11. Adding oil to a portfolio of stocks and bonds?

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Abstract
The work of Markowitz in the early 1950s triggered a revolution in the investment management world. The concept of efficient portfolios and efficient frontier gave an important impulse to the development of modern finance. Ever since, the concept of efficient portfolios has been widely applied in many environments. While originally restricted to stock markets, applications have been developed in the field of e.g. the optimisation of energy distribution (Letzelter, 2005). In the last decade, asset managers look at the opportunity to improve their expected return-risk trade off by adding commodities to their portfolio of stocks and bonds. In this chapter we look at the contribution of oil to such a portfolio.

The goal of this paper is to investigate if the addition of oil to an investment portfolio can improve an efficient set of traditional investments in stocks and bonds. We believe that given the counter cyclicality of oil returns compared to the stock market, that the inclusion of such assets should improve the risk-return trade-off. It appears that oil is not a safe haven for stockholders and bondholders. Oil is not a hedge for stockholders, but it does present a hedge for bondholders. When adding oil to the portfolio we see a change in efficient frontier and market portfolio. Holders of portfolios of bonds and stocks can improve their risk-return trade off by enlarging their portfolio with an investment in oil.

Key words: safe haven, hedging portfolios, efficient frontier

12.1 Introduction

Mandelbrot (1963;1966) showed that stocks are neither normally nor log-normally distributed. The condition of (log-) normality has become more and more restrictive. The 2007/2008 global financial crisis and the stock price developments after the 2011 earthquake and tsunami in Japan show that outliers are more frequent than one might expect under the (log-) normal condition. In other words, there is obesity in the tail. It is also possible that an asset is not or negatively correlated with another asset whenever market developments are difficult. Holders of the second asset see, in that case, the first asset as a safe haven. There is some evidence (Baur and Lucey, 2009 and Baur and McDermott, 2010) that gold is a safe haven for some stockholders, but not for bondholders.

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The goal of this chapter is to investigate whether the addition of oil to a traditional portfolio of stocks and bonds can improve the risk-return trade-off. Adding oil to a portfolio of stocks and bonds can be interesting for portfolio holders if it improves the expected risk -return trade-off.

Thus, our research investigates the impact of adding oil to a portfolio of bonds and stocks. We are more specifically interested to look at oil as a safe haven, at oil as a hedge for stockholders and bondholders and at the impact of oil on the efficient frontier of a portfolio made of stocks, bonds, and oil. To conduct the empirical tests, we use indices made of "risk free" U.S. government bonds, of common stocks from Standard & Poor and of an oil index.

The statistical analysis is performed with the use of Oracle Crystal Ball software. The software is used to characterise the distribution of returns for our three indices, to estimate the correlations between these indices, and to derive the efficient frontier for our portfolios. In our analysis, we also consider the consequences of obesity in the tails.

The structure of this chapter is as follows. We start with a review overview in section 11.2. In section 11.3 the data is described. The empirical results are presented in section 11.4. Section 11.5 contains a short summary and our conclusions.

11.2 Literature review

One of the problems with bond and stock portfolios is the heavy tail in the returns, to which for example Mandelbrot (1966) already drew attention. However, during the 2007/2008 financial crisis, the problem became more visible. Kousky and Cooke (2009) examined several datasets of damages from natural disasters and concluded that fat tails exist, as do tail dependence and/or micro-correlations. Micro-correlations are small, positive correlations between variables. Kousky and Cooke give the example of the El Niño effect causing fires in Australia and floods in California. These authors looked at this problem from the perspective of an insurance company. Insurance companies reduce their risk by diversifying their portfolios. However, fat tails, tail dependency and micro-correlations reduce the effect of diversification in an insurance portfolio.

For over a decade now, institutional investors try to reduce risk by diversifying their portfolios with commodities. For example, gold can be a safe haven asset to this purpose.[2] Baur and Lucey (2009) make a distinction between a hedge, a diversifier and a safe haven asset. A hedge is an asset that is uncorrelated or even negatively correlated with another asset or portfolio. A diversifier is an asset that is positively (but, not perfectly) correlated with another asset or portfolio, and a safe haven is an asset that is uncorrelated or negatively correlated with another asset or portfolio *in*

[2]Another commodity is real estate. For example Chua (1999) studied the role of international real estate in a mixed-asset portfolio while attempting to control for higher taxes, transaction costs and asset management fees incurred when investing in real estate, as well as the appraisal smoothing in real estate return indices.

times of market stress and turmoil. In the case of a safe haven, correlations are different at times of large price falls on stock and bond markets.

Baur and Lucey (2009) analyze the role of gold in combination with stocks and bonds for the markets of the US, the UK and Germany. They find evidence that gold is a safe haven for stockholders, but not for bondholders. Baur and McDermott (2010) enlarged the study of Baur and Lucey (2009) to include other markets. However, they only looked at the relationship between gold and stocks, and not to the interactions between gold and bonds. They find that gold is a safe haven for the well-developed European countries and the US, but not for Japan, Australia, Canada and in the countries of Brazil, Russia, India and China (BRIC group), which are all deemed to be at a similar stage of newly advanced economic development. The acronym has come into widespread use as a symbol of the shift in global economic power away from the developed G7 economies towards the developing world.[3] Also oil can be seen as a safe haven. In times of a substantial price decreases on the stock markets not only gold, but also oil may increase in price.

