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Preface

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International Portfolio Diversification: Commodities

Abstract

We study whether Norwegian Investors should include commodities in their portfolios. Firstly, we discuss the correlation and dispersion between commodities and international equity markets, in addition to possible time trends in the correlation and dispersion between the commodity and the equity market. Secondly, we analyze the return-to-risk tradeoff and the mean-variance efficiency when adding commodities to traditional portfolios. We find no added improvement to the mean-variance efficiency or Sharpe ratio of traditional buy-and-hold equity strategies. Moreover, we find that there are no significant time trends between the MSCI world index and S&P GSCI all commodities return correlations in both USD and NOK. We also find that there are significant, but small, positive time trends in return correlations between the Oslo Exchange All Share and the S&P GSCI all commodities.

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1. Introduction

In the few past years, as both Fabozzi *(2008)* and Tang & Xiong *(2010)* state, investing in commodity indices has become increasingly popular. This makes it important to address the possible diversification benefits of investing in commodity indices or commodities in general. Moreover, the financial literature seems to support the idea that commodities have significant diversification effect on traditional portfolios *(Gorton & Rouwenhorst (2005), Harry M. Kat (2006) and Kat & Oomen (2006b)*. Eiling & Gerard *(2010)* state that the equity markets are increasingly getting more and more integrated on a ‘global level’, which makes looking for alternative assets important. Bannister & Forward *(2002)*, however, show that stocks and commodities have alternated relative and absolute price leadership in cycles. This means that the effects of diversification supported by traditional finance might not be constant over time. In other hands, there might not be any diversification benefits between different periods or business cycles.

With this paper we, therefore, wish to address the diversification effect of commodities on traditional portfolios. Moreover, with this paper, we might make it possible to construct a more mean-variance efficient portfolio if our tests show a significant increase in Sharpe-ratio when including commodities on top of traditional equity portfolios. The analysis will mainly focus and examine the impact of commodities on a Norwegian investor holding an international portfolio versus a Norwegian investor holding only Norwegian stocks.

To address the issue we employ a quarterly correlation measure and the dispersion measure employed by Bauer *(2006)*. However, it is equally or even more important to analyze if the diversification benefits of commodities are statistically significant. We therefore employ the spanning test provided by Huberman and Kandel (*1987*) and the Sharpe ratio test employed by DeRoon et al. *(2009)* to look at the possible reward gained for the risk taken. Our results show that there are positive time trends in the correlation between commodities and equity markets when returns are denominated in USD and NOK, with the exception of the S&P GSCI all commodity. We also find no statistically significant increases in the Sharpe ratio when commodities are added to traditional buy-and-hold equity portfolios.

The rest of the paper is structured as follows: Section 2 reviews the background literature. Section 3 presents the framework of the tests and measures that are used in our paper. Section 4 describes the data set. Section 5 reports the results of our various tests and measures. In section 6 we investigate whether the results are robust. Section 7 concludes and summarizes what we found in our results. Section 8 includes the figures and tables, which report our findings.

2. Background and Literature

In the past few years, as both Fabozzi *(2008)* and Tang & Xiong *(2010)* state, investing in commodity indices has become increasingly popular. Previous research and traditional financial literature seems to support the idea that commodities have significant diversification effect on traditional portfolios *(Gorton & Rouwenhorst (2005), Harry M. Kat (2006) and Kat & Oomen (2006b).* Previous papers suggest that the reason for this significant diversification effect seems to be due to nature of the risk factors that commodity futures are exposed to, which are different compared to equity risk factors. It is also claimed that commodity futures have powers to diversify systematic risk and hence making commodities significantly uncorrelated to traditional financial markets *(Gorton & Rouwenhorst, 2005)*. Cheung and Miu *(2010)* state that the alleged diversification benefits of commodities exist and are statistically significant in the long run. However, these papers and traditional literature use data pre-2005era and there has been a large increase in commodity prices since 2005.

It is believed that the recent increase in commodity prices is partially due to the increasing pressure on the demand of raw materials from emerging markets such as China and Brazil *(Harry M. Kat, 2006)*. China and Brazil are two of the major emerging economies that are believed to drive the current commodity boom *(Fabozzi, 2008)*. Tang and Xiong (*2010*) explain that the rapid growth in emerging economies in the 2000s increased the demand for commodities in sectors like energy and metals, which could have led to the price boom that these commodities have experienced the last decade. Then there is also the issue of under-investment by commodity producers due to many years of price weakness and hence lower production ability to meet new increased demands *(Harry M. Kat, 2006)*. Investing in commodity production means often a very large increase in production. This makes commodity producers hesitant to react right away to market changes.

Further on, it turns out that the equity markets are increasingly getting more and more integrated on a ‘global level’ *(Eiling & Gerard, 2010)*. This makes looking for alternative assets that are uncorrelated with traditional equity assets for diversification benefits, such as commodities, important in the near future. Bannister & Forward *(2002)*, however, show that stocks and commodities have alternated relative and absolute price leadership in cycles. This means that the diversification benefits might be time varying. Furthermore, Fabozzi *(2008)* explains that commodity indices might be exposed to currency risk factors due to the indices and commodities themselves being denominated in U.S dollars. Since equity market integration has increased, the significance of global factors effects on equity markets has also increased *(Eiling & Gerard, 2010)*. Hence, if equity markets are driven by global and currency risk factors, as is stated by Eiling et Al. *(2009)*, there might be some comovement between positions held in commodity indices and the equity market.

Although Gorton & Rouwenhorst *(2005)*, Harry M. Kat *(2006)* and Kat & Oomen *(2006b)* showed that commodities are uncorrelated with stocks and bonds, it seems that in specific phases, the correlation admittedly increases and hence may reduce the diversification benefits of commodities for portfolio diversification in different market phases *(Fabozzi, 2008)*. For example *Fabozzi (2008)* states that the conditional correlations between commodities and fixed income increase during times of increased bond volatility. Moreover, Silvennoinen and Thorp (*2010*), Tang and Xiong (*2010*) and Büyükshain & Robe. (*2011*) find that the return correlations between commodities and equities have increased substantially during the recent sub-prime crisis.

Buyuksahin, Haigh & Robe *(2010)* show that correlation has increased between traditional financial assets and commodities, but that commodities still provide substantial diversification benefits. On the other hand, they report that the diversification benefits are not prominent when they are needed the most. Cheung and Miu *(2010)* find similar results even though they use data pre-2005. They find that commodity futures display regime switching behavior and that the diversification benefits of commodities are nowhere found when the US and

Canadian equity markets are bearish. This is to some extent to the contrary to what is reported by the empirical papers, reviewed above, that examine the pre-2005 era. Their findings imply that the diversification benefits of commodities are more pronounced over turbulent periods. (*Gorton & Rouwenhorst, 2006; Kat & Omen, 2007b; Chong and Miffre, 2010*) Hence, even if commodities are known to be uncorrelated to traditional equity markets, it seems that there might be a relationship between holding a commodity position through commodity indices and the equity market. The newer papers examining the last decade of price movements in commodities show evidence of results that are not in accordance with previous papers. These aspects of commodities might affect the possible diversification benefits of including commodities in traditional equity portfolios.

2.1 Commodities and commodity indices

A commodity futures contract is an agreement to buy or sell a specified sum or quantity of commodity in the future at a specific date at a price agreed when entering into the contract *(Gorton, Rouwenhorst, 2005).* According to Gorton and Rouwenhorst (*2005*) commodity futures differs from stocks, bond and other conventional assets in form of that they are derivative securities, they are short maturity claims on real assets and many commodities have pronounced seasonality in price levels and volatilities. The prices of commodities change continuously. The difference between the futures price and the futures spot price is called the risk premium, which is the risk the investor takes to either make or lose money. Hence, the risk premium is the realized payoff plus any unexpected deviation of the futures spot price from the expected futures spot price. *(Gorton, Rouwenhorst, 2005*)

As stated above, Commodity indices have become an increasingly popular investment strategy *(Tang, Xiang, 2010).* Commodity indices function similar to equity indices both in the aspect that the index's value is derived from the total value of a basket of commodities. The returns are comparable to passive long positions in listed commodity futures contracts. This is true due to the way the futures contracts are "rolled". When a first-month contract matures, the second-month contract becomes the first-month contract. Hence, the current contract is replaced by a following contract, i.e. the "roll" (see also *Erb and Harvey, 2006*). The indices performances are measured by the basket of commodities. S&P Goldman Sachs Commodity index (GSCI), which is the largest commodity index besides the DOW-Jones UBS Commodity index (DJ-UBS), is such an index. *(Tang, Xiang, 2010.)*According to Tang and Xiang 2010, the commodities in the indices are assigned a specified weight and they are all built on the values of the futures contracts. *(Tang, Xiang, 2010)*

Both, the S&P GSCI and DJ-UBS are traded indices and they have a wide range of commodity futures. The difference between these indices is that the S&P GSCI is weighted by each commodity`s world production, while DJ-UBS relies on the relative amount of trading activity of a particular commodity. *(Tang, Xiang, 2010)* S&P GSCI is also more energy heavy than DJ-UBS. Such commodity indices, as these two, are also an informative source to cash commodity and futures commodity market trends so they can be used as benchmarks for commodity trading. *(Greer, 2002)*

Robert J. Greer (*2002*) investigates the correlation between commodity indices, stocks and bonds and the rate of inflation, which is argued in the literature as one of the common factors that drives prices of most commodities *(Tang, Xiang, 2010).* According to Greer (*2002*) the commodity indices seem to be negatively correlated with stock and bond returns, and positively correlated with the rate of inflation and even more positively correlated with changes in the rate of inflation. He also states that stock and bonds are negatively correlated with rate of inflation and the changes in the rate of inflation *(Greer, 2002).* Hence, commodity futures are usually used as a hedging tool against inflation, when the investors are especially exposed to changes in the CPI, i.e. the inflation rate.
However, as explained above, Gorton and Rouwenhorst (*2005*) suggest that commodity futures have the power to diversify systematic risk and they further argue that the diversification benefits do not come from opposite exposure to unexpected inflation but from the performance of futures over the business cycle. *(Gorton, Rouwenhorst, 2005)*

It is important to keep in mind that there are many aspects and types of commodities, for example, energy commodities like electricity, gas, coal and oil to name a few and non-energy commodities such as soybeans, aluminum and coffee beans to name a few. Another classification could be soft and hard commodities, where soft commodities are goods that are grown and hard commodities could be commodities which are extracted through mining. These classifications can be used when applying the main types of commodity futures pricing models like the Cost-of-Carry arbitrage model or other equilibrium models. The Cost-of-Carry approach can be used when we have storable commodities and equilibrium models can be used for the non-storable commodities. This means that price movements between these commodities might be different and uncorrelated. This is also called the theory of storage, and is only one of several models used to explain commodity returns, such as the CAPM (probably best used where you need to commit cash, such as ETFs), the insurance perspective and the hedging pressure hypothesis. Using commodity futures as a hedging tool is widely known and acknowledged today, and the hedging pressure hypothesis states that commodity futures prices rise when that specific commodity is sought to mitigate risk *(Erb, Harvey. 2006)*. On the other hand, however, it seems that after 2005 the close relationship between inventory levels and oil price changed. A report from Commerzebank *(2011)* explains that, while traditionally increases in inventory levels usually drove oil prices down. It seems this relationship broke after 2005 and behaved rather randomly relative to inventory levels. Indicating that the possible role of commodities might have changed from being a hedging tool to being dominated by speculation.

3. Empirical Framework

In portfolio analysis, one is often interested in finding out whether one set of risky assets can improve the investment opportunity set of another set of risky assets. If an investor chooses n portfolios based on mean and variance, then the question becomes whether adding a new set of risky assets can allow the investor to improve the minimum-variance frontier from a given set of risky assets *(Kan, Zhou, 2001).* As Robert J. Greer (*2002*) states, an asset class must satisfy two main criteria before an investor should consider adding it to a portfolio. First, the asset should increase the expected utility of a portfolio, usually that is higher return for the risk taken (Sharpe ratio), but it can also include higher order moments (*Daskalaki, Skiadopoulos. 2011*). Secondly, the returns from the asset class cannot be replicated with combinations of other assets. We therefore state the following null hypothesis that we wish to test in this paper:

Ho: *Including commodities in your equity portfolio does not increase its mean-variance efficiency and sharpe ratio*

To address the issue we use the spanning tests implemented firstly by Huberman and Kandel (*1987*). They proposed a regression-based test of the hypothesis that the minimum variance frontier of a set of *K* benchmark assets is the same as the minimum-variance frontier of the *K* benchmark assets plus a set of *N* additional test assets *(Kan, Zhou, 2001).*The benefits of international diversification on portfolio management are well documented in the literature and the mean-variance spanning tests have been used to study such benefits. *(Switzer, Haibo, 2006).*

We also employ the Sharpe-Ratio test proposed by DeRoon et al *(2009)*. We use the spanning regression to look at Jensen's alpha, which is commonly used to measure the improvement in efficiency of a portfolio by testing the significance of the excess return. The Sharpe ratio, on the other hand, is a good measure for evaluating performances between e.g. two different portfolios. DeRoon and Nijman (*2001*) show that the Sharpe ratio and Jensen's Alpha are linked together when considering that Jensen's alpha and the covariance matrix of the error terms determine the achievable Sharpe ratio. In other words, since the null hypothesis of the spanning test implies a restriction that Jensen's alpha is zero, means that there is no potential gains on the Sharpe ratio too. We also examine how the correlation between commodities and equity markets changes over time. To do this we employ both 63 trading days quarterly correlation computed from daily returns and a dispersion measure proposed by Bauer *(2006)*. Since we are interested in finding the benefits of commodities for Norwegian investors, we will be running our tests and regressions in both U.S Dollars (USD) and Norwegian Kroner (NOK). This will help us look at the possible effects of exchange rates on the diversification benefits of commodities. We also look at the differences between adding energy commodities and non-energy commodities to our benchmark portfolios.

3.1 Spanning Tests

According to Kan and Zhou (*2001*) there are several tests that has been developed the last decades subsequent to Huberman and Kandel`s study which tries to address the question of mean-variance spanning in different applications, such as

DeSantis (*1993*), Bakaert and Urias (*1996*), Ferson, Foerster, and Keim (*1993*), DeRoon, Nijman, and Werker (*2001*), Hansen and Jagannathan (*1991*) and Korkie and Turtle (*2001*).Spanning tests have also been used to assess the efficiency of investing in alternative asset classes such as commodity and currency futures. DeRoon, Nijman and Werker (*1996*) show how regression techniques can be used to test for spanning with zero-investment and non-traded assets, and for other classes of utility functions; they examine whether a set of three international stocks indices spans the set of the indices plus a number of commodity and currency futures contract. However, we choose to use the spanning test developed by Huberman and Kandel (1987) due to its simplicity of calculation and interpretation.

Suppose that the CAPM holds for equity returns. This implies that pricing of equities is exact and that a linear combination of our portfolios is mean-variance efficient (DeRoon et al. 2009). This will also be correct for commodity returns since we use commodity indices as a proxy for commodities. As long as you commit cash to invest in commodities, the CAPM should hold (there are a number of ETFs that replicate the commodity indices). Hence, we can test whether an investor can improve the mean-variance efficiency of the portfolio by expanding the investment universe and including the test asset by using the following regression:

$$r_t^T = \alpha_T + Br_t^B + u_t$$

Where r_t^T is the excess return(s) on the test asset(s) i.e. commodities and r_t^B is the excess return(s) of the benchmark asset(s). Since we use excess returns, we assume that there exists a unique risk-free rate or asset. Therefore, we only test for the intercept, i.e. Jensen's alpha. If there is exact pricing, the intercept α_T or Jensen's alpha should be zero and hence under the null hypothesis Jensen's alpha is zero. If the Jensen's alpha is different from zero, mean-variance efficiency can be improved by expanding the investment universe and adding the test asset *(DeRoon et al, 2009).* This means that the weight(s) of the benchmark portfolio(s) have to be changed to include the test asset(s) and increase the mean-variance efficiency.

3.2 Sharpe Ratio Tests

Since we assume that a unique risk free rate or asset exists it means that there is a tangency portfolio. Basic financial theory implies that the efficient portfolio for a mean-variance maximizing investor is where the CAL is tangent to the mean-variance frontier, i.e. the tangency portfolio. Since we assume that the average Norwegian investor is a mean-variance maximizing individual, it follows that we look at the slope of the CAL also known as the Sharpe ratio. To test whether adding the test asset to the benchmark portfolio significantly increases the Sharpe ratio statistically, we employ the Sharpe ratio test proposed by DeRoon et al. *(2009)*:

$$H_0: \theta_{BT}^2 - \theta_B^2 = 0$$

Where:

$$\theta_B^2 = \mu_B' \Sigma_{BB}^{-1} \mu_B$$

$$\theta_{BT}^2 = \mu_{BT}' \Sigma_{BTBT}^{-1} \mu_{BT}$$

θ_B^2andθ_{BT}^2 represent the squared maximum Sharpe ratios of the benchmark portfolio and the benchmark plus the test asset portfolio, respectively. Here, μ_B' and μ_{BT}' represent the excess returns of the benchmark portfolio and the benchmark plus the test asset portfolio, respectively. While Σ_{BB} and Σ_{BTBT} are the covariance matrices associated with the excess returns of the benchmark portfolio and the benchmark plus test asset portfolio. The significance of the difference between the two Sharpe ratios can be tested by using a simple student t-test, where the t-stat is given by:

$$t = \frac{\hat{\theta}_{BT}^2 - \hat{\theta}_B^2}{2\left(\frac{V}{T}\right)^{\frac{1}{2}}}$$

Where *V* can be seen as the variance of the combined portfolio, i.e. test asset and benchmark asset, and is computed as follows:

$$V = \mu_{BT}' \Sigma_{BTBT}^{-1} \mu_{BT} + \mu_B' \Sigma_{BB}^{-1} \mu_B - 2\mu_{BT}' \Sigma_{BTBT}^{-1} \Sigma_{BT,B} \Sigma_{BB}^{-1} \mu_B$$

3.3 Dispersion and Correlation

We define the conditional correlation $\rho_{ij,t}$ between returns r_i and r_j at time *t* as:

$$\rho_{ij,t} = \frac{E_{t-1}(r_{i,t}r_{j,t})}{\sqrt{E_{t-1}(r_{i,t}^2)E_{t-1}(r_{j,t}^2)}}$$

implying that the conditional correlation at time *t* relies on the information at *t-1 (Karagozoglu& Jacobs, 2009).* In our case the specific formula that we implement to find the conditional correlation is as follows:

$$\rho_{BJ,t} = \frac{\sum_{d=1}^{D_t}(r_{Bd,}r_{Jd})}{\sqrt{\sum_{d=1}^{D_t}(r_{Bd}^2)\sum_{d=1}^{D_t}(r_{Jd}^2)}}$$

Where $D_t$is the number of trading days during the period *t* (i.e. in our case a quarter or 63 trading days).Here r_{Bd} and r_{Jd} represent the return of the benchmark and the test asset at trading day *d*, respectively. Of course then, $\rho_{BJ,t}$ represents the conditional correlation between our benchmark *B* and test asset *J* for the period *t*.

