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Is the Leverage Effect Caused by Leverage?

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Oppgavens (foreløpige) tittel **Is Leverage Effect caused by Leverage?**	
Oppgavetekst/Problembeskrivelse The term leverage effect refers to the observed relationship between stock returns and volatility. The volatility is known to increase after stock/market goes down. One possible explanation ties this phenomenon to the effect a change in the market valuation of a firm's equity has on the degree of leverage in its capital structure. A fall in the market value of equity makes a firm more levered during a crisis and the volatility of the levered equity will increase. The main objective is to examine this explanation for the "leverage effects" for stocks on the Norwegian stock exchange, Oslo Børs. The study will elaborate if there is a strong/weak "leverage effect" associated with failing stock prices and whether this effect can be explained by the leverage.	
Hovedveileder ved institutt **Post doktor Peter Molnar**	Medveileder(e) ved institutt
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4. Underskrift

Student: Jeg erklærer herved at jeg har satt meg inn i gjeldende bestemmelser for mastergradsstudiet og at jeg oppfyller kravene for adgang til å påbegynne oppgaven, herunder eventuelle praksiskrav.

Partene er gjort kjent med avtalens vilkår, samt kapitlene i studiehåndboken om generelle regler og aktuell studieplan for masterstudiet.

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Preface

This thesis is written as the conclusion of the Master of Science degree in Industrial Economics and Technology Management at the Norwegian University of Science and Technology (NTNU). My master profile is Investments, Finance and Financial Management where I have specialized in Empirical Finance. The thesis investigates if the “leverage effect” hypothesis for stocks can explain the asymmetrical volatility on the Norwegian stock exchange. The term leverage effect refers to the observed relationship between returns and volatility. The topic has been chosen due to personal as well as academic interest. Working with the thesis has been both interesting and educational where I have gained new knowledge about volatility fluctuations in the financial markets.

The thesis has been written and edited in Microsoft Word. The tables in the thesis are made in Microsoft Excel and edited in Microsoft Word. The empirical analysis and the estimations have been performed in EVIEWS 7, a statistical software package for Windows. The thesis follows the style guidelines for Financial Management. Data and estimations can be obtained upon request.

I would like to thank my academic supervisor Peter Molnar at the Department for Industrial Economics and Technology Management at NTNU for his counselling and guidance. I take full responsibility for any errors in this thesis.

Trondheim, June 11th 2012

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Abstract

Asymmetric equity volatility is crucial for many financial applications and has in the last few decades become a focus and an important research area in empirical studies. The term leverage effect refers to the observed relationship between returns and volatility. The volatility is known to increase when the market and the stock prices experience a fall. One possible explanation for this phenomenon is based on financial leverage, where a fall in the market value of a firm's equity makes a firm more levered, resulting in an increase in the stock return volatility. The main objective in this study is to examine if the leverage effect hypothesis can explain the asymmetric volatility of stocks on the Norwegian stock exchange. Linear regressions have been performed in the empirical tests, where stock returns, market returns and changes in leverage are the explanatory variables. The study has used three different volatility estimators to account for robustness in the analysis. The main assumption in this empirical research is that the measured leverage is calculated from the book values of debt and not from the market value of debt. The findings determine that asymmetric equity volatility exists on the Norwegian stock exchange. The magnitude of the leverage effect is substantially higher when the stock prices are declining and when the market is experiencing a downfall. The results show that market returns has the highest significance level and the greatest explanatory power, which implies that market returns have a bigger impact on volatility than individual stock returns. Since market returns is the dominant variable when determining asymmetric volatility and the fact that leverage effect diminishes over time, it is clear that the leverage effect is not only caused by leverage. The results suggests that the leverage effect hypothesis is mainly a down market effect, since the effect is much stronger when the market is falling.

Sammendrag

Betydningen av asymmetrisk volatilitet er viktig innen mange finansielle aspekter og har de siste tiårene blitt et fokus og viktig forskningsfelt innen finans. Gearing-effekt referer til det observerte forholdet mellom avkastning på aksjer og volatiliteten. Volatiliteten er kjent for å øke når prisene på aksjene faller og når market opplever et fall. En mulig forklaring på dette fenomenet er basert på finansiell gjeld, hvor et fall i markedsverdien til egenkapital vil øke gjeldsandelen i bedriften som da vil forårsake at volatiliteten øker. Formålet med oppgaven er å undersøke om gearing-effekt teorien stemmer for den asymmetriske volatiliteten på Oslo Børs. Lineære regresjoner har blitt tatt i bruk i de empiriske testene. Forklaringsvariablene i analysen er avkasting på aksjer, avkastningen på OBX Indeksen og forandringer i gjeldgraden til bedrifter. Oppgaven har brukt tre ulike metoder til å regne ut volatiliteten, for å oppnå en mer robust analyse. Den viktigste forutsetingen i oppgaven er at gjeldsgraden til bedrifter er hentet fra bokførte verdier og ikke fra markedsverdien av gjeld. Resultatene viser at asymmetrisk volatilitet eksiterer på Oslo Børs og at volatiliteten øker kraftig når markedet faller. Undersøkelsene viser at avkastningen på OBX Indeksen har størst forklaringskraft og at gearing-effekten har en tendens til å forsvinne over tid. Resultatene fastslår at gjeld ikke har en stor innvirkning på volatiliteten, men at markedsavkastning er den dominerende faktoren når volatiliteten øker. Basert på resultatene, virker det som at gearing-effekten er i hovedsak en markedsfall effekt, siden volatiliteten påvirkes ytterligere når markedet faller.

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1. Introduction

Return to equity is for many investors, one of the most important financial stakeholder factors in corporate financing decisions. The dominant perspective in finance and accounting literature is that a firm should maximise the return to stockholders as a first objective. Other non-financial constituencies, such as employees, customers and creditors should only be restriction to a stockholder wealth maximisation. This study will focus on whether financial leverage has any effect on the volatility for equity. There are different opinions on whether financial leverage in a firm's capital structure has a dominant effect when the equity volatility increases. Since return on equity is related to volatility it is important for an investor to know if leverage may have any severe effect on stock returns. Several "stylized effects" such as non-normality in the distribution of returns and the positive dependence between volatility on consecutive days has in the last few decades become a focus and an important research area in empirical studies.

The leverage effect hypothesis is spurred out from a broad research on asymmetric equity volatility. This subject is widely discussed and documented in finance, describing that stock returns and volatility are negatively correlated and that the relationship is more significant for negative returns. The phenomenon elaborates the relationship between volatility and expected returns. One explanation is that an increase in volatility will lead to an increase in expected return on equity, which would result in a decline in the stock price. Another explanation is based on financial leverage, where a drop in stock prices will lead to an increase in financial leverage resulting in an increase in the stock return volatility. This study will focus on the latter explanation. The term "leverage effect" is usually mentioned in the context of volatility asymmetry, which was first discussed by Black (1976). The importance of asymmetric equity volatility is crucial for many financial applications. One is option pricing, where it is important to determine the characteristics of the market volatility dynamics. This would imply asset pricing implication. The option pricing formula derived by Black and Scholes (1973) assumes that volatility of the underlying assets is a constant parameter, although it is well known that volatility of returns tend to vary over time. This raises the argument for time-varying market risk premium. The knowledge regarding hedging and risk predictions in the market is also increased by studying asymmetric volatility. Asymmetric volatility can in addition help to explain the negatively skewed distribution, which is elaborated in the empirical study conducted by Bollerslev, Chou and Kroner (1992).

Volatility tends to increase more when the market is experiencing a downfall compared to when the market is rising. Empirical studies show that this phenomenon is stronger for indices and less pronounced for individual stocks. One thought might be that that the correlation between firm returns increase when the market falls. According to Miller and Modigliani (1958) proposition II, return on equity should rise as a linear function when the debt ratio increases. If that was the case, return on equity would rise in a falling market due to increased leverage in the firm. The market capitalization decreases and debt becomes a larger part of a firm's capital structure. If debt is risk-free and the creditors receive what they are promised, the shareholders carry all of the excess risk when the market crashes. Black (1976) found that that current returns and future volatility are negatively related. According to Black (1976), a price drop in the stock increases the risk of bankruptcy, and the company's stock therefore becomes more volatile. He therefore proposes that a price drop induces increase in volatility. Corporate finance theory states that a more levered firm would tend to have higher volatility due to the systematic risk. Christie (1982) found empirical results confirming that there is a positive correlation between the degree of leverage on a firm's balance sheet and the volatility of its stock. Christie (1982) and Schwert (1990) conducted studies where they measured the effect of financial leverage on volatility and found evidence for that a negative relationship between current returns and future volatility is due to the leverage effect.

Another term used to describe the increased volatility is the volatility feedback effect. Campbell and Hentschel (1992) explained how no news is good news about future volatility. They elaborated in their study that a volatility feedback implies that the stock price movements are correlated with the future volatility. In other words the volatility feedback effect involves contemporaneous negative relationship between returns and volatility. Assuming that the volatility is persistent as supported by Bollerslev, Chou and Kroner (1992), Bekaert and Wu (2000) did an empirical study based on both leverage and feedback effects. The hypothesis is based on market's reaction to news. If the shocks on conditional variance and the feedback effects on current prices happen simultaneously, leverage and feedback effects interact.

The main objective of this study is to investigate if the leverage effect hypothesis can explain the asymmetric equity volatility on the Norwegian stock exchange, Oslo Børs. The study will determine if there is any asymmetric volatility in the Norwegian stock market and if the leverage effect can explain this phenomenon. The study will also elaborate if there is a strong or weak leverage effect associated with falling stock prices and whether this effect can be explained by financial leverage. The empirical tests will be performed on data samples containing individual stocks and the OBX Index. The empirical tests containing stock returns are conducted on daily, weekly, monthly and quarterly observations. The regressions with measured leverage are based on quarterly observations due to the data available. The study will first investigate the leverage effect with returns. This will provide a good estimate for the existence of asymmetric equity volatility. Regressions containing individual stock returns and market returns have been executed to determine if the change in volatility is a market effect or simply due to the nature of the stock.

Volatility should be a variable dependent on a firm's capital structure. Hence a change in firm leverage should change the stock volatility permanently. To verify this theory a regression is run to investigate if the leverage effect induces a permanent change in volatility or if the effect diminishes over time. The final regressions are executed with measured leverage as the independent variable to determine if the asymmetric volatility could be explained with leverage. To observe if leverage has a more severe and significant impact on equity volatility compared to stock returns, a regression based on both of the variables is run. A regression based on stock returns, market returns and changes in leverage have been executed, to determine which of the explanatory variables have the largest impact on equity volatility. The study uses a similar approach as Figlewski and Wang (2000), but conducts a more thorough analysis by examining the explanatory variables individually and together, in the empirical tests. The study also compute the elasticity of stock volatility with respect to changes in leverage, which provides a theoretical value for the impact a leverage effect should have. Linear regressions are used in this empirical research with various dummy variables to determine if the volatility asymmetry exists and if the leverage effect hypothesis is a good explanation for this phenomenon. This will also determine if the leverage effect is stronger when the market is falling. To account for robustness in the analysis, the study has used three separate volatility estimators. These are squared returns, Parkinson volatility estimator and Garman-Klass volatility estimator.

The empirical results confirm that the equity volatility asymmetry exists on the Norwegian stock exchange. The magnitude of the leverage effect is substantially higher when the stock prices are declining and when the market is experiencing a downfall. The results show that market returns has the highest significance level and the greatest explanatory power, which implies that market returns have a bigger impact on equity volatility than individual stock returns and changes in leverage. The results also reveal that the leverage effect diminishes over time, which implies that a change in the financial leverage in a firm's capital structure does not lead to a permanent change in the equity volatility. Since market returns is the dominant variable in explaining the asymmetric volatility and the fact that leverage effect diminishes over time, it is clear that the leverage effect is not only caused by leverage. The results suggests that the leverage effect hypothesis is mainly a down market effect, since the effect is much stronger when the market is falling.