Arouri and Nguyen (2010) examined oil–stock market relationships over the last turbulent decade. Steering clear previous empirical investigations, which have largely focused on broad-based national and regional market indices, they investigate short-term linkages on an aggregate level as well as on the sector by sector level in Europe. Their main finding is that the responses of stock returns to oil price changes differ greatly depending on the industry.

Geman and Karroubi (2008) look at the diversification effect brought by crude oil futures contracts into a portfolio of stocks. They prefer oil futures because it is the most liquid of commodity futures. However, introducing futures into the database introduces new problems. Firstly, the maturity of a future is limited. At a certain moment, one has to switch to a future with a longer maturity. Their finding is that, in the case of distant maturities futures (e.g., eighteen months), the negative correlation effect is more pronounced regardless whether stock prices increase or decrease. This property has the merit to avoid the hurdles of a frequent roll-over while being quite desirable in the current trendless equity markets.

11.3 The data

We study bond, stock, and oil returns. The period observed is 1989-2010. In this period, the general movement of the stock market was sometimes very positive while in other sub-periods the stock prices fell rapidly. In the nineteen eighties, stock prices showed positive economic development. After two oil crises in the seventies, the stock market began booming in the eighties. There was a large price fall in stock prices in October 1989 and again in October 1998. At the beginning of the 21st

[3] In 2005 Goldman Sachs defined The Next Eleven (or N-11). The N-11 are eleven countries—Bangladesh, Egypt, Indonesia, Iran, Mexico, Nigeria, Pakistan, Philippines, South Korea, Turkey and Vietnam—identified by Goldman Sachs investment bank as having a high potential of becoming, along with the BRICs, the world's largest economies in the 21st century.

century, we experienced the dot.com crisis and, in 2008, the global financial crisis. It is interesting to see if these different developments during the observed period also led to different optimal portfolios. Therefore we look at periods with a window of ten years, starting with 1989-1998, then 1990-1999, and finally 2001-2010.

In our study we are using the following daily data:

- US Treasury bonds 10 years
- Government bonds (code: MLUS10P)
- Standard and Poors (S & P) 500 (code: S19658)
- West Texas Intermediate (code: RWTC)

Our bond and stock indices are corrected to include interest and dividend payments. All data are priced in dollars. Therefore we have no currency problem.

There are several types of crude oil. For example, light, sweet crude is of greater use in production of gasoline, naphtha, propane and butane. Heavy sour crude is used mainly to produce heavy heating oil, asphalt and bitumen. Accordingly, the different types of crude require their own specific refineries and refining processes. Heavy sour crude needs more refinery processing than does the lightest and sweetest form, meaning that people are unwilling to pay as much for heavy sour crude as for light sweet crude. As a result, prices of the various types of oil differ. For that reason the price of West Texas Intermediate (WTI)crude will most of the time differ from, for instance, Dubai crude. It is understood that this difference does not remain steady over time, but varies as a result of many factors such as available refining capacity and reserves. Our choice to select the WTI Oil is arbitrary. Therefore, at times we will also check with the Brent Crude Oil.

Most oil contracts are bilateral between demanders and suppliers. Only a limited part is traded on the spot market. Therefore the price on the spot market is not a good indicator of the real oil price. As an alternative we use the WTI Oil futures prices. However, by using futures we are also introducing the problems of backwardation and contango. A commodity can switch from backwardation to contango and vice versa. (See, for example, Umutlu et al. (2011) in relation to the electricity market).

The data examined are values for the US treasury bonds (T bonds), which are an indicator of the risk free interest rate; government bonds for the bond market, the S&P 500 for the stock market and WTI Oil for the oil market. All data are denominated in US dollars.

Commodities are real goods, which makes them different from bonds and stocks. Arbitrage reduces possible price differences in bonds and stocks. If the prices of bonds or stocks in New York are higher than in London, arbitrageurs will sell in New York and buy in London till the price differences are (nearly) zero. The price of commodities, however, depends on location. Transport costs lead to price differences between locations that cannot be removed by arbitrage.
Another difference between commodities on one hand and stock and bonds on the other hand is that the price of commodities can have a seasonal component. In the case of oil we see a peak during the summer (driving season) and in the winter (heating).

The following hypotheses are tested.

H1: Oil is not a safe haven for stockholders and bondholders.

We expect that oil has zero or negative correlation with stocks and/or bonds during periods with negative stock and/or bond returns

H2: Oil is not a hedge for stockholders and bondholders.

We expect that oil has zero or negative correlation with stocks and/or bonds.

H3: The efficient frontier will not change when we add oil as an alternative investment opportunity for the component stocks and bonds.

We expect that adding oil to a portfolio of stocks and bonds will add value. In other words: the efficient frontier will change as for every point on the efficient frontier the risk becomes lower or the expected return becomes higher.

H4: The market portfolio of oil, bonds and stocks is constant during the observed period.