Portfolio diversification might become less effective if markets become more similar or if the degree of market association is considerably fluctuating *(Bauer, 2006).* It is common to estimate the correlation coefficient to look into the diversification benefits and it is also a fundamental element of portfolio diversification. However, the correlation coefficient may be inappropriate especially under one important condition; the correlation coefficient is biased in periods of high volatility *(Bauer, 2006).* Hence, as Bauer *(2006)* states, the analysis of market association should not entirely rely on the correlation coefficient. The dispersion measure helps us examine if the markets really are more dependent during crisis times or if the real market association is hidden by the increased volatility *(Bauer, 2006).* Following the dispersion measure proposed by Bauer *(2006),* we define dispersion as:

$$D_t = \sqrt{\frac{1}{N-1}\sum_{i=1}^{N}(r_{it} - \overline{r_t})^2}$$

Where D_t is the dispersion measure of *N* assets at time *t*, r_{it} is the return of the *i*th market at *t* and $\overline{r_t}$ is the mean of all returns at *t*. This measure, according to Bauer *(2006)*, is based on the assumption that markets move more similarly if market association is high compared to a situation where markets behave rather randomly and the market association is low *(Bauer, 2006)*. Hence, the dispersion is low if markets move similarly and high if markets evolve randomly. The specific formula that we use to implement the quarterly dispersion measure for two assets is as follows:

$$D_T = \sum_{t=1}^{T} D_t$$

where:

$$D_t = \sqrt{(r_{Bt} - \overline{r_{BT}})^2 * \left(r_{JT} - \overline{r_{JT}}\right)^2}$$

Where D_t is the dispersion for trading day *t*, D_T is the dispersion for period *T* (i.e. a quarter). Here r_{Bt} and r_{Jt} represent the returns of the benchmark and test asset at trading day *t*, respectively. Here $\overline{r_{BT}}$ and $\overline{r_{JT}}$ represent the mean of all returns at time *T* for the benchmark and test asset, respectively. Do notice that *t* does in this case represent trading days. Notice that neither of our correlation measure and dispersion measure has been corrected for autocorrelation, which is a weakness when regarding the issue that high frequency financial data usually exhibits autocorrelation.

3.4 Trends in Market Comovements

We are interested if the correlation and dispersion is time-varying between the equity and commodity markets. We employ the same method as Eiling and Gerard (*2012*), which examines whether our correlation series display significant time trends. The following regression is used:

$$y_t = \alpha + \beta t + u_t$$

Where y_t is the series of interest and *t* is a linear time trend. The null hypothesis that we wish to test from this regression is:

$$H_0 : \beta = 0$$

If β is significantly different from zero, it implies that there is a time trend in our correlation or dispersion series and hence the correlation or dispersion is changing over time.

4. Data

The MSCI world index is used as the benchmark for a Norwegian investor holding an internationally diversified portfolio, while the Oslo Exchange All share is used as a benchmark for a Norwegian investor holding only Norwegian stocks. We have access to the monthly data on MSCI world index from December 1969 to April 2012, while the monthly data for the Oslo Exchange All share stretches back from January 1983 to April 2012.

For the test asset, i.e. commodities we use only the S&P GSCI indices and choose to avoid adding the DJ-UBSCI indices since these two indexes usually employ the same commodities in their baskets; the main difference is, as described in section 2.1, the weighting on each commodity. The S&P GSCI has lately included or concentrated in energy commodities, which accounted recently for nearly 70% of the index value *(Daskalaki, Skiadopoulos. 2011)*. While the DJ-UBSCI employs a rule to ensure diversification: the minimum and maximum weight allowed for any single commodity is 2% and 15%, respectively, and the maximum allowed for any sector is 33% (*Erb, Harvey. 2006*). These two indexes are probably the most known commodity indexes today (*Stoll, Whaley. 2010; Tang, Xiong. 2010*) and represent passive investment strategies in a number of the commodity futures *(Daskalaki, Skiadopoulos. 2011)*.

On the other hand, Erb and Harvey *(2006)* discuss and describe how the return and risk differs among the commodity indexes that are partially explained by the differing weights of individual commodities. They then proceed to claim that as a result of this, there is no commodity futures market capitalization and commodity indices can best be thought of as commodity portfolio strategies. This means that using one commodity index as a proxy for the commodity market might not give the correct estimates and hence incorrect conclusion.

To look at both the possible effect of the high weight in energy commodities in the S&P GSCI all commodities index and the differences between energy and non-energy commodities, we use two additional S&P GSCI sub-indices, S&P GSCI energy and S&P GSCI non-energy. We download the monthly data for the S&P GSCI all commodity index from December 1969 to April 2012. We also have access to the S&P GSCI non-energy index from December 1969 to April

2012, while for the S&P energy index monthly data we use data from January 1983.

We construct a spliced series of Eurodollar deposit rate and LIBOR rate to be used as the risk free rate for a Norwegian Investor holding a well-diversified portfolio. The constructed series is spliced in January 1986. Hence, we use the Eurodollar deposit rate as the risk free rate from January 1971 to January 1986, and then the LIBOR rate from 1986 to April 2012. We do the same for the risk free rate used for the Norwegian investor holding only Norwegian stocks. We construct a series from December 1969 to April 2012, where we use the Norwegian discount rate from December 1969 to January 1986 and then splice the series and use the NIBOR rate from January 1986 to April 2012.

We download the data both in monthly and daily frequencies. The monthly data is used for the spanning test and the Sharpe-ratio test. We use the daily data on the indices to look at the correlation and dispersion between commodities and equity markets. The difference from the monthly data is that we have only access to the daily data on the MSCI world index from January 1980. We use the MSCI NOK to 1 USD exchange rate to convert the necessary data to NOK and USD. All the data is easily accessible on Datastream.

4.1 Descriptive Statistics

Panel A in table 2 shows the summary statistics for the five indices (in USD) that are used in the tests. The table shows that the S&P GSCI energy only index and the Oslo All Share index have the highest mean returns with 1,1071% and 1,3087%, respectively, but they also have the highest standard deviations. While MSCI world and the GSCI non-energy sub-index both have the lowest standard deviations and the smallest mean returns. It is interesting to notice that all three commodity indices have positive skewness while the two equity indices have negative skewness.

Panel B in table 2 reports the summary statistics in NOK. There are some interesting differences in the statistics from USD. We see that minimum returns for all our indices in NOK are actually less extreme, which might be the reason to the increase in positive skewness for the commodity indices. On the other hand, the negative skewness increases for the Oslo All Share, while it decreases for the MSCI world index. The returns are similar in NOK, except that the GSCI energy sub-index and the Oslo All Share index have lower returns. The similarities in standard deviation and returns between the GSCI energy sub-index and the Oslo Allshare might be due to the larger share companies in the Oslo index that are involved in the oil industry. Furthermore, the commodity indices seem to follow the risk-reward intuition, i.e. higher returns follow larger standard deviation. The return and the standard deviation of the S&P GSCI all commodity index in both USD and NOK are neither as high as the energy sub-index, but not as low as the non-energy sub-index either.

The correlations between each of the indices in USD are reported in Table.1.The figure shows that there is high correlation between S&P GSCI all commodity index and the S&P GSCI energy commodities index. This might be due to the high weight that the S&P GSCI all commodity index has in energy commodities. The figure also shows that the Oslo All Share has higher correlation with the S&P GSCI all commodity index than the MSCI world index. Intuitively it could be assumed that a portfolio replicating the MSCI world would benefit more from adding commodity positions to the portfolio, since it has a lower correlation with the MSCI world than the Oslo All Share.

Panel B in table 1 reports the correlation between the indices in NOK. There are differences in the correlations between the indices in NOK compared to USD. Although the correlation between the S&P GSCI indices stays relatively the same, there is a decrease in correlation between nearly all indices, except the increase in correlation between S&P GSCI non-energy and the MSCI world index. This indicates that there are possibly large currency effects on the correlation between these indices.

5. Empirical Results

We examine whether including a position in commodities increases the Sharpe-ratio and the mean-variance efficiency of traditional equity portfolios. As explained above we use the S&P GSCI all commodity and its sub-indices as the proxies for the commodity market. We run the tests and analyze the test assets, the S&P GSCI all commodity, S&P GSCI non-energy and S&P GSCI energy, on the MSCI world index and the Oslo All Share, i.e. our two benchmarks. In addition, we look at the correlation and dispersion between the commodity market and the equity market. This helps us discuss and analyze whether the diversification benefits are prominent through our entire data sample period. Since we look at this problem from a Norwegian investor's point of view, we do all our analyses and tests in both NOK and USD as to look at the currency effect.

In this section we report our results and discuss the possible reasons and implications of these results. Firstly, we discuss the correlation and dispersion between our indices and whether the correlation is time varying. Secondly, we report and discuss the results from the spanning test and the Sharpe ratio test that we employ. All our results are reported firstly in USD and then in NOK.

5.1 Dispersion and correlation results

5.1.1 MSCI world and S&P GSCI indices

Panel A to C in Figure.1 show the quarterly correlation between MSCI world index and the S&P GSCI indices. The correlation between the S&P GSCI all commodities and MSCI world seems to vary a lot. It is also worth noticing that the correlations between the MSCI world index and all three of the S&P GSCI indices have stayed in general below 0.2, with a few peaks above 0.2 and valleys below zero. However, there is an increase in the correlations starting from the years 2000. The trend line shows and increasing trend for the correlations between the MSCI world index and the S&P GSCI indices. Furthermore, the panels show a large increase in correlation between the indices before the credit crunch in 2007. This seems to be in accordance with Daskalaki, Skiadopoulos *(2011)* and Tang & Xiong *(2010)*. However, there are large valleys both before and after the rapid increase in correlation starting late 2007. The figures show in addition that in specific periods, during regime changes or crisis', the correlation is highly negative, but only for a short period of time.

Panel A to C in figure 2, show the quarterly correlation between the GSCI indices and the MSCI world index when returns are denominated in NOK. The panels show that the correlation between the MSCI world index and the S&P GSCI indices differs from the correlations computed with returns in USD. The correlation between the MSCI world index and the S&P GSCI all commodities and non-energy rests above 0.2. While the correlation between the MSCI world index and the S&P GSCI Energy seems to rest between 0 and 0.2. Moreover, the trend lines show no increasing trends contrary to the correlations computed with returns in USD, although there are similar movements. Similar to the correlations between MSCI world index and the S&P GSCI indices computed from returns in USD, there is a valley starting late 2008 and then an increase in correlation.

5.1.2 Oslo All Share and the S&P GSCI indices

Panel A to C in figure 3 show the quarterly correlation between Oslo Exchange All Share and the S&P GSCI indices. The panels show that the correlations between the Norwegian Stocks or Oslo All Share and commodities or the S&P GSCI indices have less extreme movements than between the MSCI world index and the S&P GSCI indices. The correlation between the Oslo All Share and the S&P GSCI indices seems to rest between zero and 0.2. However, similar to the correlation between the MSCI world and the S&P GSCI indices, the correlation between the Oslo Exchange All share and the S&P GSCI indices are increasing, more evidently from the year 2000 and onwards.

Panel A to C in figure 4 show the correlation between the Oslo Exchange All Share and the S&P GSCI indices computed from returns in NOK. The change in correlation when using returns in NOK instead of returns in USD is similar to the change between the MSCI world index and S&P GSCI indices. The increase in correlation becomes less evident when we use daily returns in NOK.

5.1.3 Trends in Correlations between S&P GSCI indices and MSCI world

Panel A in table 3 reports the results from the trend regression run on the correlation series, in USD, between the S&P GSCI indices and the MSCI world. Expectedly, the correlation time trend between S&P GSCI all commodities and the MSCI world index is not statistically significant, although if the increase in correlation lately persists, performing this test might in the future show different results. On the other hand, the correlation time trends for the S&P GSCI energy and non-energy indices and the MSCI world seem to be statistically significant. Our tables show that the correlation between the S&P GSCI non-energy and the MSCI world index has on average increased by 0.21 % per year or 0,05% per quarter. The increase in correlation between the S&P GSCI energy and the MSCI world index has been 0.32% per year or 0,079% per quarter.

Looking at the correlation figure provided in Panel A to C in figure.1, the reason that there is no significant trend in the correlation between S&P GSCI all commodities and the MSCI world index might be due to the different behavior of energy and non-energy over time. It seems these two commodity types have changes in correlation with the MSCI world index on different times. Since the S&P GSCI all commodities has weights in both types of commodities, the large negative movements from both type of commodities will affect the statistical significance of the trend in correlation between the S&P GSCI all commodities and MSCI world index.

The results from running the trend regression on the correlation series, in NOK, between the S&P GSCI indices and the MSCI world index are represented in panel A in table 3. As our correlation in panel A to C in figure 2 indicated, there are no statistically significant trends at the 5% level in correlation between any of the S&P GSCI indices and the MSCI world index when returns are in NOK. However, the positive trend in the correlation between the S&P GSCI non-energy and the MSCI world is statistically significant at the 10% level.

5.1.4 Trends in Correlation between the S&P GSCI indices and Oslo exchange all share

Panel B in table 3 reports the results of running the trend regression in both USD and NOK. The results for returns in USD show that there are statistically significant correlation trends between the Oslo all share and the S&P GSCI indices. The correlation between the S&P GSCI all commodities and the Oslo all share has increased on average by 0.43% per year or 0,11% per quarter. Moreover, the correlation between the S&P GSCI energy and non-energy indices and the Oslo All Share have increased by 0,3946% and 0.4067% per year, respectively.

The trends in correlation between the S&P GSCI indices and the Oslo All Share with returns in NOK are also reported on table 3, panel B. On the contrary to the results of the correlation between the MSCI world index and the S&P GSCI indices in NOK, there are statistically significant correlation trends between both the S&P GSCI all commodities and the Oslo All Share and the S&P GSCI energy and the Oslo Exchange All share. The correlation between the S&P GSCI all commodities and Oslo All share has on average increased by 0.1825% per year, and 0.1935% per year between the S&P GSCI energy and the Oslo All Share. Panel B in table 3 reports that there is no statistically significant correlation trend between the Oslo Exchange All share and the S&P GSCI non-energy.

The positive trends in correlation between the S&P GSCI indices and our two benchmarks when returns are denominated in USD, indicate that commodities might add less diversification benefits when held in USD and added to portfolios with positions in equities that pay returns in USD. Traditionally, commodities have been driven by global factors *(Fabozzi. 2008)*, which might also increase correlation with equity markets that are becoming more prone to global factors *(Eiling & Bruno. 2012)*. However, as stated by Bauer *(2006)*, correlation is sensitive to increases in volatility and hence we look at the dispersion measure in addition to the correlation coefficient before implying the economic effect of the changes in correlation.

5.1.5 Bivariate dispersion of MSCI world and S&P GSCI indices

Panel A to C in figure 5 show the bivariate dispersion of MSCI world and the S&P GSCI indices computed from returns in USD. These panels indicate an upward trend in dispersion between the MSCI world index and the S&P GSCI indices. The larger the dispersion the less associated the markets are meaning that at the peaks the markets are highly unassociated. Hence, it seems that over our entire sample the S&P GSCI energy index and the MSCI world index seems to be the least associated indices. All our three S&P GSCI indices are not associated with the MSCI world index, but the S&P GSCI energy index is the one that is the least associated with the MSCI world index.

In contrast to our correlation figures and trend tables discussed above, the dispersion figures indicate that the diversification benefits of commodities have actually increased over time, which is in correspondence with Büyükşahin, Haigh and Robe (*2010*) results. They observe that the correlation since the year 2003 has increased between the traditional financial market and the commodity market, but that the diversification benefits have not decreased. Our results show that the correlation has indeed increased, but the possible diversification benefits are still present.

Panel A to C in figure 6 show the dispersion between the MSCI world index and the S&P GSCI indices in NOK. Similar to the changes in correlation when changing currencies from USD to NOK, the dispersion between the MSCI world index and the S&P GSCI indices increases. This means that, when the two markets are denominated in NOK, the markets are less associated relative to when the markets are denominated in USD. In common with the dispersion in USD, the dispersion panels indicate upward trends in dispersion.

5.1.6 Bivariate dispersion of the Oslo Exchange All Share and S&P GSCI indices

Panels A to C in Figure 7 show the dispersion between the Oslo All Share and the S&P GSCI indices in USD. The dispersion panels indicate an increase or an upward trend in dispersion over time between the Oslo All Share and all three S&P GSCI indices. Similar to the dispersion measure between the MSCI world index and the S&P GSCI indices, the dispersion between the Oslo All share and the S&P GSCI indices spikes around the times of the latest crisis and other earlier crisis'. Surprisingly, the Oslo All Share seems to have a higher resting level of dispersion with the S&P GSCI energy index than the two other S&P GSCI indices. However, the dispersion level seems to be more stable between the Oslo All Share and the S&P GSCI energy index, except the few extreme spikes during crisis times, such as the S&L crisis in the 1980s and 1990s and then the sub-prime crisis in 2007 and onwards.

The panels A to C in figure 8 show the dispersion measures for the Oslo All share index and the S&P GSCI indices in NOK. The panels indicate that in NOK the dispersion is less extreme relative to the peaks in USD. Moreover, the market association decreases between the Oslo All Share and all three S&P GSCI indices. However, the dispersion in NOK and USD have it both in common that the panels indicate of an upward trend in dispersion.

Spikes in both NOK and USD, indicates fundamental risk factors of commodities still retain their diversification benefits during crisis times unconditional on what currency the returns are denominated in. However, the dispersion between returns in USD seems to be larger and more volatile than when returns are denominated in NOK. In the next section we examine for possible trends in dispersion.

5.1.7 Trends in Bivariate dispersion between the MSCI world index and the S&P GSCI indices

Panel A in table 4 reports the results for the trend regression run on the dispersion between the MSCI world index and the GSCI indices. The dispersion between the GSCI all commodities and the MSCI world index has increased by 0,4221% per year. Moreover, the dispersion has increased between the GSCI non-energy and the MSCI world index by 0,2321% per year. The dispersion between the GSCI energy and the MSCI world index has increased by 0,2978% per year, which is statistically significant at the 10% level.

Our results for the trends in dispersion when returns are denominated in NOK are seen in table 4 panel A. The results show that the dispersion has increased by 0,2840% per quarter year the GSCI all commodities and the MSCI world index. On the other hand, the positive trend in the dispersion between the MSCI world and the S&P GSCI non-energy index is only significant at the 10% level. As the tables show, the dispersion has increased by 0,1693% per year between the MSCI world and the GSCI non-energy index, while the trend in dispersion between the GSCI energy and the MSCI world is not statistically significant.

