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Cointegration analysis and the evolution of market efficiency: Evidence from Norway and the Brent spot market

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Preface

This thesis examines the existence of a cointegration relationship between the degree of efficiency in the Norwegian stock market and the European Brent spot market. The study utilises the Adjusted Market Inefficiency Magnitude (AMIM) as a measure of market efficiency and the Engle-Granger Cointegration test. I find that both markets are on average efficient with periods of inefficiency in response to shocks to the system. Furthermore, the efficiency of the markets is affected by positive and negative shocks to the market. The most significant in the study results is that efficiency in the oil market drive the degree of efficiency in the stock market in the long term. This co-movement is present in periods of extreme shocks to both markets such as the 2007 financial crisis and the 2014 oil price crash. For the rest of the sample period, empirical tests show no correlation and short-term granger causality between the degree of efficiency in these markets. The findings of this study have implications for portfolio management as well as supporting the Adaptive Market Hypothesis (AMH).

This thesis is written in an article-based format. It is composed of two segments: The Introductory chapter and the main Research paper. The Introductory chapter offers a summary of the research paper with emphasis on the background, methodology and findings of the study. The research paper is written with the aim of submission in the Journal of Banking and Finance. To this purpose, the research paper is structured according to the guidelines provided by the journal. The author guideline for the Journal of banking and finance can be found in Appendix 1 of this thesis.

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1 Introductory Chapter

1.1 Background of the study

The main focus of my thesis is to study the relationship between the efficiency in the oil and stock market. The literature in this area cannot be over emphasised. Over the decades due to trade liberalisation and technological advancement, nations are becoming more interconnected and a global economy now exists alongside individual economies. Events in the US affect the global economy and finally the individual economy of several nations which may not even be engaged in direct trade with the US. While this link offers immerse benefits, it also has the associated cost of making a national economy vulnerable to factors which may not always be within its control. It is therefore beneficial that knowledge as to how several economic factors in the global environment affect activities within a national framework.

One such market which plays an important role in driving the economic activities in most nations is the oil market. Several studies have identified how crucial a role oil plays in the national economy dating as far back as the seminal work by Hamilton (1983). Aside from the contribution of these studies, one can intuitively observe how important oil has become to the global market. Currently, oil in its raw and processed forms, either forms a necessary production input or is a production output of most nations. The implication is that it either influences the cost and/or the revenue to most economies. This explains the attention events in the oil market has enjoyed in academic literature (Arouri, 2011; Syed Abul Basher, Haug, & Sadorsky, 2012; Bjørnland, 2009; Broadstock & Filis, 2014; Dagher & El Hariri, 2013; Halaç, Dilvin, & Çağlar, 2013; Hamilton, 2003; Kilian, 2009; Wei & Guo, 2017). These studies have examined several components of the market such as return, volatility, investor perception in relation to other economic variables such as GDP, exchange rate, stock return among others, with ground breaking results. Studies into the relationship between the oil and stock market has been particularly successful, having identified features such as the existence of cointegration between returns, investor herd effect and in some studies bi-directional causality. However, one area of the market that has thus far not received as much attention, despite of its importance, is the degree of market efficiency within the market for commodities in general and oil in particular. For the stock market, although an incredible amount of research has been varied out to analyse the concept of market efficiency, one gap in existing literature can be identified in methodology which fails to capture time varying feature of market efficiency.

Studies into the relationship between the oil and stock market have generated results which vary based on country of focus, use of aggregate or sectoral return, frequency of data just to name a few points of deviation. One point that has been frequently examined is the response difference between oil importing and exporting countries. The response of oil exporting countries to shocks in the oil market has been found to vary from that of oil importing countries Wang, Wu, and Yang (2013). For oil exporting countries, oil shock impact may begin from its revenue stream and finally make its way to the rest of the economy. In the case of the oil importing countries, this shock may first be experienced through higher cost of inputs i.e. a cost side effect. One of the most significant studies in this field is the discovery by Hamilton (2003) that oil price has a non-linear effect on GDP, with oil price increases having a more significant effect. Hamilton's finding goes beyond the study of oil and GDP and has been supported by other studies into the relationship between oil and many other indices. For example, the level of efficiency in the oil market was found to have a response-variance to different oil shocks (Zhang et al, 2014). Wang et al. (2013) go further to identify that the distinguishing factor which influences this asymmetrical relationship between oil and economic variables is how important oil is to the national economy. This study contributes to literature by determining if there is non-linearity in how economic events affect efficiency in the oil and stock market.

Another area of difference in the literature is the focus on sectoral and aggregate returns which is examined in studies such as Arouri (2011), Broadstock and Filis (2014), Fowowe (2013) and Wei and Guo (2017). Arouri (2011) finds that each sector of the economy responds differently to oil shocks which implies that there is the risk that when aggregate rather than sectoral returns are used there is a higher chance of getting misleading result. This is in fact true for studies based on return. If a stock market is dominated by financing firms then a weaker relationship is shown between oil and stock with little recognition for other sectors in the economy, as was found in Fowowe (2013). However, the focus of our study is on market efficiency and it is doubtful that the efficiency experienced for the agricultural stock market index is different from that for the oil servicing index. As a result, we take the liberty of using the aggregate benchmark index in this study.

Establishing the direction of causation has also been the aim of several studies. While some studies found unidirectional movement, from the oil to the stock market, others found that activities in the stock market of developed (Bjørnland, 2009; El Hedi Arouri, Jouini, & Nguyen, 2011) and developing (Syed Abul Basher et al., 2012; Dagher & El Hariri, 2013) countries were capable of influencing global oil price. This study contributes to knowledge by determining the direction of causation in the relationship between the degree of efficiency in the oil and stock market over time.

The study into market efficiency has been quite controversial such that to date no consensus has been reached in academia on the topic. Market efficiency studies have themselves evolved over time. The starting point is the assertion of the Efficient Market Hypothesis (EMH) by Fama (1970) that all capital markets are inherently efficient. Based on his seminal paper, Fama states that price reflects all available information within the market and as such it is impossible to profit at the expense of the market from monopoly information. This is of course based on a market structure where information is readily available at negligible cost, transaction costs are also minimal, and investors are rational and can hence reach a consensus on how current information affects future price.

This proposal by Fama is criticised by findings from empirical studies as well as the area of Behavioural finance. For example, Subrahmanyam (2010) finds over fifty variables that can stock returns to a varying degree. Alizadeh and Muradoglu (2014) in their study refuted the existence of market efficiency by showing that international shipping rates can predict stock returns in 24 out of 28 countries. Earlier studies have established return predictability through return reversal (Fluck, Malkiel, & Quandt, 1997), the January effect (Keim, 1983) and dividend yield (Campbell & Shiller, 1988).These are just a few of many studies which refute the EMH and show that in practise markets are not actually efficient. In addition, it is presumptuous and unrealistic to assume that investors would always behave rationally which is the focal point of the criticism of Behavioural economists. Studies from behavioural finance conclude that most investor decision making is subjective driven by bias such as overconfidence (Barber & Odean, 2001), overreaction (Bondt, Werner, & Thaler, 1987), loss aversion (Odean, 1998) to name a few. While information may be more readily available and trading costs may no longer exist due to technological advancement, there is no certainty as to how investors choose to interpret or process the information made available. In practise, we see investor attitude move from over confidence prior to a market crash to extreme risk aversion after a crash, all of which may not be governed by information but their perception of the market.

Several studies have since found confirmatory evidence of both school of thoughts, adding more inconclusiveness to this topic. In a review of his seminal paper, Fama (1991) arrives at the decision that it is impossible to reach a conclusion as to the existence of efficient markets.

Fama (1991) assigns blame for this to the fact that the study of market efficiency work hand in hand with equilibrium asset pricing models and is hence affected by faulty models, this is called the joint hypothesis problem. Perhaps a more realistic problem with the EMH is its static point of view, it assumes that a market would continue to operate at a level of efficiency in continuity. The pioneering study by Lo (2004) corrects this assumption by putting forward that the level of efficiency in a market varies with time and is determined by conditions in the market. This position is termed the Adaptive Market Hypothesis (AMH). The AMH provides a realistic middle ground between the EMH and the position of behavioural finance. Market conditions such as revolutionary technological advancement or market deregulation affect how investors perceive the market. This in turn affects how these investors choose to interpret information from that market. Market regulation requiring more transparency by firms would create a more optimistic perception of the stock market by investors and hence give greater confidence in information from the market. Such an investor is more likely to actively trade in the stock market, hence making the market more efficient. The reverse is the case when the investor has a negative perception of the market. The findings of Lo (2004) has influenced several other studies which have examined the evolving efficiency of several markets for different asset class (Ito, Noda, & Wada, 2014); Ito, Noda, and Wada (2015); Lim and Brooks (2011); Vu and Leirvik (2018); Wang and Liu (2010); Zhang, Li, and He (2014); Zhuang, Wei, and Ma (2015).

One of the areas in which the AMH has influenced the study of market efficiency is in how market efficiency is measured. Prior studies into the area of market efficiency have faced challenges in measuring market efficiency. Pioneering papers studied market efficiency in association with asset pricing models such as the constant expected return hypothesis and return predictability (Fama & French, 1989; Ferson & Harvey, 1991), Volatility tests (LeRoy & Porter, 1981) among others. Like Fama (1991) indicated, this resulted in the joint hypothesis problem such that it was difficult to determine when a market is inefficient and when an equilibrium model is simply wrong. Other methods utilised by other studies in analysing market efficiency is the multifractal and detrended fluctuation analysis (Gu & Zhang, 2016; Wang, Liu, & Gu, 2009; Wang, Wei, & Wu, 2011; Zhuang et al., 2015), generalised method of moments (Green & Mork, 1991), new variance ratio tests (Charles & Darné, 2009), method of generalised spectrum (Lv & Pan, 2009), mean variance and stochastic dominance approach (Lean, McAleer, & Wong, 2010) . The shortcoming of some of these models is that they fail to capture the changes in market efficiency over time. For example, Sharma (2017) measures market efficiency based on the existence of profitable opportunities within the market. This measure of market efficiency can be linked to a revised definition of market efficiency as a situation where marginal benefits do not exceed the marginal costs of acting on monopoly information (Jensen, 1978). If positive net benefit is obtained from information monopoly, then the market can be termed inefficient. However, this method is vague, fails to capture the degree of market efficiency and it is therefore not as useful when examining the evolution of efficiency in time. For example, does reduced profit directly translate to increased efficiency in the stock market or is it the result of increased transaction costs? Models such as the Time Varying Autoregressive model (Ito et al., 2014, 2015; Noda, 2016) and Adjusted Market Inefficiency Magnitude (Vu & Leirvik, 2018) are much suitable in capturing the evolving efficiency in these markets and is not subject to ambiguity as to the interpretation of values. The model by Vu and Leirvik (2018) is preferred and chosen for this study over other time varying models for several reasons. First unlike the other models, it offers flexibility in relation to the frequency of data used in the study. Second, the AMIM model can be applied to different asset class which is ideal for this research. Third the AMIM is easier to compute to interpret. While the model by Ito et al. (2014, 2015) is easy to compute, it is not as easy to interpret. More details on this model is presented in the methodology.