We expect that the weights in the optimal portfolio for oil, stocks and bonds will not change substantially during the observed period.

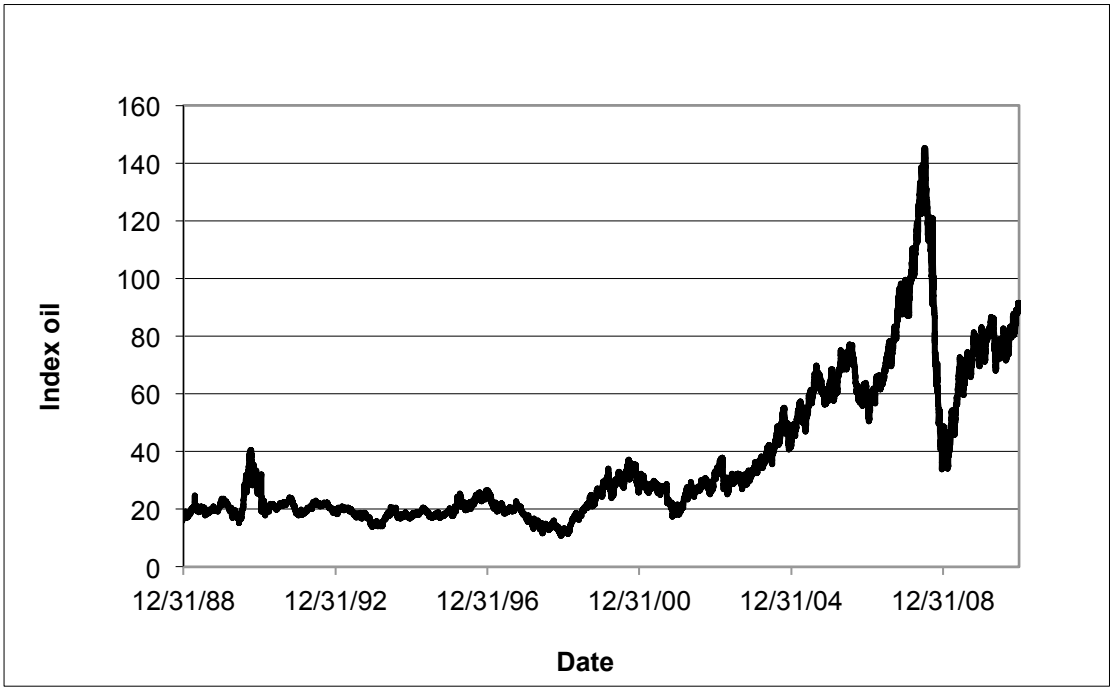
11.4 Empirical results

Before starting with the econometric analyses we will have a short look at the figures and descriptive analysis of bonds, stocks and oil individually. The reason for comparing the graphs of bonds, stocks and oil is that a quick scan can sometimes improve the econometric analyses. During the observed period the graph of the bond, Figure 11.1a, shows an upward trend for bonds caused by a global decreasing of the interest rate. During the period 1989-2010 the development of stocks (Figure 11.1b) and oil (Figure 11.1c) differ from the development of bonds. The graph of the stocks shows the effect of the internet crisis in 2001-2002 and the financial crisis in 2007-2008. The internet crisis in 2001-2002 had no influence on the price of the oil, but the financial crisis in 2007-2008 had. The time series presented in figure 11.1a (bonds), figure 11.1b (stocks) and figure 11.1c (oil) show substantial volatility. By comparing these figures we see sometimes a co-movement (financial crisis) in stocks and oil) and sometimes an independent development of the stock price and the oil price. Our general conclusion is that specific cyclical or counter cyclical patterns cannot be identified and neither can the potential for diversification.

Figure 11.1a The price development of bonds during the period 1989-2010.

Figure 11.1b The price development of stocks during the period 1989-2010.

Figure 11.1c The price development of oil during the period 1989-2010.



However, the individual evolution of each time series can be explained by market developments. Perusal of the price development of stocks (Figure 11.1b) reveals large prices decrease in 2000/2002 and again in 2007/2008. These periods refer to the internet crisis and the financial crisis respectively. During the internet crisis, oil prices did not move significantly, while during the financial crisis the oil price dropped dramatically. The bond prices in figure 11.1aexhibit a steady growth during the observed period. Only during the financial crisis the bond prices got hit substantially, but not as severely as the stock prices and the oil prices. As previously inferred, these figures lead to a mixed interpretation. It is not clear from inspection of these graphs, whether oil is a safe haven or a hedge for stock and/or bondholders.

The returns on oil prices, stock prices and bond prices are not normally distributed, because in all cases the minimum values of oil, stocks and bonds are zero. Therefore we use - in line with other researchers - the log-returns instead of normal returns to get distributions that are not capped. Table 11.1 contains a summary of the descriptive analysis of the log-returns on oil prices, stock prices and bond prices. In appendix A we give some of these statistics for each of the years of the observed periods.