5.1.8 Trends in Bivariate dispersion between the Oslo Exchange All Share and the S&P GSCI indices

As our panel B in table 4 shows, there are statistically significant positive trends in dispersion between the MSCI world and all three GSCI indices at the 5% level for returns denominated in USD. The dispersion between the Oslo All share and the GSCI all commodities has increased by 0,6562% per year. While the dispersion has increased by 0,5052% and 0,4528% per year between the Oslo All Share and the GSCI non-energy and energy, respectively.

Panel B in table 4 reports the trend results when the returns are denominated in NOK. Contrary to the trends in dispersion when the returns are denominated in USD, only the dispersion between the GSCI all commodities and the Oslo All Share has a positive trend that is statistically significant at the 5% level. The dispersion has increased by 0,4337% per year. On the other hand, the dispersions between the GSCI non-energy and the Oslo All Share is significant at the 10% level and has increased by 0,2924% per year. There is no significant time trend in the dispersion between the GSCI energy index and the Oslo All Share when returns are denominated in NOK.

5.2 Implications of the dispersion and correlation results

As expected our results are similar to the results Tang & Xiang *(2010),* which show that correlation has increased the last years. However, we can see that there is no increase in correlation over time between the MSCI world index and the S&P GSCI index. While there are positive time trend in in correlation between the MSCI world index and the S&P GSCI energy and non-energy indices, the increases have not been large. We therefore see that correlations between the commodity market and the equity market have stayed rather stable over time, even though the rapid recent increase in correlation drives the statistical significance of our time trends. Moreover, our correlation measure shows no significant increases in correlation over time between international equity markets and the commodity markets when returns are denominated in NOK.

The trends in dispersion show that the diversification benefits of commodities has increased or stayed the same over time, which are in accordance with the results reported by Büyükşahin, Haigh and Robe (*2010*). Since the dispersion measure is more robust in periods with high volatility in returns, it seems the right choice is to put the weight of our reasoning on the dispersion measure. On the other hand, both our dispersion measure and the correlation figures discussed above have in common that the commodity market and the equity market are highly unassociated right after the start of the recent financial crisis. This is partially in accordance with Gorton & Rouwenhorst *(2005)* and the other papers that investigate the pre-2005 era, who state that the diversification benefits are more pronounced during turbulent periods.

However, the negative spikes in correlation do not happen when the equity markets are actually experiencing the worst part of a financial crisis. The negative correlation and the dispersion between the commodity indices and the equity market spike only after the equity market is well into the crisis. This indicates that the commodity and the equity market seem to be highly unassociated during a crisis, but possibly not when it is needed the most. This is similar to what Buyuksahin, Haigh & Robe *(2010)* and Cheung & Miu *(2010)* find in their papers. Furthermore, the important spikes in negative correlation and dispersion between the commodity market and the equity market only persist for a very short amount of time before they drop to their “normal” level.

Furthermore, although we do not test for how large the effect of currencies is on commodities, our correlation figures indicate large currency effects in addition to small time-varying changes in the correlation between equities and commodities. Moreover, what drives the differences in correlation when using different currencies might be many. The USD might be more bound today to similar risk factors that also drive the correlation with commodities, e.g. global factors. It could also be that the volatility in USD compared to NOK has increased lately and hence drives the correlation or simply that the fundamental drivers of correlation between commodities and equities are changing. A report from Bank of Japan reports that the increase in correlation might be because once a financial investor faces mounting risks, the selling pressure increases. Meaning that the outnumbering speculators in the commodity market would want to sell their holdings, and hence drive prices during regime changes.

However, even though our measure shows that commodities as diversifiers retain their diversification benefits to some extent in the long run, we must test and analyze if the reward gained for adding the commodity is substantial or not. In the next section we look at the mean-variance efficiency and the risk-reward relationship for commodities, and whether the recent large increases in commodity prices have made or make commodities beneficial over time.

5.3 Spanning Test results

5.3.1 Spanning test results for the MSCI world and the S&P GSCI indices

Panel A in table 5 reports the results from our spanning tests for our overall sample in USD, from January 1970 (March 1983 for the GSCI non-energy) to April 2012.The table reports the alpha values in percent, together with the t-statistic and p-values. The test's null hypothesis that Jensen's alpha is equal to zero, as can be seen on panel A in table 5, cannot be rejected for any of our test assets. We see that only when including the S&P GSCI all commodity index and MSCI world does the alpha come close to be significant at the 15% level.

The results are similar when running the spanning regression on our series in NOK, the null hypothesis cannot be rejected. Moreover, the alphas become more insignificant when the returns are denominated in NOK. Even though the alphas are economically different and reasonable, the Jensen's alphas are not significantly different from zero, statistically. If the alpha is not statistically significant, you can replicate the mean-variance efficient portfolio (the one on the left side in the spanning regression) by using the benchmark. Hence, there is no necessity in this instance to include the test assets since they offer no improvement to our portfolio even though the R-square show low values, indicating that there is low correlation between the benchmark and test asset.

5.3.2 Spanning test results for the Oslo Exchange All Share and the S&P GSCI indices

Panel B in table 5 reports the results from running the spanning regression on our entire sample in USD and NOK, which stretches back from March 1983 to April 2012. The results show that the benchmark asset, the Oslo Exchange All Share, is mean-variance efficient. In other words, the null hypothesis that Jensen's alpha is equal to zero cannot be rejected when running the spanning regression on all three test assets.

The results are similar when we run the spanning regression on the series in NOK. The exception is the Jensen's alpha between Oslo All Share and the S&P GSCI non-energy, which is statistically significant at 15% level with a negative alpha at 0,2919%. In this case the mean-variance efficiency can be improved by adding short positions in the test asset, i.e. non-energy commodities. Moreover, the R-square in this case is very low, which tells us that the two series are not correlated with each other and there should be improvements in the Sharpe ratio.

5.4 Sharpe-Ratio Test results

5.4.1 The Sharpe ratio test results for the MSCI world index and the S&P GSCI indices

Panel A in table 6 reports the results from the Sharpe ratio tests in USD and NOK. The MSCI world index in itself has an annualized Sharpe ratio of 0,279 (0,384 from January 1983). Including a position in the S&P GSCI all commodities index and S&P GSCI non-energy commodities index, increases the Sharpe ratio to 0,350 and 0,299, respectively. The Sharpe ratio when including the S&P GSCI energy increases to 0,442 from 0,384, when the sample runs from January 1983. Although economically these are good increases in the Sharpe ratio, statistically, as are shown in Table.11, adding any of the tree test assets does not increase the Sharpe ratio significantly enough.

Our results are similar, statistically, when the returns are denominated in NOK. The Sharpe ratio for the MSCI world in NOK is lower compared to its Sharpe ratio when returns are denominated in USD. The Sharpe ratio for the MSCI world alone is 0,183 (0,194 from January 1983). Including the S&P GSCI all commodities index and the S&P GSCI non-energy index to the MSCI world index, increases the Sharpe ratio to 0,249 and 0,190, respectively. Furthermore, the Sharpe ratio increases to 0,247 from 0,194 when the S&P GSCI energy only is included in the portfolio. However, none of the increases in the Sharpe Ratios are statistically significant and hence we cannot reject the null hypothesis of equal Sharpe ratio before and after adding the test asset.

5.4.2 The Sharpe Ratio test results for Oslo Exchange All Share and the S&P GSCI indices

Our results are similar, statistically, for the Oslo All share and the S&P GSCI indices. Panel B in table 6 reports that the Sharpe ratio of the Oslo All Share is 0,424. Including the S&P GSCI all commodities does only increase the Sharpe ratio minimalistic. While including the S&P GSCI non-energy and energy indices, increases the Sharpe ratio to 0,454 and 0,445, respectively. Furthermore, as seen on table 5 panel B, the Sharpe ratio does drop in general when the series are denominated in NOK compared to when they are denominated in USD. The Sharpe ratio when including all commodities and the Oslo All Share drops from 0,424 in USD to 0,317 in NOK, which happens when we add the non-energy and energy indices too. Notice that on the contrary to the statistically significant negative alpha at the 15% level in the spanning test, the Sharpe ratio shows that the increase in Sharpe ratio when the GSCI non-energy index is included with the Oslo All Share index is far from being statistically significant. On the other hand, the Sharpe ratios are improved when the test assets are included, economically, but the statistical test shows that we cannot reject the null hypothesis.

5.5 Implications of the Spanning and Sharpe-ratio test results

Intuitively, you would assume that by looking at our correlation measures from section 4.1, over time the low correlation between the MSCI world index and our commodity indices would drive statistically higher Sharpe ratios when these two assets are combined. Our results, however, from our Spanning and Sharpe-ratio tests indicate that over the long term, including commodities to traditional equity portfolios do not increase the Sharpe ratio statistically, either with returns in NOK or USD. These results are also conclusive when we add either non-energy or energy indices to traditional equity portfolios. In addition, we see that over time the increases in the Sharpe ratios are not statistically significant when adding either non-energy or energy commodities to our benchmarks.

Notice that we allow for short selling in our methods, which might not always be implementable in realistic investment strategies. Short selling often puts extreme weights in the assets, which might be very hard to accomplish in realistic strategies. Furthermore, short selling is often not allowed or restricted by governments when changes in the business cycle occur. Our results are, however, in accordance with Daskalaki & Skiadopoulos*(2011)*, that in a mean-variance optimizing setting, commodities do not seem to add any benefits to the investors. Basically, commodities will not be included in traditional equity portfolios with long-term objectives in a mean-variance optimizing setting.

6. Robustness check: Sub-sample analysis

Our analysis' and tests have in this paper only considered the entire samples of our indices. As a robustness check, whether our results would hold in general, we splice our entire sample into sub-samples of 117 months. This gives us four sub-samples to test with the MSCI world as benchmark, and three sub-samples with the Oslo All Share as benchmark. Moreover, since we use a constructed risk free rate in our tests and analysis above, we choose as a robustness check to use the Eurodollar rate and the Norwegian discount rate instead as the risk free rates for our series in USD and NOK, respectively. Notice that the first sub-sample for the S&P GSCI energy commodities only index starts first in 1983, which is the time when the index was first created.

6.1 Spanning test results for MSCI world and the S&P GSCI indices

Panel A in table 7 reports the results from the spanning test done on the sub-samples in USD. As panel B in table 7 shows, in general over all our sub-samples the null hypothesis that alpha is different from zero is not rejected. However, there are two exceptions where the null hypothesis is rejected. The null hypothesis is rejected at the 15% level between MSCI world and the S&P GSCI energy in the sub-sample running from February 1983 to October 1992. The null hypothesis is also rejected at the 5% level when we run the S&P GSCI non-energy on MSCI world index between November 1992 and July 2002. Panel B in table 7 reports the results when the returns are denominated in NOK. As can be seen, in general the null hypothesis is not rejected across our sub-samples, except for the sub-sample between November 1992 and July 2002, where the null hypothesis is rejected at the 10% level.

6.2 Spanning test results for Oslo All Share and the S&P GSCI indices

Panel C in table 7 reports the results between The Oslo All Share and the S&P GSCI indices when the returns are denominated in USD. Since we only have access to data on the Oslo All Share from 1983, we only look at three sub-samples of 117 months. The results are similar as when the MSCI world is used as benchmark. In general the null hypothesis cannot be rejected. However, the null hypothesis is rejected at the 5% level in the sample between Oslo All Share and the S&P GSCI non-energy running from November 1992 to July 2002.

Panel D in table 7 reports the results when the returns are denominated in NOK.As seen in panel D the null hypothesis is rejected at the 15% level for the sample running from November 1992 to July 2002. This means that between November 1992 and July 2002 non-energy commodities would have been able to increase the mean-variance efficiency of a Norwegian Investor holding either Norwegian stocks or an internationally diversified portfolio in either currency. The null hypothesis is strongly rejected when returns are denominated in USD for this period. On the other hand, the significance of the alpha is less obvious when the returns are denominated in NOK.

6.3 Sharpe ratio test results for MSCI world and the S&P GSCI indices

Panel A and B in table 8 report the results from our Sharpe-ratio test run on the sub-samples in USD and NOK, respectively. Comparable to the results from the spanning regression, we see that there are economically significant changes or improvements in the Sharpe-ratio when our test assets are added to the benchmark asset. However, in general the null hypothesis that the two Sharpe ratios are equal between MSCI world index and the MSCI World index plus the S&P GSCI indices, cannot be rejected.

Looking at the differences in the results between NOK and USD indicate large currency effects. For the sub-sample running from 1973 to 1983 the Sharpe-ratio for the benchmark and the increase in Sharpe-ratio when adding the test assets are larger in NOK. However, for all our sub-samples from February 1983 until 2012 the Sharpe ratio and the improvements in the Sharpe ratio when adding the test assets are larger when denominated in USD, even though our correlation figures show an increasing trend for returns in USD.

6.4 Sharpe ratio test results for Oslo All share and the S&P GSCI indices

Panel C and D from Table.8 report the results of the Sharpe ratio test done on the sub-samples of Oslo All Share and the S&P GSCI indices. Similar to the results reported in the Sharpe ratio test for the overall sample, the null hypothesis cannot be rejected under any of the sub-sample, both when returns are denominated in USD and NOK. However, the null hypothesis comes close to be rejected at the 20% level when the S&P GSCI non-energy is “added” to the benchmark portfolio for the sub-sample running from November 1992 to July 2002. In comparison with the results between the MSCI world and the GSCI indices, the Sharpe ratios are higher when returns are denominated in USD relative to NOK.

As can be seen from the robustness check the results from our analysis run on the overall sample cannot be entirely generalized. There are periods where the Jensen’s alpha, as shown above, is significant even at the 5% level, meaning that the mean-variance efficiency can be increased. Although economically there are large improvements in the Sharpe ratios and the Jensen’s alpha is different from zero in our sub-sample tests, the increases in the Sharpe ratio and the Jensen’s alpha are not statistically significant for any of our sub-samples.

Furthermore, even though there are negative alphas between the test assets and the two benchmarks, there are increases in all the Sharpe ratios for all the sub-samples when commodities are included in the investment universe. This is true for non-energy commodities, which have the lowest mean return and the lowest standard deviation, see panels from table 2, relative to our other assets discussed in this paper. This shows that even though commodity markets are underperforming when it comes to size of returns, they still might have a large effect on reducing volatility and hence increasing the Sharpe ratio. Although the increases are of different magnitude, it shows that the commodities might be interesting for investors that are very risk averse and seek to minimize volatility.

6.5 The changing nature of raw correlation

Notice that in the above section the Sharpe-ratios change from one sub-sample to another. In addition to changes in returns in the different sub-samples, we see in our table that the raw correlation between different sub-samples that are used in section 6 changes depending on the period. This shows the changing nature of the correlation between the equity indices and the commodity indices. Hence, in addition to changes in indices returns over different periods, the correlation is also changing. This makes it more complex to draw any conclusion about the diversification benefits of the commodities in the short term. On the other, the correlations between our equity indices and commodity indices remains rather stable over time, except the past 10 years as is described in section 5.1. Implying that in the long run it is probably easier to determine the diversification benefits of commodities when returns are denominated in either USD or NOK.

7. Conclusion

With this paper we wanted to investigate if Norwegian investors holding either an internationally diversified portfolio or a portfolio with only Norwegian stocks should include commodities in their respective portfolios. The criterion that we analyze is whether the attractive low correlation between equities and commodities has changed over time. We also analyze if commodities retain their attractive diversification abilities. We use both a quarterly correlation and the dispersion measure proposed by Bauer *(2006)* to look into these issues. To identify whether there are any time trends in the diversification benefits of commodities, we use a simple linear trend regression to analyze possible trends in either correlation or dispersion between equities and commodities. Furthermore, in this paper the mean-variance efficiency and Sharpe ratio improvement are analyzed when commodities are added to traditional equity portfolios. To analyze this issue we use the spanning test first employed by Huberman and Kandel *(1987)* and the Sharpe ratio test developed by Bruno and Eiling *(2009)*.

Our results show that there is no time trend in correlation between the MSCI world index and the S&P GSCI all commodity index when returns are either denominated in NOK or USD. On the other hand, our results show that there are positive time trends between the MSCI world index and the S&P GSCI energy and non-energy indices when returns are denominated in USD, although the increase in correlation is rather modest. Furthermore, our results show that there are in general no time trends in correlation between equity and commodity markets when returns are denominated in NOK. We find, in addition, positive time trends in correlation between the Oslo Exchange All Share and all three S&P

GSCI indices that we investigate. The positive time trends in correlation are present both when returns are denominated in NOK and USD.

Furthermore, we find that there are either no trends or only positive trends in dispersion between equity and commodity markets, both when returns are denominated in USD and NOK. This means that the diversification abilities of commodities has not changed or even increased over time. We also show that the resting level of dispersion between commodities and equities is higher when returns are denominated in NOK relative to when returns are denominated in USD. This implies larger diversification benefits of commodities for Norwegian investors that hold assets that give returns in NOK.

Our results show, hence, the potential diversification benefits of commodities changes a lot during shorter periods, i.e. the diversification benefits are stronger in some crisis periods. However, we find that the negative spikes in correlation between commodities and the equity market does not happen when the diversification benefits of commodities are needed the most. Hence, implying that during the start of a crisis the potential diversification benefits commodities are lower compared to when the economy is well into the crisis.

Nonetheless, for investors that wish to take advantages of possible diversification benefits in the short term, should rebalance their portfolios to take advantage of the movements in correlation. In the long run, however, we see that the correlation between commodities and the equity market has stayed rather stable over time. This means that investors that have a very long-term perspective on their portfolios will experience stability in the diversification effects of adding commodities to their portfolios. In other words, the uncertainty of the diversification benefits of commodities in the short term will, in most cases, be enough for investors to avoid commodities. Hence, only the investors with the knowledge on how commodities behave will include commodities in the right situations. However, since in the long run the diversification benefits of commodities remain rather stable, the investors that seek to minimize risk and sacrifice higher returns will want to add commodities to their portfolio.

Furthermore, we see that the increase in correlation between the commodity market and the equity market might not be due to changes in fundamental risk factors. The increase in correlation might be due to increased volatility in USD, which commodities are denominated in (*Fabozzi, 2008*). It could also be due to the increased popularity of investing in indexes (*Tang & Xiong, 2010*), which increased the cash flow into indexes and hence turns out as increased correlation between commodity indices and other indices. Moreover, the spanning test and the Sharpe ratio test for the overall sample show that the null hypothesis for either of the tests cannot be strongly rejected. This implies that even though the recent increase in commodity prices, adding commodities to traditional equity portfolios does not increase the mean-variance efficiency and the Sharpe ratio significant enough, statistically. However, there are large improvements in the Sharpe ratio and significantly different alphas economically.