1.1.1 Norway's introduction to the global oil market

Norway entry into the global oil market began in 1966. However, it was not until 1971 before production of oil began in the Ekofisk field. Although foreign companies initially dominated production, government participation became more pronounced with the creation of Statoil in 1972. Government participation evolved from determination by parliament to government involvement being split into two; state interest in the oil company and state direct financial interest (SDFI). SDFI was determined at the point of issuance of the oil license and the state contributed a proportionate amount of production costs in exchange for share of petroleum income. Currently the Norwegian government has sold off 21.5% of its SDFI (15% to Statoil and 6.5% to other licenses) and the rest of its interests are managed on behalf of the government by Petoro.

Oil revenue has contributed immensely to the development of the Norwegian economy. In 2012 it was said to contribute 23% of the value created in the economy and is a major financier of the Norwegian welfare state. To ensure a well-balanced economy, the Norwegian government has always ensured that foreign oil companies patronise domestic goods and services, transfer of knowledge and investment in industrial joint ventures (Noreng, 2004). The extent to which this has affected the reliance of the economy on oil has been the focus of several studies such as Bjørnland (2009) and Wang et al. (2013). Due to events in the global market, between 2012 to 2016 Norway experienced a decline in export value of 58%. According to the Norwegian Petroleum Directorate, the level of oil activity in the Norwegian shelf is expected to continue for the next fifty years although continued production relies heavily on the discovery of new oil wells as well as heavy and continuous investment in the sector. Figure 8 shows a plot of the historical and forecast production from oil fields obtained from the directorate. Although there is the believe that increase in the demand for oil in emerging markets is capable of compensating for declining demand in developed countries (Syed Abul Basher et al., 2012), there are also concerns that the global climate concerns and environmental reforms mean that oil prices may never recover.

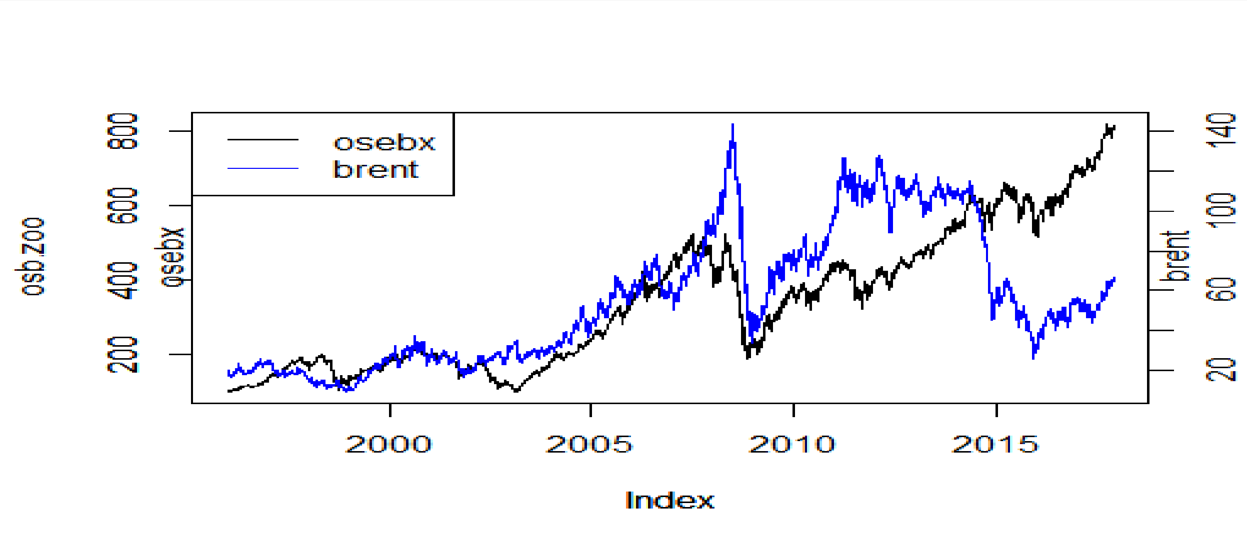


Figure 1: Historical price movement from 1996 to 2017

1.1.2 Norwegian stock market-OSEBX

The only regulated market for the trading of securities in Norway is the Oslo Børs. Founded in 1819, Oslo Børs offers a central platform for listing and trading in financial instruments such as equity, fixed income and derivative instruments. Oslo Børs Benchmark Index (OSEBX) contains a selection of all listed shares in Oslo Børs. However, the exchange has gained recognition for its energy, seafood and shipping platforms. Currently, Statoil accounts for an estimated 23.92% of the market value of all domestic firms while the energy sector accounts for approximately 14.5% of the market value of all sectors. The historical price movement of European Brent spot and OSEBX price is shown in Figure 1.

1.1.3 Research Gap

As discussed above, there has been a steady interest in the relationship between oil and other macroeconomic variables, especially stock market variables. However, few have focused on the relationship between the efficiency in the oil and stock market. This is mostly because models which can explicitly measure the evolving efficiency in a market are recent and few in literature. Studies which have examined cointegration in relation to market efficiency have simply sought to disprove the notion that the existence of cointegration is an indication of market inefficiency (Dwyer Jr & Wallace, 1992).

This study has a twofold contribution to gaps in existing knowledge. First, it applies the model of Vu and Leirvik (2018) in measuring the efficiency in the Norwegian stock and the European Brent crude market. This allows the examination of how the efficiency in both markets have evolved over time and in the presence of various shocks to the system. Second, this study investigates the presence of a cointegration relationship between the efficiency in both markets. This is also an innovative approach and contributes to literature by identifying if it is possible for the degree of efficiency in markets to evolve and develop together.

Market efficiency has several implications for market participants. In the oil and stock market, market efficiency influences investment strategy utilised by portfolio managers. The level of efficiency in the market can also ironically affect investor perception and decision-making as well as asset price in the market. If investors know that a market is inefficient, they are motivated to take advantage of this inefficiency, thereby influencing price within the market and making the market efficient. In the same manner the existence of a cointegration relationship between the efficiency in both markets means that the level of efficiency in the stock market can be forecasted based on the current level of efficiency in the oil market.

1.2 Methodology

This study utilises European Brent crude price and the Oslo Børs benchmark index as data on oil and stock price. The data series is daily spanning the period January 1996 - December 2017. Below the methodology applied in analysing these data is discussed in two phases. The first phase examines the model for measuring the degree of efficiency in the market. The second phase examines models and tests used in examining cointegration properties in the data series.

1.2.1 Adjusted Market Inefficiency Magnitude (AMIM)

I calculate the degree of market efficiency in the market using the AMIM model developed by Vu and Leirvik (2018). The adjusted market inefficiency magnitude measures the degree of market efficiency in a market. The value of the AMIM could take any value, however values greater than zero indicate market inefficiency i.e. AMIM values reduce as market efficiency increase. A maximum value of 1 indicates the highest level of market inefficiency although there are no lower bounds for the level of market efficiency.

$$AMIM_t = \frac{MIM_t - CI}{1 - CI} \quad (1)$$

The AMIM is computed from the Market Inefficiency Magnitude (MIM). The equation for the MIM model is given below.

$$MIM_t = \frac{\sum_{j=1}^{q} |\widehat{\beta}_{j,t}^{standard}|}{1 + \sum_{j=1}^{q} \left|\widehat{\beta}_{j,t}^{standard}\right|} \quad (2)$$

Where $\hat{\beta}_{j,t}^{standard}$ is the standardised beta coeficients from an autoregressive model with q number of lags AR(q). The coefficients are standardised by means of cholesky decomposition. The number of lags in the base auroregressive equation is determined through the Akaike Information Criteria (AIC). The equation utilises the absolute values of the standardised beta coefficients to prevent instances of the elimination effect leading to false results of market efficiency. However this also means that the MIM is positively correlated with the number of lags in the base AR equation and hence tends to give high values even when markets tend to be efficient. The adjusted MIM which is basically the ratio of the distance between the MIM and the Confidence interval of each observation to the distance between the theoretical maximum value of MIM and the confidence interval. The denominator of the AMIM equation offers a common ground and enables comparison across different periods, assets and regions.

The confidence interval used in calculating the AMIM is unique to the number of lags.This means that a table of confidence intervals does not need to be constructed for every study as the CI only depends on the number of lags. A table of the confidence interval for each number of lag is provided by Vu and Leirvik (2018) in their study.

As mentioned above the number of lags (q) used in the AR(q) equation in each MIM observation is determined with reference to the Akaike Information Criteria (AIC). The AIC is designed to choose the model whose distribution has the least deviation from the true distribution.It measures the quality of a model relative to other models. AIC is based on information theory i.e. it measures how much information is lost when a model is used to measure an information generating process (the true model). As a result, the model with the lowest AIC is preferred indicating the least amount of information lost.

The beta coefficients are standardised through the use of Cholesky decomposition. $\hat{\beta}$ is defined as a vector of all beta coeffiecients from the base AR(q) equation and which is assumed to be aymptotically distributed as $\hat{\beta} \sim N(\beta, \sum)$. Here β is the true unknown beta and $\sum$ is the asymptotic co-variance matrix. Cholesky decomposition is used to separate $\sum$ into two triangular matrices such that $\sum = P\grave{P}$. The beta coefficents are then standardised through $\hat{\beta}^{standard} = P^{-1}\hat{\beta}$. The process of standardising the beta coefficients makes each coefficient independent and identically distributed.

1.2.2 Stationarity Test

One of the prequisites for cointegration is that the variables are non-stationary random walks. As a result, the first test in our test for cointegration is to determine the stationarity properties of the data series. Two tests are applied towards this purpose, the Augmented Dickey Fuller unit root (ADF) test and Kwiatkowski-Phillips-Schmidt-Shin stationarity (KPSS) test.

The ADF test is a popular test that checks for the presence of unit roots in an autoregressive process AR(1). The ADF test has 3 variations of the regression equation. A random walk with :

- no constant and no trend: $Y_t = \beta Y_{t-1} + u_t$
- with constant and no trend: $Y_t = \alpha + \beta Y_{t-1} + u_t$
- with constant and trend: $Y_t = \alpha + \beta Y_{t-1} + \delta_t + u_t$

The test concludes that the AR(1) process is stable if $|\beta| < 1$ and unstable or a random walk if $\beta = 1$. This is tested against the null hypothesis of non-stationarity.

Although it is customary that when the entire sample is tested for stationary, sub-samples no longer require testing, this study conducts tests on the sub-samples. The rationale for this is that the duration of the study period as well as the frequency of the data make it probable that the sub samples may have a different process from the entire series taken as a whole.