2. Literature Review

MM proposition I suggests that capital structure is irrelevant, when operating with the market efficiency hypothesis. Although there has been broad research on this subject, Dhaliwal, Heitzman and Li (2006) and Miller (1977), MM proposition II states that the cost of capital of total assets is constant. The required rate on equity increases as a linear function when the debt ratio increases. At some point, the increase in the required rate on equity stops and becomes more stable. At the same time the required rate on debt increases due to bankruptcy cost. Myers (1984) explains that a static trade-off framework works by setting a target debt-to-value ratio and gradually moving towards it. A firm's capital structure adds value up to an optimal point and decline after that point, since they cross the target debt ratio and becomes overlevered. The reason for the decline is the present value of financial distress. If debt is risk-free and the debtholders claim on firm value is limited to the face value of the bonds, the main risk and fluctuation on return lies within the equity and the shareholders.

The common explanation for volatility asymmetry relies on Miller and Modigliani (1958) propositions. Due to the fundamental principles in capital structure from Miller and Modigliani (1958), the impact of leverage on stock price behaviour has been widely discussed by economists. Black and Scholes (1973) mentioned the impact of debt in their research and the issue has also been discussed by economists such as Merton (1974), Galai and Masulis (1976) and Geske (1979).

Asymmetric volatility is widely discussed and reviewed within finance and the econometric literature. The empirical results have been conflicting, where some studies find a positive relationship between volatility and expected returns, while other studies reveal a negative relationship. Black (1976) and Christie (1982) were among the first economists to devote time and research into understanding the precise nature and cause of changes in variance. They argued that the financial leverage explained some of the volatility fluctuations. Christie (1982) discovered based on a sample of large firms, that volatility is an increasing function of financial leverage. He found that this relation can induce the elasticity of stock volatility with respect to a change in firm equity to be negative. This implies that the influence of financial leverage on equity volatility declines as leverage increases. If considering Miller and Modigliani (1958) propositions, equity volatility should be a positive increasing function of financial leverage, since it is increasing the firm's chances of financial distress. However, Christie (1982) found that the riskless interest rate has a strong positive effect on volatility. Schwert (1990) confirmed this result by obtaining evidence that interest rate is correlated with stock return volatility. The findings also confirmed that the stock market volatility increases with financial leverage. He discovers that this phenomenon only explains a small part of the variation in the stock market volatility and that leverage alone cannot explain the historical volatility movements. The study also reveals that the stock market volatility tends to increase during recessions. He also explores if the stock market trading volume is correlated with volatility. French and Roll (1986) found that variance could be proportional to trading time, but Schwert (1990) does not find any significant evidence for this theory. On the contrary, Avramov, Chordia and Goyal (2006) found that asymmetric effects in daily volatility are affected by the selling activity. They found evidence for that the uninformed investors often sell when prices decline, which results in an increase in volatility, and the informed investors sell after the prices rise leading to a reduction in volatility.

Figlewski and Wang (2000) used a similar approach as Christie (1982) when they investigated if the "leverage effect" is a leverage effect. They used a leverage model under riskless debt with constant interest rate and no dividend pay-outs. Further they assumed constant volatility for the firms. The argument for not applying a GARCH model as many other studies related to asymmetric volatility, is that the leverage parameter is a structural parameter that should be related to the a firm's capital structure. In a GARCH model the leverage parameter is treated as a coefficient to be estimated from returns data. Another obstacle when operating with models related to the GARCH-family is that the data sample has to be without missing observations, which could be difficult to obtain when analysing historical returns. Their study revealed that there is a leverage effect when the stock prices are falling, but the effect is much weaker when the market is generating positive stock returns. To understand if the leverage effect is diminishing over time, they used returns over time with their respective dummies to see if the effect became stronger or weaker over time. They discovered that the leverage effect tends to die out over time, since the coefficients for the dummies become less significant as the returns ages. The study also showed a much stronger leverage effect for an index compared to individual stocks, which is consistent with a study conducted by Braun, Nelson and Sunier (1995). They also discovered that the leverage effect in implied volatility is much stronger and has a greater significance level compared to the realized volatility, but only when the markets are falling. Figlewski and Wang (2000) showed that a 10% drop in the OEX Index over a month would increase the volatility by 4.52%, but this result is far from being significant. On the contrary, a shorter sample for implied volatility showed that a 10% drop on the OEX Index is expected to increase the call options implied volatility more than 17%. Their conclusion was that the leverage effect is really a down market effect that may have a little direct connection to the firm leverage.

Empirical studies with ARCH models and continuous-time stochastic volatility models have revealed negative correlation between stock returns and volatility. Glosten, Jagannathan and Runkle (1993) found evidence for a negative relationship between conditional mean and conditional variance of the excess return on stocks. They approached their research by incorporating dummy variables in the GARCH-in-mean model to involve seasonal effects, which revealed that positive unanticipated returns appear to result in a downward reversion of the conditional volatility, and negative unanticipated returns results in an upward reversion of the conditional volatility. Booth, Martikainen and Tse (1997) explained in their empirical study that the volatility transmission is asymmetric and that spillovers are more pronounced for bad news than good news. This is also consistent with Koutmos and Booth (1995), who found that there are significant spillovers between the different stock exchanges in the world due to the time differences.

Bollerslev, Litvinova and Tauchen (2006) used high frequency data in their study to investigate the existence of the leverage effect and the volatility feedback effect. The study found evidence for a negative correlation between stock market movements and stock market volatility. They discovered that a steep decline in the market over a five-minute interval could result in increased volatility in the market for several days. This is consistent with studies such as Campbell and Hentschel (1992) who argued that bad news increase the conditional volatility. They also developed a price model that elaborates volatility feedback, with the dividend shock being their only state variable. Wu (2001) further extended the asymmetric volatility model based on dividend growth and dividend volatility to determine the leverage effect and the volatility feedback effect. He found that both leverage effects and volatility feedback effects are important determinants of asymmetric volatility, and the volatility feedback is significant both statistically and economically. Results from the study showed that both dividends news and volatility feedback are important factors in the process that generates returns. However Bekaert and Wu (2000) did a study where they found support for the volatility feedback effect in the Japanese market. They proposed a conditional CAPM model with a GARCH-in-mean parameterization ensuring time variation in conditional means, variances and covariance. They observed that the leverage effect on volatility is small compared to the asymmetry generated through the shocks in the GARCH specification. They found a strong asymmetric volatility in the Nikkei 225 stocks and that the leverage effect tend to appear both in the measured volatility of realized stock returns and in the implied volatility.

Bekaert and Wu (2000) elaborated that when good news arrives the market, there are two effects. First, news always raises the current period volatility and an upward revision of the conditional volatility occurs. When volatility increases, the expected return on equity increases and the stock price decline, so that the original price movements are set back to equilibrium. The volatility feedback dampens the original volatility response to the event. Second, due to good news the stock prices rises, which result in an increase in a firm's equity. Thus the leverage ratio in a firm's capital structure declines, leading to a reduction in conditional volatility. On the contrary bad news results in higher current volatility and increased conditional volatility. This is transmitted into higher expected return and decline in stock prices. A decline in the market capitalization leads to increased leverage and results in higher conditional volatility. Therefore the net impact on stock return volatility is unclear. Their results do not support the leverage model used by Christie (1982), but they are more confident towards the volatility feedback effect and a time-varying market risk premium argumentation. The argumentation elaborates that a forecasted increase in return volatility results in an increase in required expected future stock returns. This will consequently lead to an immediate decline in the stock prices. However, Duffee (1995) argued with the results Christie (1982) obtained, and concluded that the reason for an increase in stock volatility after a price decline is due to a positive contemporaneous relation between firm stock returns and firm stock return volatility. And this relation is positive for small firms and firms with little financial leverage. He found that the negative elasticity of stock volatility with respect to a change in equity does not hold when examining a large sample of firms. On the contrary he found a positive relationship. However, this study supports the relation found by Christie (1980), since the included sample of firms is small.

Recent studies suggest that market volatility may be more closely correlated to asset pricing implications rather than previous thoughts on capital structure. Aydemir, Gallmeyer and Hollifield (2007) investigated the relationship between financial leverage and the dynamics of stock volatility in an economy with realistic interest rate and market price of risk dynamics. They discovered that financial leverage increases the level of equity volatility, but the dynamics of equity volatility are mainly driven by a time-varying interest rate and a time-varying market price of risk. For small firms, they showed that financial leverage contributes more to the dynamics of risk. Their main objective was to explore the leverage effect hypothesis based on market debt valuation. This is difficult to obtain, and previous studies on this subject compute their results based on market return, and not by the financial leverage based on market debt value. However, this study has applied book values of debt, since it difficult to obtain market values of debt. Table 1 presents a list of previous studies and their explanations for asymmetric equity volatility.

Table 1. List of Relevant Studies

Table 1 is an updated version of a table Bekaert and Wu (2000) present in their study. Studies conducted with conditional volatility have usually used models related to the GARCH-family to measure volatility. Studies with gross volatility have mainly applied standard deviation of daily returns. The "unspecified" label in explanation column refers to studies where they have found evidence of volatility asymmetry, but not discussed the cause of the event. The primary cause for the asymmetry volatility remains unclear by the authors of that study.

Studies	Volatility Measure	Presence of Asymmetry	Explanation
Black (1976)	Gross volatility	Stocks, portfolios	Leverage hypothesis
Christie (1982)	Gross volatility	Stocks, portfolios	Leverage hypothesis
Schwert (1990)	Conditional volatility	Index	Leverage hypothesis
Campbell and Hentschel (1992)	Conditional volatility	Index	Time-varying risk premium theory
Glosten, Jagannathan and Runkle (1993)	Conditional volatility	Index	Unspecified
Duffee (1995)	Gross volatility	Stocks	Leverage hypothesis
Braun, Nelson and Sunier (1995)	Conditional Volatility	Stocks, Index	Unspecified
Bekaert and Wu (2000)	Conditional volatility	Index	Time-varying risk premium theory
Figlewski and Wang (2000)	Gross volatility	Stocks, index	Leverage hypothesis
Li, Yang, Hsiao and Chang (2005)	Conditional volatility	Index	Time-varying risk premium theory
Bollerslev, Litvinova and Tauchen (2006)	Conditional volatility	Index	Leverage hypothesis
Aydemir, Gallmeyer and Hollifield (2007)	Conditional volatility	Index	Asset pricing implication

3. Methodology and Data

This study uses a similar approach as Figlewski and Wang (2000). First the analysis will determine if there are any signs of asymmetric volatility in the Norwegian stock market and if the leverage effect hypothesis with returns can be a good explanation. Second the empirical test will explore the leverage effect with measured leverage, which will determine if the leverage effect is caused by leverage. To determine if a change in leverage has a bigger impact on volatility than returns, a regression will be run based on both the variables. To estimate realized volatility I have applied three different volatility estimators to obtain a more robust analysis. First the sum of squared returns is applied. Second the Parkinson (1980) volatility estimator is used to calculate the volatility from intraday high and low prices. Third is the Garman and Klass (1980) volatility estimator, which in addition to Parkinson's volatility estimator includes open and close prices in order to increase precision. Volatility for the OBX Index has only been computed by using squared returns, due to the data available. The analysis containing returns are conducted on daily, weekly, monthly and quarterly returns and the analysis with measured leverage is based on quarterly data. The historical volatility is computed from daily observations. So when the historical monthly volatility and historical quarterly volatility are computed, the volatility is expressed on a daily basis. In other words the volatility in this study has been rescaled to daily volatility. Returns are calculated on daily, weekly, monthly and quarterly observations.

3.1 Data

All of the calculations in this sample are performed on data extracted from the stock database obtained by the Norwegian School of Economics (NHH). The sample contains of 25 firms listed on the OBX Index at Oslo Stock Exchange. The OBX Index consists of the 25 most traded securities in the OSEBX Index, which is the Oslo Børs Benchmark Index[1]. There are numbers of firms in this Index that has recently been listed at the exchange. To obtain a more robust and significant sample, 5 of the firms listed on the OBX Index has been replaced by 5 other securities, which have been listed at the stock exchange over a longer period and with a fair amount of trading volume. Appendix A shows the firms listed on the OBX Index and displays the firms that have been replaced. The data sample used in this study is from 01/01 1990 to 31/12

[1] http://www.oslobors.no/markedsaktivitet/stockIndexOverview?newt__ticker=OBX

2010 and adjusted for dividend payouts and events. The sample for OBX Index is from 29/12 1995 to 31/12 2010 as it was then the Index was first introduced. When applying measured leverage in the regressions, the sample size has been reduced from 01/01 2000 to 31/12 2010 due to missing book values from the period previous to year 2000.