These results cannot be entirely generalized as our robustness check shows. For several sub-samples when adding non-energy commodities to traditional equity buy and hold portfolios, the null hypothesis of the spanning test is rejected meaning that the mean-variance efficiency can be improved in certain circumstances by adding non-energy commodities. However, in general the Sharpe ratio tests shows that when adding any of the test assets to any of our two benchmarks, the increase in the Sharpe ratio is not enough to make the improvements statistically significant. This means that we cannot reject the null hypothesis that we seek to investigate in this paper, i.e. the null hypothesis that adding commodities to your traditional equity portfolio will not increase the Sharpe ratio of the portfolio.

Hence, our results indicate, statistically, that in general Norwegian investors holding either an internationally diversified portfolio or a portfolio of only Norwegian stocks will not include commodity positions. In addition to changes in correlation from period to period, currency has a large impact and the highly relative opposite movements between equity markets and commodities only happens in shorter periods. The implication of this is that the image of how well commodities achieve the sought after diversification benefits changes with business cycles or regime changes.

We want to point out that our paper is limited in the aspects of portfolio construction techniques that are investigated. The paper only assumes and investigates the naïve strategy of buy and hold. Rebalancing the portfolio weights is commonly accepted as a technique that increases the Sharpe ratio of the portfolio. Moreover, we only investigate the benefits of commodities in a mean-variance optimizing universe where all investors seek to maximize the mean-variance efficiency of their portfolio. There are other criteria that need to be researched and looked into, such as second order benefits like utility of commodities for different investors. Commodities have the benefit, in addition to low correlation with equities, of being highly liquid, making them possibly a necessity for portfolio managers that need to increase the liquidity of their portfolio, especially in times of crisis.

Future research should look at how currencies effect the correlation between commodities and equity markets at different business cycles and how large this effect is. In addition looking into the cash flow of investments in both equity and commodity indices might be important as to identify partially the sharp increase in correlation between commodity and equity markets the past 10 years. Tang and Xiong*(2010)* mention that the level of correlation between a commodity and the equity market is dependent on if it is listed on the S&P GSCI index or DJ-UBSCI. This is also an important issue that should be looked into.

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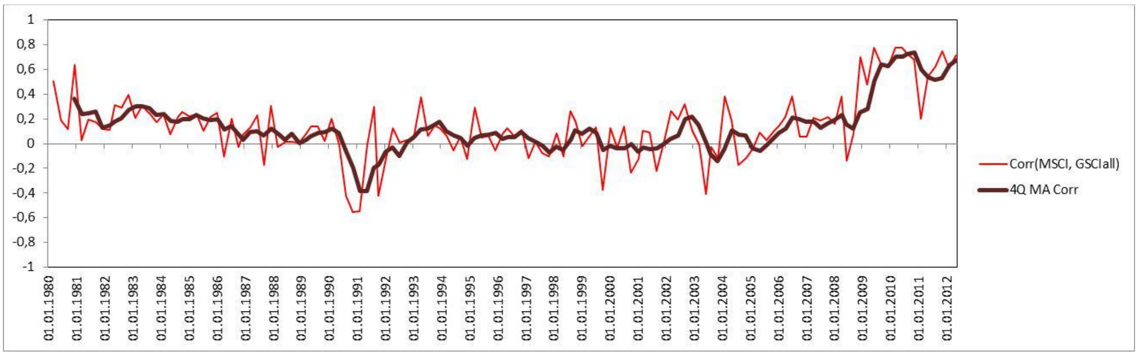
8. Appendix

8.1 Figures

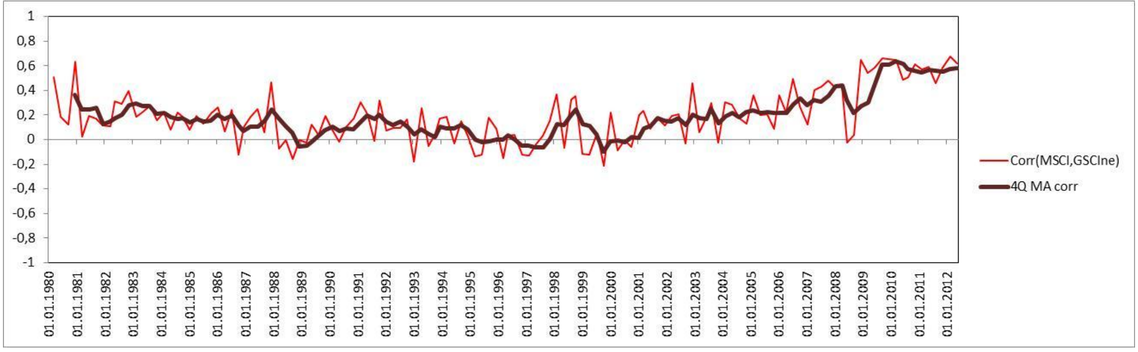
Figure 1

Panel A, B and C display the quarterly correlation between the S&P GSCI indices and the MSCI world index constructed from daily returns in USD. Panel A displays the quarterly correlation between the S&P GSCI all commodities index and the MSCI world. Panel B displays the quarterly correlation between the S&P GSCI non-energy commodities index and the MSCI world index. Both panel A and B run from January 1980 to April 2012. Panel C display the quarterly correlation between the S&P GSCI energy only commodities index and the MSCI world index, running from February 1983 to April 2012. In the panels, MSCI represents the MSCI world index, GSCIall represents the S&P GSCI all commodity index, GSCIne represents the S&P GSCI non-energy commodity index, GSCIen represents the S&P GSCI energy commodity index and '4Q MA Corr' is the four quarter moving average of the correlation between the respective indices in each panel. These notations are used for all panels in figure 1 and 2. For example Corr(MSCI,GSCIall) is the quarterly correlation between the MSCI world index and the S&P GSCI all commodity index.

Panel A, the quarterly correlation between the MSCI world index and the S&P GSCI all commodities returns in USD



Panel B, the quarterly correlation between the MSCI world index and the S&P GSCI non-energy commodities returns in USD



Panel C, the quarterly correlation between the MSCI world index and the S&P GSCI energy commodities returns in USD

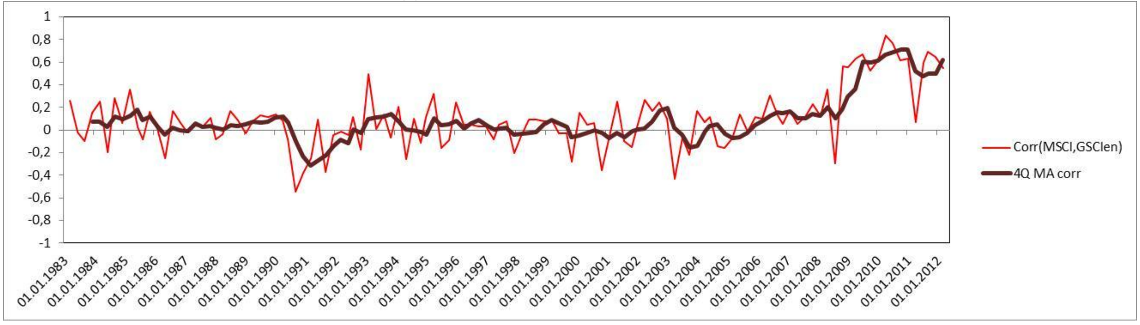
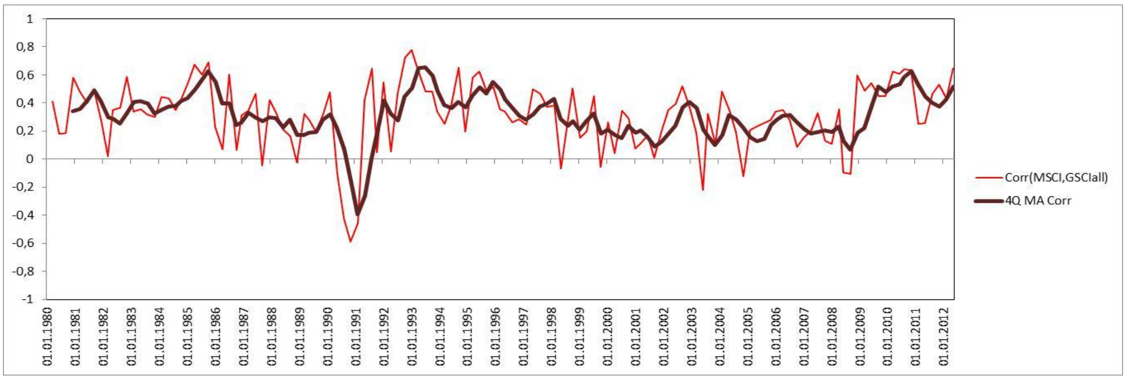


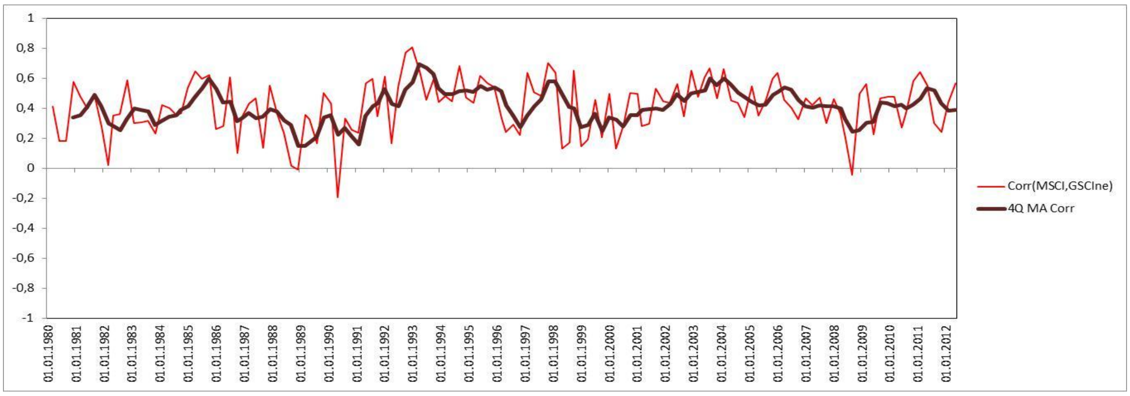
Figure 2

Panels A, B and C display the quarterly correlation between the S&P GSCI indices and the MSCI world index constructed from daily returns in NOK. Panel A displays the quarterly correlation between the S&P GSCI all commodities index and the MSCI world. Panel B displays the quarterly correlation between the S&P GSCI non-energy commodities index and the MSCI world index. Both panels A and B run from January 1980 to April 2012. Panel C display the quarterly correlation between the S&P GSCI energy only commodities index and the MSCI world index, running from February 1983 to April 2012.

Panel A, the quarterly correlation between the MSCI world index and the S&P GSCI all commodities returns in NOK



Panel B, the quarterly correlation between the MSCI world index and the S&P GSCI non-energy commodities returns in NOK



Panel C, the quarterly correlation between the MSCI world index and the S&P GSCI energy commodities returns in NOK

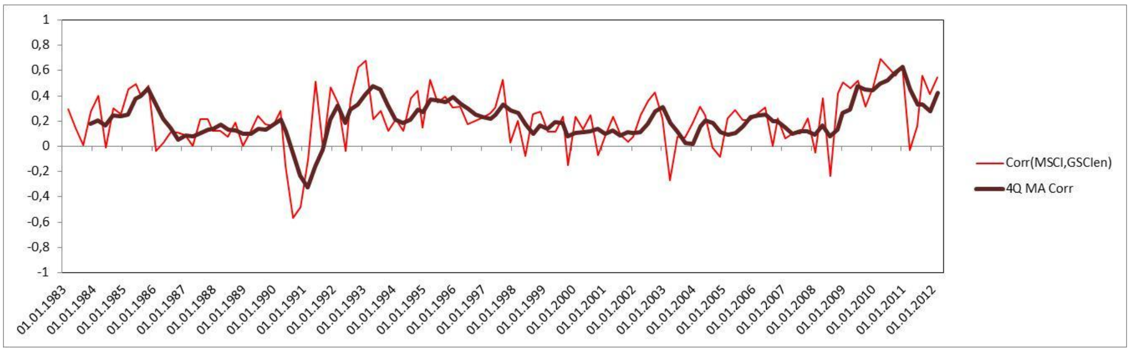
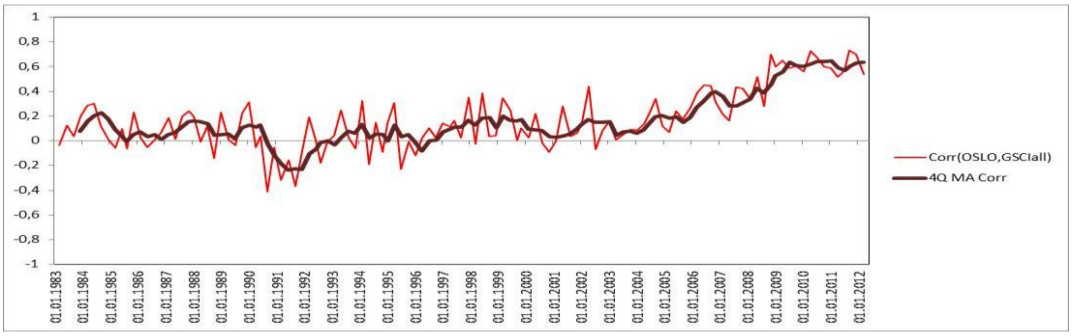


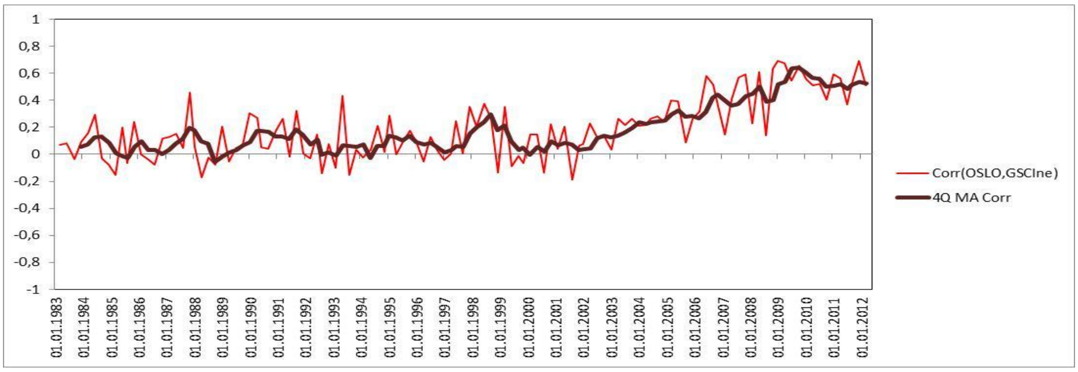
Figure 3

Panels. A, B and C display the quarterly correlation between the S&P GSCI indices and the Oslo Exchange All Share index constructed from daily returns in USD. Panel A displays the quarterly correlation between the S&P GSCI all commodities index and the Oslo All Share index. Panel B displays the quarterly correlation between the S&P GSCI non-energy commodities index and the Oslo Exchange All Share index. Panel C displays the quarterly correlation between the S&P GSCI energy only commodities index and the Oslo Exchange All Share index. All the panels run from March 1983 to April 2012. In the figures, OSLO represents the Oslo All Share index, GSCIall represents the S&P GSCI all commodity index, GSCIne represents the S&P GSCI non-energy commodity index, GSCIen represents the S&P GSCI energy commodity index and '4Q MA Corr' is the four quarter moving average of the correlation between the respective indices in each panel. These notations are used for panels in figure 3 and 4. For example Corr(OSLO,GSCIall) is the quarterly correlation between the Oslo All Share index and the S&P GSCI all commodity index.

Panel A, the quarterly correlation between the Oslo Exchange All Share and the S&P GSCI all commodities returns in USD



Panel B, the quarterly correlation between the Oslo Exchange All Share and the S&P GSCI non-energy commodities returns in USD



Panel C, the quarterly correlation between the Oslo Exchange All Share and the S&P GSCI energy commodities returns in USD

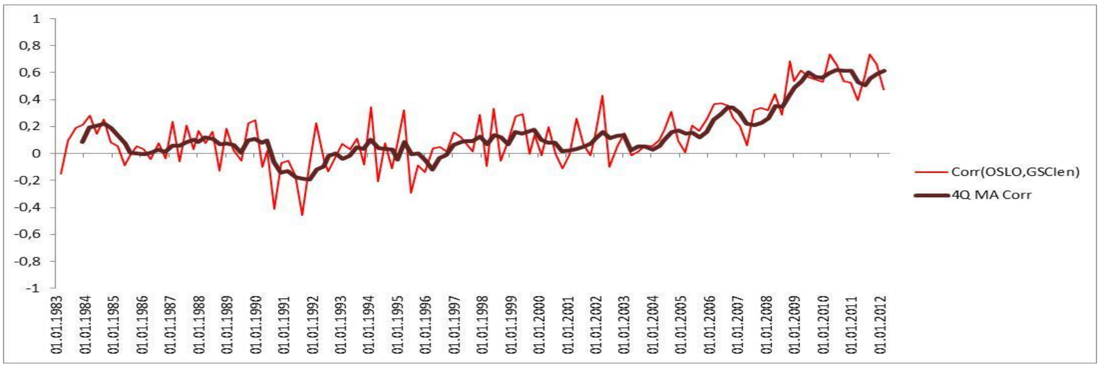
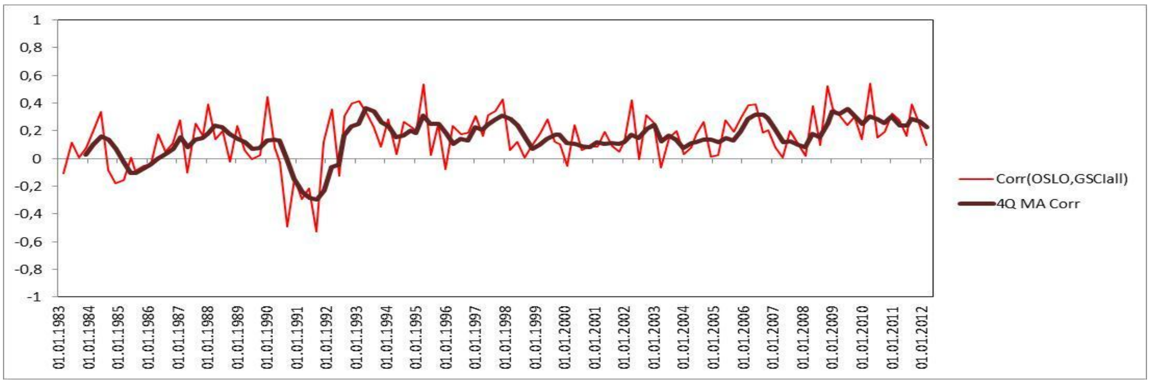


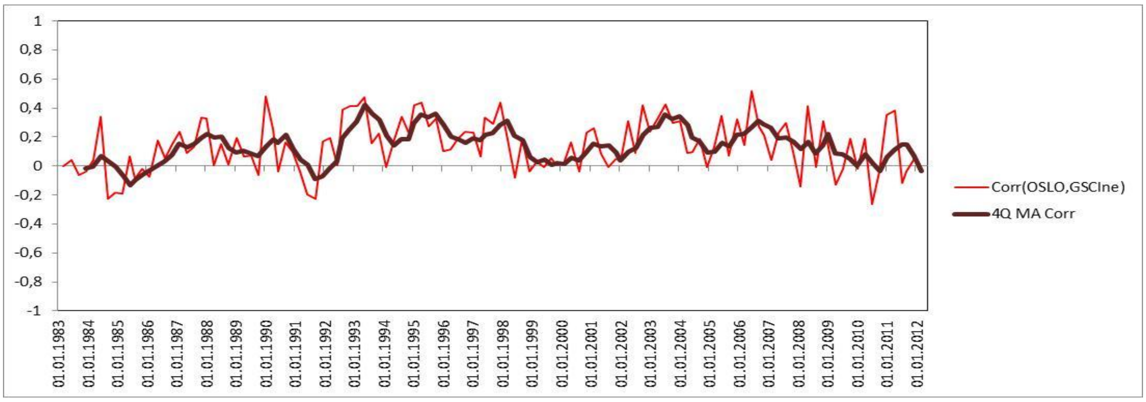
Figure 4

Panel A, B and C display the quarterly correlation between the S&P GSCI indices and the Oslo Exchange All Share index constructed from daily returns in NOK. Panel A displays the quarterly correlation between the S&P GSCI all commodities index and the Oslo All Share index. Panel B displays the quarterly correlation between the S&P GSCI non-energy commodities index and the Oslo Exchange All Share index. Panel C displays the quarterly correlation between the S&P GSCI energy only commodities index and the Oslo Exchange All Share index. All the panels run from March 1983 to April 2012.