1.2.3 Cointegration Test

A series of variables can be said to be cointegrated if a long term equilibrium relationship exists between them such that the linear combination of these variables produces stationary residuals.There are two requirements to be met before we can determine the existence of a cointegration relationship. First, the variables, in this case the effiency in the stock and oil market must be integrated of order one I(1), i.e. a non-stationary process. Second, the linear combination of these variables must result in residuals that are stationary. In general, the linear combination of non-stationaty variables are non-stationary. The only exception to this rule is when a cointegrating relationship exists between the variables.

I test for cointegration between both variables. First, I test for the existence of a long term equilibrium relationship using the Engle-Granger cointegration (EG) test. The cointegration test is made up of the Augmented Dickey fuller test with EG critical values. Using the EG two step method, I estimate a long term equation which captures the equilibrium relationship between these variables. The long term equation is given by

$$AMIM_{osebx,t} = \alpha + \beta_1 AMIM_{brent,t} + \delta_t + \varepsilon_t \qquad (3)$$

I include a trend (δ_t) in the equation under the assumption that efficiency in the stock market may be affected by the efficiency in the brent crude market and trends in the stock market. For example, if in the last trading period the investor has had some profitable stock return prediction, this investor is more likely to attempt to capitalise on this information assymetry in the current period thereby affecting the degree of efficiency in the market. In order to reject the null hypothesis of no cointegration, $\varepsilon_t \sim I(0)$.

1.2.3.1 Prior Knowledge of Break Points

When testing for cointegration in a sample covering a long period of time, there is the possibility of a structural break. Structural breaks are changes in the time series which have consequences for forecasting using that data. In the presence of structural breaks, the linear combination has shifted at some point(s) in the sample (Gregory & Hansen, 1996). While in the study by Gregory and Hansen (1996) the break point is assumed to be unknown, this study is based on prior knowledge of the points at which the linear combination exists. I identify five sub sample periods and apply the Engle Granger cointegration test to the samples. The first sub sample covers the period 1996 – 2006. This is prior to the major global financial crisis of 2007 and will be instrumental in identifying the relationship between these markets prior to any major event much like a stable state relationship between the markets. The second sub sample (2007 - 2009) covers the Financial crisis period and is aimed at identifying the relationship between these variables during a major economic event in the stock market. The third sub sample (2010 - 2013) is aimed at highlighting what the relationship between these variables is during a recovery period from a shock to the market. The response of the relationship between these variables to an oil price driven shock is captured within the fourth sub sample period 2014 - 2016. The fifth sample period consists of one year, 2017, and is aimed at examining the relationship as the markets recover from the oil price shock. All sub samples are chosen strategically to reflect major events within these markets during the period of the study.

1.2.4 Correlation Tests

Correlation tests are performed on the data series to determine the strength and direction of the linear relationship between these variables. In this study we apply three cointegration tests, the Pearson Product Moment, Kendall and Spearman Rank correlation tests. It is important to note that these tests do not identify causality between variables. For example, if X moves upward when Y moves up, correlation tests only show a positive relationship between these variables. Correlation tests cannot identify whether Y causes X or vice versa. Another shortcoming of correlation tests is that they are only ideal for capturing linear relationships, when the relationship between variables are non-linear, tests show low or insignificant correlation between the variables. To compensate for these shortcomings, this study utilises cointegration and granger-causality tests to analyse the relationship between efficiency in the oil and stock market.

1.2.5 Granger Causality

It is a well-known fact in econometrics that correlation does not mean causation. When examining two variables, correlation tests can only indicate the possibility of a causal relationship. Pioneering study by Clive W. J. Granger (1969) introduces a model for investigating causal relationship between variables. X granger causes Y if past values of X help predict Y more accurately than past values of Y alone can. In such a scenario, it can be inferred that Y does not move independently of X and the absence of X in a model for Y leads to forecast error. A variable X can be said to granger cause variable Y, if the lagged values of X in equation for Y produces statistically significant coefficients. This can be displayed mathematically as

$$\binom{\Delta Y_t}{\Delta X_t} = \binom{\mu_1}{\mu_2} + \binom{\alpha_1}{\alpha_2}(Y_{t-1} - \beta_2 X_{t-1}) + \binom{\varepsilon_{1,t}}{\varepsilon_{2,t}} \qquad (4)$$

Where:

$(Y_{t-1} - \beta_2 X_{t-1})$ is equal to the lagged residual $\boldsymbol{\varepsilon_t}$ from the long-term equilibrium equation i.e. $Y_{t-1} - \beta_2 X_{t-1} = \varepsilon_{t-1}$.

X granger-causes Y if $\alpha_1 \neq 0$

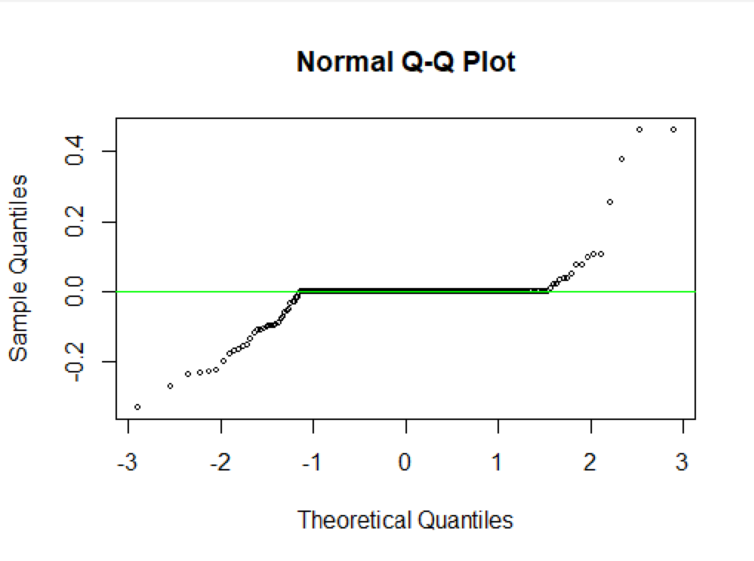
Y granger causes X if $\alpha_2 \neq 0$

If both α_1 and α_2 are not equal to zero, then it can be said that there is bidirectional Granger causality between the variables. If $\alpha_2 = 0$, then it can be said that X is weakly exogenous i.e. it is not determined within the model. This also applies if α_1 is equal to zero. We test for long term granger causality within the VECM framework and short-term causality using Wald test

1.3 Findings

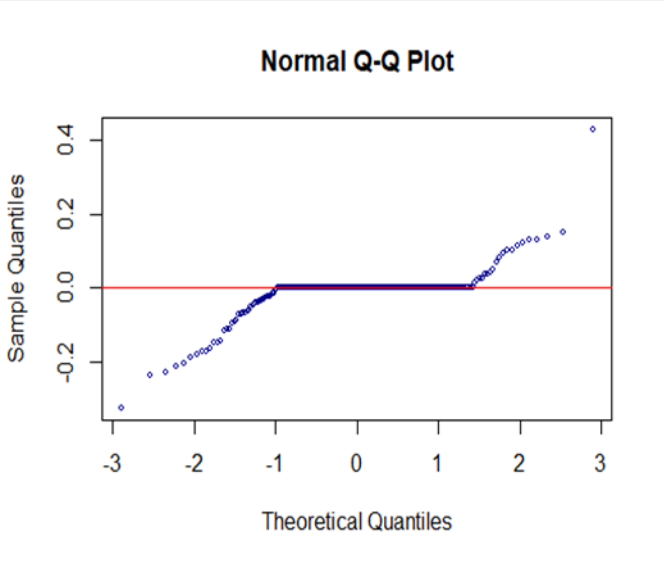
From the AMIM model, I obtained AMIM values for both variables. The descriptive statistics of both data show that both markets are on average efficient with low deviation from this efficiency level. I also find that the distributions of both series are not normally distributed based on the result obtained from the QQ-plot in Figure 2 and Figure 3, Jarque-Bera test, skewness and kurtosis.

Figure 2:Quantile-Quantile plot of the AMIM values of Brent



The result obtained from the Adjusted Market efficiency model is presented in Figure 4. AMIM value higher than zero is indicative of market inefficiency. From the figure, we see that the efficiency of both markets has been stable with moments of inefficiency usually in response to changes in market conditions. This is not different from findings by Alvarez-Ramirez, Alvarez, and Rodriguez (2008) in their study of the efficiency of crude market. The 1999 - 2000 oil price recovery resulting from increased demand for oil in the Asian market, efficiency in the oil market fluctuates, this can be traced to the uncertainty in the oil market during this period. In mid 2000s, the oil price increases due to increased Asian demand following economic recovery and reduced supply due to stagnant production in Saudi Arabia. As a result, during this period, we see significant fluctuations in the oil market evidenced by noticeable high and low AMIM values. During the 2007 - 2008 financial crisis, we see the efficiency in both markets start to move together briefly as the oil and stock market price both experience a drop during this period. After the crisis, both markets remain fairly stable. From 2011, the erstwhile stable stock market experiences significant fluctuations in its efficiency due to the European sovereign debt crisis and the global stock market crash that lasts from August - December 2011. During this period, the oil market registers marginal shifts from market efficiency. From 2014, we see the oil market barely register a change in efficiency during the initial oil price drop. However, as oil price continues to decrease in 2015 and 2016, the market experiences its most erratic shifts in efficiency. The initial response of the market in 2014 may be due to the perception of investors that the price reduction in the oil market would be short-lived due to the oil market adjusting to renewed production in the middle east following Western intervention. But as non - OPEC production continues to increase causing oil price to further reduce, we can see market efficiency begin to respond to changes in the oil market. These market shocks make their way to the stock market although not at as great a scale.

Figure 3:Quantile-Quantile plot of the AMIM values of OSEBX



It is important to note that the market experiences fluctuations in its efficiency in response to both negative and positive shocks to the market. It also appears that the market responds more to negative shocks than positive shocks. This is confirmed in studies such as Zhang et al. (2014) and related to the oil asymmetrical effect proposed by Hamilton (2003). This position is not in itself irrational, it can be observed in reality that investors tend to become overly cautious in response to a current crash than they respond confidently to booms. This is not contrary to the popular research by Behavioural scientists Kahneman and Tversky (1979),which found that investors when given two alternatives, preferred to minimize loss than maximise profit from an investment. When the share price of a formerly profitable firm drops, it is normal that other investors adopt a distrustful perception of the general market. To minimise future loss, investors overcompensate by shying away from profitable trades, even in firms with good fundamentals.