Table 11.1 Descriptive statistics of the log returns of oil, stocks and bonds

Parameter	Bond	Stock	Oil
Number of observations	5741	5741	5741
Mean	0.032%	0.035%	0.029%
Std. Error of Mean	0.008%	0.015%	0.032%
Median	0.039%	0.033%	0.000%
Std. Deviation	0.581%	1.138%	2.448%
Variance	0.003%	0.013%	0.060%
Skewness	-0.20	-0.23	-0.94
Kurtosis	2.26	9.46	17.23
Jarque-Bera	1255.81	21462.71	71822.21
Hill estimator	3.6	3.2	2.7
Sum	181.891%	199.310%	166.779%
Minimum	-3.173%	-9.460%	-40.048%
Maximum	3.810%	10.958%	16.410%

Table 11.1 shows that during the observed period the mean values of bonds, stocks and oil do not differ much. However, the standard deviation of bonds is substantially lower than the standard deviation of stocks, which is again substantially lower than the standard deviation of oil. This ranking makes sense if one considers the relative riskiness of each instrument. The Hill estimator is used to determine whether or not there is obesity in the tails. The Hill estimator estimates the α-parameter of a Pareto distribution (see Kousky & Cooke (2009). Based on the log-return distributions, it becomes clear that neither stocks nor oil exhibit fat tails. Resnick (2007) finds that only when the log-returns are Pareto-distributed the Hill-estimator works well. In the cases of other distributions, Resnick finds that the results of the Hill-estimator are unstable. We find a Hill-estimator of α for bonds, stock and oil of 3.6, 3.2 and 2.7 respectively, which indicates that there is obesity in the tails.

The bond index shows a distribution close to the normal distribution. The kurtosis of the bond distribution is with 2.26 relatively low and the skewness, - 0.20, differs not much from zero. Also for the stock index we see a small skewness, - 0.23. However, the stock index exhibits a significant kurtosis of 9.46, more than three times that of a normal distribution. The departure from normality is even more significant for the oil index with a skewness of -0.94 and a kurtosis of 17.23. These departures from normality necessitate a further investigation for the appropriate distribution. We conclude that the bond distribution does not deviate much from the normal distribution, while the oil price cannot be described by a normal distribution. The stock index is somewhere in between.

In order to determine the efficient frontier and the optimal portfolio composition, conventional portfolio theory has been applied. The data have not been modeled with a probability density function (PDF), but the real data are used in the model. An analysis of the data shows that neither the stock, nor the bonds, and oil returns contained fat tails. The α's which have been determined for the various asset classes are well and above two, which indicates that there are no undefined first and second statistical moments. This proves that both the mean and the variance of the data are defined. For real fat tails these moments are not defined and the statistics change as more data are added. In case α would have been smaller than two, no stable variance

or standard variation would be available. The consequence of an undefined variance would be that the portfolio does not apply. Diversification and portfolio theory are based on the idea taking advantage of the difference in variance. Fat tails with undefined second moments (variance) smash the foundation on which the portfolio theory is built.

Using Oracle Crystal Ball software we learn that the log-distributions are not normal, but follow a student t-distribution. In the Markowitz portfolio theory the standard deviation of a portfolio is a function of the standard deviation, weights and correlations of the components of the portfolio. Also, in the case of a student t-distribution, this equation holds. In Table 11.2 we present the correlations between oil, stocks and bonds.

Table 11.2: The correlations between oil, stock and bonds during the period 1989-2010

Year	Bond-stock	Bond-oil	Stock-oil
1989	0.237	0.009	-0.014
1990	0.489	-0.289	-0.347
1991	0.395	-0.267	-0.243
1992	0.206	-0.045	0.060
1993	0.375	-0.055	-0.033
1994	0.616	-0.200	-0.181
1995	0.497	0.052	0.027
1996	0.612	0.007	-0.048
1997	0.236	0.013	-0.105
1998	-0.273	-0.043	0.080
1999	0.272	-0.087	-0.032
2000	-0.056	-0.152	-0.061
2001	-0.124	-0.060	-0.065
2002	-0.532	-0.183	0.147
2003	-0.330	0.141	-0.255
2004	-0.037	0.073	-0.099
2005	0.010	-0.022	-0.044
2006	0.101	0.022	0.006
2007	-0.385	-0.032	0.062
2008	-0.392	-0.300	0.258
2009	-0.298	-0.412	0.458
2010	-0.486	-0.368	0.651
1989-2010	-0.101	-0.143	0.055

Perusal of the results for the entire period 1989-2010 reveals that the correlation between bonds and stocks is negative (- 0.101). Also the correlation between bonds and oil is negative and even smaller. However, during the whole period the correlation between stocks and oil is positive (0.055).

The correlations are not constant during the observed period. In the cases of bonds and stocks, the correlation is negative in 10 years and positive in 12 years and moves between - 0.532 in 2002 and + 0.616 in 1994 respectively. In 15 of the 22 yearly observations the correlation between bonds and oil is negative and fluctuates from a minimum in 2009of – 0.412, to a maximum in 2003of + 0.141. The correlation between stocks and oil in 13 years is negative with a minimum of – 0.347 in 1990 and in 11 years, positive with a maximum of + 0.651 in 2010.