Panel A, the quarterly correlation between the Oslo Exchange All Share and the S&P GSCI all commodities returns in NOK



Panel B, the quarterly correlation between the Oslo Exchange All Share and the S&P GSCI non-energy commodities returns in NOK



Panel C, the quarterly correlation between the Oslo Exchange All Share and the S&P GSCI energy commodities returns in NOK

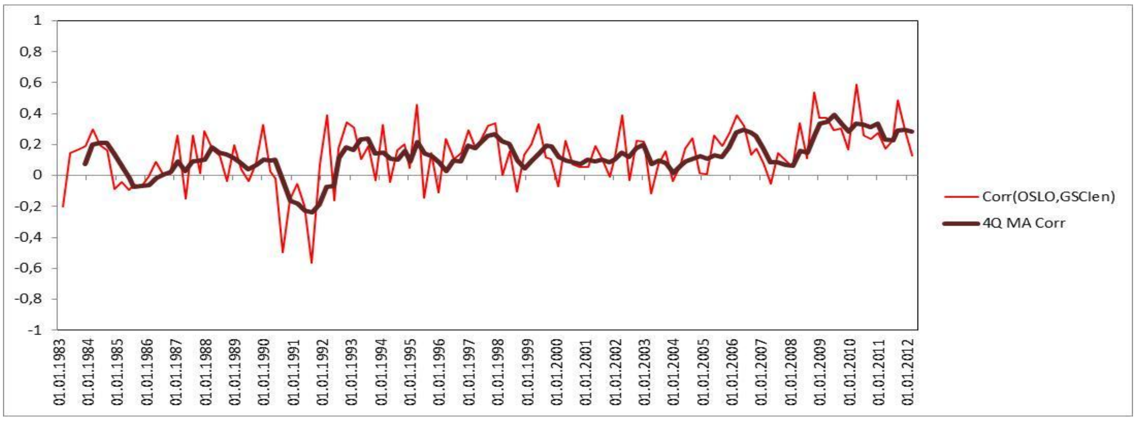


Figure 5

Panel A, B and C display the quarterly dispersion between the S&P GSCI indices and the MSCI world index constructed from daily returns in USD. Panel A displays the quarterly dispersion between the S&P GSCI all commodities index and the MSCI world. Panel B displays the quarterly dispersion between the S&P GSCI non-energy commodities index and the MSCI world index. Both panels A and B run from January 1980 to April 2012. Panel C displays the quarterly correlation between the S&P GSCI energy commodities only index and the MSCI world index, running from February 1983 to April 2012. In the panels, MSCI represents the MSCI world index, GSCIall represents the S&P GSCI all commodity index, GSCIne represents the S&P GSCI non-energy commodity index, GSCIen represents the S&P GSCI energy commodity index and '4Q MA dispersion' is the four quarter moving average of the dispersion between the respective indices in each panel. These notations are used for all panels in figure 1 and 2. For example Dispersion(MSCI,GSCIall) is the quarterly dispersion between the MSCI world index and the S&P GSCI all commodity index. For Figures 5 to 8 the dispersion is calculated as follows:

$$D_T = \sum_{t=1}^{T} D_t$$

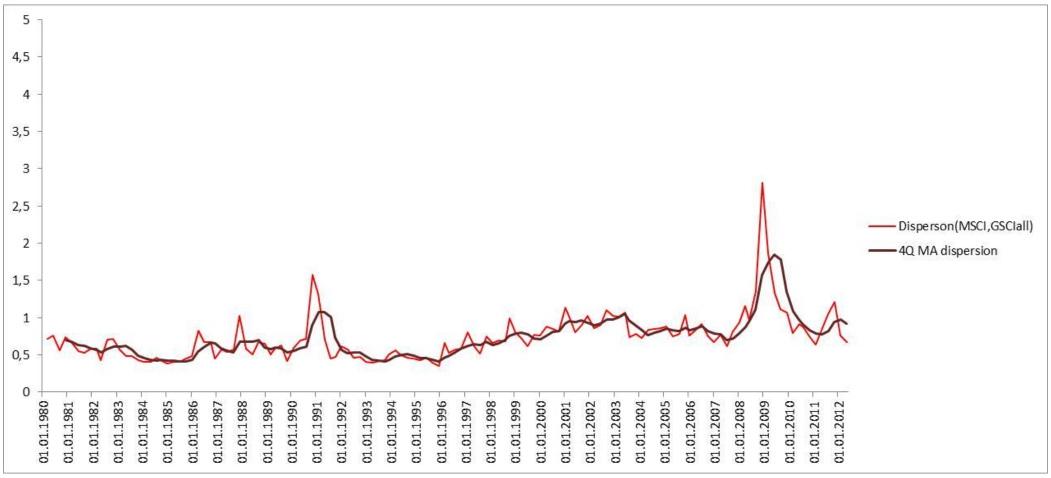
where:

$$D_t = \sqrt{(r_{Bt} - \overline{r_{BT}})^2 * \left(r_{JT} - \overline{r_{JT}}\right)^2}$$

Where D_t is the dispersion for trading day *t*, D_T is the dispersion for period *T* (i.e. a quarter). Here r_{Bt} and r_{Jt} represent the returns of the benchmark and test asset at trading day *t*, respectively. Here $\overline{r_{BT}}$ and $\overline{r_{JT}}$ represent the mean of all returns at time *T* for the benchmark and test asset, respectively

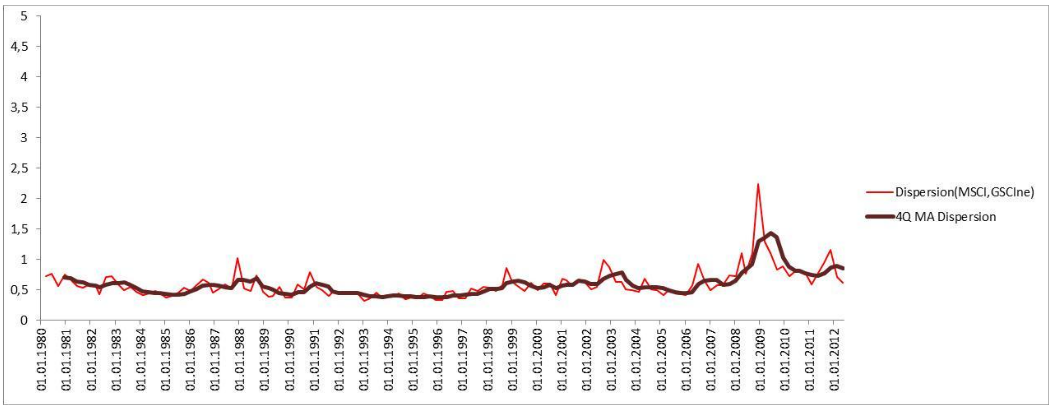
Panel A

Quarterly dispersion between the GSCI all commodities index and the MSCI world in USD



Panel B

Quarterly dispersion between the GSCI non-energy commodities index and the MSCI world in USD



Panel C

Quarterly dispersion between the GSCI energy commodities index and MSCI world index in USD

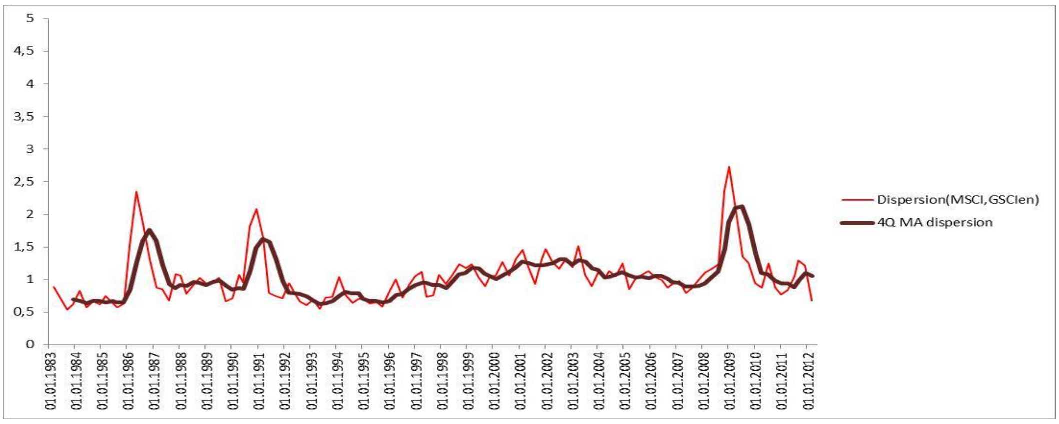
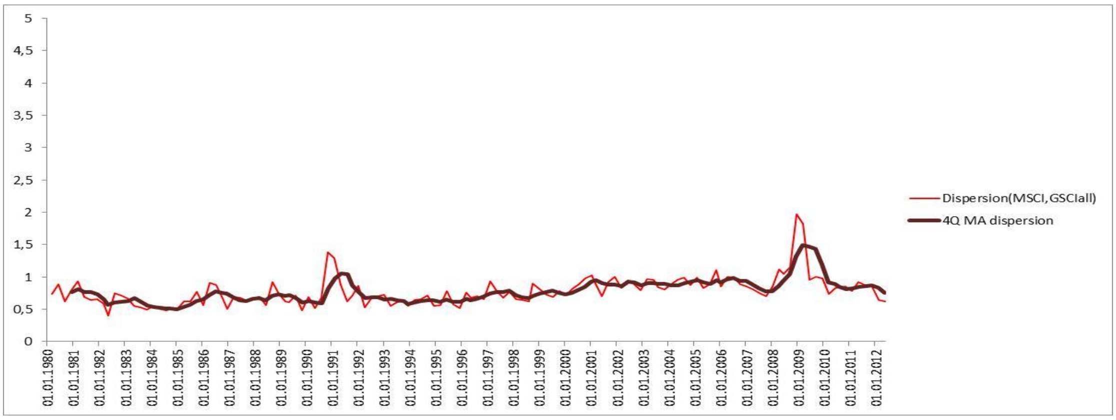


Figure 6

Panels A, B and C display the quarterly dispersion between the S&P GSCI indices and the MSCI world index constructed from daily returns in NOK. Panel A displays the quarterly dispersion between the S&P GSCI all commodities index and the MSCI world. Panel B displays the quarterly dispersion between the S&P GSCI non-energy commodities index and the MSCI world index. Both Panel A and B run from January 1980 to April 2012. Panel C displays the quarterly correlation between the S&P GSCI energy commodities only index and the MSCI world index, running from February 1983 to April 2012. The filled part of the panels shows the dispersion and the linear line shows an indication of trend in the dispersion.

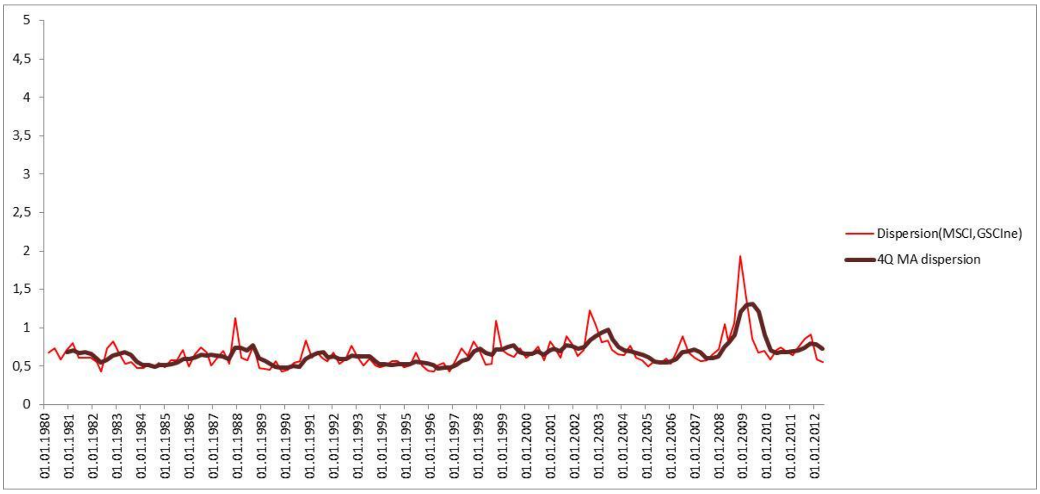
Panel A

Quarterly dispersion between the GSCI all commodities index and MSCI world index in NOK



Panel B

Quarterly dispersion between the GSCI non-energy index and the MSCI world index in NOK



Panel C

Quarterly dispersion between the GSCI energy commodities index and MSCI world index in NOK

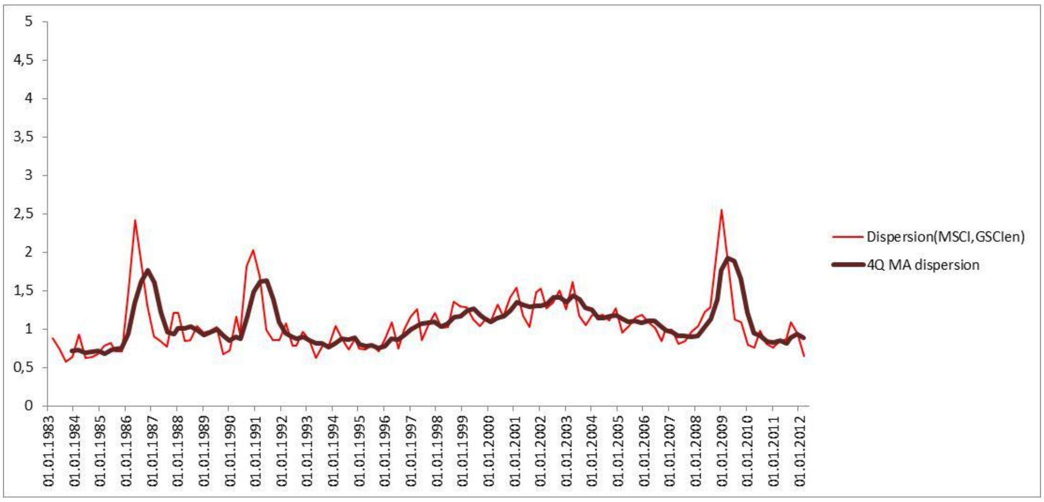
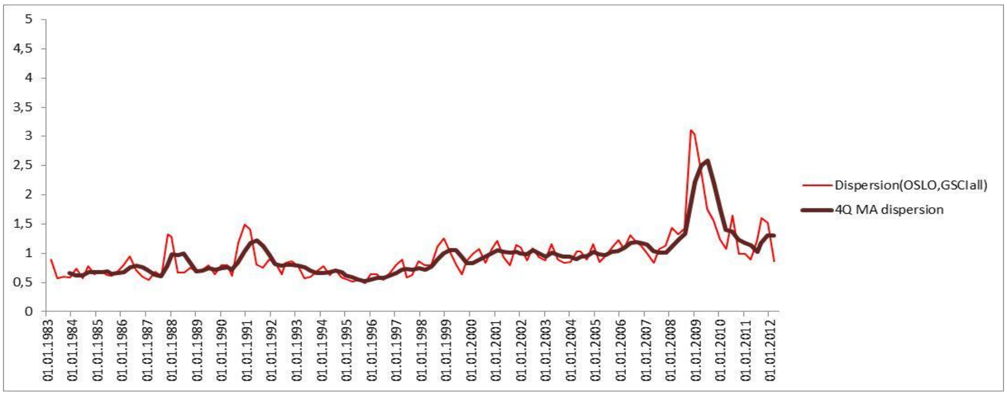


Figure 7

Panels A, B and C display the quarterly dispersion between the S&P GSCI indices and the Oslo Exchange All Share index running from February 1983 to April 2012, constructed from daily returns in USD. Panel A displays the quarterly dispersion between the S&P GSCI all commodities index and the Oslo All Share. Panel B displays the quarterly dispersion between the S&P GSCI non-energy commodities index and the Oslo All Share. Panel C displays the quarterly dispersion between the S&P GSCI energy commodities only index and the Oslo All Share. The filled part of the panels shows the dispersion and the linear line shows an indication of trend in the dispersion. In the figures, OSLO represents the Oslo All Share index, GSCIall represents the S&P GSCI all commodity index, GSCIne represents the S&P GSCI non-energy commodity index, GSCIen represents the S&P GSCI energy commodity index and '4Q MA Corr' is the four quarter moving average of the dispersion between the respective indices in each panel. These notations are used for panels in figure 3 and 4. For example Dispersion(OSLO,GSCIall) is the quarterly dispersion between the Oslo All Share index and the S&P GSCI all commodity index.