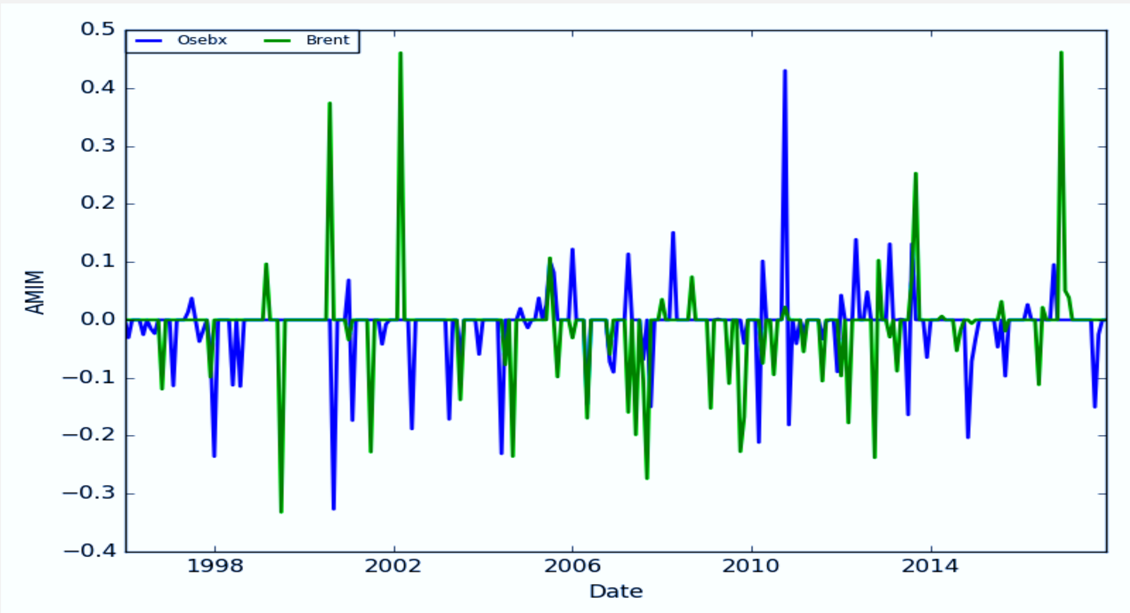


Figure 4: Evolution of Market Efficiency from 1996-2017

Although we notice some periods where the markets appear to move together, the correlation test showed no correlation between the markets. However, tests on sub samples shows that there is a cointegration relationship between them in the period 2007 - 2009 and 2014 - 2016. This cointegration relationship can be explained by the fact that these markets where exposed to similar shocks within these periods. Events in the global market reverberated to the individual markets causing a similar response by the efficiency in these markets. The result from fitting an error correction model showed Granger causality from the Brent crude market to the Norwegian stock market in the long run but no causality in the short run. This is not contrary to other studies into the relationship between the oil and stock market whether it is returns, volatility or investor sentiment that is examined (Dutta, Nikkinen, & Rothovius, 2017; El Hedi Arouri et al., 2011). Norway is a major exporter, and although the Norwegian government has taken steps to ensure a well-balanced economic growth, it is still vulnerable to events in the oil market as found in the study by Bjørnland (2009) . The gradual information diffusion hypothesis by Hong, Torous, and Valkanov (2002) can also lend some explanations to the cointegration relationship found between these markets. Having established that oil price plays a significant role in stock returns in Norway, then it is probable that conditions which affect the oil market will also affect the Norwegian stock market. If information on these conditions are slow in being transmitted to the Norwegian stock market, then you find a situation where efficiency level in the European Brent crude market precedes that in the Oslo Børs. Of course, it is difficult to determine how this information would be processed by investors in Oslo Børs when finally received. If investors perceive a profitable opportunity for Norwegian firms based on negative information in the oil market, then this hypothesis would cease to hold true between these markets. While information is said to be the most important factor in market efficiency, it is the opinion of the author that market efficiency is in fact driven by investors. Price does not just reflect information but rather it is the attempt by investors to act on information that cause markets to become efficient. Because market efficiency is based on investor action and hence indirectly by the investor’s perception, it is difficult to have definite theories on market efficiency.

1.3.1 Conclusion

We find long-term causality moving from Brent to the stock market. From the absence of correlation and the result from the Wald test, we can infer that there is no short run causality between these variables. This may indicate that co-movements between these variables may simply be due to their similar exposure to extreme shocks from the global environment such as the 2007 financial crisis and the 2014 oil price drop. In other events that occur in each market, such as the 2010 European sovereign debt crisis and even the Oil price increase due to the Arab spring in 2011, the efficiency in both markets move independent of each other. On the other hand, we may see these events as correcting deviation from equilibrium level of market efficiency, although it is difficult to establish what the equilibrium efficiency level is.

Another conclusion which may be reached is that the variables in the model do not have strong explanatory power. This is especially so for the Brent crude market whose results from the analysis of its residual indicate that a significant variable is missing from the model. However, based on the result from the stock market we can conclude that the efficiency in both markets become cointegrated during major global events and causation runs from the Brent spot market to the Norwegian stock exchange.

Market efficiency has implications for market participants and the exchange market in general. While speculative traders benefit from the arbitrage opportunity market inefficiency provides, the exchange market is left worse off as information asymmetry in the market leads to adverse selection. The development of the AMIM model opens doors for further research in cointegration and market efficiency study. Further research into this area of study can seek out other variables for possible influence on the level of market efficiency such as investor sentiment. The level of efficiency in emerging markets may also be examined in comparison with efficiency in developed countries.

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Cointegration Analysis and the Evolution of market efficiency: Evidence from Norway and the Brent spot market.

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Abstract

This paper examines the existence of a cointegration relationship between the degree of efficiency in the Norwegian stock market and the European Brent spot market. The study utilises the Adjusted Market Inefficiency Magnitude (AMIM) as a measure of market efficiency and the Engle-Granger Cointegration test. I find that both markets are on average efficient with periods of inefficiency in response to shocks to the system. Furthermore, the efficiency of the markets is affected by positive and negative shocks to the market. The most significant in the study results is that efficiency in the oil market drive the degree of efficiency in the stock market in the long term. This co-movement is present in periods of extreme shocks to both markets such as the 2007 financial crisis and the 2014 oil price crash. For the rest of the sample period, empirical tests show no correlation and short-term granger causality between the degree of efficiency in these markets. The findings of this study have implications for portfolio management as well as supporting the Adaptive Market Hypothesis (AMH).

JEL Classification: G14; C22; C10

Keywords: Market efficiency; Cointegration analysis; AMIM; AMH

2 Introduction

The level of efficiency within the financial market has implications for the continued relevance of the market. While market inefficiency is beneficial to speculative traders, in the long run it hinders the function of the financial market. Market inefficiency implies that the market is unable to allocate resources in a manner that facilitates economic activities. Market inefficiency indicates the presence of monopoly information and information asymmetry. Studies have since linked information asymmetry to adverse selection or the more popularly known lemon market (Ackerloff, 1970). For this reason, market efficiency has received great attention in literature due to its effect on not just the financial market but the economy in general.

The efficiency of any market evolves with time and is dependent on the conditions within the market. This is the proposition of the Adaptive Market Hypothesis (AMH) introduced by Lo (2004). The AMH has revolutionised the study of the degree of efficiency, which was previously viewed in a static and inconclusive manner. The seminal paper by Lo (2004) has motivated several other studies into market efficiency(Charles et al., 2012; Hiremath & Narayan, 2016; Khuntia & Pattanayak, 2018). Prior to the AMH, the efficient market hypothesis (EMH) by Fama (1970) provided the best explanation on market efficiency. The EMH received criticism mainly for its assumption that all investors are rational. Its major opposition comes from behavioural economists, who find that investors are rather irrational mostly governed by bias (Bondt et al., 1987; Odean, 1998). The introduction of the AMH provides a logical middle ground for both positions by allowing market efficiency to vary as conditions within the market vary and thereby capturing the volatility of investor attitude. The AMH has also been an influence in how market efficiency is measured and has formed the foundation for models such as the Time Varying-Autoregressive model (TV-AR) (Ito et al., 2014; Noda, 2016) and the Adjusted Market Inefficiency Magnitude (AMIM) (Vu & Leirvik, 2018). Although several other studies have since corroborated the AMH, one area that has not been examined is the possibility that efficiency in two markets can evolve together. This paper departs from the AMH and aims to determine if a long-term equilibrium relationship exists between the efficiency in the two markets.

This paper contributes to knowledge in the following ways. First it applies the AMIM model in measuring efficiency in the Norwegian stock market and enables the investigation of how efficiency in the market has evolved over time. Second, we perform a cointegration test to determine if a long-term equilibrium relationship exists between the degree of efficiency in the Norwegian and European Brent spot market. This study utilises the Adjusted Market Inefficiency Magnitude (AMIM) by Vu and Leirvik (2018) in measuring the degree of efficiency in both markets. The AMIM model is preferred as it is easy to compute and enables comparison across different asset classes which is ideal for the nature of this study. The existence of a cointegration relationship is investigated using the Engel-Granger Cointegration (EG)test.

I find that both markets are efficient except for periods of inefficiency in response to shocks to the system. This finding corroborates the AMH and other studies which have examined efficiency in the oil market(Ito et al., 2014; Urquhart & McGroarty, 2016; Verheyden et al., 2015). It is also found that the level of efficiency in both markets is influenced by both negative and positive shocks to the system. The cointegration analysis shows the existence of cointegration relationship during the period of the 2007 financial crisis and the 2014 oil price glut. In other periods, the efficiency in both markets are uncorrelated.

The findings of this study have implication for cointegration studies as well as portfolio managers. The existence of a cointegration relationship would indicate that an equilibrium relationship exists between these markets and hence there is the possibility of predicting future levels of efficiency in the market. Prior studies into the Norwegian stock market and the oil market have also found a mutual relationship between the return of both markets (Bjørnland, 2009; Wang et al., 2013).

The rest of this paper is organised as follows: the second section examines prior literature on this topic, the third section examines the model applied in the empirical analysis, the fourth section discusses the empirical result and the fifth section concludes based on the empirical results.

3 Literature Review

The concept of market efficiency is one of the most controversial issues in Financial economics. While the concept of market efficiency continues to be debated, one cannot ignore the importance of market efficiency to any exchange market. The function of any financial market is to facilitate the allocation of resources from the surplus to the deficit side of the economy. A channel for allocation of these resources is the price mechanism. Investors representing the surplus side of the economy choose firms with lucrative growth opportunities and decide to buy shares in this market thereby providing funds for firms.

Subsequent demand for these firm's stock drives its price up signalling it as a prime investment target. Price now becomes a resource allocation tool and hence efficient resource allocation hinges on price (market) efficiency. Conditions necessary for market efficiency to exist have been identified as: No transaction costs in trading securities; All available information is available to all participants at no cost; All participants are rational and agree on the implication the current information has on current and future prices (Fama, 1970). Trading costs can be expected to decline with technological advancement and individual investors can participate in large trades via mutual funds. Information asymmetry and investor attitude represent a more challenging factor. Information asymmetry leads to the lemon problem via adverse selection and weakens the role of the Financial market (Ackerloff, 1970; Mishkin, 2007).