To accomplish a more robust data sample, the data collected for each firm have none or few missing observation. If a firm has missing observations for two consecutive days in the data sample, the observations for that firm will not be included until it has a complete set of observations. If the intraday high price is the same as the intraday low price for an individual stock, the observation has been excluded from the sample. This could occur if the stock only has one trade that particular day, or if the trades are stopped as a consequence of an event. It is important to account for this issue, since volatility estimators such as Parkinson and Garman-Klass will reveal that the intraday volatility is zero if high price is equal to low price, which is a rare phenomenon in the market. This also prevents some outliers in the sample, which would create a bias in the analysis. Observations containing negative leverage ratios have also been removed to avoid any bias in the results. The negative leverage ratio is a result of negative equity, which would imply that the outstanding debt has a higher face value than the total assets of the firm. Only the book value of the debt has been used in this analysis. Figlewski and Wang (2000) actually elaborate that the usage of only book values for debt is a problem in the analysis. They state that the leverage ratio should be computed by using market values of firm's securities, but that is difficult to compute. Outliers due to extreme values do not have any severe effects on the analysis, since all the regressions are run in log form.

3.2 Ordinary Least Squares Method

Since the study is a time series analysis it is important to prevent overlapping observation in the data sample, both for the dependent variable and the explanatory variables. The overlapping data would create a moving average error term, which would make the regressions results inefficient and hypothesis tests biased when applying ordinary least squares (OLS) method, Hansen and Hodrick (1980). Autocorrelation is a violation to the OLS assumption regarding that the error terms should be uncorrelated. Multicollinearity in the time series data is also reduced, when controlling for overlapping data. This also reduces the changes for heteroscedasticity in the errors, remaining the series uncorrelated and contributes to decrease the noise in the data.

To test the normality I use the Jarque-Bera (JB) test. The test determines if the sample has skewness and kurtosis matching the normal distribution. The statistics has a chi^2 distribution with two degrees of freedom, one for skewness and one for kurtosis. The null hypothesis is a joint hypothesis of skewness and kurtosis being equal to zero. So if JB > $Chi^2_{critical}$, the null hypothesis is rejected.

3.3 Volatility and Leverage

Firm's equity, E is denoted by multiplying the number of outstanding shares, N and the stock price, S. Hence the total value of a firm, V is equal to market capitalization plus debt, D. If assumed that debt is risk-free and the systematic risk is transferred to equity holders, all the changes in stock price and firm value will affect the shareholders. This will create an equilibrium between change in firm value and change in equity, $\Delta V = \Delta E$. Since the overall change in stock price reflect the change in equity, the percentage change between these two variables will be the same, resulting in the following equation

$$\frac{\Delta S}{S} = \frac{\Delta E}{E} = \frac{\Delta V}{V}\frac{V}{E} = \frac{\Delta V}{V}\left(\frac{D+E}{E}\right) = \frac{\Delta V}{V}\left(1+\frac{D}{E}\right) \qquad [1]$$

assuming that the number of outstanding shares are fixed. This is consistent with corporate finance theory, implying that the stock is more volatile as debt increases in the firm's capital structure. If (1+D/E) is defined as L, the following equation takes form

$$\sigma_S = \sigma_E = \sigma_V L \qquad [2]$$

where σ_S is the stock volatility, which is equal to volatility on equity, σ_E. $\sigma_V L$ is the volatility of the firm multiplied by the leverage ratio. Since the equity parameter is in the denominator the stock volatility will increase as prices fall and decrease when prices rise.

To determine how change in leverage would influence the dependent variable, elasticity of stock volatility with respect to a change in equity, debt and leverage is computed.

For equity

$$\theta_S = \theta_E = \frac{d\sigma_V}{dE}\frac{E}{\sigma_V L} = -\frac{D}{EL} = -\frac{D}{D+E} \qquad [3]$$

For debt

$$\theta_D = \frac{d\sigma_V}{dD}\frac{D}{\sigma_V L} = \frac{D}{EL} = \frac{D}{D+E} \qquad [4]$$

For leverage

$$\theta_L = \frac{\partial\sigma_S}{\partial L}\frac{L}{\sigma_S} = \frac{\sigma_V L}{\sigma_S} = 1 \qquad [5]$$

The boundary layer for elasticity of stock volatility with respect to a change in equity is $-1 \le \theta_E \le 0$ and to a change in debt it is $0 \le \theta_D \le 1$. This implies that there is a negative relationship between equity and volatility. If a firm's debt is nearly equal to the firm value the elasticity would be approximately -1 and increase gradually towards 0 when the D/E ratio decreases. Equation [5] estimates a theoretical value for the leverage coefficient in the tests and indicates that the elasticity of stock volatility with respect to a change in leverage should be 1. However Figlewski and Wang (2000) elaborate that if volatility is not constant, there would be a second influence on equity volatility. Taking the total derivative of equation [2] gives

$$d\sigma_S = \sigma_V \frac{dL}{dV} dV + L\frac{d\sigma_V}{dV} dV \qquad [6]$$

where

$$\frac{dL}{dV} dV = \frac{dL}{dE}\frac{dE}{dV} dV = -\frac{D}{E^2} dV \qquad [7]$$

can be substituted into the elasticity formula

$$\theta_L = \frac{d\sigma_S}{dL}\frac{L}{\sigma_S} = \left[\sigma_V - \frac{L}{D/E^2}\frac{\partial\sigma_V}{\partial\sigma_S}\right]\frac{L}{\sigma_S} = 1 - \frac{E^2 L^2}{D\sigma_S}\frac{\partial\sigma_V}{\partial V} \qquad [8]$$

Since the coefficient for the second term in equation [8] is negative, the result implies that a drop in firm value is correlated with an increase in firm volatility. The measured elasticity of the stock volatility with respect to leverage will therefore be greater than 1. However, if the firm in near to insolvency, θ_L will be less than 1 due to creditors will also be affected by the fluctuations in the firm value. If the market fully incorporates the change in capital structure into the firm's stock price, the elasticity should be equal to 1.

The empirical tests in this study are set up as regressions of the following form.

$$\Delta \ln \sigma_S = \beta_0 + \beta_1 \Delta \ln L + dummies \qquad [9]$$

where the second coefficient is the estimate for elasticity of the stock volatility with respect to changes in leverage, θ_L.

3.4 Volatility Estimators

To assure a more accurate estimate for volatility on daily basis, the average volatility has been computed for the respective periods. This is to achieve a more accurate estimate for volatility when working with weekly, monthly and quarterly returns. There are different amount of trading days during a period due to holidays and number of days in a month. The following equation has been applied to calculate volatility with squared returns

$$\hat{\sigma}_t^2 = r_t^2 \qquad [10]$$

where *t* determines the time period.

whereas the change in volatility is estimated by the following equation

$$\Delta\sigma_t = \ln\left[\left(\ln\left(\frac{C_{t+1}}{C_t}\right)\right)^2\right] - \ln\left[\left(\ln\left(\frac{C_t}{C_{t-1}}\right)\right)^2\right] \qquad [11]$$

$\Delta\sigma$ is the volatility change in natural log. *C*, is the closing price

Parkinson (1980) derived a volatility estimator, which is based on differences in high and low prices of a stock. Assuming that intraday prices follow a geometric Brownian motion this estimator is ought to be less noisy than the squared daily returns and is unbiased when expected returns are zero. However the estimator may be biased for other stochastic processes. This also provides much of the information about the volatility in the stock price for a complete intraday and is defined as

$$\hat{\sigma}_p^2 = \frac{(h-l)^2}{4\ln 2} \qquad [12]$$

where *h* and *l* are high price and low price, respectively. The changes in volatility is calculated in natural log and is estimated by the following equation

$$\hat{\sigma}_p^2 = \ln\left(\frac{(h_{t+1}-l_{t+1})^2}{4\ln 2}\right) - \ln\left(\frac{(h_{t-1}-l_{t-1})^2}{4\ln 2}\right) \qquad [13]$$

The volatility estimator derived by Graman and Klass (1980) also includes opening and closing prices in addition to high and low price for intraday. This makes the estimates even less noisy than the Parkinson volatility estimator. Rogers and Satchell (1991) explained two drawbacks with the Garman-Klass volatility estimator. First, the estimator would be biased if used in the case of a nonzero expected return. Second, in simulations, the numerical value obtained would not be as close to the true value as it should be, but this would not generate any problems in this study. The Garman-Klass volatility estimator is defined as

$$\hat{\sigma}_{GK}^2 = 0.5(h-l)^2 - (2\ln 2 - 1)c^2 \qquad [14]$$

where c = *ln(close price)–ln(open price)*. The changes in volatility is calculated in natural log and is estimated by the following equation

$$\hat{\sigma}_{GK}^2 = \ln\left[(0.5(h_{t+1}-l_{t+1})^2 - (2\ln 2-1)c_{t+1}{}^2)\right] - \ln\left[(0.5(h_{t-1}-l_{t-1})^2 - (2\ln 2-1)c_{t-1}{}^2)\right] \quad [15]$$

3.4.1 Jump Component

To observe less noisy data a jump component is added to the Parkinson volatility estimator and to the Garman-Klass volatility estimator. The component is added due to the deviation between the closing price and the opening price the next day. There is often a jump in the price when the stock exchange opens due to events and global news. The price jump between the closing price and the opening price for the next day should be included when estimating the volatility for a whole trading day. The formula for jump is defined as

$$Jump = \ln(O_t) - \ln(C_{t-1}) \qquad [16]$$

where O is the opening price and C is the closing price. The jump adjusted Parkinson volatility estimator is then defined as

$$\hat{\sigma}^2_{pwjump} = \frac{(h_t - l_t)^2}{4\ln 2} + \left[\ln\left(\frac{O_t}{C_{t-1}}\right)\right]^2 \qquad [17]$$

and the jump adjusted Garman-Klass volatility estimator is defined as

$$\hat{\sigma}^2_{GKwjump} = 0.5(h_t - l_t)^2 - (2\ln 2 - 1)c_t^{\,2} + \left[\ln\left(\frac{O_t}{C_{t-1}}\right)\right]^2 \qquad [18]$$

3.5 The Leverage Effect with Returns

The following equation is used to regress the relationship between volatility and returns. The regression is run in logs

$$\Delta\sigma = \beta_0 + \beta_1 R + \varepsilon \qquad [19]$$

where β_0 is the constant, β_1 is the coefficient for return, ε is the error term in the regression and R are the returns. $\Delta\sigma$ is the volatility change in natural log. The regression is run for both individual stocks and when the sample is treated as a panel data. Time-fixed effects are incorporated in the regressions when the sample is in a panel data to prevent bias in the analysis. The time-fixed effect will than enclose all the variables affecting the dependent variable over time, but the effect will not vary over cross-sections. This would capture the heterogeneity that is enclosed in the fixed effects by a method that allows different intercepts for each time, Brooks (2008). Dummy variables are also included in all the regression to analyze if negative returns have a bigger impact on equity volatility than positive returns. When applying time-fixed effects the dummy variables will capture time variation rather than cross-sectional variation. The dummy variable has been added in equation [20] and is equal to 1 if the return is negative and 0 otherwise.

$$Down = \begin{cases} 1 \text{ if R} < 0 \\ 0 \text{ otherwise} \end{cases}$$

The equation is defined as

$$\Delta\sigma = \beta_0 + \beta_1 R + \beta_2 R \times Down + \varepsilon \qquad [20]$$

where β_0 is the constant and β_1 is the coefficient for return. β_2 is the coefficient for the dummy variable. The leverage effect is measured by β_1 in the upward market and $\beta_1 + \beta_2$ in the down market. If this dummy coefficient is statistically significantly and negative it would indicate that the effect is stronger when the market is falling, which would imply asymmetric volatility. The equations above will also be applied when exploring the leverage effect on the OBX Index. To analyse if market returns have a better explanatory power than individual stocks, a regression based on these two variables has been run. The regression equations are similar to equation [19] and equation [20], but have an explanatory variable, R_M for the OBX Index in addition.

$$\Delta\sigma = \beta_0 + \beta_1 R_S + \beta_2 R_M + \varepsilon \qquad [21]$$

$$\Delta\sigma = \beta_0 + \beta_1 R_S + \beta_2 R_M + \beta_3 R_s \times Down_s + \beta_4 R_M \times Down_M + \varepsilon \qquad [22]$$

Equation [22] has two separate dummies, each for the stock returns and the market returns. If the coefficient for market returns is significantly greater than the coefficient for the individual stock returns it would imply that the effect is a down market effect. The expected result is that market returns has a greater impact on the volatility than the individual stock retruns. Previous studies such as Figlewski and Wang (2000) reveal that the magnitude of the leverage effect is much greater for the index compared with the individual stocks.

