	0.97	2/23/2007	0.30	0.96	0.97	2/23/2007	0.30	0.89	1.00										
3/02/2007	0.29	0.99	1.22	3/02/2007	0.29	0.93	1.09	3/02/2007	0.29	0.93	1.09	3/02/2007	0.29	0.93	1.09	3/02/2007	0.32	0.87	1.11										
3/09/2007	0.32	1.02	1.14	3/09/2007	0.32	0.90	1.01	3/09/2007	0.32	0.90	1.01	3/09/2007	0.32	0.90	1.01	3/09/2007	0.33	0.84	1.05										
3/16/2007	0.30	1.01	1.17	3/16/2007	0.30	0.91	1.03	3/16/2007	0.30	0.91	1.03	3/16/2007	0.30	0.91	1.03	3/16/2007	0.33	0.85	1.08										
3/23/2007	0.28	0.96	1.20	3/23/2007	0.28	0.96	0.95	3/23/2007	0.28	0.96	0.95	3/23/2007	0.28	0.96	0.95	3/23/2007	0.30	0.89	1.05										
3/30/2007	0.31	0.97	1.11	3/30/2007	0.31	0.95	0.84	3/30/2007	0.31	0.95	0.84	3/30/2007	0.31	0.95	0.84	3/30/2007	0.29	0.89	0.94										
4/06/2007	0.32	0.97	1.08	4/06/2007	0.32	0.95	0.81	4/06/2007	0.32	0.95	0.81	4/06/2007	0.32	0.95	0.81	4/06/2007	0.29	0.89	0.91										
4/13/2007	0.30	0.95	1.07	4/13/2007	0.30	0.97	0.92	4/13/2007	0.30	0.97	0.92	4/13/2007	0.30	0.97	0.92	4/13/2007	0.31	0.91	1.04										
4/20/2007	0.28	0.94	1.09	4/20/2007	0.28	0.99	1.05	4/20/2007	0.28	0.99	1.05	4/20/2007	0.28	0.99	1.05	4/20/2007	0.32	0.92	1.11										
4/27/2007	0.27	0.96	1.15	4/27/2007	0.27	0.97	1.10	4/27/2007	0.27	0.97	1.10	4/27/2007	0.27	0.97	1.10	4/27/2007	0.32	0.90	1.19										
5/04/2007	0.27	0.96	1.13	5/04/2007	0.27	0.96	1.01	5/04/2007	0.27	0.96	1.01	5/04/2007	0.27	0.96	1.01	5/04/2007	0.31	0.90	1.16										
5/11/2007	0.26	0.97	1.13	5/11/2007	0.26	0.96	1.10	5/11/2007	0.26	0.96	1.10	5/11/2007	0.26	0.96	1.10	5/11/2007	0.33	0.89	1.26										
5/18/2007	0.27	0.96	1.09	5/18/2007	0.27	0.96	1.01	5/18/2007	0.27	0.96	1.01	5/18/2007	0.27	0.96	1.01	5/18/2007	0.32	0.90	1.18										
5/25/2007	0.27	0.95	1.11	5/25/2007	0.27	0.97	0.96	5/25/2007	0.27	0.97	0.96	5/25/2007	0.27	0.97	0.96	5/25/2007	0.34	0.90	1.27										
6/01/2007	0.25	0.95	1.23	6/01/2007	0.25	0.97	1.02	6/01/2007	0.25	0.97	1.02	6/01/2007	0.25	0.97	1.02	6/01/2007	0.35	0.91	1.40										
6/08/2007	0.24	0.95	1.53	6/08/2007	0.24	0.97	1.07	6/08/2007	0.24	0.97	1.07	6/08/2007	0.24	0.97	1.07	6/08/2007	0.44	0.90	1.86										
6/15/2007	0.25	0.96	1.69	6/15/2007	0.25	0.96	1.73	6/15/2007	0.25	0.96	1.73	6/15/2007	0.25	0.96	1.73	6/15/2007	0.74	0.89	2.98										
ER17R 31CBK										LUP7E 80CBK										GAZ7D 45CBK									
Forecasted	Implied	S/K	Ratio	Forecasted	Implied	S/K	Ratio	Forecasted	Implied	S/K	Ratio	Forecasted	Implied	S/K	Ratio	Forecasted	Implied	S/K	Ratio										
2/16/2007	0.32	0.83	1.00	2/15/2007	0.31	0.89	1.43	2/16/2007	0.32	0.89	1.43	2/16/2007	0.25	0.97	2.17														
2/23/2007	0.30	0.83	1.05	2/22/2007	0.30	0.88	1.41	2/22/2007	0.30	0.88	1.41	2/02/2007	0.24	0.96	2.34														
3/02/2007	0.29	0.81	1.15	3/01/2007	0.29	0.92	1.48	2/09/2007	0.22	0.96	1.48	2/09/2007	0.22	0.96	2.49														
3/09/2007	0.32	0.79	1.09	3/08/2007	0.32	0.91	1.40	2/16/2007	0.23	0.91	1.40	2/16/2007	0.23	0.94	2.26														
3/16/2007	0.30	0.80	1.14	3/15/2007	0.32	0.91	1.45	2/23/2007	0.23	0.91	1.45	2/23/2007	0.23	0.96	2.18														
3/23/2007	0.28	0.84	1.13	3/22/2007	0.31	0.98	1.40	3/02/2007	0.22	0.98	1.40	3/02/2007	0.22	0.90	2.64														
3/30/2007	0.31	0.83	1.01	3/29/2007	0.44	1.03	0.97	3/09/2007	0.27	1.03	0.97	3/09/2007	0.27	0.88	1.91														
4/06/2007	0.32	0.83	0.98	4/05/2007	0.42	1.03	1.06	3/16/2007	0.26	1.03	1.06	3/16/2007	0.26	0.88	2.04														
4/13/2007	0.30	0.85	1.12	4/12/2007	0.39	1.02	1.08	3/23/2007	0.26	1.02	1.08	3/23/2007	0.26	0.89	1.65														
4/20/2007	0.28	0.86	1.16	4/19/2007	0.37	1.01	1.15	3/30/2007	0.30	1.01	1.15	3/30/2007	0.30	0.93	1.70														
4/27/2007	0.27	0.84	1.26	4/26/2007	0.35	0.97	1.21	4/06/2007	0.28	0.97	1.21	4/06/2007	0.28	0.92	1.76														
5/04/2007	0.27	0.84	1.28	5/03/2007	0.34	0.95	1.33	4/13/2007	0.27	0.95	1.33	4/13/2007	0.27	0.93	1.90														
5/11/2007	0.26	0.83	1.42	5/10/2007	0.33	0.94	1.42	4/20/2007	0.26	0.94	1.42	4/20/2007	0.26	0.90	2.92														
5/18/2007	0.27	0.84	1.36	5/17/2007	0.32	0.91	2.44																						
5/25/2007	0.27	0.84	1.53																										
6/01/2007	0.25	0.85	1.77																										
6/08/2007	0.24	0.84	2.51																										
6/15/2007	0.25	0.84	4.36																										