Fama (1970) in his paper states that an efficient market is one in which price reflects all available information and goes further to declare that most markets are indeed efficient, This has come to be known as the Efficient Market Hypothesis(EMH). Fama (1970) paper makes further contribution to theory by recognising various degrees of market efficiency. The weak form of efficiency, where price only reflects past information and hence trading based on trend analysis is unable to predict the market. This form of efficiency resonates with the random walk literature, stock do not follow past performances but follow a random walk. This is the most basic form of efficiency. A market with semi-strong form efficiency reflects all publicly available information, past and present while in a market with strong-form efficiency, price reflects all information both public and private. A more relaxed definition of market efficiency is given by Jensen (1978), as the marginal benefit obtained from acting on monopoly information not exceeding the marginal costs incurred from the transaction. This is realistic as even if current price may adjust to quickly reflect available information, the question of how quickly it can adjust is raised. It is realistic to assume that some profit would be gained from monopoly information and that in reality there are sometimes significant transaction costs. This definition requires that although profit may be made, for a market to truly be efficient the marginal benefit obtained from information possessed must not exceed the cost of acting on such information. Fama (1991) in a review of his seminal paper, revises his earlier position. The author identifies that limited information and trading costs are not the main challenge to the efficient market model but rather the "joint efficiency problem" which makes it impossible to reach precise conclusions on the existence of market efficiency. The joint efficiency problem implies that testing for market efficiency requires a model that defines the equilibrium, usually in the form of an equilibrium asset pricing model. Several other studies have gone ahead to disprove the EMH by identifying the predictability of stock returns (Alizadeh & Muradoglu, 2014; Fluck et al., 1997; Subrahmanyam, 2010). However, the greatest challenge to the EMH are the conditions under which markets are assumed to be efficient. While it is possible that with technological advancement, transaction costs would decline, and information will be available to all participants faster and at reduced cost, there is however no guarantee as to how investors choose to interpret information. This is the major criticism of the EMH by behavioural finance. The critique targets the assumption that investors are rational and can hence agree on the implication current information will have on the future price. They argue that investors assess and make judgement on information subjectively, which creates bias such as confirmation bias and loss aversion (Odean, 1998).

The EMH view assumes a somewhat rigid view of market efficiency, it implies that once a market has attained a level of efficiency, it will continue to operate at that level. Lo (2004), in a ground-breaking study offers a logical interpretation to market efficiency. The point of departure for this study was the criticism of the EMH by the behavioural finance, citing the irrationality of investors. Lo (2004) reconciles the divide by putting forward the Adaptive Market Efficiency Hypothesis (AMH) which introduces the theory of evolution to the study of financial interactions. AMH puts forward that the level of market efficiency in any market varies from time to time in response to conditions within the market. It also explains the irrational behaviour of investors such as overconfidence or extreme loss aversion as simply a response to the investor adjusting to changes in the financial environment. Although qualitative in nature, this seminal work by Lo (2004) has several consequences for portfolio management and financial markets and has formed the background of several other studies. Some of the factors which are capable of changing market conditions and hence affecting the level of efficiency in the market are: financial bubbles, technological innovations, legal reforms, market deregulation among others (Lo, 2004). Other studies have gone ahead to examine the efficiency in several other markets based on the AMH (Ito et al., 2015; Lim & Brooks, 2011; Wang & Liu, 2010). Models measuring the degree of efficiency in the market are recent in literature. Prior to these models, market efficiency was measured via volatility tests (LeRoy & Porter, 1981), constant expected return hypothesis (Fama & French, 1989; Ferson & Harvey, 1991), method of generalized spectrum (Lv & Pan, 2009), existence of profit making opportunities (Sharma, 2017) among other models. However, the shortcoming of most of these methods is that they are incapable of capturing the evolving nature of market efficiency. Recent studies such as (Noda, 2016; Vu & Leirvik, 2018) have developed models capable of measuring and capturing market efficiency movements over time. These models make it possible to capture and compare evolving market efficiency over time. This study applies the AMIM model by Vu and Leirvik (2018) in measuring the level of efficiency in the Norwegian stock and European Brent crude market with the aim of capturing the evolution of market efficiency in this market over time.

The existence of cointegration in the returns of stocks also has implication for the level of efficiency in individual markets. If the returns of a market are cointegrated with those of another market, then movement of price from equilibrium offers profitable opportunity via mean reversion. This profit-making opportunity indicates inefficiency in the market. Several studies have documented the cointegration relationship that exists between the oil and stock market (Elian & Kisswani, 2017; Guesmi et al., 2016; Halaç et al., 2013; Maghyereh et al., 2007; Narayan & Narayan, 2010). However this point of view is contradicted by papers such as Dwyer Jr and Wallace (1992) who argue that the existence of arbitration and cointegration relationships are not to be equated. This argument is valid because, if the stock market has a cointegration relationship with the stock market, then this equilibrium relationship would already be reflected in stock price in an efficient market. Another hypothesis which has come to explain the co-movement between the market efficiency of several markets is the gradual information diffusion hypothesis forward by (Hong et al., 2002). The gradual information diffusion hypothesis in summary proposes that information that affects the conditions in Market A may gradually diffuse to market B, causing the degree of efficiency in both markets to be cointegrated with market A driving efficiency in market B. This paper contributes to existing literature by testing for cointegration between the efficiency level in the oil and stock market.

Zhang et al (2013) while examining the efficiency of the crude spot market in US, UAE, Europe and China, found these markets to be mostly efficient with brief moments of efficiency. Their study also found that the level of efficiency in the markets responded asymmetrically to return-volatility i.e. the market responded more strongly to bad news than good news. This is not different from the proposition of Hamilton (2003) and not farfetched . Following a market crash it is not uncommon to observe investors becoming extremely risk averse as opposed to the over confidence they exhibit following a period of boom. It is important to note that market booms can result in market inefficiency in the same manner that market crashes do. In their study Sharma (2017), studied market efficiency in the oil future market of the US and India. Their study defined market efficiency as the absence of profit opportunities within the market, and this was the basis upon which the level of market efficiency within the market was measured. Their study found bi-directional flow of information between both markets in the short term but in the long term the US market is seen to dominate information flow to other countries. This paper contributes to existing knowledge by determining the direction of causation between the efficiency level in the oil and the stock market. It also examines non-linear or asymmetric impact of events on market efficiency.

Market efficiency studies have moved from the position of the EMH to that of the AMH. Several studies have since then attempted to confirm the AMH while others have developed models for measuring market efficiency based on the AMH. This study is innovative and hence contributes to existing knowledge as it seeks to investigate the possibility that the evolving efficiency in two markets can display a long-term equilibrium relationship.

4 Methodology and Data Description

4.1 Data

This research is aimed at examining the relationship between the degree of efficiency in the Oil and stock market. Towards this purpose the study data comprises of oil price and stock price. The oil price data is European Brent crude price obtained from the American Energy Information Administrate (EIA). Stock price data is the Oslo Børs benchmark index (OSEBX) obtained from the database TITLON. The study utilizes daily data covering the period January 1996 - December 2017. This data is transformed into returns and later into AMIM values before they are suitable for the purpose of this research. The method utilized is discussed further under the methodology. Graph showing return series of both variables is found in Figure 5 and Figure 6 in Appendix 2.

4.2 Methodology

In answering the research question posed, this study utilises several models and tests aimed at measuring the Degree of efficiency in both markets, the stationary qualities of the data, correlation and cointegration between the series as well as autocorrelation, normality and heteroskedasticity in the regression residuals.

4.2.1 Adjusted Market Inefficiency Magnitude

The degree of efficiency in each market is first measured using the Adjusted market inefficiency magnitude by Vu and Leirvik (2018). The model for AMIM is given by

$$AMIM_t = \frac{MIM_t - CI}{1 - CI} \qquad (1)$$

Where:

$$MIM_t = \frac{\sum_{j=1}^{q} |\hat{\beta}_{j,t}^{standard}|}{1 + \sum_{j=1}^{q} |\hat{\beta}_{j,t}^{standard}|} \qquad (2)$$

CI = is the confidence interval determined with reference to and unique for each number of lags

$\hat{\beta}_{j,t}^{standard}$ = are the autoregressive beta coefficients standardised through Cholesky decomposition of the vector of beta coefficients.

MIM_t = is the Market inefficiency Magnitude calculated for each observation where ***t*** is monthly observations.

The second equation utilises the absolute values of the standardised beta coefficients to prevent instances of the elimination effect leading to false results of market efficiency. However, this also means that the MIM is positively correlated with the number of lags in the base AR equation and hence tends to give high values even when markets tend to be efficient. Therefore, the MIM is adjusted to resolve this issue. The adjusted MIM (AMIM) is the ratio of the distance between the MIM and the confidence interval of each observation to the distance between the theoretical maximum value of MIM and the confidence interval. The denominator of the AMIM equation offers a common ground and enables comparison across different periods. Because the Confidence interval is unique to the number of lags and not simulated for each study, Vu and Leirvik (2018) have created a table of confidence intervals which can be obtained from their study.

4.2.2 Engle-Granger Cointegration test

The Engle-Granger 2 step cointegration test (Engle & Granger, 1987) is performed on the entire series and on sub samples of the series. The sub samples are chosen exogenously based on knowledge of past events and fluctuations within both markets. Five sub-samples are determined, and they are as follows:

- Pre-2007 financial crisis: 1996-2006
- During the 2007 financial crisis: 2007-2009

- After the 2007 financial crisis: 2010-2013
- During the oil glut of 2014: 2014-2016
- After the oil glut of 2014: 2017

The result of the EG cointegration test shows the existence of a cointegration relationship in the second and fourth sub samples corresponding to the 2007 financial crisis and the 2014 oil price glut. Below is the long-term equation used where $\boldsymbol{\delta_t}$ is the trend capturing past levels of efficiency in the stock market.

The EG test is performed by testing the residuals from the linear combination of the variables for stationarity. The linear combination is represented by a long-term equation which captures the equilibrium relationship between the variables. The long-term equation is given by

$$AMIM_{osebx,t} = \alpha + \beta_1 AMIM_{brent,t} + \delta_t + \varepsilon_t \qquad (3)$$

Where:

α = is the model intercept which captures changes in stock market efficiency independent of any other factor within the model.

β = captures changes in the efficiency level of the stock market due to changes in oil market efficiency.

δ_t = captures changes in the degree of efficiency in the stock market owing to trends in the market.

4.2.3 Error Correction Model

We fit an error correction model to the market efficiency data based on the discovery of a cointegration relationship. The equation for the vector error correction model (VECM) is given by

$$\Delta AMIM_{osebx,t} = \hat{v} + \hat{\alpha}_1 \hat{u}_{t-1} + \gamma_1 \Delta AMIM_{osebx,t-1} + \gamma_2 \Delta AMIM_{brent,t-1} + \varepsilon_{1,t} \qquad (4)$$

$$\Delta AMIM_{brent,t} = \hat{v} + \hat{\alpha}_2 \hat{u}_{t-1} + \gamma_1 \Delta AMIM_{osebx,t-1} + \gamma_2 \Delta AMIM_{brent,t-1} + \varepsilon_{2,t} \qquad (5)$$

Where:

$\Delta AMIM_{osebx,t}, \Delta AMIM_{brent,t}$ = is the first difference of the AMIM values of the Brent and Osebx market.