Under the term leverage effect it is important to establish the assumption that a change in a firm’s capital structure and leverage ratio should make a permanent change in stock volatility. If considering Miller and Modigliani (1958) propositions, volatility should be a variable dependent on firm's capital structure, not by the change in leverage. The change in leverage over a period should reflect the stock price and the cumulative volatility for this period should be induced by the changes in the capital structure. In other words a change in leverage should make a permanent change in stock volatility. To determine if this theory resembles the propositions, the study explores if the leverage effect diminishes over time. The analysis is done on a sample based on monthly returns and by adding the previous returns for the second lag and the third lag into equation [19].

$$\Delta\sigma = \beta_0 + \beta_1 R_t + \beta_2 R_{t-1} + \beta_3 R_{t-2} + \varepsilon \qquad [23]$$

$\Delta\sigma$ is the change in volatility over a period of 3 months and R_t, R_{t-1}, R_{t-2} are the returns in the last month of the period, the month before that and the month before that. If the magnitude and the significance level for the coefficients are approximately equal, then the results would be consistent with the theory. That would imply that the leverage effect is due to actual change in firm leverage, which corresponds to a change in the stock price. Equation [24] has been applied to investigate if the diminishing effect is stronger in a falling market. Two new dummy variables have been added to this equation, one for the second lag and one for the third lag.

$$\Delta\sigma = \beta_0 + \beta_1 R_t + \beta_2 R_{t-1} + \beta_3 R_{t-2} + \beta_4 R_t \times Down_t + \beta_5 R_{t-1} \times Down_{t-1} + \beta_6 R_{t-2} \times Down_{t-2} + \varepsilon \qquad [24]$$

3.6 The Leverage Effect with Leverage

The following equation is used for determining if measured leverage can explain the asymmetric equity volatility. The regression is run in logs

$$\Delta\sigma = \beta_0 + \beta_1 LEV + \varepsilon \qquad [25]$$

where LEV is the change in leverage in natural log.

$$LEV = \ln\left(\frac{L_t}{L_{t-1}}\right) \qquad [26]$$

The regression in only applied when the stocks are in panel data. There have been no attempts to calculate the financial leverage for the OBX Index. Since the sample is in a panel data, time-fixed effects have also been accounted for in these regressions. A dummy variable has been added in equation [27] to verify if the volatility increases when financial leverage increase. The dummy variable is defined as 1 if the change in LEV is bigger than zero and 0 otherwise.

$$Up = \begin{cases} 1 \text{ if LEV} > 0 \\ 0 \text{ otherwise} \end{cases}$$

$$\Delta\sigma = \beta_0 + \beta_1 LEV + \beta_2 LEV \times Up + \varepsilon \qquad [27]$$

The coefficient for LEV is the estimate for the elasticity of stock volatility with respect to a change in leverage. As mentioned earlier, elasticity of stock volatility with respect to a change in leverage should be equal to 1 if the volatility is constant and when the changes in firm value are transferred to the equity. On the contrary, if the firm is near to bankruptcy the elasticity, θ_L will be less than 1, due to the increased risk to the creditors. Hence, the burden will be transmitted to the debt holders as well, reducing the elasticity of equity volatility. If the firm value falls and the volatility increases under normal circumstances the burden will be totally borne by the equity holders and the θ_L will be greater than 1. However, most of the firms in this analysis are among the largest corporations in Norway with a healthy financial strategy. Therefore the estimates should not be biased towards under 1. Since the dummy variable is positive, the dummy coefficient is expected to be positive, which would imply that a positive change in leverage should give an increase in volatility.

To determine if a change in leverage ratio has a better explanatory power than stock returns, a regression based on a panel of stock returns and LEV is run on quarterly data.

$$\Delta\sigma = \beta_0 + \beta_1 R_t + \beta_2 LEV_t + \varepsilon \qquad [28]$$

And to determine if the volatility increases when the market is falling I add a dummy variable to each of the independent variables in equation [29]

$$\Delta\sigma = \beta_0 + \beta_1 R_t + \beta_2 LEV_t + \beta_3 R_t \times Down + \beta_4 LEV_t \times Up + \varepsilon \qquad [29]$$

If the dummy coefficient for LEV is statistically significant and has greater explanatory power than the dummy coefficient for stock returns, it would indicate that the “leverage effect” is caused by leverage. Change in leverage will then be the dominant variable and have a stronger impact on equity volatility. However, if the opposite result should occur it would simply imply that the leverage effect is more of a down market effect.

The final equations are based on stock returns, market returns and leverage as explanatory variables. Since all three independent variables are run separately first to determine the effect on volatility, it would be important to examine the effect when they are combined into one regression. The coefficient estimates from equation [30] will elaborate if asymmetric equity volatility can be explained entirely by leverage, or if the returns have a better explanatory power to verify this phenomenon.

$$\Delta\sigma = \beta_0 + \beta_1 R_S + \beta_2 R_M + \beta_3 LEV + \varepsilon \qquad [30]$$

Equation [31] includes dummy variables for each of the independent variables and determines if the magnitude of the leverage effect is stronger when the returns are negative and the changes in leverage are positive.

$$\Delta\sigma = \beta_0 + \beta_1 R_S + \beta_2 R_M + \beta_3 LEV + \beta_4 R_s \times Down_s + \beta_5 R_M \times Down_M + \beta_6 LEV \times Up + \varepsilon \quad [31]$$

4. Empirical Results

4.1 Summary Statistics

Table 2 presents the summary statistics. As mentioned, the historical monthly volatility and historical quarterly volatility are expressed on a daily basis. The summary statistics show that the average daily historical volatility for the OBX Index during a month is 1.31%. According to the Jarque-Bera statistics, non-normality exists in the sample. The kurtosis is 12.348 and the skewness coefficient is 2.608. The average monthly market return is 0.8%, spanning over range between -29% and 15%. The average daily historical volatility for the stocks during a month is 2.8% and ranging from 0.4% to 34%. The Jarque-Bera statistics show that non-normality exists in the sample, with a kurtosis coefficient of 47.243 and skewness of 4.864. The leverage ratio parameter is highly dispersed and ranges from 1.220 to 58.410 with a high standard deviation. Non-normality exists in the leverage sample, which could be observed from the Jarque-Bera statistics and has a skewness coefficient of 3.182 and kurtosis of 19.070, which implies fat tails in the distribution.

Table 2. Summary Statistics

Table 2 present the summary statistics for the data sample used in this empirical study. The sample consists of 25 firms listed on the OBX Index at Oslo Børs. The OBX Index consists of the 25 most traded securities in the OSEBX Index, which is the Oslo Børs Benchmark Index. Numbers of observations (NOBS) are listed in the table along with the sample period. Historical volatility is calculated as average of squared returns and expressed on a daily basis. Return on OBX is calculated by taking the natural log of (C_t / C_{t-1}), where *C* represents the closing price and t is the time period. Measured leverage is obtained from book values and calculated by (1+ debt/equity). To test the normality I use the Jarque-Bera test. The test determines if the sample has skewness and kurtosis matching the normal distribution. The statistics has a chi^2 distribution with two degrees of freedom, one for skewness and one for kurtosis. The null hypothesis is a joint hypothesis of skewness and kurtosis being equal to zero. So if JB > Chi$^2_{critical}$, the null hypothesis is rejected. All the variables in this sample are extracted from the stock database obtained by the Norwegian School of Economics (NHH).

Monthly Sample for the OBX Index, 1995-2010								
	Mean	Max	Min	Std. Dev.	Skewness	Kurtosis	Jarque-Bera	NOBS
Historical Vol.	0.0131	0.0594	0.0044	0.0079	2.608	12.348	859.498	180
Return on OBX	0.0082	0.1469	-0.2906	0.0709	-1.416	6.711	163.451	180
Quarterly Sample for the OBX Index, 1995-2010								
	Mean	Max	Min	Std. Dev.	Skewness	Kurtosis	Jarque-Bera	NOBS
Historical Vol.	0.0136	0.0512	0.0065	0.0072	2.781	13.957	377.499	60
Return on OBX	0.0247	0.2547	-0.4052	0.1429	-1.337	4.506	23,542	60
Monthly Sample for the 25 Firms, 1990-2010								
	Mean	Max	Min	Std. Dev.	Skewness	Kurtosis	Jarque-Bera	NOBS
Historical Vol.	0.0280	0.3413	0.0044	0.0207	4.864	47.243	290118.1	3393
Quarterly Sample for 25 firms, 1990 - 2010								
	Mean	Max	Min	Std. Dev.	Skewness	Kurtosis	Jarque-Bera	NOBS
Historical Vol.	0.0291	0.2036	0.0079	0.0197	3.776	24.795	25250.07	1139
Leverage*	4.5544	58.4096	1.2201	5.0769	3.182	19.070	11900	956

*The data sample for leverage is from 2000-2010

Table 3. Leverage Effect with Stock Returns

Table 3 presents the panel data regression results based on daily, weekly, monthly and quarterly stock returns. Squared return is the volatility estimator and the dependent variable in the regression. Equation [19] has been used to compute the results in the first row of each of the periods, while equation [20] has a dummy variable in addition to determine the asymmetrical volatility. The sample consists of 25 firms listed on the OBX Index at Oslo Børs. The OBX Index consists of the 25 most traded securities in the OSEBX Index, which is the Oslo Børs Benchmark Index. There are numbers of firms on this index that has recently been listed at the exchange. To obtain a more robust and significant sample 5 of the firms on the OBX Index has been replaced by 5 other securities. Numbers of observations (NOBS) are listed in the table and are from a period between years 1990 to 2010. β_1 is the coefficient for stock returns and β_2 is the coefficient for the dummy variable, which is defined as 1 if the stock return is less than zero and 0 otherwise. R^2 determines how well the independent variables are explained by the dependent variable. All of the variables in this sample are extracted from the stock database obtained by the Norwegian School of Economics (NHH).

(t-statistics in parentheses)

Return Period	Constant β_0	Return β_1	Return Down, β_2	R^2	NOBS
Daily Returns	-0.000 (-0.397)	0.094 (36.928)		0.076	70360
	0.006 (71.472)	-0.221 (-59.528)	0.611 (109.329)	0.219	70360
Weekly Returns	0.000 (0.154)	-0.001 (-0.501)		0.071	7730
	0.000 (0.695)	-0.004 (-0.985)	0.005 (0.859)	0.071	7730
Monthly Returns	-0.009 (-0.749)	-0.387 (-3.861)		0.391	3343
	-0.061 (-3.366)	0.201 (1.128)	-0.994 (-3.989)	0.394	3343
Quarterly Returns	-0.035 (-1.817)	-0.239 (-2.791)		0.515	1088
	-0.119 (-4.178)	0.280 (1.804)	-0.852 (-3.997)	0.523	1088

4.2 Leverage Effect with Return

The regression results from equation [19] and equation [20] are quite similar for all the volatility estimators. Table 3 present the results for when stock returns are treated as a panel data and the volatility estimator is squared returns. The table consists of regression results based on daily, weekly, monthly and quarterly returns. The leverage effect coefficient β_1 reveals a negative value in three of the four return periods, when looking at the estimated coefficients from equation [19]. Results with daily returns have a positive coefficient for leverage effect and that particular observation also has a high significance level, which could be a consequence of the noisy data and give a poor estimate. The most significant results are obtained from the regression with monthly returns, where the estimated coefficient for leverage effect is -0.387. This implies that if the market falls 10% during a month, the daily equity volatility would be expected to increase 3.87%. That would imply a rise in daily volatility from 2.8% to 2.91%. The estimated coefficient for the regression with quarterly returns is statistically significant and is -0.239, implying a drop of 10% in the market over a quarter is expected to increase the daily volatility by 2.39%. For monthly and quarterly returns the results are significant at a 5% significant level.