Next, in an optimisation exercise the ideal portfolio is determined in terms of returns for a given risk level. Different portfolio compositions with varying percentages of stocks, bonds, and oil are considered. For each composition the return and standard deviation is calculated according to portfolio theory. The total return is given by:

$$r = \sum w_i r_i \qquad (11.1)$$

in which r_i is the return of component i and w_i the percentage of component i with respect to the total portfolio. The variance of the total portfolio is

$$\sigma^2 = \sum_i w_i^2 \sigma_i^2 + 2\sum_{i \neq j} w_i \sigma_i w_j \sigma_j \rho_{ij} \qquad (11.2)$$

in which σ_i is the standard deviation of component i and the correlation ρ_{ij} between components i and j. The return is plotted against the standard deviation in a cluster of points in which each point is a certain composition. The efficient frontier follows from the upper line of this cloud of points. The market portfolio follows from the composition with the highest expected return-risk ratio in which the gain is the difference between the return of the portfolio and the return of US Treasury bonds.

After the quick scan of the individual graphs of bonds, stocks, and oil and the descriptive statistics of the individual variables, we now look at advanced modelling techniques that allow for the inclusion of fat tail phenomena, tail dependence, and micro-correlations are required. Due to the fact that we look at the attributive value of oil to a portfolio of bonds and stocks we take the oil price as response variable (dependent variable) and the bonds price and stock price as explanatory variables (independent variables). We also add to the equation quantile variables to test the influence of extreme variables.

To test hypothesis H1 we estimate the parameters of the following equation:

$$R(\text{oil}) = a + b_0 R(\text{stock},q100) + b_1 R(\text{stock},q10) + b_2 R(\text{stock},q5) + b_3 R(\text{stock},q1) + b_4 R(\text{bond},q100) + b_5 R(\text{bond},q10) + b_6 R(\text{bond},q5) + b_7 R(\text{bond},q1) + e \qquad (11.3)$$

Where:

R (oil) = the log-return of oil
R (stock, qx) = log return of stocks that are in the x% lower quantile
R (bond, qy) = log return of bonds that are in the y% lower quantile
e = error term

In case of a safe haven all the parameters b_0 ,…, b_7 have to be negative. A negative value means that the associated parameter is a hedge for oil.

Table 11.3 Oil as a safe haven for stockholders and /or bondholders

Parameter	Mean	t-value
a	0.001	1.802
b0	-0.066	-1.551
b1	-1.003	-0.984
b2	1.691	1.443
b3	-0.129	-0.105
b4	-0.363	-4.694
b5	-0.657	-0.333
b6	2.244	1.021
b7	-4.843	-1.549
Durbin-Watson	2.04	

In Table 11.3 we present the test results of Equation (11.3). Only b4 is significantly different from zero.[4] Therefore we do not reject hypothesis H1 (that *oil is not a safe haven for stockholders and bondholders*).When we apply the Brent Oil future (code: OILBREN) instead of the WTI future we obtain the same conclusions when testing hypothesis H1.

We use the following regression equationn to test our hypothesis H2 (that *oil is not a hedge for stockholders and bondholders*).

$$R\,(oil) = a + b_1\,R\,(stock) + b_2\,R\,(bond) + e \qquad (11.4)$$

Where:

R (oil) = the log-return of oil
R (stock) = log return of stocks
R (bond) = log return of bonds
e = error term

If oil is a hedge for stockholders and bondholders, the variables b_1 and b_2 are <= 0.

Table 11.4 Oil as a hedge for stockholders and /or bondholders

Parameter	Mean	t-value
a	0.000	1.390
b1	0.089	3.147
b2	-0.585	-10.597
Durbin-Watson	2.02	
Adjusted R^2	0.0222	

[4]The values found for R^2 are irrelevant for equation 11.3 since the function is only locally linear and not globally. Calculating the adjusted R only makes sense when the function is linear over the whole domain of variables.

Based on these results we reject hypotheses H2 (that *oil is not a hedge for stockholders and bondholders*) in case of stocks as well as bonds. Also in testing hypothesis H2 we used also Brent Oil instead of WTI. This replacement had no influence on our conclusions. In table 11.4, the adjusted R^2 is close to zero which means that the uncertainty of the coefficients a, b1 and b2 is high. Consequently, the conclusions regarding H2 are not reliable.

In Figure 11.2 we present the efficient frontier in the cases of stocks and bonds and stocks, bonds and oil respectively. Table 11.5 and Table 11.6 present for the various sub-periods the weights of the components in the market portfolio in case this portfolio does not contain respectively contains an investment in oil.