$\hat{\alpha}_1, \hat{\alpha}_2$ = are the adjustment coefficients which correct deviations from the equilibrium, these coefficients tell how fast variables return to equilibrium when a deviation from equilibrium occurs.

$\hat{u}_{t-1}$ = are the lagged values of the residuals of the long-term equilibrium equation which are $\sim I(0)$.

ε_t = is the error term from the error correction equation.

5 EMPIRICAL RESULTS

5.1 Adjusted Market Inefficiency Series

I obtain the degree of market efficiency in both markets from the AMIM model. AMIM values greater than zero indicate periods of inefficiency. Figure 1 shows the evolving market efficiency for both markets over the study period. Both markets on average display efficiency in the early period of the study, this lasts until early 2000 where the oil market efficiency record significant inefficiency level in response to uncertainty in the market such as a significant fall in oil demand in Asia due to the Asian financial crisis and the terrorist attack of 2001. After the Asian oil demand recovers, efficiency in the oil market is restored. Shifts to inefficiency in the Norwegian stock market can be observed following the 2007 financial crisis. During this period the efficiency in the oil market is barely affected by this event save for brief moments of inefficiency.

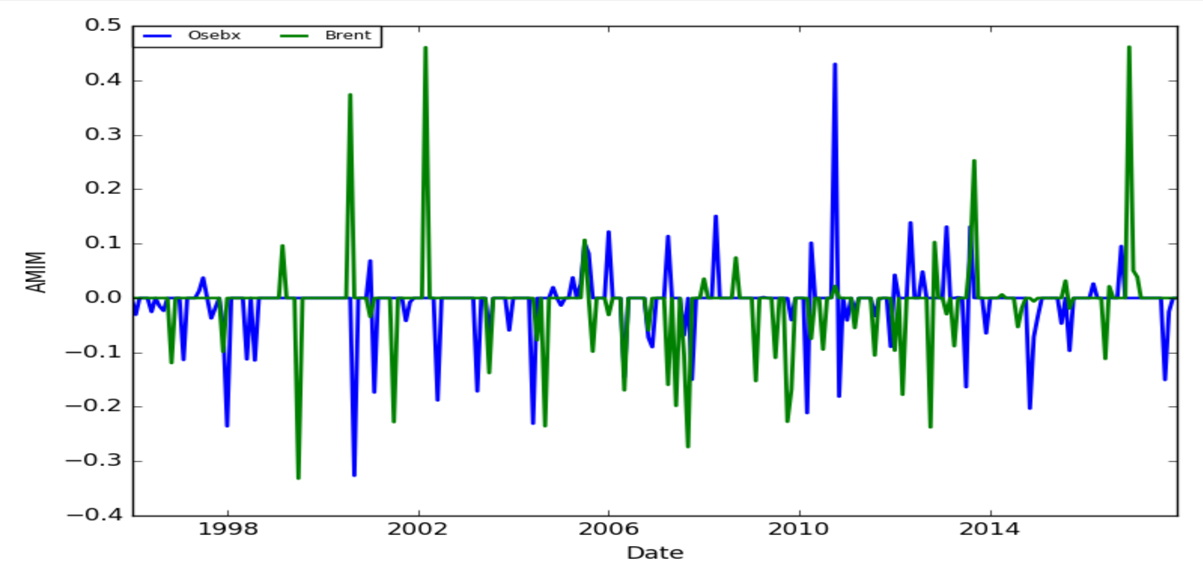

Figure 3: Evolution of Market efficiency from 1996 to 2017

Brief moments when the markets appear to move together can also be observed during the 2007 and 2014 crisis. The fluctuation in the stock market continues as its conditions are affected by other events such as the European sovereign debt crisis of 2010 and the market crash of August - December 2011. For the oil market, continued efficiency is observed in 2014 until the most significant change to inefficiency is recorded in 2016. This may be explained as resulting from a delayed reaction by investors. Although oil price initially begins to decline in late 2012 to early 2013, it may have been perceived as a temporary decline. However, as the price continued its steady decline well into 2015, the market reacts to the shock by displaying significant inefficiency level, probably due to over reaction by investors.

The descriptive statistics for the estimated AMIM is displayed in the table below. The mean result indicates that on average both markets are efficient due to the negative mean value. The data series has a low variance and standard deviation which means that the data points are located not far from the mean. For an efficiency series it can be interpreted that level of efficiency in the market does not deviate far from the average. Both data series have positive kurtosis indicating that the tail of the data distribution is fatter than the normal distribution due to having more observations in the tails. The distribution for market efficiency in the Norwegian stock market is negatively skewed while that for the Brent is positively skewed indicating that they are both not normal distributions. The rejection of normality for both distribution is confirmed by the Jarque-Bera test which is highly significant and leads us to reject the null hypothesis of normality. Another confirmation comes from the QQ-Plot in Figure 2 and Figure 3 which shows that both observations have too many extreme values to have come from a normal distribution.

Table 1:Summary statistics of the AMIM and return series from 1996 to 2017

	AMIM.OSEBX	AMIM.Brent	Return.OSEBX	Return.Brent
Mean	-0.0081	-0.0075	0.0005	0.000099
Standard. Deviation	0.0603	0.0728	0.0141	0.0099
Median	0	0	0.0011	0.0002
Sample variance	0.0036	0.0053	0.0002	0.000098
Kurtosis	15.4686	17.9582	6.3823	4.6959
Skewness	-0.0588	1.4526	-0.4166	-0.0198
Jarque-Bera[1]	2680.3***	3704.7***	9542.1***	5165.6***
Range	0.7570	0.7940	0.2062	0.1651
Maximum	0.4304	0.4620	0.1067	0.0787
Minimum	-0.3267	-0.3320	-0.0995	-0.0864

[1] Jarque-Bera is a hypothesis test and *** represents highly significant p.value. This indicates that H0: Normality can be rejected.

5.2 Stationarity

We see differing results on the stability of these series from both tests. While both tests show the entire series as stationary, we however find non-stationary roots in the second (2007 - 2009), fourth (2014 - 2016) and the fifth (2017) structural break. These periods correspond to the 2007 financial crisis, the 2014 oil price glut and the aftermaths of the oil price drop.

Table 2: Result of unit root and stationarity test[2]

SAMPLE	*Variable*	*ADF* [3]				*KPSS* [4]		
		Order of integration	No drift and trend	With Drift	With drift and trend	No drift and trend	With Drift	Drift and Trend
Entire set	Osebx	1(0)	-6.94 (0.01)	-7.37 (0.01)	-7.57 (0.01)	2.88 (0.01)	0.34 (0.10)	0.08 (0.10)
	Brent	1(0)	-6.49 (0.01)	-6.65 (0.01)	-6.65 (0.01)	1.28 (0.09)	0.18 (0.10)	0.18 (0.02)
1996-2006	Osebx	1(0)	-3.89 (0.01)	-4.67 (0.01)	-4.74 (0.01)	3.09 (0.01)	0.12 (0.10)	0.05 (0.10)
	Brent	1(0)	-5.14 (0.01)	-5.18 (0.01)	-5.18 (0.01)	0.10 (0.10)	0.09 (0.10)	0.07 (0.10)
2007-2009	Osebx	1(1)	-3.15 (0.01)	-3.08 (0.04)	-3.03 (0.17)	(0.07) (0.10)	0.07 (0.10)	0.07 (0.10)
	Brent	1(1)	-1.34 (0.20)	-1.84 (0.39)	-1.62 (0.71)	1.26 (0.09)	0.17 (0.10)	0.16 (0.03)
2010-2013	Osebx	1(0)	-3.85 (0.01)	-3.99 (0.01)	-3.92 (0.02)	0.16 (0.10)	0.05 (0.10)	0.05 (0.10)
	Brent	1(0)	-2.93 (0.01)	-3.05 (0.04)	-3.24 (0.09)	1.17 (0.10)	0.24 (0.10)	0.13 (0.07)
2014-2016	Osebx	1(1)	-2.40 (0.02)	-2.60 (0.11)	-3.02 (0.17)	0.10 (0.10)	0.25 (0.10)	0.09 (0.10)
	Brent	1(1)	-0.75 (0.40)	-0.40 (0.90)	-0.17 (0.99)	0.05 (0.10)	0.28 (0.10)	0.12 (0.10)
2017-	Osebx	1(1)	-1.56 (0.11)	-1.87 (0.38)	-1.67 (0.69)	0.04 (0.10)	0.11 (0.10)	0.09 (0.10)
	Brent	1(1)	-4.87 (0.01)	-0.42 (0.01)	-0.31 (0.17)	0.12 (0.10)	0.08 (0.10)	0.07 (0.10)

When sub-samples are taken, the aggregate effect is removed, and we can see how the markets respond to the shock experienced during this period. During the 2007 financial crisis we can see that OSEBX shows significant non-stationarity, indicating that the stock market efficiency does not recover immediately when hit by the market crash. This shock also spills over to the oil market as we see that Brent is non-stationary during this period. During the 2014 oil price drop, we see that the Brent series becomes significantly non-stationary indicating the market does not quickly recover from the shock to the system. As expected this oil shock spills over to the stock market which also experiences considerable instability

[2] Probability values (p.values) are given in parenthesis
[3] H0: presence of unit roots indicating non-stationary series
[4] H0: stationarity

during this period. The fifth structural break is intended to capture the aftermath of the 2014 crisis. We see from the test results that both markets remain non-stationary. Based on these findings, I proceed to test for the possibility of a cointegration relationship during the above-mentioned sub samples. Detailed result of the unit root test can be found in Table 2.

5.3 *Correlation Tests*

Based on the findings that there is a possibility of a cointegrating relationship between these series, we conduct tests to check for correlation between the series. We apply the Pearson, Kendall and Spearman test. I find that in all the tests and for all sub samples that the correlation coefficient is not significantly different from zero, indicating no correlation between the series. This implies that the efficiency in both markets move independently of each other. This is based on the statistically insignificant correlation coefficient obtained from the correlation test. This finding is surprising when the importance of the oil market to the Norwegian market is taken into consideration. Detailed result of the correlation test can be found in the Table 3.