When looking at the estimated coefficients from equation [20], it could be observed that results from daily returns are still highly statistically significant and may have the same error as the estimated coefficients from equation [19]. Regression results obtained with monthly and quarterly returns give significant coefficients for the dummy variable, which are negative since the dummies are 1 if the returns are negative. The coefficients for the dummy variables are statistically significant and greater than the coefficients for returns, which indicate that the leverage effect is stronger when the stock prices are falling compared to when the stock prices are rising. The dummy coefficient for monthly returns is -0.994 resulting in an increase of (0.201-0.994) = 7.93% in daily volatility if the prices fall 10% during a month. If the stock prices rise 10% during a month the daily volatility would be expected to increase by only 2.01%. The results with quarterly returns show that the daily volatility is expected to increase (0.280-0.852) = 5.72% if the prices fall 10% during a quarter. And if the prices rise 10% during the same period the daily volatility would be expected to increase by 2.8%. The elasticity of stock volatility with respect to changes in equity is expected to be between the theoretical values -1 and 0. From table 3 it is clear that in most cases the elasticity seems to fit the theory. The regression results with Parkinson and Garman-Klass as the volatility estimators are presented in the Appendix.

Table 4. Leverage Effect with OBX Index

Table 4 presents the regression results based on daily, weekly, monthly and quarterly market returns. Squared return is the volatility estimator and the dependent variable in the regression. Equation [19] has been used to compute the results in the first row of each of the periods, while equation [20] has a dummy variable in addition to determine the asymmetrical volatility. The sample consists of 25 firms listed on the OBX Index at Oslo Børs. The OBX Index consists of the 25 most traded securities in the OSEBX Index, which is the Oslo Børs Benchmark Index. Numbers of observations (NOBS) are listed in the table and are from a period between years 1995 to 2010. β_1 is the coefficient for market returns and β_2 is the coefficient for the dummy variable, which is defined as 1 if the market return is less than zero and 0 otherwise. R^2 determines how well the independent variables are explained by the dependent variable. All of the variables in this sample are extracted from the stock database obtained by the Norwegian School of Economics (NHH).

(t-statistics in parentheses)

Return Period	Constant β_0	Return β_1	Return Down, β_2	R^2	NOBS
Daily Returns	-0.000 (-0.129)	0.004 (4.873)		0.006	3763
	0.000 (23.771)	-0.036 (-25.899)	0.072 (34.495)	0.245	3763
Weekly Returns	0.006 (0.161)	-5.007 (-4.281)		0.023	781
	-0.051 (-0.882)	-2.285 (-0.995)	-4.679 (-1.376)	0.025	781
Monthly Returns	0.041 (0.615)	-3.901 (-4.130)		0.088	178
	-0.113 (-1.057)	-0.481 (-0.232)	-5.580 (-1.847)	0.106	178
Quarterly Returns	0.098 (0.925)	-2.490 (-3.417)		0.173	58
	-0.048 (-0.255)	-0.945 (-0.524)	-2.426 (-0.935)	0.186	58

The regression results for the OBX Index are presented in table 4. The regression results from equation [19] are similar to the results obtained for the stock returns. The leverage effect coefficient β_1 is positive when the regression is run with daily returns, but negative for the other three return periods. The coefficient is highly statistically significant for all four return periods and the leverage effect appears to be stronger for the Index than for the stock returns. Results from weekly returns reveal that a 10% drop in the market within a week, will increase the daily equity volatility by 50%. For monthly and quarterly returns, a drop of 10% in the market during their respective periods will result in an increase in the daily equity volatility by 39% and 25%. This would imply that the daily volatility during a month would be expected to increases from 1.31% to 1.82%.

The findings from equation [20] are not significant at a 5% significance level for weekly, monthly and quarterly returns, but they reveal an interesting result. The findings show that the dummy coefficients, β_2 are far more significant and negative compared to the coefficients that determines the leverage effect when the market rises. A 10% drop in the market prices during a month corresponds to a (-0.481-5.580) = 60.67 % increase in daily equity volatility. If the market rise 10% during the same period, the daily volatility is expected to decrease by 4.81%. The estimated coefficients for quarterly returns show a 10% drop in the market will correspond to a (-0.945-2.426) = 33.71% increase in the daily equity volatility. A 10% rise in the market during the same period will decrease the daily volatility by 9.45%. The results show extreme asymmetric equity volatility, evidencing a much stronger response when the market falls compared to when the market rises. The estimated elasticity of stock volatility with respect to changes in equity is greater than 5 for monthly returns and greater than 2 for quarterly returns.

To summarize the findings from table 3 and table 4, it is clear that there is a stronger effect on equity volatility when the market is falling. The empirical findings show that there is asymmetric equity volatility in the Norwegian stock market and the effect is much stronger when the market is experiencing negative returns. According to the theory there should be symmetry in equity volatility when the stock market rises and falls. It appears that the market returns have a greater impact on the equity volatility than the individual stocks. The results are consistent with Figlewski and Wang (2000), where they achieve a substantially larger effect when the returns are negative and they also obtain much stronger effect for the index than with the individual stocks. The results also confirm studies conducted by Christie (1982) and Schwert (1990). However, according to the obtained results the leverage effect appear to more of a down market effect.

Table 5. Leverage Effect with Stock in Panel Data and OBX Index

Table 5 presents the panel data regression results based on stock returns and market returns. Squared return is the volatility estimator and the dependent variable in the regression. Equation [21] has been used to compute the results in the first row, while equation [22] has dummy variables in addition to determine the asymmetrical volatility. The sample consists of 25 firms listed on the OBX Index at Oslo Børs. The OBX Index consists of the 25 most traded securities in the OSEBX Index, which is the Oslo Børs Benchmark Index. There are numbers of firms on this Index that have recently been listed at the exchange. To obtain a more robust and significant sample 5 of the firms on the OBX Index has been replaced by 5 other securities. Numbers of observations (NOBS) are listed in the table and are from a period between years 1995 to 2010, since the OBX Index was first introduced in 1995. β_1 is the coefficient for stock returns and β_2 is the coefficient for the market returns. β_3 and β_4 are the dummy coefficients for stock returns and market returns, respectively. The dummy variable is defined as 1 if the stock/market return is less than zero and 0 otherwise. R^2 determines how well the independent variables are explained by the dependent variable. All of the variables in this sample are extracted from the stock database obtained by the Norwegian School of Economics (NHH).

(t-statistics in parentheses)

Volatility Estimator	Constant β_0	Stock Return, β_1	OBX Return, β_2	Stock Down, β_3	OBX Down, β_4	R^2	NOBS
Squared Returns	0.014	-0.277	-2.596			0.057	3188
	(0.904)	(-2.365)	(-10.341)				
	-0.130	0.134	-0.285	-0.714	-3.681	0.070	3188
	(-4.854)	(0.649)	(-0.550)	(-2.474)	(-4.995)		

Equation [21] and equation [22] determines if market returns have a stronger impact on the equity volatility than individual stock returns. The regression results will clarify which of the variables explain most of the asymmetric volatility when the prices and the market decline. Table 5 presents the results from these equations based on the monthly returns using squared returns as the volatility estimator. The coefficients determining the leverage effect varies considerably for the stock returns and the market returns when looking at the estimated coefficients from equation

[21]. Both of the estimated coefficients are negative and statistically significant at a 5% significance level. The findings reveal that the daily volatility would be expected to increase 29%, if there is a 10% fall in the stock prices and the market during a month. The estimated coefficient for market returns is approximately four times more significant than the coefficient for stock returns. This result implies that market returns have a better explanatory power towards equity volatility than stock returns. The estimated coefficient for stock returns and market returns are -0.277 and -2.596, respectively. This implies that the OBX Index has a stronger effect on equity volatility. The results are consistent with the expected outcome, where the Index has a distinctly lager impact on the equity volatility. The estimated coefficients from equation [22] reveal asymmetric equity volatility in the Norwegian market. The dummy coefficient for market returns appears to have a larger effect on volatility compared with the dummy coefficient for stock returns. The dummy coefficient for market returns is also twice as significant, showing that the stock market becomes more volatile due to the negative returns on the Index. The coefficients for positive returns appear to be insignificant and much smaller compared to the coefficients for negative returns for both the variables, which indicate the existence of asymmetric equity volatility. The results show that a 10% fall in the stock prices and the market would expect to increase the daily volatility over 45% during a month, while a rise in the prices and market of the same magnitude will decrease the daily volatility by only 2%. Since the coefficients for market returns have a higher significance and greater explanatory power, it confirms that the leverage effect is mainly a down market effect. The regression results with Parkinson and Garman and Klass as the volatility estimators are presented in the Appendix.

To determine if the leverage effect is consistent or diminishes over time, regression based on equation [23] and equation [24] has been run. The regressions are run with monthly returns for both stocks in panel and the OBX Index. The results are presented in table 6 and the results for stocks in panel will be reviewed first. From the estimated coefficients in equation [23] it can evidently be found that the elasticity for the stock volatility with respect to changes in equity are between the theoretical values $-1 \leq \theta_E \leq 0$. The coefficients are not consistent over time and the statistically significance at a 5% significance level varies over the periods. The estimated dummy coefficients from equation [24] tend to become smaller and less significant over time, indicating that the leverage effect diminishes over time. According to the theory a change in leverage

Table 6. Diminishing Leverage Effect over Time Using Returns

Table 6 presents the panel data regression results for the diminishing leverage effect over time using monthly returns. Squared return is the volatility estimator and the dependent variable in the regression. Equation [23] has been used to compute the results in the first row, while equation [24] has dummy variables in addition to determine the asymmetrical volatility. The top section represents the results from stock returns, while the bottom section represents the dying out effect for market returns. The sample consists of 25 firms listed on the OBX Index at Oslo Børs. The OBX Index consists of the 25 most traded securities in the OSEBX Index, which is the Oslo Børs Benchmark Index. There are numbers of firms on this index that has recently been listed at the exchange. To obtain a more robust and significant sample 5 of the firms on the OBX Index has been replaced by 5 other securities. The Numbers of observations (NOBS) are listed in the table and the data sample is from year 1995 to 2010, since the OBX Index was first introduced in 1995. β_1 , β_2 , β_3 are the coefficients for the expected volatility the next month, the second month and the third month. β_4 , β_5 , β_6 are the respective dummies to the returns over time, which are defined as 1 if the market return is less than zero and 0 otherwise. The dummies elaborate if the leverage effect is asymmetrical. R^2 determines how well the independent variables are explained by the dependent variable. All of the variables in this sample are extracted from the stock database obtained by the Norwegian School of Economics (NHH).

(t-statistics in parentheses)

Data Sample	Constant β_0	Return(t) β_1	Return(t-1) β_2	Return(t-2) β_3	Down(t) β_4	Down(t-1) β_5	Down(t-2) β_6	R^2	NOBS
Stock Panel Data	-0.024 (-1.822)	-0.261 (-2.484)	-0.192 (-1.840)	-0.317 (-3.050)				0.475	3293
	-0.095 (-3.933)	0.263 (1.365)	0.096 (0.512)	-0.240 (-1.289)	-0.867 (-3.218)	-0.446 (-1.689)	-0.073 (-0.278)	0.478	3293
OBX Index	0.079 (1.024)	-3.891 (-3.540)	-2.357 (-2.095)	-1.561 (-1.417)				0.128	176
	-0.162 (-0.881)	-1.400 (-0.581)	-0.187 (-0.078)	-0.536 (-0.224)	-4.081 (-1.146)	-3.272 (-0.924)	-1.162 (-0.334)	0.140	176

should lead to a permanent change in stock volatility. The results present a different outcome and show that a 10% drop in the stock prices would increase the daily stock volatility by (0.263-0.867) = 6.04% the next month, (0.096-0.446) = 3.5% two months later and (-0.24-0.073) = 3.13% three months later. The regression results with Parkinson and Garman-Klass as the volatility estimators are presented in the Appendix.