GAZTD 50CBK

YH007D 30CBK

YH007D 35CBK

	Forecasted	Implied	S/K	Ratio	Forecasted	Implied	S/K	Ratio	Forecasted	Implied	S/K	Ratio
1/26/2007	0.25	0.54	0.87	2.13	1/26/2007	0.47	0.39	0.93	1/26/2007	0.47	0.39	0.83
2/02/2007	0.24	0.54	0.86	2.29	2/02/2007	0.44	0.37	0.94	2/02/2007	0.44	0.38	0.85
2/09/2007	0.22	0.54	0.87	2.43	2/09/2007	0.42	0.38	0.98	2/09/2007	0.42	0.37	0.84
2/16/2007	0.23	0.51	0.85	2.20	2/16/2007	0.41	0.37	1.01	2/16/2007	0.41	0.37	0.87
2/23/2007	0.23	0.49	0.86	2.12	2/23/2007	0.43	0.36	1.06	2/23/2007	0.43	0.35	0.91
3/02/2007	0.22	0.54	0.81	2.51	3/02/2007	0.39	0.50	1.03	3/02/2007	0.39	0.43	0.88
3/09/2007	0.27	0.51	0.79	1.88	3/09/2007	0.42	0.45	1.01	3/09/2007	0.42	0.42	0.86
3/16/2007	0.26	0.51	0.79	1.98	3/16/2007	0.43	0.43	1.00	3/16/2007	0.43	0.44	0.85
3/23/2007	0.26	0.44	0.80	1.69	3/23/2007	0.41	0.33	1.03	3/23/2007	0.41	0.38	0.89
3/30/2007	0.30	0.49	0.83	1.65	3/30/2007	0.41	0.43	1.05	3/30/2007	0.41	0.42	0.90
4/06/2007	0.28	0.49	0.83	1.76	4/06/2007	0.38	0.40	1.05	4/06/2007	0.38	0.41	0.90
4/13/2007	0.27	0.60	0.84	2.25	4/13/2007	0.37	0.51	1.05	4/13/2007	0.37	0.52	0.90
4/20/2007	0.26	1.28	0.81	4.94	4/20/2007	0.36	0.56	1.01	4/20/2007	0.36	1.00	0.87