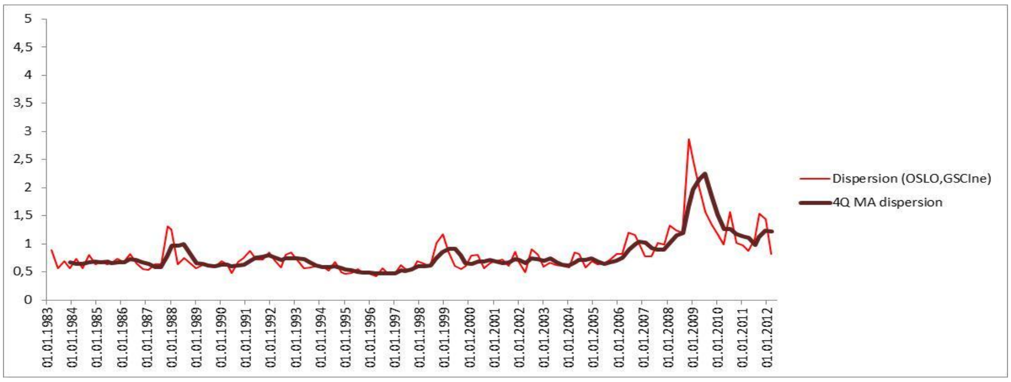
Panel A

Quarterly dispersion between the GSCI all commodities index and the Oslo All Share index in USD



Panel B

Quarterly dispersion between the GSCI non-energy commodities index and Oslo All Share index in USD



Panel C

Quarterly dispersion between the GSCI energy commodities index and the Oslo All share in USD

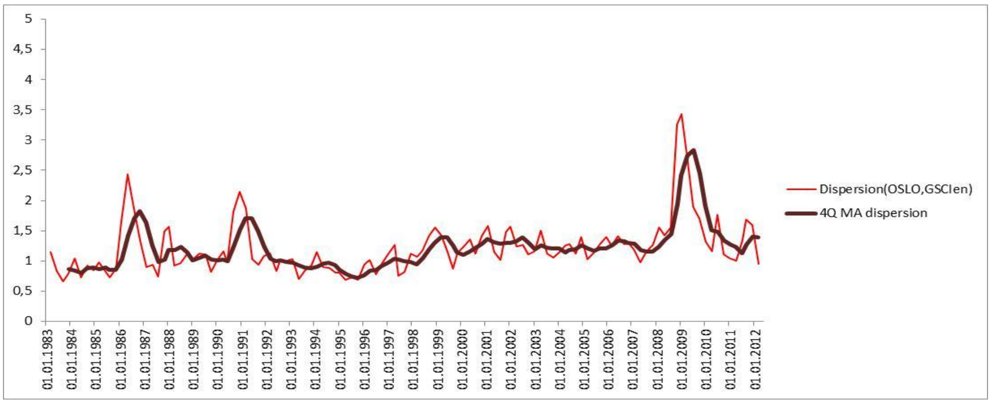
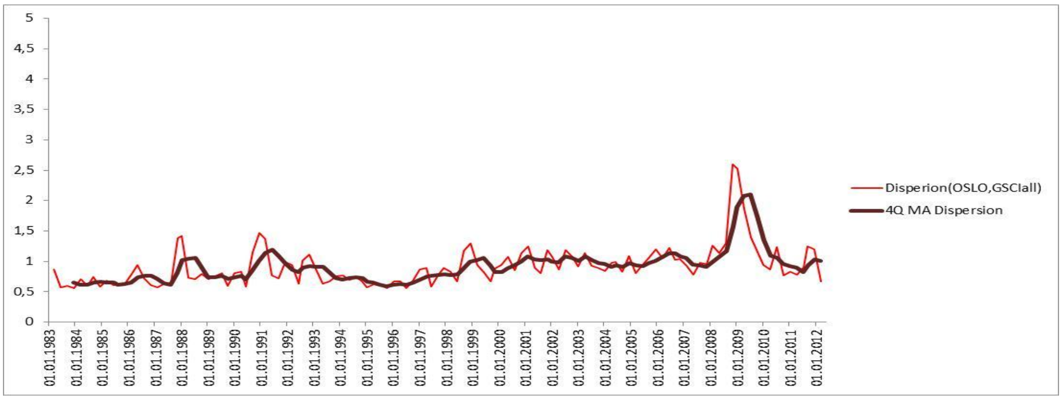


Figure 8

Panel A, B and C display the quarterly dispersion between the S&P GSCI indices and the Oslo Exchange All Share index running from February 1983 to April 2012, constructed from daily returns in NOK. Panel A displays the quarterly dispersion between the S&P GSCI all commodities index and the Oslo All Share. Panel B displays the quarterly dispersion between the S&P GSCI non-energy commodities index and the Oslo All Share. Panel C displays the quarterly dispersion between the S&P GSCI energy commodities only index and the Oslo All Share. The filled part of the panels shows the dispersion and the linear line shows an indication of trend in the dispersion.

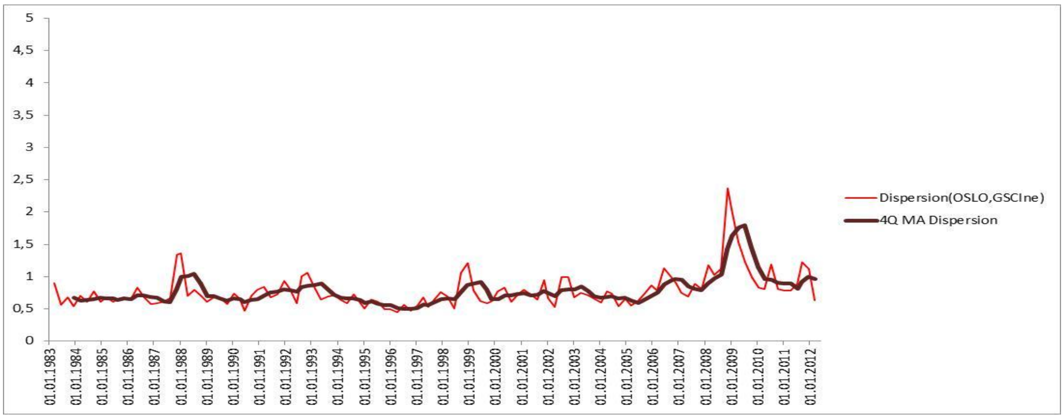
Panel A

Quarterly dispersion between the GSCI all commodities index and the Oslo All Share index in NOK



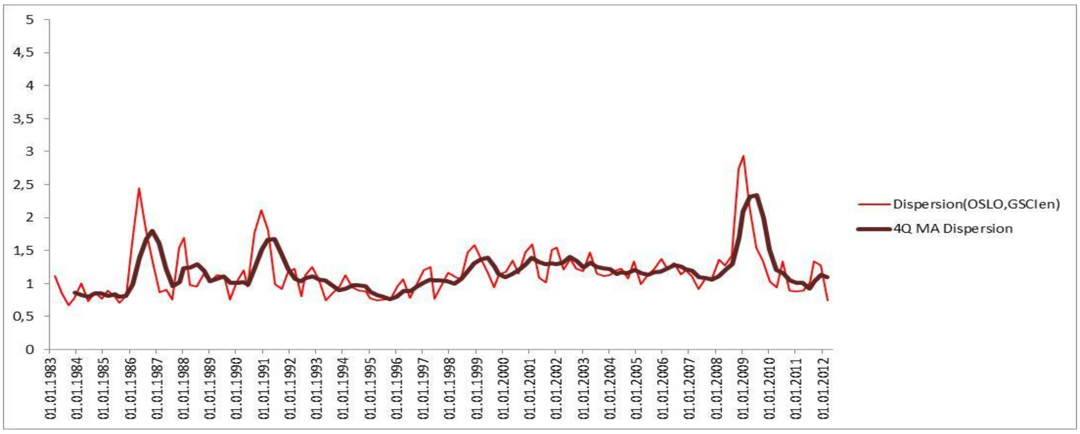
Panel B

Quarterly dispersion between the GSCI non-energy index and the Oslo All Share index in NOK



Panel C

Quarterly dispersion between the GSCI energy commodities index and the Oslo All Share index in NOK



8.2 Tables

Table 1

Table 1present the correlation matrix between the assets for the sample from February 1983 to April 2012. Panel A and B present the correlations from monthly returns denominated in USD and NOK, respectively. The correlations that are presented here are between five indices, The S&P GSCI all commodities, The S&P GSCI energy commodities only, The S&P GSCI non-energy commodities only, the MSCI world index and the Oslo Exchange All Share.

Panel A Correlations between indices in USD

	S&P GSCI Commodity	*S&P GSCI Energy*	*S&P GSCI Non-Energy*	*MSCI WORLD U$*	*OSLO EXCHANGE ALL SHARE*
S&P GSCI Commodity	1				
S&P GSCI Energy	0,925362168	1			
S&P GSCI Non-Energy	0,475177201	0,213770267	1		
MSCI WORLD U$	0,216253971	0,128884602	0,364648587	1	
OSLO EXCHANGE ALL SHARE	0,436636894	0,353251037	0,425662977	0,702328642	1

Panel B Correlations between indices in NOK

	S&P GSCI Commodity	*S&P GSCI Energy*	*S&P GSCI Non-Energy*	*MSCI WORLD U$*	*OSLO EXCHANGE ALL SHARE*
S&P GSCI Commodity	1				
S&P GSCI Energy	0,914302637	1			
S&P GSCI Non-Energy	0,458773048	0,164851864	1		
MSCI WORLD U$	0,190998927	0,076271756	0,410312477	1	
OSLO EXCHANGE ALL SHARE	0,317523852	0,26727342	0,249484572	0,582613655	1

Table 2

Panel A and B contain the summary statistics for monthly returns(%) in USD and NOK, respectively, on three commodity indices and two equity indices. The commodity indices are the S&P GSCI all commodities (GSCI ALLCOMMODITY), the S&P GSCI Energy commodities only (GSCI ENERGY) and the S&P GSCI Non-energy commodities only (GSCI NONENERGY). The sample period runs from December 1969 to April 2012 for the S&P GSCI All commodities and the S&P GSCI non-energy commodities, while the sample period for the S&P GSCI energy commodities runs from February 1983. The Equity indices are the MSCI world index (MSCI WORLD) and the Oslo Exchange All Share (OSLO ALL SHARE). The sample period for the MSCI world index runs from December 1969 to April 2012, while the sample period for the Oslo All Share runs from March 1983 to April 2012.

Panel A: Monthly Index returns(%) in USD

	GSCI ALLCOMMODITY	GSCI ENERGY	GSCI NONENERGY	MSCI WORLD	OSLO ALL SHARE
Mean	0.94	1.11	0.74	0.85	1.31
Median	0.97	0.91	0.65	1.14	1.76
Maximum	25.77	37.71	25.77	14.71	20.27
Minimum	-28.20	-31.20	-18.67	-18.93	-31.08
Std. Dev.	5.77	9.13	4.43	4.36	7.36
Skewness	0.044557	0.418157	0.362237	-0.533688	-0.748337
Kurtosis	5.652954	4.885090	7.713627	4.568778	5.103382
Jarque-Bera	149.1426	62.37715	481.3966	76.20751	97.46457
Probability	0.000000	0.000000	0.000000	0.000000	0.000000
Observations	508	352	508	508	351

Panel B: Monthly Index returns(%) in NOK

	GSCI_ALLCOMMODITY	GSCI_ENERGY	GSCI_NONENERGY	MSCI_WORLD	OSLO_ALLSHARE
Mean	0.90	1.02	0.71	0.80	1.18
Median	0.91	0.67	0.51	1.12	2.06
Maximum	25.76	37.49	25.76	14.08	17.45
Minimum	-18.24	-27.23	-18.13	-19.08	-27.44
Std. Dev.	5.82	8.83	4.81	4.37	6.48
Skewness	0.221967	0.450169	0.420232	-0.422747	-0.856250
Kurtosis	4.553848	4.657696	5.855104	3.970849	5.027362
Jarque-Bera	55.27718	52.19224	187.4943	35.08176	103.0017
Probability	0.000000	0.000000	0.000000	0.000000	0.000000
Observations	508	352	508	508	351

Table 3

Panel A and B presents the trend tests on our correlation measures. Panel A presents the results for the trend tests done on the correlation between the MSCI world index and the S&P GSCI indices. The first panel in panel A presents the results when returns are denominated in USD and the second panel presents the results when returns are denominated in NOK. Panel B presents the results for the trend tests done on the correlation between the Oslo All Share index and the S&P GSCI indices. Panel B presents the results when returns are denominated in USD and the second panel presents the results when returns are denominated in NOK. The sample period for the tests correspond to the sample periods used for the construction of the correlation figures explained above in this paper. Here, the MSCI World + All commodities corresponds to the quarterly correlation between the MSCI world index and the S&P GSCI All commodities. The same reasoning is used for the entirety of panel A and panel B. Notice that to avoid autocorrelation, the quarterly correlation used in these tables have no overlapping dates. The regression that is used for this test is as follows:

$$y_t = \alpha + \beta t + u_t$$

Where y_t is the quarterly correlation series between the MSCI world index or the Oslo All Share and any of the three S&P GSCI indices.The trending coefficient$\beta$is reported as Trend in the tables together with the associated t-values and p-values of the trend test.

Panel A

Correlation			
MSCI World and the GSCI indices (USD)			
	MSCI World + all commodities	MSCI World + non-energy	MSCI World + energy
Trend	0,0017	0,0021	0,0032
t-stat	0,8629	4,3071	4,5042
p-value	0,3898	0,0000	0,0000
MSCI World and the GSCI indices (NOK)			
	MSCI World + all commodities	MSCI World + non-energy	MSCI World + energy
Trend	-0,0001	0,0007	0,0011
t-stat	-0,1633	1,6723	1,1985
p-value	0,8705	0,0968	0,2331

Panel B

Correlation			
Oslo Allshare and the GSCI indices (USD)			
	Oslo Allshare + all commodities	Oslo Allshare + non-energy	Oslo Allshare + energy
Trend	0,0043	0,0041	0,0039
t-stat	8,7472	9,1322	8,0904
p-value	0,0000	0,0000	0,0000
Oslo Allshare and the GSCI indices (NOK)			
	Oslo Allshare + all commodities	Oslo Allshare + non-energy	Oslo Allshare + energy
Trend	0,0018	0,0006	0,0019
t-stat	4,0159	1,2262	4,4027
p-value	0,0001	0,2225	0,0000

Table 4

Panel A and B present the trend tests on our dispersion measures. Panel A presents the results for the trend tests done on the dispersion between the MSCI world index and the S&P GSCI indices. Panel A presents the results in USD and the second panel presents the results in NOK. Panel B presents the results for the trend tests done on the dispersion series between the Oslo All Share and the S&P GSCI indices. Panel B presents the results in USD and the second panel presents the results in NOK. The sample period for the tests correspond to the sample periods used for the construction of the dispersion figures explained above in this paper. Here, the MSCI World + All commodities corresponds to the quarterly dispersion between the MSCI world index and the S&P GSCI All commodities. The same reasoning is used for the entirety of panel A and B. Notice that to avoid autocorrelation, the quarterly dispersion used in these tables have no overlapping dates. The regression that is used for this test is as follows:

$$y_t = \alpha + \beta t + u_t$$

Where y_t is the quarterly dispersion series between the MSCI world index or the Oslo All Share and any of the three S&P GSCI indices. The trending coefficient $\beta$is reported as Trend in the tables together with the associated t-values and p-values of the trend test.

Panel A

Trends in Dispersion

MSCI World and the GSCI indices (USD)

	MSCI World + all commodities	MSCI World + non-energy	MSCI World + energy
Trend	0,0042	0,0023	0,0030
t-stat	3,0749	4,7573	1,7222
p-value	0,0026	0,0000	0,0876

MSCI Worldand the GSCI indices (NOK)

	MSCI World + all commodities	MSCI World + non-energy	MSCI World + energy
Trend	0,0028	0,0017	0,0018
t-stat	3,9535	1,9290	1,0395
p-value	0,0001	0,0559	0,3007

Panel B

Trends in Dispersion

Oslo Allshare and the GSCI indices (USD)

	Oslo Allshare + all commodities	Oslo Allshare + non-energy	Oslo Allshare + energy
Trend	0,0066	0,0051	0,0045
t-stat	3,2419	2,9664	2,0938
p-value	0,0015	0,0036	0,0384

Oslo Allshare and the GSCI indices (NOK)

	Oslo Allshare + all commodities	Oslo Allshare + non-energy	Oslo Allshare + energy
Trend	0,0043	0,0029	0,0025
t-stat	2,7544	1,8635	0,0018
p-value	0,0068	0,0649	0,1808

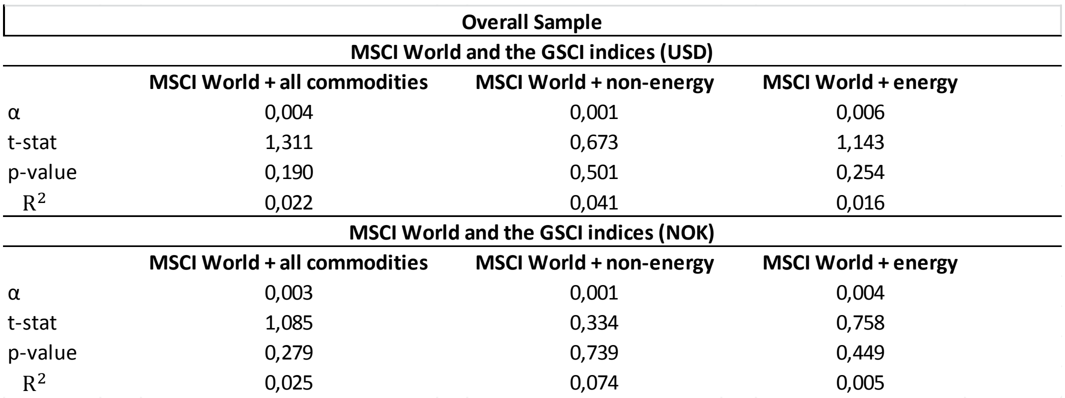
Table 5

Panel A and B present the results from the spanning tests. The sample period for the tests done between the MSCI world and the S&P GSCI All commodities index (MSCI world + all commodities) runs from January 1971 to April 2012. The same applies for the tests run between the MSCI world index and the S&P GSCI non-energy index (MSCI World + non-energy). The sample period for the tests done between the MSCI world index and the S&P GSCI energy commodities (MSCI World + Energy) runs from January 1983 to April 2012. For the tests between the Oslo Exchange All Share index and S&P GSCI indices, the sample runs from January 1983 to April 2012. Panel A presents the results when the test is run on the MSCI world index and the S&P GSCI indices. The first part in panel A presents the results in USD and the second part presents the results in NOK. Panel B presents the results when the test is run on the Oslo All Share and the S&P GSCI indices. The first part in panel B reports the results in USD and the second part reports the results in NOK. The regression that is used to calculate the alphas or the Jensen's measure is:

$$r_t^T = \alpha_T + B r_t^B + u_t$$

Here r_t^T represents the excess returns of any of the S&P GSCI indices, while r_t^B is the excess return of any of our benchmarks, i.e. the MSCI world or the Oslo All Share. The t-values (t-stat) and the p-values are the corresponding values for the test of significance of the alphas.