The results for the OBX Index have a similar pattern as the stock returns and the results show clearer signs for that the leverage effect diminishes over time. The regression results from equation [23] show that the coefficients become weaker and less significant over time. Results obtained from equation [24] shows a similar pattern for the dummy coefficients over time. A 10% drop in the market would increase the daily equity volatility by (-1.4-4.081) = 54.81% the next month, (-0.187-3.272) = 34.59% two month later and (-0.536-1.162) = 16.98% three months later. If the leverage effect is caused by leverage, the reduction in equity volatility should not occur according to the theory. The results for both individual stocks and the OBX Index are consistent with the results obtained by Figlewski and Wang (2000), where they find evidence for that the leverage effect has a tendency to diminish over time.

To summarize the subsection with leverage effect with returns as the independent variable, it could be concluded that the existence of asymmetric equity volatility is present, but it is not only caused by leverage. Both the market returns, and the individual stock returns show a strong effect on the volatility when the market is falling, but when the market is generating positive returns the volatility does not correspond to the same extend. Considering the theory of leverage effect, there should be a symmetrical increase and decrease in equity volatility caused by a change in leverage. The results show that the phenomenon leverage effect appears only when the market is falling, hence indicating more of a down market effect. After looking at the regressions containing both the market returns and the stock returns as the independent variables, it can be confirmed that the Index has a stronger impact than the individual stocks on equity volatility. The results thereby confirm the statement that the leverage effect appears to be more of a down market effect. When exploring the leverage effect over a period of three months, it is clear that the effect diminishes over time. The coefficients become less negative and less significant as return ages. This appears to be a violation to the theory regarding that the change in leverage should have a consistent and a permanent impact on stock volatility, not just temporary. The findings disclose this phenomenon for both the OBX Index and the individual stocks.

4.3 Leverage Effect with Leverage

Table 7 present the regression results obtained from equation [25] and equation [27]. The table displays the results for stocks in panel based on the different volatility estimators. The estimated coefficients are statistically significant at a 5% significance level when the regressions are executed with Parkinson and Garman-Klass as the volatility estimators. The jump component is included in both the estimators to obtain the aggregated volatility for a whole day. The regression results obtained from equation [25] reveals that the estimated coefficient for determining the leverage effect is positive for all of the volatility estimators. The elasticity of stock volatility with respect to change in leverage are under the theoretical value of 1. This could occur as mentioned when the changes in leverage are not fully seized in the stock volatility. However, the estimated coefficients for leverage effect are statistically significant and positive when applying Parkinson and Garman-Klass as the volatility estimators. The estimated coefficient when Parkinson is the volatility estimator reveals that a 10% increase in leverage would increase the daily volatility by 2.25%. The regression results when Garman-Klass is the volatility estimator shows that a 10% increase in leverage is expected to increase the daily volatility by 2.31%.

Looking at the estimated coefficients from equation [27], it shows that reduction in leverage induces a decrease in the volatility. The results obtained from Parkinson, reveal a 10% reduction in leverage would expect to decrease the daily equity volatility by 4.95%. Notice that the sign for the leverage coefficient β_1 is negative, since it only contains observations with negative changes in leverage. When Garman-Klass is the volatility estimator the regression results reveal a reduction of 5.09% in daily equity volatility when leverage decreases by 10% in the capital structure. The estimated dummy coefficients are negative, but less significant than the coefficients without the dummies. The regression results from equation [25] and equation [27] clearly show that an increase in leverage will increase the equity volatility and a reduction in leverage will decrease the equity volatility. The results are asymmetrical, but not to any severe extent. The results are consistent with the theory, stating that leverage increases equity volatility.

Table 7. Leverage effect with leverage

Table 7 presents the panel data regression results with changes in leverage (LEV) as the explanatory variable based on quarterly observation. The results with all three volatility estimators are presented in the table, where the first column determines the estimators. The jump component is included in two of the estimators, to obtain the volatility for a whole day. Equation [25] has been used to compute the results in the first row; while equation [27] has a dummy variable in addition to determine if the leverage effect is asymmetrical. The sample consists of 25 firms listed on the OBX Index at Oslo Børs. The OBX Index consists of the 25 most traded securities in the OSEBX Index, which is the Oslo Børs Benchmark Index. There are numbers of firms on this index that has recently been listed at the exchange. To obtain a more robust and significant sample 5 of the firms on the OBX Index has been replaced by 5 other securities. Numbers of observations (NOBS) are listed in the table and are the data sample is from year 2000 to 2010. β_1 is the coefficient for change in leverage and β_2 is the coefficient for the dummy variable, which is defined as 1 if the change in leverage is positive and 0 otherwise. R^2 determines how well the independent variables are explained by the dependent variable. All of the variables in this sample are extracted from the stock database obtained by the Norwegian School of Economics (NHH).

(t-statistics in parentheses)

Volatility Estimator	Constant β_0	LEV β_1	LEV Up β_2	R^2	NOBS
Squared Returns	-0.037	0.222		0.513	834
	(-1.662)	(1.957)			
	-0.013	0.434	-0.485	0.516	834
	(-0.526)	(2.700)	(-1.859)		
Parkinson*	-0.036	0.225		0.612	834
	(-1.880)	(2.302)			
	-0.006	0.495	-0.616	0.615	834
	(-0.278)	(3.582)	(-2.753)		
Garman-Klass*	-0.034	0.231		0.609	834
	(-1.772)	(2.342)			
	-0.003	0.509	-0.634	0.613	834
	(-0.157)	(3.649)	(-2.807)		

*volatility estimator with jump

Table 8. Leverage Effect with Stock Returns and Leverage

Table 8 presents the panel data regression results with changes in leverage (LEV) and stock returns as explanatory variables based on quarterly observation. The results with all three volatility estimators are presented in the table, where the first column determines the estimators. The jump component is included in two of the estimators, to obtain the volatility for a whole day. Equation [28] has been used to compute the results in the first row, while equation [29] has a dummy variable in addition to determine if the leverage effect is asymmetrical. The sample consists of 25 firms listed on the OBX Index at Oslo Børs. The OBX Index consists of the 25 most traded securities in the OSEBX Index, which is the Oslo Børs Benchmark Index. There are numbers of firms on this index that have recently been listed at the exchange. To obtain a more robust and significant sample 5 of the firms on the OBX Index has been replaced by 5 other securities. Numbers of observations (NOBS) are listed in the table and the data sample is from year 2000 to 2010. β_1, β_2 are the coefficients for stock returns and changes in leverage. β_3 and β_4 are the dummy coefficients for stock returns and change in leverage, respectively. The dummy variable for return is defined as 1 if the stock return is less than zero and 0 otherwise. The dummy variable for leverage is defined as 1 if the change in leverage is positive and 0 otherwise. R^2 determines how well the independent variables are explained by the dependent variable. All of the variables in this sample are extracted from the stock database obtained by the Norwegian School of Economics (NHH).

(t-statistics in parentheses)

Volatility Estimator	Constant β_0	Return β_1	LEV β_2	Return Down, β_3	LEV Up β_4	R^2	NOBS
Squared Returns	-0.036 (-1.645)	-0.224 (-2.382)	0.206 (1.814)			0.517	834
	-0.122 (-3.745)	0.569 (3.214)	0.551 (3.450)	-1.268 (-5.266)	-0.866 (-3.265)	0.535	834
Parkinson*	-0.035 (-1.863)	-0.219 (-2.714)	0.209 (2.141)			0.615	834
	-0.118 (-4.257)	0.597 (3.963)	0.616 (4.530)	-1.307 (-6.377)	-1.009 (-4.469)	0.638	834
Garman-Klass*	-0.034 (-1.754)	-0.223 (-2.733)	0.215 (2.181)			0.613	834
	-0.116 (-4.168)	0.602 (3.962)	0.631 (4.600)	-1.321 (-6.388)	-1.031 (-4.526)	0.636	834

*volatility estimator with jump

The regressions based on equation [28] and equation [29] determines if change in leverage or stock returns has the greatest explanatory power towards the equity volatility. The regression results are presented in table 8. The estimated coefficients for stock returns from equation [28] are statistically significant and negative for all of the volatility estimators. The coefficient for leverage is positive and significant for the regressions run with Parkinson and Garman-Klass as the volatility estimators. The results are consistent with theory, stating that a negative return will increase the equity volatility as well as an increase in leverage will result in an increase in the volatility. The dummy coefficients for stock returns and leverage in equation [29] are negative and statistically significant at a 5% significance level. The dummy coefficients for stock returns appear to have a higher significance level than the dummy coefficients for leverage, implying that stock returns have better explanatory power. This might suggest that stock returns have a stronger impact on volatility and cause the asymmetric equity volatility. Again, the dummy coefficient for leverage is negative, which is not consistent with the theory. The sample for leverage might be biased since the measured leverage is obtained from the book values of debt and not from the market value of debt. However, when all the estimated coefficients from equation [29] are added to observe the overall effect, it reveals that the volatility increases when the leverage increases and when the stock prices are falling.

The final regression is based on stock returns, market returns and change in leverage (LEV) as explanatory variables. The results will determine if change in leverage has a better explanatory power towards asymmetric volatility than stock returns and market returns. Equation [30] and equation [31] are used in these regressions and squared returns is the volatility estimator. The empirical tests are based on quarterly returns and the regression results are presented in table 9. The estimated coefficients from equation [30] shows that market returns have the strongest explanatory power. The coefficient has a much higher significance level and is greater than the coefficients for stock returns and LEV. The results are consistent with the theory, indicating that a positive change in leverage and negative returns for both stocks and the Index will increase the equity volatility. The estimated coefficients without dummies from equation [31] show that the coefficient for market returns have the highest significance level and the greatest explanatory power. This implies that market returns has a larger impact on equity volatility than stock returns and LEV. The coefficients for the dummy variables reveal asymmetric equity volatility on the

Table 9. Leverage Effect with Stock Returns, Market Returns and Leverage

Table 9 presents the panel data regression results with changes in leverage (LEV), stock returns and market returns as the explanatory variables based on quarterly observations. Squared return is the volatility estimator and the dependent variable in the regression. Equation [30] has been used to compute the results in the first row, while equation [31] has dummy variables in addition to determine if the leverage effect is asymmetrical. The sample consists of 25 firms listed on the OBX Index at Oslo Børs. The OBX Index consists of the 25 most traded securities in the OSEBX Index, which is the Oslo Børs Benchmark Index. There are numbers of firms on this index that has recently been listed at the exchange. To obtain a more robust and significant sample 5 of the firms on the OBX Index has been replaced by 5 other securities. Numbers of observations (NOBS) are listed in the table and the data sample is from year 2000 to 2010. β_1 , β_2 , β_3 are the coefficients for the stock returns, market returns and changes in leverage, respectively. β_4 , β_5 , β_6 are the respective dummies to each of the independent variables, which are defined as 1 if the market\stock returns is less than zero and 0 otherwise. The dummy variable for leverage is defined as 1 if the change in leverage is positive and 0 otherwise. The dummies elaborate if the leverage effect is asymmetrical. R^2 determines how well the independent variables are explained by the dependent variable. All of the variables in this sample are extracted from the stock database obtained by the Norwegian School of Economics (NHH).

(t-statistics in parentheses)

Volatility Estimator	Constant β_0	Stock Return β_1	Market Return, β_2	LEV β_3	Stock Ret. Down, β_4	Market Ret. Down, β_5	LEV Up β_6	R^2	NOBS
Squared Returns	0.033	-0.243	-3.411	0.211				0.525	834
	(1.110)	(-2.601)	(-3.558)	(1.877)					
	-0.341	0.543	-3.144	0.507	-1.267	-5.565	-0.767	0.542	834
	(-0.401)	(3.084)	(-3.313)	(3.150)	(-5.205)	(-0.330)	(-2.884)		

Norwegian stock exchange, since the coefficients determine that the magnitude of the effect is substantially greater when the market is experiencing a downfall. Since market returns appear to be the dominant variable for explaining the asymmetric volatility, it confirms that the leverage effect is not only caused by leverage. Thus it seems that the leverage effect is more likely a down market effect. The regression results with Parkinson and Garman-Klass as the volatility estimators are presented in the Appendix.