Figure 11.2 The efficient frontier for portfolios of stocks and bonds (lower graph) and the efficient frontier for portfolios of oil, stocks and bonds (top graph) over period 1989 till 2010

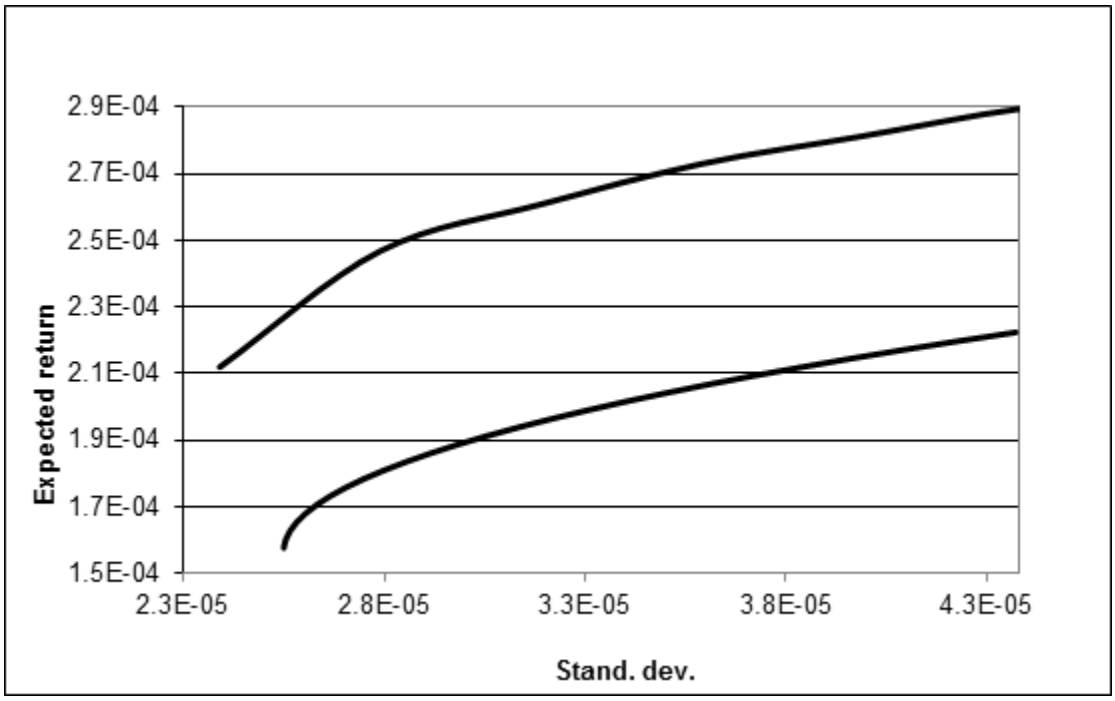


Table 11.5: The weights of stock and bonds in the market portfolio without oil for each of the sub-periods.

Period	Stock	Bond	Mean	Standard deviation	Expected return-risk ratio
1989-1998	27%	73%	4.9E-04	2.4E-05	19.8
1990-1999	31%	69%	4.2E-04	2.5E-05	15.7
1991-2000	25%	75%	4.3E-04	2.3E-05	17.4
1992-2001	24%	76%	3.5E-04	2.4E-05	13.7
1993-2002	20%	80%	3.4E-04	2.4E-05	13.5
1994-2003	24%	76%	3.2E-04	2.5E-05	12.0
1995-2004	23%	77%	3.7E-04	2.4E-05	14.9
1996-2005	23%	77%	2.9E-04	2.3E-05	11.7
1997-2006	22%	78%	2.9E-04	2.1E-05	13.1
1998-2007	22%	78%	2.6E-04	2.0E-05	12.2
1999-2008	14%	86%	2.5E-04	2.4E-05	10.0
2000-2009	16%	84%	2.3E-04	2.6E-05	8.4
2001-2010	21%	79%	2.0E-04	2.6E-05	7.5
1989-2010	24%	76%	3.2E-04	2.5E-05	12.9

Table 11.6: The weights of oil, stock and bonds in the market portfolio for each of the sub-periods.

Period	Oil	Stock	Bond	Mean	Standard deviation	Expected return-risk ratio
1989-1998	4%	27%	69%	4.6E-04	2.2E-05	20.6
1990-1999	5%	30%	65%	4.0E-04	2.3E-05	16.8
1991-2000	4%	24%	72%	4.1E-04	2.2E-05	18.1
1992-2001	4%	23%	73%	3.4E-04	2.3E-05	14.2
1993-2002	5%	18%	77%	3.4E-04	2.2E-05	14.2
1994-2003	6%	22%	72%	3.2E-04	2.3E-05	13.0
1995-2004	5%	22%	73%	3.7E-04	2.2E-05	15.8
1996-2005	6%	22%	72%	2.9E-04	2.2E-05	12.8
1997-2006	5%	21%	74%	2.9E-04	2.0E-05	14.0
1998-2007	7%	20%	73%	2.8E-04	1.9E-05	14.0
1999-2008	7%	12%	81%	2.7E-04	2.3E-05	11.5
2000-2009	7%	14%	79%	2.5E-04	2.4E-05	9.7
2001-2010	8%	17%	75%	2.3E-04	2.5E-05	8.9
1989-2010	6%	21%	73%	3.2E-04	2.2E-05	14.0

Figure 11.2 shows that adding oil to a portfolio of stocks and bonds means that the efficient frontier moves upwards. From Tables11.5 we see that the optimal portfolio without oil has 24% stocks, 76% bonds, an expected return of 0.0032, a standard deviation of 0.000025 and an expected return-risk ratio of 11.9. The optimal portfolio with oil, Table 11.6, has6% oil, 21% stocks, 73% bonds, an average return of 0.00032, a standard deviation of 0.000022 and an expected return-risk ratio of 14.0. Comparing the two portfolios, we see a small reduction of risk and a small(nearly zero) increment of return when we add oil to the portfolio. When we apply oil Brent future (code: OILBREN)instead of WTI(see appendix Table A4 and A5) we see that the optimal portfolio with oil has 8% oil, 15% stocks, 77% bonds, an average return of 0.000189 a standard deviation of 0.0000254 and an expected return-risk ratio of 7.1. The addition of Oil Brent futures exhibits a greater change in the efficient frontier.