Table 3:Correlation test result showing linear relationship between efficiency in the oil and stock market

	Entire set	1996 -2006	2007 -2009	2010 -2013	2014 -2016	2017
PEARSON:						
t-stat	0.5474	0.8591	-0.1936	0.2663	0.2471	0.4563
p.value	0.5846	0.3919	0.8476	0.7912	0.8063	0.6563
Cor.coef.	0.0338	0.0751	-0.0332	0.0392	0.0423	0.1306
KENDALL:						
z-stat	1.6232	1.2070	0.6147	0.4003	1.4600	0.5973
p.value	0.1046	0.2274	0.5388	0.6890	0.1443	0.5503
Tau coef.	0.0898	0.0964	0.0943	0.0505	0.2240	0.1600
SPEARMAN:						
s-stat	2758900	342870	6904.9	17297	5870.9	379.62
p.value	0.1039	0.2287	0.518	0.6796	0.1508	0.5714
Rho coef.	0.1003	0.1055	0.1113	0.0612	0.2444	0.1657

There are several reasons for the statistically insignificant correlation coefficient obtained. First, the correlation coefficient is low because the relationship between the efficiency level in both markets are probably non-linear and as a result would not be adequately measured by the correlation tests. The Pearson correlation test for example, measures the strength of the linear relationship between two variables. Secondly, the correlation test simply indicates that in a given period when there is efficiency in the Brent market there may or may not be efficiency in the stock market. When we consider that one of the factors that affects market efficiency is investor attitude, this empirical result is not as surprising. As behavioural studies have shown, investors respond to information with varying bias which affects their investment strategies and may cause efficiency in both markets to appear uncorrelated. Thirdly, while variables may appear to be uncorrelated, it is still possible for an equilibrium relationship to exist between them. The implication is that while the variables show no mutual relationship in the short term, they eventually return to the equilibrium relationship in the long term. This reversion is usually in response to trends within the markets.

5.4 Cointegration Test

Having found non-stationarity in some sample periods we test for cointegration by applying the EG test to the sub samples identified in prior sections. Applying the EG cointegration test to these sample periods, we only find significant cointegration relationship in the period 2007-2009 and 2014-2016, although the relationship during the 2014 crisis period is marginally significant. For these periods we can reject the null hypothesis of no cointegration. The cointegration discovered during these periods may be due to the shock transmitted to both markets from the global market. This finding is significant and may imply that co-movement can only be expected in periods of significant global events. The results of the cointegration test on the sub-samples are in Table 4.

Table 4:Engle-Granger cointegration test results for sub-samples[5]

	2007-2009	2014-2016	2017
No trend	-3.10	-2.68	-1.24
	(0.04)	(0.09)	(0.10)
Linear Trend	-0.20	0.40	0.22
	(0.10)	(0.10)	(0.10)
Quadratic Trend	0.06	-1.75	2.67
	(0.10)	(0.10)	(0.10)

The regression result obtained from the error correction equation is presented in the table below All the variables are in first difference to ensure stationarity and prevent spurious regression problem (C.W.J. Granger & Newbold, 1974). $\hat{u}_{t-1}$ which is the lagged equilibrium error is also included in the equation as an explanatory variable. The adjustment coefficient α_1 in the model is responsible for correcting deviations from equilibrium. From the results we that only the adjustment coefficients are statistically significant and their non-zero value indicates that efficiency in the Brent crude market granger causes the efficiency in the Norwegian stock market.

[5] H0: No cointegration. p values are given in parenthesis.

Table 5:Regression results from the VECM showing the direction of Granger causality between the variables[6]

OSEBX			**Brent**		
	Coefficients	t-stat		Coefficients	t-stat
Intercept	5.051e-05	0.014 (0.989)	Intercept	-1.208e-06	0.000 (1.000)
Diff(Osebx)	-1.093e-02	-0.175 (0.861)	Diff(Brent)	-5.071e-01	-9.470 (2e-16) ***
Diff(Brent)	-2.560e-02	-0.690 (0.491)	Diff(Osebx)	9.783e-02	1.086 (0.279)
Residual	-1.099e+00	-11.788 (2e-16) ***	Residual	-1.994e-02	-0.148 (0.882)

From the regression result we find that only the lagged values of Brent are significant in the error correction equation for Brent crude. The adjustment coefficients $\boldsymbol{\alpha_2}$ are statistically non-significant i.e. $\boldsymbol{\alpha_2 = 0}$, this indicates that efficiency in the Brent crude market is not driven by efficiency in the stock market. It also implies that efficiency in the Brent market is not determined within this model.

Dependent Variable	Wald-stat	p-value
Osebx	0.5518	0.4583
Brent	2.1589	0.143

Table 6:Short-term Granger causality test with Wald statistic

5.5 Residual Analysis

The residuals from the error correction equation are analysed for presence of autocorrelation, normality and heteroskedasticity. The results are presented in the table below. The Ljung-Box tests whether the autocorrelation coefficients are significantly different from zero. From the results, I can conclude that the autocorrelation coefficients in the VECM for Osebx in equation 4 is not significantly different from zero. This means the null hypothesis of no autocorrelation cannot be rejected. The null hypothesis is however rejected in the VECM for Brent in equation 5, indicating the presence of autocorrelation. The consequences of autocorrelation in autoregressive models include spurious regression as the estimators are biased and inconsistent. The possible reasons for autocorrelation in the Brent model is the omission of important variables. Because we have included an insignificant variable (efficiency in the stock market) and omitted an unknown variable which is now forcibly grouped in the regression residual ($\boldsymbol{\varepsilon_{2,t}}$). The best solution for this is to identify other variables that are better influences of changes in efficiency in the oil market.

[6] * indicate statistically significant p values. p values are in parenthesis.

The Jarque-Bera is used to test that residuals are normally distributed. The results below indicate the residuals are not normally distributed. We can however relax the normality requirement due to the Central Limit Theorem which states that as the sample size increases, the distribution approximates a normal distribution. Therefore, the residuals are asymptotically normally distributed.

Table 7:Result from the residual analysis of the VECM

	Ljung-Box	Jarque-Bera	ARCH
VECM-Osebx	1.18 (0.9472)	2578.3 (2.2e-16) ***	7.956 (0.01872)
VECM-Brent	32.68 (4.362e-06) ***	776.67 (2.2e-16) ***	12.7712 (0.0017)

The Autoregressive Conditional Heteroskedasticity (ARCH) is used to test if there is conditional heteroskedasticity between the residuals in the time series models. Conditional heteroskedasticity means that conditional on the regressor, there is unequal variance between the residuals. Conditional homoskedasticity (equal variance) is one of the asymptotic properties of OLS estimators. From the results, we see that in both error correction models we must reject the null hypothesis of no ARCH(k) effect. The consequences of conditional heteroskedasticity in the model is that although the coefficients remain unbiased, the standard errors and t-stat are unreliable.

6 Discussion

Prior to the 2007 crisis, events in the global market barely affected the level of efficiency in the Norwegian stock market. However, following the crisis, the stock market responds to the global financial crisis by becoming significantly inefficient. This is not surprising as stock market crises are usually accompanied by higher risk aversion and temporary loss of confidence in the market. Investors may shy away from active trading in the market and hence price fail to reflect all information in the market. Upon closer examination of the plot in Figure 4, a period of significant market efficiency in the periods leading to the 2007 financial crisis can be observed. This indicates an actively traded market which is not uncommon when a market is overheated. However, there are moments during the financial crisis when the market experienced periods of efficiency. One explanation for this is that during the crisis, investors risk aversion increases causing the demand and value for certain stocks in the market to decline. This inadvertently causes the price to reflect information about the stock such as its low earnings and growth potential or poor management abilities.

Markets are not exclusively efficient when the conditions are bearish or bullish, however if we have a bull market that is contrary to existing information, then a stock price crash restores market efficiency levels. However, we do see that the market responds more to negative shocks than positive shocks. This is also found in Zhang et al. (2014) study and confirms Hamilton (2003) oil price's asymmetric effect. We can find an explanation for this in a behavioural study by Kahneman and Tversky (1979) where investors where seen to make decisions primarily driven by a desire to minimise loss rather than maximise profit. We can interpret this as investors are more likely to be risk averse than overconfident and this has implications for the level of efficiency within the market.

How do markets evolve from periods of efficiency to inefficiency? This can be answered by examining investor attitude. From the period 2002-2005 we see persistent market efficiency. This means price reflects all information available. As discussed in previous sections, market efficiency does not preclude profitable trades, it only implies that that these gains cannot be consistently made at the expense of the market. Investors by nature are always looking for undervalued stocks or prime investment opportunity. While behavioural finance considers this "investor greed", based on the AMH one can consider this a rational response to a market that has been erstwhile stable. This trend of stability makes investors over confident, risk seeking in their attempt to find profitable investment and hence vulnerable to overvalued stocks. Investment decision become driven by optimism rather than the available information and the result is not only a deviation from efficiency but a budding financial crisis.

Based on the results obtained from the error correction model, we find the degree of efficiency in the Brent market to drive efficiency in the Norwegian stock market during these periods. There are several reasons why a long-term equilibrium relationship may exist between both markets. First one of the major sectors in the Norwegian stock market is the energy sector of which crude oil is an important component. It is reasonable to expect that factors which drive the crude market will eventually make its way to the Norwegian stock market. The gradual information diffusion hypothesis (Hong et al., 2002) can be used to explain this. As information originates in the oil market, it gradually makes it way to the stock market and systematically influences investment decision, price and finally the level of efficiency in the market. As discussed under the AMH, market efficiency is determined by conditions within the individual market. As a result, events which affect both markets would cause these markets to exhibit equilibrium relationship.

However, despite the existence of a cointegration relationship, no correlation was found between the efficiency in both markets. In other periods of the study, we see the efficiency level in both markets move independently of each other. This finding is surprising given that prior studies into returns in these markets have found significant mutual relationship with causality running from the oil to the stock market. While the oil market may influence stock, market returns it is insignificant in explaining changes in efficiency within this market. These findings are significant for cointegration studies. It calls into question the ability for efficiency level between markets to possess mutual relationships outside of global shocks. One explanation for this may also lie with investor attitude and sentiment. Market efficiency is usually termed as information efficiency however the most important factor in market efficiency in investor attitude. This is because it affects the way investors interpret market information, the investment decision they act on and finally market price. Expecting two markets to display correlated efficiency level implies that all investors in both markets interpret information in the same manner and have the same conclusion on the significance of the information. This was the same assumption by the EMH and has been disproven by several behavioural studies. It may be found that investors in Norway perceive the oil market crash as an opportunity for firms in other sectors of the Norwegian economy to realise their growth potential. As a result, in the peak of the oil price glut, shares are still actively traded by confident investors and as such the market remains efficient throughout the crisis. The inability of these study to find correlation between the efficiency in these markets which enjoy mutual relationship in other aspects draws focus on how important investor attitude and perception is for the study of market efficiency.

6.1 Conclusion

The aim of this paper is to test for cointegration between the degree of efficiency in the Brent crude and Norwegian stock market over time. There have been several studies which have identified that a mutual relationship exists between these markets although not all have found cointegration relationship. Evidence of a cointegration relationship is found only during the 2007 and 2014 crisis. This infers that the efficiency in these markets only show co-movement in response to major global events.

These findings have implications for portfolio managers and policy decisions within Norway. If efficiency in the oil market does not affect the stock market efficiency beyond significant global events, then this provides some shield to the national economy from fluctuations in the oil market. However, the findings of this study only imply that no short-term equilibrium relationship exists between the markets. As oil continues to be one of the most significant economic resource for most nations and events in the global economy continue to have significant effects, no individual economy can be indifferent to echoes from the global and oil market. Policy makers and regulators within the financial market must continue to make regulations that ensure continued transparency and information symmetry within the market. Further research may seek to find other variables that may explain changes in the level of efficiency, especially in the oil market. One of such variables that may be of interest is investor sentiment.