Panel A



Overall Sample

	MSCI World and the GSCI indices (USD)		
	MSCI World + all commodities	**MSCI World + non-energy**	**MSCI World + energy**
α	0,004	0,001	0,006
t-stat	1,311	0,673	1,143
p-value	0,190	0,501	0,254
R^2	0,022	0,041	0,016
	MSCI World and the GSCI indices (NOK)		
	MSCI World + all commodities	**MSCI World + non-energy**	**MSCI World + energy**
α	0,003	0,001	0,004
t-stat	1,085	0,334	0,758
p-value	0,279	0,739	0,449
R^2	0,025	0,074	0,005

Panel B

Overall Sample			
Oslo All Share and the GSCI indices (USD)			
	Oslo All Share + all commodities	**Oslo All Share + non-energy**	**Oslo All Share + energy**
α	0,0004	-0,0015	0,0033
t-stat	0,111	-0,832	0,664
p-value	0,912	0,406	0,507
R^2	0,191	0,1822	0,1242
Oslo All Share and the GSCI indices (NOK)			
	Oslo All Share + all commodities	**Oslo All Share + non-energy**	**Oslo All Share + energy**
α	-0,0008	-0,002919*	0,0023
t-stat	-0,258	-1,455	0,498
p-value	0,797	0,147	0,619
R^2	0,103	0,066	0,072

Table 6

Panel A and B present the results from the Sharpe ratio tests. The sample period for the tests done between the MSCI world and the S&P GSCI All commodities index (MSCI world + all commodities) runs from January 1971 to April 2012. The same applies for the tests run between the MSCI world index and the S&P GSCI non-energy index (MSCI World + non-energy). The sample period for the tests done between the MSCI world index and the S&P GSCI energy commodities (MSCI World + Energy) runs from January 1983 to April 2012. For the tests between the Oslo Exchange All Share index and S&P GSCI indices, the sample runs from January 1983 to April 2012. Panel B presents the results when the test is run on the MSCI world index and the S&P GSCI indices. The first panel presents the results in USD and the second panel presents the results in NOK. Panel B presents the results when the test is run on the Oslo All Share and the S&P GSCI indices. The first panel reports the results in USD and the second panel reports the results in NOK. The Sharpe Ratio (SR) is presented in the table for each benchmark and when any of the three S&P GSCI indices are added. SR* presents the Sharpe Ratio of the benchmark starting from January 1983. The t-value (t-stat) and the p-values are the corresponding values for the Sharpe Ratio test used to test the significance of the improvement of the Sharpe ratio when each of the test assets are added individually.

Panel A

Overall Sample

MSCI World and the GSCI indices (USD)

	MSCI World	MSCI World + all commodities	MSCI World + non-energy	MSCI World + energy
SR	0,279	0,350	0,299	
SR*	0,384			0,442
t-stat		0,679	0,346	0,592
p-value		0,498	0,729	0,554

MSCI World and the GSCI indices (NOK)

	MSCI World	MSCI World + all commodities	MSCI World + non-energy	MSCI World + energy
SR	0,183	0,249	0,190	
SR*	0,194			0,247
t-stat		0,548	0,167	0,416
p-value		0,584	0,867	0,678

Panel B

Overall Sample

Oslo All Share and the GSCI indices (USD)

	Oslo All Share	Oslo All Share + all commodities	Oslo All Share + non-energy	Oslo All Share + energy
SR	0,424	0,424	0,454	0,445
t-stat		0,068	0,439	0,365
p-value		0,946	0,661	0,715

Oslo All Share and the GSCI indices (NOK)

	Oslo All Share	Oslo All Share + all commodities	Oslo All Share + non-energy	Oslo All Share + energy
SR	0,313	0,317	0,414	0,327
t-stat		0,140	0,732	0,259
p-value		0,889	0,464	0,796

Table 7

Panels A to D report the results from the robustness check when the spanning regression is run on sub-samples of 117 months. The sample periods are presented in each table. The values presented in the tables have the same interpretation as the values in table 3 panel B and table.4 panel B. Notice that the first sub-sample for the S&P GSCI Energy commodities index starts first in February 1983, which is the time it was created. Panel A and B present the results of the robustness check between the MSCI world index and the three S&P GSCI indices in USD and NOK, respectively. Panel C and D present the results of the robustness check between the Oslo Exchange All Share index and the S&P GSCI indices in USD and NOK, respectively. For panels A and B,values noted by a * implies a value that is significant at the 15% level. Hence values noted with ** and *** represent values significant at the 10% and the 5% level, respectively.

Panel A

	MSCI World and the GSCI indices (USD)		
	Sample 31.05.1973 - 31.01.1983		
	MSCI World + all commodities	**MSCI World + non-energy**	**MSCI World + energy**
α	0,00288	0,00317	
t-stat	0,472	0,519	
p-value	0,638	0,605	
R^2	0,000	0,000	
	Sample 28.02.1983 - 30.10.1992		
	MSCI World + all commodities	**MSCI World + non-energy**	**MSCI World + energy**
α	0,00630	0,00154	0,013392*
t-stat	1,448	0,574	1,487
p-value	0,150	0,567	0,140
R^2	0,010	0,031	0,013
	Sample 30.11.1992 - 31.07.2002		
	MSCI World + all commodities	**MSCI World + non-energy**	**MSCI World + energy**
α	-0,00084	-0,005128***	0,00262
t-stat	-0,178	-2,137	0,325
p-value	0,859	0,035	0,746
R^2	0,028	0,050	0,017
	Sample 30.08.2002 - 30.04.2012		
	MSCI World + all commodities	**MSCI World + non-energy**	**MSCI World + energy**
α	0,00150	0,00062	0,00299
t-stat	0,204	0,003	0,304
p-value	0,839	0,998	0,762
R^2	0,180	0,300	0,120

Panel B

MSCI World and the GSCI indices (NOK)			
Sample 31.05.1973 - 31.01.1983			
	MSCI World + all commodities	**MSCI World + non-energy**	**MSCI World + energy**
α	0,00723	0,00750	
t-stat	1,094	1,134	
p-value	0,276	0,259	
R^2	0,008	0,009	
Sample 28.02.1983 - 30.10.1992			
	MSCI World + all commodities	**MSCI World + non-energy**	**MSCI World + energy**
α	0,00125	-0,00253	0,00767
t-stat	0,347	-0,739	0,892
p-value	0,729	0,462	0,374
R^2	0,015	0,139	0,000
Sample 30.11.1992 - 31.07.2002			
	MSCI World + all commodities	**MSCI World + non-energy**	**MSCI World + energy**
α	-0,00081	-0,005317**	0,00286
t-stat	-0,172	-1,747	0,365
p-value	0,864	0,083	0,716
R^2	0,082	0,260	0,018
Sample 30.08.2002 - 30.04.2012			
	MSCI World + all commodities	**MSCI World + non-energy**	**MSCI World + energy**
α	0,00019	-0,00091	0,00174
t-stat	0,028	-0,004	0,172
p-value	0,978	0,997	0,864
R^2	0,027	0,117	0,010

Panel C

Oslo All Share and the GSCI indices (USD)

Sample 28.02.1983 - 30.10.1992

	Oslo All Share + all commodities	**Oslo All Share + non-energy**	**Oslo All Share + energy**
α	0,00488	0,00188	0,01020
t-stat	1,246	0,704	1,217
p-value	0,215	0,483	0,226
R^2	0,034	0,021	0,033

Sample 30.11.1992 - 31.07.2002

	Oslo All Share + all commodities	**Oslo All Share + non-energy**	**Oslo All Share + energy**
α	-0,00194	-0,005449***	0,00096
t-stat	-0,443	-2,349	0,125
p-value	0,659	0,021	0,901
R^2	0,162	0,114	0,117

Sample 30.08.2002 - 30.04.2012

	Oslo All Share + all commodities	**Oslo All Share + non-energy**	**Oslo All Share + energy**
α	-0,00264	-0,00161	-0,00183
t-stat	-0,013	-0,411	-0,009
p-value	0,990	0,682	0,993
R^2	0,348	0,370	0,263

Panel D

Oslo All Share and the GSCI indices (NOK)

Sample 28.02.1983 - 30.10.1992

	Oslo All Share + all commodities	**Oslo All Share + non-energy**	**Oslo All Share + energy**
α	0,00113	-0,00212	0,00698
t-stat	0,293	-0,589	0,894
p-value	0,770	0,557	0,373
R^2	0,062	0,048	0,051

Sample 30.11.1992 - 31.07.2002

	Oslo All Share + all commodities	**Oslo All Share + non-energy**	**Oslo All Share + energy**
α	-0,00148	-0,004992*	0,00145
t-stat	-0,324	-1,497	0,192
p-value	0,746	0,137	0,848
R^2	0,142	0,114	0,084

Sample 30.08.2002 - 30.04.2012

	Oslo All Share + all commodities	**Oslo All Share + non-energy**	**Oslo All Share + energy**
α	-0,00271	-0,00178	-0,00184
t-stat	-0,013	-0,504	-0,009
p-value	0,990	0,616	0,993
R^2	0,125	0,053	0,098

Table 8

Panel A and B report the results from the robustness check when the Sharpe ratio test is run on sub-samples of 117 months. The sample periods are presented in each table. The values presented in the tables have the same interpretation as the values in the panels from table.5. Notice that the first sub-sample for the S&P GSCI Energy commodities index starts first in February 1983, which is the time it was created. Panel A and B present the results of the robustness check between the MSCI world index and the three S&P GSCI indices in USD and NOK, respectively. Panel C and D present the results of the robustness check between the Oslo Exchange All Share index and the S&P GSCI indices in USD and NOK, respectively. For panels A to D, values noted by a * implies a value that is significant at the 15% level. Hence values noted with ** and *** represent values significant at the 10% and the 5% level, respectively.

Panel A

MSCI World and the GSCI indices (USD)

Sample 31.05.1973 - 31.01.1983

	MSCI World	MSCI World + all commodities	MSCI World + non-energy	MSCI World + energy
SR	0,140	0,206	0,217	
t-stat		0,236	0,259	
p-value		0,814	0,796	

Sample 28.02.1983 - 30.10.1992

	MSCI World	MSCI World + all commodities	MSCI World + non-energy	MSCI World + energy
SR	0,511	0,713	0,547	0,715
t-stat		0,776	0,303	0,780
p-value		0,439	0,762	0,437

Sample 30.11.1992 - 31.07.2002

	MSCI World	MSCI World + all commodities	MSCI World + non-energy	MSCI World + energy
SR	0,255	0,262	0,725	0,277
t-stat		0,091	1,059	0,168
p-value		0,927	0,292	0,867

Sample 30.08.2002 - 30.04.2012

	MSCI World	MSCI World + all commodities	MSCI World + non-energy	MSCI World + energy
SR	0,372	0,381	0,376	0,390
t-stat		0,126	0,079	0,184
p-value		0,900	0,937	0,854

Panel B

MSCI World and the GSCI indices (NOK)

Sample 31.05.1973 - 31.01.1983

	MSCI World	MSCI World + all commodities	MSCI World + non-energy	MSCI World + energy
SR	0,206	0,408	0,419	
t-stat		0,550	0,571	
p-value		0,583	0,569	

Sample 28.02.1983 - 30.10.1992

	MSCI World	MSCI World + all commodities	MSCI World + non-energy	MSCI World + energy
SR	0,195	0,224	0,285	0,349
t-stat		0,173	0,325	0,453
p-value		0,863	0,746	0,651

Sample 30.11.1992 - 31.07.2002

	MSCI World	MSCI World + all commodities	MSCI World + non-energy	MSCI World + energy
SR	0,189	0,218	0,661	0,206
t-stat		0,169	0,989	0,129
p-value		0,866	0,325	0,898

Sample 30.08.2002 - 30.04.2012

	MSCI World	MSCI World + all commodities	MSCI World + non-energy	MSCI World + energy
SR	0,043	0,051	0,152	0,060
t-stat		0,044	0,227	0,067
p-value		0,965	0,821	0,947

Panel C

Oslo Exchange All Share and the S&P GSCI indices (USD)

	Oslo All Share	Oslo All Share + all commodities	Oslo All Share + non-energy	Oslo All Share + energy
Sample 28.02.1983 - 30.10.1992				
SR	0,332	0,516	0,407	0,508
t-stat		0,616	0,367	0,600
p-value		0,539	0,714	0,550
Sample 30.11.1992 - 31.07.2002				
	Oslo All Share	**Oslo All Share + all commodities**	**Oslo All Share + non-energy**	**Oslo All Share + energy**
SR	0,293	0,324	0,803	0,296
t-stat		0,216	1,167	0,066
p-value		0,829	0,246	0,948
Sample 30.08.2002 - 30.04.2012				
	Oslo All Share	**Oslo All Share + all commodities**	**Oslo All Share + non-energy**	**Oslo All Share + energy**
SR	0,602	0,623	0,621	0,608
t-stat		0,247	0,237	0,127
p-value		0,805	0,813	0,899

Panel D

Oslo Exchange All Share and the S&P GSCI indices (NOK)

	Oslo All Share	Oslo All Share + all commodities	Oslo All Share + non-energy	Oslo All Share + energy
Sample 28.02.1983 - 30.10.1992				
SR	0,134	0,169	0,204	0,299
t-stat		0,162	0,239	0,417
p-value		0,872	0,811	0,677
Sample 30.11.1992 - 31.07.2002				
	Oslo All Share	**Oslo All Share + all commodities**	**Oslo All Share + non-energy**	**Oslo All Share + energy**
SR	0,255	0,300	0,622	0,257
t-stat		0,245	0,885	0,054
p-value		0,807	0,378	0,957
Sample 30.08.2002 - 30.04.2012				
	Oslo All Share	**Oslo All Share + all commodities**	**Oslo All Share + non-energy**	**Oslo All Share + energy**
SR	0,471	0,512	0,527	0,483
t-stat		0,311	0,367	0,164
p-value		0,756	0,714	0,870

Table.9

Table.9 presents the raw correlation between our indices. The correlations are shown for three periods, where sample.1 ranges from February 1983 to October 1992, sample.2 ranges from November 1992 to July 2002 and sample.3 ranges from August 2002 to April 2012. Panel.A presents the raw correlations between our indices from returns in USD. While Panel.B present the raw correlations between our indices from returns in NOK.

Panel.A

USD return correlations between our indices for different sub-samples.

Sample.1 (28.02.1983 - 30.10.1992)

	S&P GSCI Commodity	*S&P GSCI Energy*	*S&P GSCI Non-Energy*	*MSCI WORLD U$*	*OSLO EXCHANGE ALL SHARE*
S&P GSCI Commodity	1				
S&P GSCI Energy	0,873215807	1			
S&P GSCI Non-Energy	0,375694736	-0,016852065	1		
MSCI WORLD U$	-0,099919058	-0,112818796	0,174802865	1	
OSLO EXCHANGE ALL SHARE	0,190464396	0,186467311	0,151121626	0,558475087	1

Sample.2 (30.11.1992 - 31.07.2002)

	S&P GSCI Commodity	*S&P GSCI Energy*	*S&P GSCI Non-Energy*	*MSCI WORLD U$*	*OSLO EXCHANGE ALL SHARE*
S&P GSCI Commodity	1				
S&P GSCI Energy	0,975482805	1			
S&P GSCI Non-Energy	0,379668201	0,162415305	1		
MSCI WORLD U$	0,172387495	0,135240751	0,227387438	1	
OSLO EXCHANGE ALL SHARE	0,406025737	0,346021856	0,338370991	0,653008568	1

Sample.3 (30.08.2002 - 30.04.2012)

	S&P GSCI Commodity	*S&P GSCI Energy*	*S&P GSCI Non-Energy*	*MSCI WORLD U$*	*OSLO EXCHANGE ALL SHARE*
S&P GSCI Commodity	1				
S&P GSCI Energy	0,990821503	1			
S&P GSCI Non-Energy	0,556527578	0,395129663	1		
MSCI WORLD U$	0,425879455	0,347242082	0,551270825	1	
OSLO EXCHANGE ALL SHARE	0,594281141	0,516763638	0,612269250	0,858343281	1

Panel.B

NOK return correlations between our indices for different sub-samples.

Sample.1 (28.02.1983 - 30.10.1992)

	S&P GSCI Commodity	*S&P GSCI Energy*	*S&P GSCI Non-Energy*	*MSCI WORLD U$*	*OSLO EXCHANGE ALL SHARE*
S&P GSCI Commodity	1				
S&P GSCI Energy	0,858130100	1			
S&P GSCI Non-Energy	0,602370071	0,180201441	1		
MSCI WORLD	0,123275276	0,002026754	0,377757140	1	
OSLO EXCHANGE ALL SHARE	0,246943750	0,224621635	0,216192672	0,537579695	1

Sample.2 (30.11.1992 - 31.07.2002)

	S&P GSCI Commodity	*S&P GSCI Energy*	*S&P GSCI Non-Energy*	*MSCI WORLD U$*	*OSLO EXCHANGE ALL SHARE*
S&P GSCI Commodity	1				
S&P GSCI Energy	0,945417128	1			
S&P GSCI Non-Energy	0,479967698	0,163739122	1		
MSCI WORLD	0,290032890	0,135054558	0,516028439	1	
OSLO EXCHANGE ALL SHARE	0,378683436	0,290881869	0,339180085	0,630267443	1

Sample.3 (30.08.2002 - 30.04.2012)

	S&P GSCI Commodity	*S&P GSCI Energy*	*S&P GSCI Non-Energy*	*MSCI WORLD U$*	*OSLO EXCHANGE ALL SHARE*
S&P GSCI Commodity	1				
S&P GSCI Energy	0,989571099	1			
S&P GSCI Non-Energy	0,325078964	0,142009494	1		
MSCI WORLD	0,159265857	0,096188127	0,335965621	1	
OSLO EXCHANGE ALL SHARE	0,350676637	0,311452952	0,220193330	0,630043655	1

Data and computation CD

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Abstract

We study the possibility of the existence of a commodity factor in equity markets and if so, the possible impact of commodity risk factors on equity markets. The possible existence and effect of these factors or factor will be examined in this paper through several steps. Firstly, the paper discusses the correlation between commodities and international equity markets and will highlight possible time varying correlation between these markets during different macroeconomic cycles. Secondly, the return-to-risk tradeoff when adding commodities to traditional portfolios is analyzed by formally testing for improvements in return-to-risk. This is done by using spanning tests to check for mean-variance efficiency versus traditional portfolios that do not include positions in commodities. The tests will primarily be based on using data from the S&P GSCI indices.