Our third hypothesis is *H3 (that the efficient frontier will not change when we add oil as an alternative investment opportunity for the components stocks and bonds).*
Based on our results we accept this hypothesis. Holders of portfolios of stocks and bonds can improve their expected return –risk ratio by adding oil to their portfolio.

To test our fourth hypothesis, (*that the market portfolio of oil, bonds and stocks is constant during the observed period*), we examine the weights of the portfolios for every sub-period of ten years. We started with the period 1989-1998, then 1990-1999, etc. till 2001-2010. In Table 11.5 and Table 11.6we present also the weights of oil, stock and bonds for these sub-periods. The weight of oil moves from 4% (several sub-periods) to 8% (2001-2010). We do not reject the fourth hypothesis. Holders of portfolios of stocks and bonds who want to diversify their portfolio with oil could opt for a 6% oil, 21% stock and 73% bond split. This distribution is more or less stable during the observed period.

11.5 Summary and conclusions

Over the last two decades, institutional investors have been diversifying their portfolios by including therein investments in commodities. One of the main commodities is oil. For benchmark reasons the market also developed commodity indices.

In this chapter we have looked at the impact of adding oil to a portfolio made up of stocks and bonds on the set of efficient portfolios. To derive the set of efficient portfolios, three value based indices have been used: Government bonds S&P 500 for stocks and West Texas Intermediate for oil. Our choice of a value based index for stocks and bonds is based on the same rationale as for the CRISP data base, namely to avoid the complex tax treatment of dividend and interest payments.

The conclusions are as follows:

1. Not with standing adding oil to a portfolio of stocks and/or bonds mitigates the negative portfolio returns in case of extreme negative stock and/or bond returns, oil is not a safe haven.

2. However, a second finding shows that although oil cannot be considered as a safe haven, oil can serve as a hedge for both stocks and bonds.

3. Finally, adding oil to a portfolio of stocks and bonds improves the risk-return trade-off of the efficient frontier. So, for a fixed expected return we get less risk and/or for a fixed risk we get more expected return.

4. During the period 2001-2010 the distribution of oil (6%), stocks (21%) and bonds (73%) in the portfolio are more or less stable.

During the observed period 1989-2011 the markets were confronted with a serious price falls. These occurred in the option markets in 1989, the internet crisis in 2001-2002 and the financial crisis in 2007-2008 and the euro-crisis in 2010-2011. The impact of the first two crises on the real world was limited, while the last two crises seriously damaged global markets and therefore affected also the oil price.

Also we see that emerging markets (for example the BRIC and next-11 countries) and commodity countries like Australia show a different economic development than the mature countries in Europe and the US. This study was limit to US-based data. Further study has to show whether the results found in this chapter also can be found for other periods and other countries.

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Appendix A

Table A1 Descriptive statistics of the daily log returns of oil for every year during the observed period 1989-2010

Year	Mean	Median	Standard deviation	Minimum	Maximum
1989	0.0906%	0.1555%	2.1807%	-14.5131%	8.6385%
1990	0.1015%	0.0000%	3.7504%	-17.4480%	13.5724%
1991	-0.1521%	0.0000%	3.5109%	-40.0478%	12.6819%
1992	0.0075%	0.0000%	1.2312%	-7.1345%	4.9381%
1993	-0.1223%	-0.1450%	1.5353%	-6.7555%	4.7982%
1994	0.0869%	0.0841%	1.7942%	-7.1924%	6.5426%
1995	0.0369%	0.0000%	1.2575%	-6.2365%	3.3114%
1996	0.1076%	0.2204%	2.4417%	-9.1199%	9.4076%
1997	-0.1475%	-0.1136%	1.7758%	-4.5261%	5.3060%
1998	-0.1460%	-0.1789%	2.8957%	-11.5463%	14.2309%
1999	0.2887%	0.3224%	2.1848%	-7.1541%	6.5372%
2000	0.0176%	0.1779%	2.6968%	-12.9400%	8.1129%
2001	-0.1152%	0.0000%	2.6915%	-16.5445%	8.0748%
2002	0.1735%	0.0767%	2.1525%	-6.2753%	6.1330%
2003	0.0159%	0.0000%	2.4389%	-11.5404%	6.3004%
2004	0.1106%	0.1609%	2.2517%	-7.6977%	5.9621%
2005	0.1307%	0.0707%	1.9894%	-4.8965%	6.7362%
2006	0.0001%	0.0474%	1.7194%	-4.3478%	5.2189%
2007	0.1734%	0.1233%	1.9171%	-4.7942%	7.3689%
2008	-0.2925%	-0.0707%	3.8357%	-12.5952%	16.4097%
2009	0.2208%	0.1269%	3.3682%	-13.0654%	13.1363%
2010	0.0540%	0.0000%	1.7110%	-5.1170%	4.1633%
1989-2010	0.0291%	0.0000%	2.4480%	-40.0478%	16.4097%