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Appendices

Appendix 1: Author guide for the Journal of Banking and Finance.

Appendix 2: FIGURES

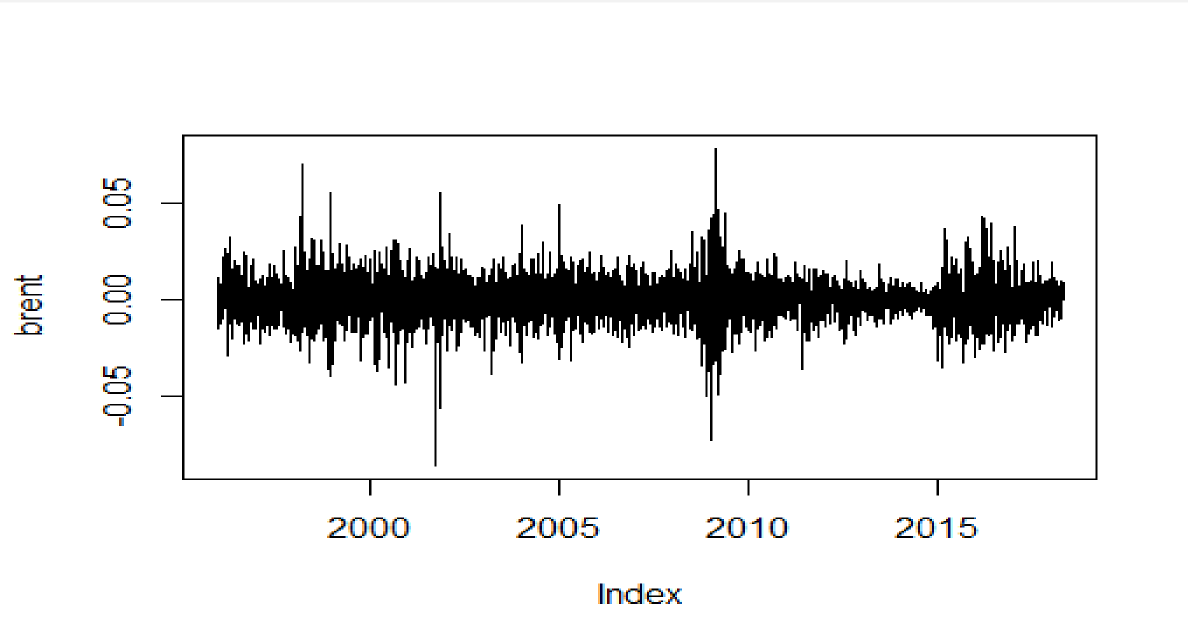

Figure 5:Daily Brent log return from 1996 to 2017

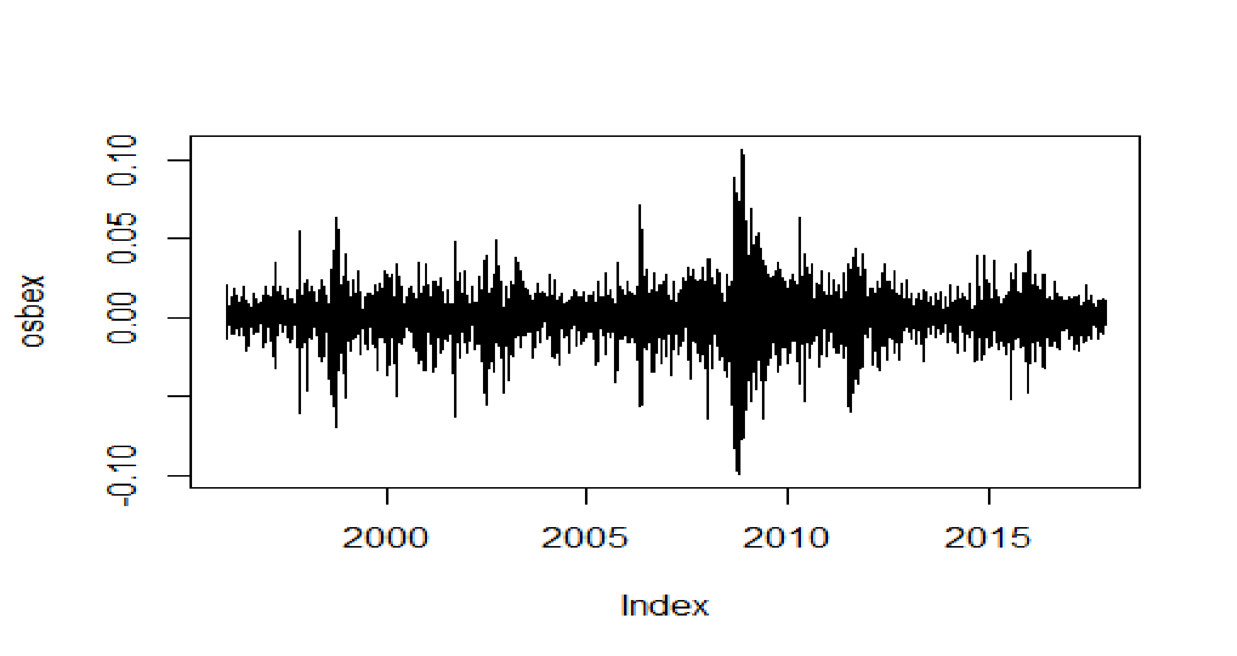

Figure 6:Daily OSEBX log return from 1996 to 2017

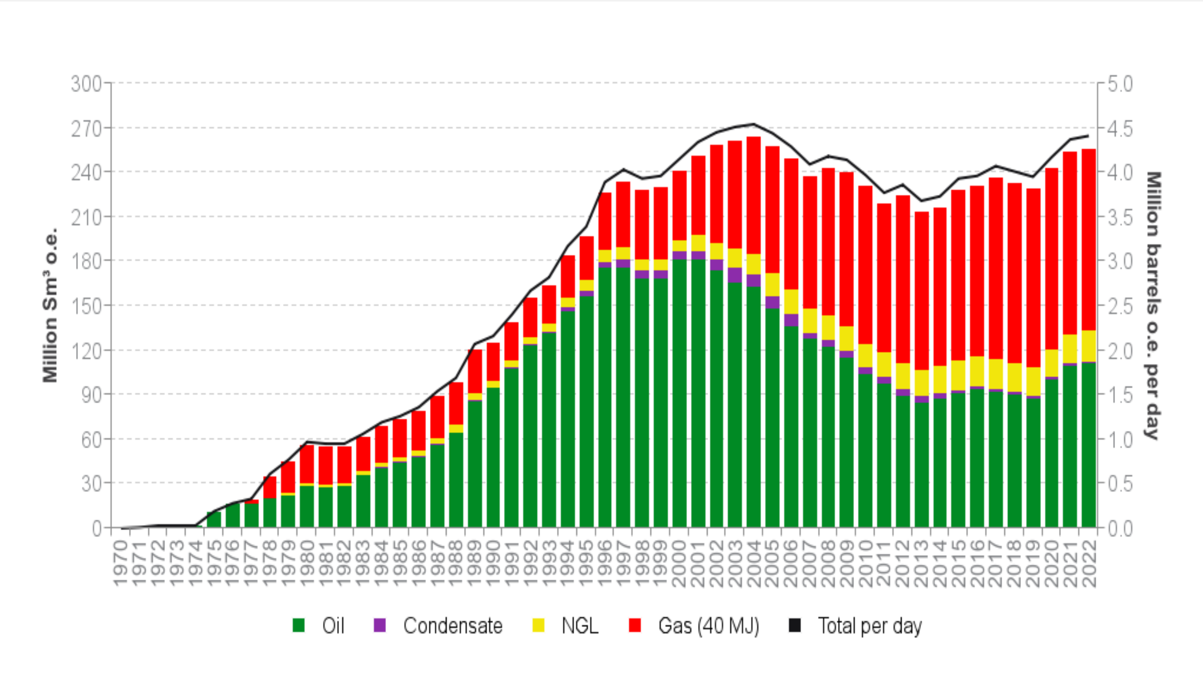

Figure 7: Production from the Norwegian shelf showing decomposition into oil and other crude components. Source: Norwegian petroleum Directorate

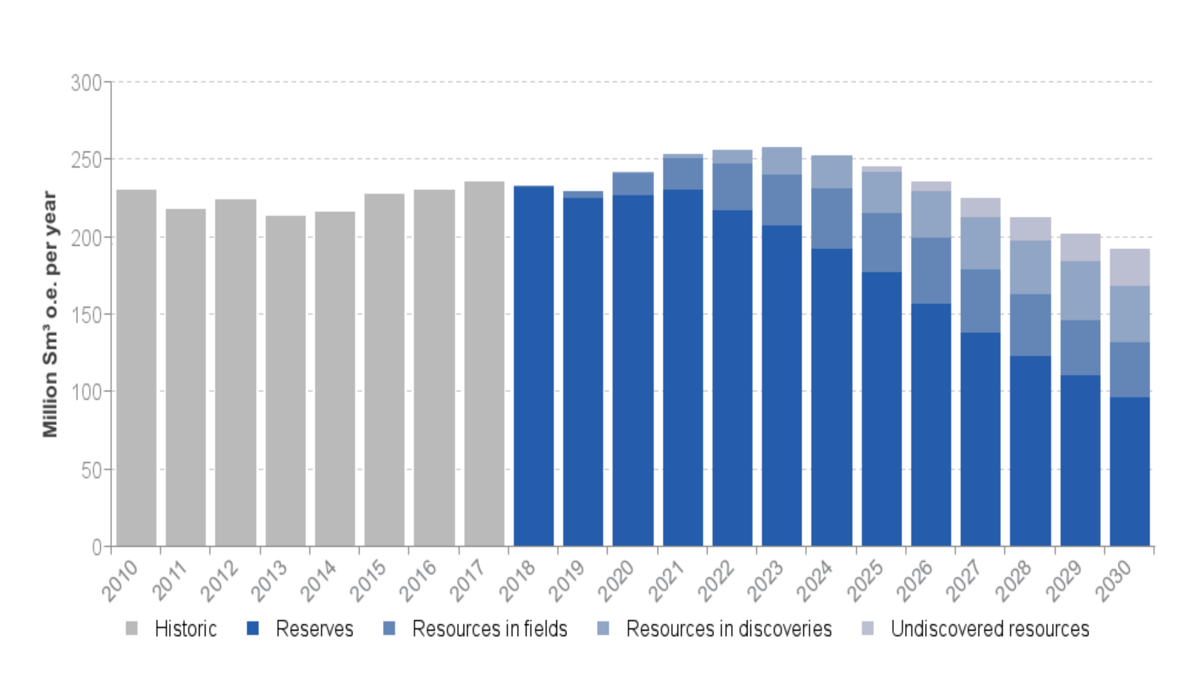

Figure 8: Historical and forecast production of oil from current and potential reserves. Source: Norwegian petroleum directorate