Introduction

As Eiling et al. (2009) state, one of the core questions in International finance is which factors drive international equity returns. Based on what is stated in their article it can be said that there is an ongoing discussion on what spans what when it comes to global, country and industry portfolios. They find that under their conditional analysis equity returns are mainly driven by global factors and currency risk factors. This seems reasonable since it turns out that the equity markets are increasingly getting more and more integrated on a ‘global level’ *(Esther & Gerard, 2010)*. To expand on their findings, the main concern in this paper will be to address which, if at all, equity returns are driven by commodity risk factors. With this paper we also wish to come to a conclusion on the diversification effect of commodity futures on traditional portfolios and whether the diversification effect or in general the mean-variance efficiency of including commodity futures/indices in portfolios is time varying or not.

Bannister & Forward *(2002)* state that stocks and commodities have alternated relative and absolute price leadership in cycles. Further on several papers conclude that commodity futures have significant diversification effect on traditional portfolios *(Harry, 2006)*. The reason for this significant diversification effect seems to be due to nature of the risk factors commodity futures are exposed to, which might be different compared to equity risk factors. It is also claimed that commodity futures have powers to diversify systematic risk due to the reasons explained above and hence making commodities significantly uncorrelated to traditional financial markets *(Gorton & Rouwenhorst, 2005)*.

Another important aspect to why examine commodity futures from our point of view is due to the increasing pressure on the demand of raw materials from emerging markets such as China and Brazil *(Harry M. Kat, 2006)*, which are seen as the major economies to drive the current commodity boom *(Fabozzi, 2008)*. Also Tang and Xiong (*2010*) explain the commodity price boom as a possible consequence of the rapid growth in emerging economies like for example China. The rapid growth in emerging economies in 2000s increased the demand for commodities in sectors like energy and metals, which could have lead to a price boom of these commodities under the last decade. *(Tang, Xiong, 2010*)

Then there is also the issue of under-investment by commodity producers due to many years of price weakness and hence lower production ability to meet new increased demands *(Harry M. Kat, 2006)*. The reasons behind these possible short-term price increases can possibly be explained by commodity super cycle theory. Where a super cycle is a lasting boom in real commodity prices, usually brought on by urbanization and industrialization in a major economy *(Fabozzi, 2008)*, which is what is happening in the two countries mentioned above. Hence this could possible mean that commodity risk factors might have a major role as equity market drivers as China and Brazil continue to become major economies of the world.

Further on Fabozzi *(2008)* mentions that there’s been a boom on investments in commodity futures lately which makes it important to understand how these commodity futures react to their risk factors and how this in return can drive equity markets. Also what is interesting is that Fabozzi *(2008)* explains that commodity indices might be exposed to currency risk factors due to the indexes and commodities themselves being denominated in U.S dollars. Hence even if commodity futures are known to be uncorrelated to traditional equity markets, which might mean that commodity risk factors should or might not drive equity markets at all, it seems that they might be connected to equity markets if what Eiling et Al. *(2009)* conclude with in their article that equity markets are driven by global and currency risk factors.

Although Gorton & Rouwenhorst*(2005)*, Harry M. Kat*(2006)* and Kat & Oomen *(2006b)* show that commodities are uncorrelated with stocks and bonds, it seems that in specific phases, the correlation admittedly increases and hence makes not all commodities useful for portfolio diversification in every market phase *(Fabozzi, 2008)*. For examples *Fabozzi (2008)* states that the conditional correlations between commodities and fixed income increase during times of increased bond volatility. Also Silvennoinen and Thorp (*2010*), Tang and Xiong (*2010*) and Büyükshain et al. (*2010*) find that the return correlations between commodities and equities have increased substantially during the recent sub-prime crisis. (*Daskalaki, Skiadopoulos, 2011*) This might mean that during certain phases there might be common drives of equity markets and commodity markets. On the other hand there are a number of empirical papers that examine the pre-2008 era. Their findings imply that the diversification benefits of commodities are more pronounced over turbulent periods (*Gorton & Rouwenhorst, 2006; Kat & Omen, 2007b; Chong and Miffre, 2010; Büyüksahin et al., 2010*), (*Daskalaki, Skiadopoulos, 2011)*

As Robert J. Greer (*2002*) states, an asset class must satisfy two main criteria before an investor should consider adding it to a portfolio. First, the asset should increase the expected utility of a portfolio, usually that is higher return for the risk taken (Sharpe ratio), but it can also include higher order moments. (*Daskalaki, Skiadopoulos. 2011*) Secondly, the returns from the asset class cannot be replicated with combinations of other assets. Hence our contribution is to highlight possible drivers of equity markets that might not have been considered to be of significance when constructing a portfolio strategy. This paper might make it possible to construct a more mean-variance efficient portfolio if this paper will show a significant increase in Sharpe-ratios due to including commodity futures/indices on top of traditional cross-border portfolio strategies. The analysis will then be used to examine the impact of commodities on Norwegian investors holding international portfolios versus Norwegian investors holding only Norwegian stocks.

Commodities – a preliminary analysis

A commodity futures contract is an agreement to buy or sell a specified sum or quantity of commodity in the future at a specific date at a price agreed when entering into the contract. *(Gorton, Rouwenhorst, 2005)* According to Gorton and Rouwenhorst (*2005*) commodity futures differs from stocks, bond and other conventional assets in form of that they are derivative securities, they are short maturity claims on real assets and many commodities have pronounced seasonality in price levels and volatilities. The prices of commodities can change on a weekly or even on daily basis. The difference between the futures price and the futures spot price is called the risk premium, which is the risk the investor takes to either make or lose money. Hence the risk premium is the realized payoff plus any unexpected deviation of the futures spot price from the expected futures spot price. *(Gorton, Rouwenhorst, 2005*)

Lately Commodity indices have become an increasingly popular investment strategy. *(Tang, Xiang, 2010)* Commodity indices function similar to equity indices both in the aspect that the index's value is derived from the total value of a basket of commodities and when it comes to return. The returns are comparable to passive long positions in listed commodity futures contracts. This true due to the way the futures contracts are "rolled". When a first-month contract matures, the second-month contract becomes the first-month contract. Hence the current contract is replaced by a following contract, i.e. the "roll" (see also *Erb and Harvey, 2006*). The indices' performances are measured by the basket of commodities. S&P Goldman Sachs Commodity index (GSCI), which is the largest commodity index besides the DOW-Jones UBS Commodity index (DJ-UBS), is such an index. *(Tang, Xiang, 2010)* According to Tang and Xiang 2010, the commodities in the indices are assigned a specified weight and they are all built on the values of the futures contracts. *(Tang, Xiang, 2010)*

Both, the S&P GSCI and DJ-UBS are traded indices and they have a wide range of commodity futures. The difference between these indices is that the S&P GSCI is weighted by each commodity`s world production, while DJ-UBS relies on the relative amount of trading activity of a particular commodity. *(Tang, Xiang, 2010)* S&P GSCI is also more energy heavy than DJ-UBS. Such commodity indices, as these two, are also an informative source to cash commodity and futures commodity market trends so they can be used as benchmarks for commodity trading. *(Greer, 2002)*

Robert J. Greer (*2002*) investigates the correlation between commodity indices, stocks and bonds and the rate of inflation, which is argued in the literature as one of the common factors that drives prices of most commodities. *(Tang, Xiang, 2010)* According to Greer (*2002*) the commodity indices seem to be negatively correlated with stock and bond returns, and positively correlated with the rate of inflation and even more positively correlated with changes in the rate of inflation. He also states that stock and bonds are negatively correlated with rate of inflation and the changes in the rate of inflation. *(Greer, 2002)* Hence commodity futures are usually used as a hedging tool against inflation, when the investors are especially exposed to changes in the CPI, i.e. the inflations rate.
However, As explained above, Gorton and Rouwenhorst (*2005*) suggest that commodity futures have the power to diversify systematic risk and they further argue that the diversification benefits do not come from opposite exposure to

unexpected inflation but from the performance of futures over the business cycle. *(Gorton, Rouwenhorst, 2005)*

It is important to keep in mind that there are many aspects and types of commodities, for example, we have energy commodities like electricity, gas, coal and oil to name a few and non-energy commodities such as soybeans, aluminum and coffee beans to name a few. Another classification could be soft and hard commodities, where soft commodities are goods that are grown and hard commodities could be commodities which are extracted through mining. These classifications can be used when applying the main types of commodity futures pricing models like the Cost-of-Carry arbitrage model or other equilibrium models. The Cost-of-Carry approach can be used when we have storable commodities and equilibrium models can be used for the non-storable commodities. This means that price movements between these commodities might be different and uncorrelated. This is also called the theory of storage, and is only one of several models used to explain commodity returns, such as the CAPM (probably best used where you need to commit cash, such as ETFs), the insurance perspective and the hedging pressure hypothesis. Using commodity futures as a hedging tool is widely known and acknowledged today, and the hedging pressure hypothesis states that commodity futures prices rise when that specific commodity is sought to mitigate risk *(Erb, Harvey. 2006)*.

Spanning Tests

In portfolio analysis, one is often interested in finding out whether one set of risky assets can improve the investment opportunity set of another set of risky assets. If an investor chooses portfolios based on mean and variance, then the question becomes whether adding a new set of risky assets can allow the investor to improve the minimum-variance frontier from a given set of risky assets. *(Kan, Zhou, 2001)*

To address this issue we are planning to use spanning tests implemented firstly by Huberman and Kandel (*1987*). They proposed a regression-based test of the hypothesis that the minimum variance frontier of a set of K benchmark assets is the same as the minimum-variance frontier of the K benchmark assets plus a set of

N additional test assets. *(Kan, Zhou, 2001)* The benefits of international diversification on portfolio management are well documented in the literature and the mean-variance spanning tests have been used to study such benefits. *(Switzer, Haibo, 2006)* According to Kan and Zhou (*2001*) there are also several other tests that has been developed the last decades subsequent to Huberman and Kandel`s study which tries to address the question of mean-variance spanning in different applications, such as DeSantis (*1993*), Bakaert and Urias (*1996*) Ferson, Foerster, and Keim (*1993*), De Roon, Nijman, and Werker (*2001*), Hansen and Jagannathan (*1991*) and Korkie and Turtle (*2001*). Spanning tests have also been used to assess the efficiency of investing in alternative asset classes such as commodity and currency futures. DeRoon, Nijman and Werker (*1996*) show how regression techniques can be used to test for spanning with zero-investment and non-traded assets, and for other classes of utility functions; they examine whether a set of three international stocks indices spans the set of the indices plus a number of commodity and currency futures contract.

Huberman and Kandel`s spanning test will be used in our thesis to check for common factors between equity markets and commodities, where we say that a set of K risky assets, also called benchmark assets in the literature, spans a larger set of N + K risky assets (N is also called the test assets) if the mean-variance frontier of the K assets is identical or coincides to the mean-variance frontier to the K assets plus an additional N assets. Hence when the two frontiers coincide, we have spanning, which also means that we will not get any benefit from adding the test assets (N-assets) into our existing optimal portfolio. Since such an asset can only add to the variance of portfolios and not to the expected return, mean-variance optimizing agents will not include such an asset in their portfolio (*DeRoon, Nijman. 2001)*.

Methodology

Our analysis will first off include a short analysis on the correlations between commodities and equity markets. It is common knowledge that the correlation between two variables measures the degree of linear association between them. If it is stated that y and x are correlated, it means that y and x are being treated in a completely symmetrical way. In other words this can be indicative of a common factor between *x* and *y*, but it does not imply that changes in x cause changes in y or vice versa, i.e. that there really exists is a common factor. (*Brooks, 2010)*. In addition the correlation between commodities and equity markets seems to be changing over time, as was explained above, hence the potential benefits might be time varying and may differ in recessions from expansions.

To examine the relationship, we need to deploy statistically robust tests, where one of them is the spanning tests described above. In our case the spanning or intersection will show if there are in fact commodity factor(s) that act as a driver(s) for equity markets. This section will explain how the steps to test for this will be done.

We will be using the Holding Period Return (usable due to the "roll" of contracts explained above) from passive investable commodity indexes as the return for our tests. The index that is used will be explained further down in the paper. Hence the return from month *t* to month *t+1* will be calculated as follows:

$$R_{S\&P\ GSCI,t} = \frac{I_{S\&P\ GSCI,t} - I_{S\&P\ GSCI,t-1}}{I_{S\&P\ GSCI,t-1}}$$

Where:

$R_{S\&P\ GSCI,t} = \ is\ the\ holding\ return\ on\ S\&P\ GSCI\ index\ in\ period\ t.$

$I_{i,t} = Price\ or\ value\ of\ S\&P\ GSCI\ index\ at\ the\ end\ of\ period\ t.$

$I_{i,t-1} = Price\ or\ value\ of\ S\&P\ GSCI\ index\ at\ the\ beginning\ of\ period\ t.$

$X = dividende\ or\ periodic\ return$

The next step will be to use the spanning analysis or test to check if the set of *K* assets, which are the traditional portfolios (bond and stock indices) in our case, spans the set containing the initial *K* assets + *N* test(Commodity indices) assets.

As Huberman and Kandel *(1987)* we assume a linear model, in our case the single index model:

$$r_t = a + BR_{m,t} + e_t$$

Furthermore, following the framework proposed by Huberman and Kandel *(1987)*, the returns on the *N* assets are denoted by the *N x 1* vector r_t, the returns on the *K* assets are denoted by the *K x 1* vector $R_{m,t}$ and *B* is *N x K* matrix. The random vector e_t is uncorrelated with the random vector R, and as DeRoon and Nijman (*2001*) show, the expected value of each element of e_t is 0, i.e:

$$E[e_t] = 0 \; and \; E[e_t R_t'] = 0$$

As DeRoon and Nijman *(2001)* explain, the restrictions imposed by the hypothesis of spanning can be stated as:

H_0: $a = 0_N \; and \; d = 0_N$, where 0_N are vectors with all elements equal to 0.

Furthermore Huberman and Kandel *(1987)* show in their proposition 1 that,

$$E[r_t] = a + BE[R_{m,t}]$$

$$=> a = E\left[R_{m,t}\right] - B * E[r_t] => we \; denote \; E\left[R_{m,t}\right] \; as \; u_2 \; and \; E[r_t] \; as \; u_1$$

$$=> \boldsymbol{a = u_2 - Bu_1}$$

Where u_2 is the expected mean return of the test assets and u_1 is the expected return on the benchmark assets, where the expected return on the *N* + *K* assets is:

$$u = \begin{bmatrix} u_1 \\ u_2 \end{bmatrix}$$

They also show that:

$$\boldsymbol{B = cov(r, R) * cov(r, R)^{-1}}$$

$$=> we \; denote \; cov(r, R) as \; \Sigma_{21} \; and \; cov(r, R)^{-1} \; as \; \Sigma_{11}^{-1}$$

Where:

$$\Sigma = \begin{bmatrix} \Sigma_{11} & \Sigma_{12} \\ \Sigma_{21} & \Sigma_{22} \end{bmatrix}$$

Here Σ denotes the covariance matrix of the *N* + *K* risky assets. See DeRoon and Nijman (*2001*) for derivation.

Further on *d* is defined as follows:

$$\boldsymbol{d = i_N - Bi_K}$$

Where i_N and i_K are *N x 1* and *K x 1* vectors, respectively. Also here we refer to DeRoon and Nijman (*2001*) for the derivation.

Hence if the $H_0: a = 0_N \; and \; d = 0_N$ restrictions hold, every point on the mean-variance frontier of the *K*-assets is also the mean-variance frontier of the *N* + *K*-asset and the two frontiers coincide (*DeRoon and Nijman. 2001*).

Further on, DeRoon and Nijman (*2001*) show that in case of an intersection of the mean-variance frontiers, the restrictions of the null hypothesis are:

$$H_0: a - \eta(i_N - Bi_K) = 0_N$$

Which corresponds to our:

$$=> H_0: a - \eta d = 0_N$$

Where η is the zero-beta return for the portfolio that is mean-variance efficient for all asset sets, i.e. for both the smaller set (*K*) and for the larger test set (*K* + *N*).

This means that the mean-variance frontiers coincide at one point, which means that on this point or intersection, adding the test asset will not improve the mean-variance efficiency of the portfolio.

Further on, if the results from the spanning test are positive or interesting, the next step would be to examine the deviations from the restrictions described above. In this case DeRoon and Nijman show that the regression estimates of the linear single index model assumed above and the test statistics can be used as measures of performance, to be more exact: Sharpe Ratio and Jensen's Alpha.

Jensen's alpha is commonly used to measure the improvement in efficiency of a portfolio by testing the significance of the excess return, if there is a excess return at all. The Sharpe Ratio, on the other hand, is a good measure for evaluating performances between e.g. two different portfolios. As explained above, DeRoon and Nijman (*2001*) show that the Sharpe ratio and Jensen's Alpha are linked together when considering that Jensen's alpha and the covariance matrix of the error terms determine the achievable Sharpe ratio. In other words, since the null hypothesis (spanning or intersection) implies a restriction that Jensen's alpha is zero, means that there is no potential gains on the Sharpe ratio too.

Data

The data that is necessary to conduct this test is available on DataStream. We plan on using, as Daskalaki and Skiadopoulos *(2011)*, the S&P 500 total return index, Barclays US aggregate bond index, Libor one-month rate to proxy the US equity market. This data and the other necessary data on the different country equity and bond indices are also available on DataStream. For the commodities "proxy" we planned initially to use the S&P GSCI indices and the DJ-UBSCI indices, however these two indexes usually employ the same commodities in their baskets; the main difference is, as described in the preliminary analysis of commodities, the weighting on each commodity. The S&P GSCI has lately included or concentrated in energy commodities, which accounted recently for nearly 70% of the index value *(Daskalaki, Skiadopoulos. 2011)*, while the DJ-UBSCI employs a rule to ensure diversification: the minimum and maximum weight allowed for any single commodity is 2% and 15%, respectively, and the maximum allowed for any sector is 33% (*Erb, Harvey. 2006*). These two indexes are probably the most known commodity indexes today (*Stoll, Whaley. 2010; Tang, Xiong. 2010*) and represent passive investment strategies in a number of the commodity futures *(Daskalaki, Skiadopoulos. 2011)*. In addition, Erb and Harvey *(2006)* discuss and describe how the return and risk differs among the commodity indexes that are partially explained by the differing weights of individual commodities. They then proceed to claim that as a result of this, there is no commodity futures market capitalization and commodity indices can best be thought of as commodity portfolio strategies. Further on we plan on to use only the S&P GSCI total return and two sub indices, where one includes only energy commodities and the other includes all commodities except energy commodities. Since energy prices behave differently, as explained above, than other commodities, it will be interesting to see the results.

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