To summarize the subsection leverage effect with leverage, it is obvious that measured leverage does not explain all of the asymmetric volatility in the Norwegian stock market. When including just stock returns and LEV in the regression, it is clear that stock returns have the greatest explanatory power towards asymmetric volatility. When all the explanatory variables are included in the regression, it reveals that market returns have substantially higher explanatory power than LEV and individual stock returns. The dummy coefficient for LEV is negative in all of the regressions containing measured leverage, but when all the coefficients from the regression are added, the result seems to be consistent with the theory. This might occur since the measured leverage is calculated with the book value of debt rather than the market face value of debt. The findings show asymmetric equity volatility, since the magnitude of the effect is more substantial when the market is falling. Since market returns is the dominant variable and the fact that the effect is stronger in a falling market, it seems that the leverage effect is mainly a down market effect.

5. Conclusion

5.1 Summary of Main Results

The term leverage effect refers to the observed relationship between returns and volatility. The volatility is known to increase when the market and the stock prices experience a fall. One possible explanation for this phenomenon is based on financial leverage, where a fall in the market value of a firm's equity makes a firm more levered, resulting in an increase in the stock return volatility. The main objective in this study is to examine if the leverage effect hypothesis can explain the asymmetric volatility of stocks on the Norwegian stock exchange. The approach is similar to a study conducted by Figlewski and Wang (2000), but this study does a more thorough analysis by examining each of the explanatory variables individually and together.

When stock returns and market returns are used as explanatory variables it is obvious that asymmetric volatility exists on the Norwegian stock exchange. The magnitude of the leverage effect is substantially higher when the stock prices are declining and when the market is experiencing a downfall. The results show that market returns has the highest significance level and the greatest explanatory power, which implies that market returns have a bigger impact on equity volatility than individual stock returns. The results also reveal that the leverage effect diminishes over time, which implies that a change in the financial leverage in a firm's capital structure does not lead to a permanent change in the equity volatility. The elasticity of stock volatility with respect to a change in leverage is calculated to be 1, but the results reveal that the effect is nearly half of the theoretical value. This implies that the magnitude of the leverage effect is lower than expected, and changes in leverage cannot alone explain the asymmetrical volatility.

When all the explanatory variables are included in one regression, it is obvious that market returns have the strongest explanatory power and the largest impact on equity volatility. The results reveal asymmetric volatility and the leverage effect appears to be stronger when the market is falling. Since market returns is the dominant variable in explaining the asymmetric volatility and the fact that leverage effect diminishes over time, it is clear that the leverage effect is not only caused by leverage. The results suggests that the leverage effect hypothesis is mainly a down market effect, since the effect is much stronger when the market is falling.

5.2 Opportunities for Further Studies

This study has examined the leverage effect hypothesis with returns and measured leverage. However, the measured leverage is extracted from book values of debt. A further study could perhaps investigate the leverage effect with market value of debt instead of book value of debt. The research is based on a sample of 25 firms, which could be extended to a larger sample to obtain a more robust analysis. A longer time series for the measured leverage may also contribute to a more robust analysis. Future work can extend this analysis by including implied volatilities from stock options and by using asset pricing frameworks to determine the asymmetric equity volatility.

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Appendix A. List of Firms

List of firms on the OBX Index
Firms in Italic are replaced

AKSO – Aker Solutions

ALGETA – Algeta

CEQ – Cermaq

DNB – DNB

DNO – DNO International

FOE – Fred. Olsen Energy

FRO – Frontline

GJF – Gjensidige Forsikring

GOL – Golnar LNG

MHG – Marine Harvest

NHY – Norsk Hydro

ORK – Orkla

PGS – Petroleum Geo-Services

PRS – Prosafe

RCL – Royal Caribbean Cruises

REC – Renewable Energy Corporation

SCH – Schibsted

SDRL – Seadrill

SFR – Statoil Fuel & Retail

STB – Storebrand

STL – Statoil

SUBC – Subsea 7

TEL – Telenor

TGS – TGS-NOPEC Geophysical Company

YAR – Yara International

List of added firms

NSG – Norske Skogindustrier

ATEA – Atea

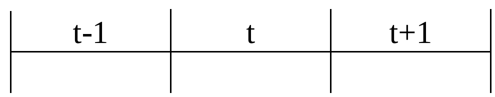
ELT – Eltek

NEC – Norse Energy Corporation

MING – SpareBank 1 SMN

Appendix B. Change in Volatility

The figure show how the change in volatility is computed. If the return is computed for period t, the change in the volatility for that observation will be from period t-1 to period t+1.



Appendix C. The Leverage Effect with Stock Returns

Appendix C presents the panel data regression results on daily, weekly, monthly and quarterly stock returns. Parkinson and Garman-Klass are the volatility estimators and the dependent variables in the regressions. The jump component is included in both of the estimators, to obtain the volatility for a whole day. Equation [19] has been used to compute the results in the first row of each of the periods, while equation [20] has a dummy variable in addition to determine the asymmetrical volatility. The sample consists of 25 firms listed on the OBX Index at Oslo Børs. The OBX Index consists of the 25 most traded securities in the OSEBX Index, which is the Oslo Børs Benchmark Index. There are numbers of firms on this index that has recently been listed at the exchange. To obtain a more robust and significant sample 5 of the firms on the OBX Index has been replaced by 5 other securities. Numbers of observations (NOBS) are listed in the table and are from a period between years 1990 to 2010. β_1 is the coefficient for stock returns and β_2 is the coefficient for the dummy variable, which is defined as 1 if the stock return is less than zero and 0 otherwise. R^2 determines how well the independent variables are explained by the dependent variable. All of the variables in this sample are extracted from the stock database obtained by the Norwegian School of Economics (NHH).

(t-statistics in parentheses)

Parkinson With Jump

Return Period	Constant β_0	Return β_1	Return Down, β_2	R^2	NOBS
Daily Returns	-0.003 (-0.589)	0.721 (4.855)		0.188	70222
	-0.063 (-10.915)	3.637 (15.443)	-5.640 (-15.934)	0.191	70222
Weekly Returns	-0.012 (-1.203)	-0.422 (-2.421)		0.573	7730
	-0.013 (-0.952)	-0.400 (-1.417)	-0.041 (-0.098)	0.573	7730
Monthly Returns	-0.011 (-1.121)	-0.284 (-3.547)		0.504	3343
	-0.071 (-4.961)	0.404 (2.846)	-1.163 (-5.859)	0.509	3343
Quarterly Returns	-0.028 (-1.637)	-0.251 (-3.365)		0.601	1089
	-0.107 (-4.319)	0.241 (1.783)	-0.808 (-4.353)	0.609	1089

Appendix C Continued

Garman-Klass With Jump

Return Period	Constant β_0	Return β_1	Return Down, β_2	R^2	NOBS
Daily Returns	-0.002	0.831		0.186	70222
	(-0.518)	(5.410)			
	-0.072	4.214	-6.544	0.190	70222
	(-12.145)	(17.312)	(-17.887)		
Weekly Returns	-0.010	-0.385		0.580	7730
	(-0.973)	(-2.218)			
	-0.010	-0.377	-0.015	0.580	7730
	(-0.740)	(-1.341)	(-0.036)		
Monthly Returns	-0.010	-0.258		0.510	3343
	(-1.019)	(-3.224)			
	-0.073	0.463	-1.219	0.516	3343
	(-5.094)	(3.265)	(-6.147)		
Quarterly Returns	-0.024	-0.253		0.598	1089
	(-1.416)	(-3.347)			
	-0.105	0.248	-0.823	0.605	1089
	(-4.190)	(1.816)	(-4.382)		

The regressions in Appendix C are performed to check for robustness in the empirical tests. The estimated coefficients for daily returns appear to be less noisy than when squared returns is used as the volatility estimator. The significance level for the coefficients does not seem to vary substantially between the different volatility estimators.

Appendix D. Leverage Effect with Individual Stock Returns and Market Returns

The table presents the regression results based on monthly returns for the individual stocks. Squared return is the volatility estimator and the dependent variable in the regression. Equation [21] has been used to compute the results in the first row, while equation [22] has dummy variables in addition to determine the asymmetrical volatility. The sample consists of 25 firms which are listed on the OBX Index at the Norwegian stock exchange, Oslo Børs. The OBX Index consists of the 25 most traded securities in the OSEBX Index, which is the Oslo Børs Benchmark Index. There are numbers of firms on this index that has recently been listed at the exchange. To obtain a more robust and significant sample 5 of the firms on the OBX Index has been replaced by 5 other securities. Numbers of observations (NOBS) are listed in the table and are from a period between years 1995 to 2010, since the OBX Index was first introduced in 1995. β_1 is the coefficient for individual stock returns and β_2 is the coefficient for the market returns. β_3 and β_4 are the dummy coefficients for individual stock returns and market returns, respectively. The dummy variable is defined as 1 if the stock/market return is less than zero and 0 otherwise. R^2 determines how well the independent variables are explained by the dependent variable. All of the variables in this sample are extracted from the stock database obtained by the Norwegian School of Economics (NHH).

(t-statistics in parentheses)

TICKER	Constant β_0	Stock Return, β_1	OBX Return, β_2	Stock Down, β_3	OBX Down, β_4	R^2	NOBS
AKSO	0.05 (0.59)	-0.352 (-0.437)	-2.838 (-1.654)			0.102	79
	0.00 (0.02)	-3.315 -1.938	3.438 (1.028)	4.505 (2.062)	-10.263 (-2.142)	0.165	79
NHY	0.03 (0.58)	-0.111 (-0.101)	-2.704 (-1.934)			0.068	179
	-0.16 (-1.71)	-0.763 (-0.461)	2.280 (0.929)	0.299 (0.120)	-7.316 (-2.212)	0.108	179
CEQ	0.02 (0.16)	-0.560 (-0.455)	-0.104 (-0.052)			0.007	61
	-0.28 (-1.19)	1.197 (0.524)	3.230 (0.770)	-3.444 (-0.782)	-3.807 (-0.561)	0.046	61
STL	0.01 (0.15)	0.436 (0.323)	-2.317 (-1.869)			0.046	113
	-0.13 (-0.98)	1.832 (0.883)	-1.121 (-0.455)	-3.649 (-0.975)	-1.175 (-0.336)	0.060	113

Appendix D Continued

TICKER	Constant β_0	Stock Return, β_1	OBX Return, β_2	Stock Down, β_3	OBX Down, β_4	R^2	NOBS
ORK	0.01	0.778	-3.471			0.049	179
	(0.21)	(0.725)	(-2.492)				
	-0.19	3.816	-2.848	-6.130	0.515	0.087	179
	(-1.68)	(2.351)	(-1.254)	(-2.308)	(0.144)		
SDRL	-0.01	2.200	-7.276			0.147	60
	(-0.06)	(1.381)	(-2.715)				
	-0.24	3.560	-4.807	-2.712	-3.040	0.180	60
	(-1.17)	(1.527)	(-0.987)	(-0.790)	(-0.460)		
TGS	0.06	-0.532	-3.192			0.082	154
	(0.75)	(-0.789)	(-2.330)				
	0.01	-0.177	-2.861	-0.688	-0.366	0.083	154
	(0.06)	(-0.150)	(-1.059)	(-0.366)	(-0.094)		
YAR	0.05	-0.447	-2.129			0.088	80
	(0.71)	(-0.546)	(-1.492)				
	-0.08	0.905	-1.739	-2.820	0.206	0.116	80
	(-0.63)	(0.699)	(-0.638)	(-1.338)	(0.053)		
TEL	0.00	0.308	-3.629			0.083	119
	(0.06)	(0.290)	(-2.479)				
	-0.16	0.258	-0.128	0.215	-5.766	0.103	119
	(-1.19)	(0.152)	(-0.046)	(0.087)	(-1.419)		
DNBNOR	0.04	0.102	-4.767			0.148	179
	(0.66)	(0.122)	(-4.146)				
	-0.05	-0.445	-1.874	1.563	-5.443	0.162	179
	(-0.54)	(-0.350)	(-0.913)	(0.722)	(-1.685)		
FOE	-0.03	1.129	-3.980			0.083	91
	(-0.35)	(1.238)	(-2.731)				
	-0.27	1.261	0.069	-2.636	-4.877	0.117	91
	(-1.71)	(1.131)	(0.023)	(-0.917)	(-1.231)		
FRO	0.00	-0.221	-1.623			0.022	158
	(0.03)	(-0.476)	(-1.486)				
	-0.29	0.495	2.996	-1.567	-6.843	0.065	158
	(-2.18)	(0.720)	(1.319)	(-1.148)	(-2.002)		
STB	0.05	-0.414	-4.853			0.145	179
	(0.78)	(-0.570)	(-3.729)				
	0.01	-2.179	-1.225	3.747	-7.856	0.172	179
	(0.06)	(-1.718)	(-0.539)	(1.954)	(-2.133)		
NSG	0.01	-0.431	-2.069			0.069	147
	(0.16)	(-0.811)	(-2.182)				
	0.00	-0.295	-2.148	-0.223	0.128	0.069	147
	(0.02)	(-0.274)	(-1.111)	(-0.146)	(0.046)		