SEBYE 250CBK

STE7Q 110 CBK

TEL7E 115CBK

	Forecasted	Implied	S/K	Ratio	Forecasted	Implied	K/S	Ratio	Forecasted	Implied	S/K	Ratio
2/16/2007	0.19	0.24	0.94	1.26	2/20/2007	0.24	0.94	1.46	2/16/2007	0.27	0.30	1.13
2/23/2007	0.20	0.24	0.92	1.21	2/27/2007	0.24	0.93	1.48	2/23/2007	0.27	0.29	1.09
3/02/2007	0.21	0.26	0.87	1.21	3/06/2007	0.24	0.95	1.60	3/02/2007	0.26	0.32	1.25
3/09/2007	0.27	0.26	0.89	0.98	3/13/2007	0.23	0.94	1.64	3/09/2007	0.31	0.34	0.90
3/16/2007	0.25	0.27	0.87	1.10	3/20/2007	0.23	0.94	1.54	3/16/2007	0.29	0.35	1.21
3/23/2007	0.29	0.27	0.91	0.95	3/27/2007	0.22	0.91	1.47	3/23/2007	0.31	0.34	0.98
3/30/2007	0.26	0.29	0.90	1.11	4/03/2007	0.22	0.90	1.49	3/30/2007	0.31	0.31	1.00
4/06/2007	0.29	0.31	0.92	1.08	4/10/2007	0.21	0.90	1.62	4/06/2007	0.29	0.29	1.03
4/13/2007	0.27	0.31	0.92	1.16	4/17/2007	0.21	0.91	1.63	4/13/2007	0.29	0.30	1.03
4/20/2007	0.27	0.31	0.97	1.17	4/24/2007	0.21	0.94	1.63	4/20/2007	0.28	0.32	1.15
4/27/2007	0.24	0.33	0.97	1.35	5/01/2007	0.21	0.91	1.74	4/27/2007	0.27	0.31	1.12
5/04/2007	0.25	0.32	0.97	1.28	5/08/2007	0.23	0.86	2.03	5/04/2007	0.26	0.27	0.99
5/11/2007	0.28	0.31	0.93	1.12	5/15/2007	0.22	0.86	3.31	5/11/2007	0.24	0.31	1.28
5/18/2007	0.28	0.31	0.94	1.13					5/18/2007	0.26	0.39	1.47
5/25/2007	0.28	0.32	0.91	1.12								
6/01/2007	0.29	0.31	0.91	1.06								
6/08/2007	0.28	0.37	0.90	1.33								
6/15/2007	0.32	0.73	0.88	2.28								

TELVE 130CBK

TELQ 95CBK

TRE7Q 150CBK

	Forecasted	Implied	S/K	Ratio	Forecasted	Implied	K/S	Ratio	Forecasted	Implied	K/S	Ratio
2/16/2007	0.27	0.31	0.85	1.17	2/16/2007	0.27	0.35	0.86	2/16/2007	0.24	0.38	0.76
2/23/2007	0.27	0.31	0.86	1.14	2/23/2007	0.27	0.35	0.85	2/23/2007	0.24	0.40	0.76
3/02/2007	0.26	0.34	0.81	1.30	3/02/2007	0.26	0.38	0.90	3/02/2007	0.26	0.43	0.83
3/09/2007	0.31	0.36	0.80	1.17	3/09/2007	0.31	0.39	0.92	3/09/2007	0.30	0.45	0.82
3/16/2007	0.29	0.37	0.84	1.29	3/16/2007	0.29	0.41	0.87	3/16/2007	0.29	0.48	0.86
3/23/2007	0.31	0.36	0.87	1.18	3/23/2007	0.31	0.42	0.84	3/23/2007	0.32	0.49	0.83
3/30/2007	0.31	0.35	0.88	1.12	3/30/2007	0.31	0.43	0.83	3/30/2007	0.30	0.49	0.83
4/06/2007	0.29	0.33	0.91	1.12	4/06/2007	0.29	0.42	0.80	4/06/2007	0.29	0.49	0.80
4/13/2007	0.29	0.36	0.91	1.23	4/13/2007	0.29	0.45	0.81	4/13/2007	0.28	0.54	0.80
4/20/2007	0.28	0.41	0.89	1.46	4/20/2007	0.28	0.54	0.82	4/20/2007	0.27	0.59	0.80
4/27/2007	0.27	0.36	0.87	1.31	4/27/2007	0.27	0.43	0.84	4/27/2007	0.26	0.60	0.74
5/04/2007	0.26	0.34	0.88	1.32	5/04/2007	0.26	0.46	0.83	5/04/2007	0.26	0.79	0.71
5/11/2007	0.24	0.52	0.84	2.14	5/11/2007	0.24	0.49	0.87	5/11/2007	0.25	0.99	0.72
5/18/2007	0.26	0.89	0.83	3.40	5/18/2007	0.26	0.63	0.88	5/18/2007	0.26	1.50	0.73
												5.74