Appendix D Continued

TICKER	Constant β_0	Stock Return, β_1	OBX Return, β_2	Stock Down, β_3	OBX Down, β_4	R^2	NOBS
PGS	0.02	-0.373	-2.477			0.064	179
	(0.25)	(-0.988)	(-2.136)				
	-0.17	0.073	0.790	-0.633	-5.427	0.090	179
	(-1.60)	(0.081)	(0.313)	(-0.586)	(-1.577)		
RCL	-0.01	-0.483	-3.186			0.164	110
	(-0.13)	(-1.025)	(-3.269)				
	0.00	-0.993	-2.338	0.996	-1.464	0.170	110
	(0.04)	(-1.287)	(-1.124)	(0.810)	(-0.501)		
ATEA	-0.02	-0.634	-2.157			0.060	150
	(-0.25)	(-1.215)	(-1.742)				
	-0.24	0.452	-0.467	-2.209	-2.338	0.083	150
	(-1.59)	(0.499)	(-0.176)	(-1.617)	(-0.653)		
SCH	0.01	0.984	-3.425			0.059	147
	(0.11)	(1.553)	(-3.003)				
	-0.05	1.323	-2.976	-0.870	-0.474	0.062	147
	(-0.39)	(1.461)	(-1.346)	(-0.538)	(-0.145)		
SUBC	0.03	-1.073	-1.467			0.077	91
	(0.37)	(-1.178)	(-0.786)				
	-0.13	-1.286	2.374	0.361	-6.237	0.098	91
	(-0.81)	(-0.827)	(0.672)	(0.165)	(-1.265)		
PRS	0.00	-0.587	-1.915			0.065	155
	(0.01)	(-0.872)	(-1.692)				
	-0.10	-1.613	1.824	1.952	-6.420	0.094	155
	(-0.91)	(-1.470)	(0.870)	(1.209)	(-2.146)		
MHG	0.02	-0.258	-1.700			0.021	133
	(0.23)	(-0.697)	(-1.140)				
	-0.22	1.137	-0.758	-2.096	-1.848	0.059	133
	(-1.22)	(1.517)	(-0.235)	(-2.111)	(-0.391)		
NEC	0.08	-0.727	-3.507			0.080	96
	(0.66)	(-1.137)	(-2.030)				
	0.08	0.085	-5.322	-1.389	2.917	0.089	96
	(0.36)	(0.076)	(-1.349)	(-0.850)	(0.518)		
DNO	0.01	-0.483	-2.700			0.063	170
	(0.17)	(-0.982)	(-2.316)				
	-0.28	0.343	1.025	-2.363	-5.221	0.106	170
	(-2.18)	(0.474)	(0.425)	(-1.765)	(-1.517)		
ELTEK	0.00	-0.430	-1.667			0.040	91
	(0.03)	(-0.884)	(-1.119)				
	-0.29	-0.003	3.228	-0.760	-7.888	0.087	91
	(-1.68)	(-0.003)	(0.918)	(-0.531)	(-1.658)		

Appendix D Continued

TICKER	Constant β_0	Stock Return, β_1	OBX Return, β_2	Stock Down, β_3	OBX Down, β_4	R^2	NOBS
MING	0.09 (0.54)	0.775 (0.916)	-4.580 (-2.040)			0.049	88
	-0.15 (-0.55)	-1.162 (-0.324)	2.408 (0.441)	2.116 (0.547)	-10.657 (-1.403)	0.071	88

Equation [21] and equation [22] determine if the market returns or the individual stock returns have the greatest explanatory power, and which of the variables has the biggest impact on volatility when the market falls. Appendix D presents the results from these equations based on monthly observations using squared returns as the volatility estimator. The leverage effect coefficients for both stock returns and market return for equation [21] varies considerably, having a range between -1.073 to 2.2 for stock returns and between -7.276 to -0.104 for market returns. For 23 of the 25 stocks the market returns has a greater explanatory power and higher significance level than for the individual stock returns. The estimated coefficients for market returns are negative for all of the stocks and show a much larger negative effect on the equity volatility. The elasticity for the stock volatility with respect to a change in firm equity appears to be between the theoretical values $-1 \leq \theta_E \leq 0$, but varies for some of the coefficients. However, the results are consistent with the expected outcome, where the Index has a distinctly lager impact on the equity volatility. The estimated coefficients from equation [22] have substantial variation. The dummy coefficients for the market returns appear to have a greater effect on volatility compared to the dummy coefficient for stock returns. The results are not statistically significant, but it is worthwhile mentioning that the findings are consistent with the expected results.

Appendix E. Leverage Effect with Stocks in Panel Data and Market Returns

Appendix E presents the panel data regression results based on stock returns and market returns. Parkinson and Garman-Klass are the volatility estimator and the dependent variables in the regression. The jump component is included in both of the estimators, to obtain the volatility for a whole day. Equation [21] has been used to compute the results in the first row, while equation [22] has dummy variables in addition to determine the asymmetrical volatility. The sample consists of 25 firms listed on the OBX Index at Oslo Børs. The OBX Index consists of the 25 most traded securities in the OSEBX Index, which is the Oslo Børs Benchmark Index. There are numbers of firms on this index that has recently been listed at the exchange. To obtain a more robust and significant sample 5 of the firms on the OBX Index has been replaced by 5 other securities. Numbers of observations (NOBS) are listed in the table and are from a period between years 1995 to 2010, since the OBX Index was first introduced in 1995. β_1 is the coefficient for stock returns and β_2 is the coefficient for the market returns. β_3 and β_4 are the dummy coefficients for stock returns and market returns, respectively. The dummy variable is defined as 1 if the stock/market return is less than zero and 0 otherwise. R^2 determines how well the independent variables are explained by the dependent variable. All of the variables in this sample are extracted from the stock database obtained by the Norwegian School of Economics (NHH).

(t-statistics in parentheses)

Volatility Estimator	Constant β_0	Stock Return, β_1	OBX Return β_2	Stock Down, β_3	OBX Down, β_4	R^2	NOBS
Parkinson*	0.014 (1.051)	-0.161 (-1.571)	-2.855 (-12.975)			0.078	3188
	-0.117 (-4.980)	0.308 (1.695)	-0.923 (-2.032)	-0.808 (-3.197)	-3.066 (-4.750)	0.091	3188
Garman-Klass*	0.016 (1.148)	-0.129 (-1.242)	-2.942 (-13.283)			0.079	3188
	-0.120 (-5.081)	0.359 (1.965)	-0.947 (-2.072)	-0.839 (-3.301)	-3.166 (-4.875)	0.093	3188

*volatility estimator with jump

Appendix F. Diminishing Leverage Effect over Time Using Returns

Appendix F presents the panel data regression results for the diminishing leverage effect over time using monthly returns. Parkinson and Garman-Klass are the volatility estimator and the dependent variable in the regression. The jump component is included in both of the estimators, to obtain the volatility for a whole day. Equation [23] has been used to compute the results in the first row, while equation [24] has dummy variables in addition to determine the asymmetrical volatility. The sample consists of 25 firms listed on the OBX Index at Oslo Børs. The OBX Index consists of the 25 most traded securities in the OSEBX Index, which is the Oslo Børs Benchmark Index. There are numbers of firms on this index that has recently been listed at the exchange. To obtain a more robust and significant sample 5 of the firms on the OBX Index has been replaced by 5 other securities. The Numbers of observations (NOBS) are listed in the table and the data sample is from year 1995 to 2010, since the OBX Index was first introduced in 1995. β_1 , β_2 , β_3 are the coefficients for the expected volatility the next month, the second month and he third month. β_4 , β_5 , β_6 are the respective dummies to the returns over time, which are defined as 1 if the market return is less than zero and 0 otherwise. The dummies elaborate if the leverage effect is asymmetrical. R^2 determines how well the independent variables are explained by the dependent variable. All of the variables in this sample are extracted from the stock database obtained by the Norwegian School of Economics (NHH).

(t-statistics in parentheses)

Volatility Estimator	Constant β_0	Return(t) β_1	Return(t-1) β_2	Return(t-2) β_3	Down(t) β_4	Down(t-1) β_5	Down(t-2) β_6	R^2	NOBS
Parkinson*	-0.021	-0.216	-0.186	-0.309				0.585	3293
	(-1.949)	(-2.537)	(-2.205)	(-3.665)					
	-0.085	0.338	-0.083	-0.165	-0.920	-0.133	-0.197	0.588	3293
	(-4.331)	(2.165)	(-0.547)	(-1.091)	(-4.211)	(-0.620)	(-0.921)		
Graman-Klass*	-0.019	-0.184	-0.182	-0.313				0.587	3293
	(-1.733)	(-2.143)	(-2.138)	(-3.700)					
	-0.087	0.409	-0.070	-0.161	-0.983	-0.144	-0.209	0.591	3293
	(-4.423)	(2.606)	(-0.457)	(-1.060)	(-4.480)	(-0.670)	(-0.969)		

*volatility estimator with jump

Appendix G. Leverage Effect with Stock Returns, Market Returns and Leverage

Appendix G presents the panel data regression results with changes in leverage (LEV), stock returns and market returns as the explanatory variables based on quarterly observations. Parkinson and Garman-Klass are the volatility estimator and the dependent variable in the regression. The jump component is included in both of the estimators, to obtain the volatility for a whole day. Equation [30] has been used to compute the results in the first row, while equation [31] has dummy variables in addition to determine if the leverage effect is asymmetrical. The sample consists of 25 firms listed on the OBX Index at Oslo Børs. The OBX Index consists of the 25 most traded securities in the OSEBX Index, which is the Oslo Børs Benchmark Index. There are numbers of firms on this index that has recently been listed at the exchange. To obtain a more robust and significant sample 5 of the firms on the OBX Index has been replaced by 5 other securities. Numbers of observations (NOBS) are listed in the table and the data sample is from year 2000 to 2010. β_1 , β_2 , β_3 are the coefficients for the stock returns, market returns and change in leverage, respectively. β_4 , β_5 , β_6 are the respective dummies to each of the independent variables, which are defined as 1 if the market\stock returns is less than zero and 0 otherwise. The dummy variable for leverage is defined as 1 if the change in leverage is positive and 0 otherwise. The dummies elaborate if the leverage effect is asymmetrical. R^2 determines how well the independent variables are explained by the dependent variable. All of the variables in this sample are extracted from the stock database obtained by the Norwegian School of Economics (NHH).

(t-statistics in parentheses)

Volatility Estimator	Constant β_0	Stock Return β_1	Market Return, β_2	LEV β_3	Stock Ret. Down β_4	Market Ret. Down β_5	LEV Up β_6	R^2	NOBS
Parkinson*	0.038	-0.240	-3.627	0.215				0.624	834
	(1.509)	(-2.996)	(-4.420)	(2.228)					
	0.946	0.562	-3.368	0.607	-1.239	19.836	-0.929	0.646	834
	(1.313)	(3.767)	(-4.192)	(4.451)	(-6.012)	(1.389)	(-4.127)		
Garman-Klass*	0.043	-0.244	-3.785	0.221				0.623	834
	(1.692)	(-3.026)	(-4.574)	(2.272)					
	1.044	0.565	-3.524	0.623	-1.247	21.689	-0.948	0.645	834
	(1.438)	(3.760)	(-4.352)	(4.533)	(-6.005)	(1.507)	(-4.180)		

*volatility estimator with jump