Table A2 Descriptive statistics of the daily log returns of stocks for every year during the observed period 1989-2010

Year	Mean	Median	Standard deviation	Minimum	Maximum
1989	0.1059%	0.1212%	0.8132%	-6.3115%	2.7386%
1990	-0.0121%	0.0812%	0.9976%	-3.0432%	3.1761%
1991	0.1019%	0.0000%	0.8850%	-3.7257%	3.6641%
1992	0.0280%	0.0073%	0.6008%	-1.8685%	1.5541%
1993	0.0368%	0.0038%	0.5341%	-2.4129%	1.9198%
1994	0.0050%	0.0159%	0.6095%	-2.2425%	2.1409%
1995	0.1227%	0.0864%	0.4852%	-1.5499%	1.8609%
1996	0.0789%	0.0381%	0.7315%	-3.1307%	1.9289%
1997	0.1103%	0.1062%	1.1271%	-7.1130%	4.9894%
1998	0.0963%	0.1090%	1.2595%	-7.0419%	4.9708%
1999	0.0732%	0.0000%	1.1178%	-2.8456%	3.4830%
2000	-0.0367%	-0.0134%	1.3780%	-6.0044%	4.6673%
2001	-0.0485%	0.0000%	1.3233%	-5.0114%	4.9007%
2002	-0.0957%	-0.1406%	1.6073%	-4.2408%	5.5754%
2003	0.0966%	0.1008%	1.0552%	-3.5859%	3.4849%
2004	0.0394%	0.0474%	0.6855%	-1.6416%	1.6229%
2005	0.0184%	0.0496%	0.6378%	-1.6857%	1.9557%
2006	0.0564%	0.0789%	0.6211%	-1.8489%	2.1379%
2007	0.0205%	0.0590%	0.9901%	-3.5255%	2.9009%
2008	-0.1763%	0.0000%	2.5385%	-9.4595%	10.9582%
2009	0.0900%	0.1428%	1.6869%	-5.4254%	6.8575%
2010	0.0538%	0.0741%	1.1184%	-3.9657%	4.3064%
1989-2010	0.0347%	0.0336%	1.1382%	-9.4595%	10.9582%

Table A3 Descriptive statistics of the daily log returns of bonds for every year during the observed period 1989-2010

Year	Mean	Median	Standard deviation	Minimum	Maximum
1989	0.0666%	0.0626%	0.4691%	-1.6727%	2.0513%
1990	0.0240%	0.0000%	0.5317%	-2.1669%	1.6311%
1991	0.0648%	0.0478%	0.4391%	-1.3497%	1.8120%
1992	0.0292%	0.0232%	0.4097%	-0.9646%	1.3717%
1993	0.0609%	0.0460%	0.4592%	-1.2375%	1.2663%
1994	-0.0297%	0.0000%	0.6101%	-3.1343%	2.0846%
1995	0.1029%	0.0584%	0.4956%	-1.6156%	1.8163%
1996	-0.0038%	0.0000%	0.5941%	-2.8071%	1.4998%
1997	0.0534%	0.0526%	0.4714%	-1.6538%	1.7770%
1998	0.0487%	0.0395%	0.5241%	-2.1514%	1.4138%
1999	-0.0345%	-0.0291%	0.5348%	-1.8114%	1.3261%
2000	0.0707%	0.0877%	0.4809%	-1.2402%	1.4957%
2001	0.0158%	0.0326%	0.6475%	-2.1747%	2.1312%
2002	0.0594%	0.0951%	0.6000%	-1.7950%	1.7745%
2003	0.0094%	0.0812%	0.6627%	-2.0644%	1.7125%
2004	0.0283%	0.0455%	0.5329%	-2.1188%	1.8362%
2005	0.0241%	0.0444%	0.4551%	-1.4505%	1.0420%
2006	0.0072%	0.0422%	0.3809%	-1.0720%	1.1992%
2007	0.0362%	0.0146%	0.4960%	-1.4191%	1.7360%
2008	0.0832%	0.0475%	0.8467%	-3.1728%	2.8990%
2009	-0.0535%	0.0138%	0.9465%	-2.7796%	3.8105%
2010	0.0342%	0.0182%	0.8117%	-2.4081%	2.6871%
1989-2010	0.0317%	0.0385%	0.5815%	-3.1728%	3.8105%

Table A4 The weights of oil. stock and bonds in the market portfolio for each of the sub-periods

Period	Oil	Stock	Bond	Mean	Standard deviation	Expected return-risk ratio
1989-1998	4%	27%	69%	4.6E-04	2.1E-05	20.7
1990-1999	5%	30%	65%	4.0E-04	2.3E-05	16.8
1991-2000	3%	25%	72%	4.1E-04	2.2E-05	17.9
1992-2001	4%	23%	73%	3.4E-04	2.3E-05	14.2
1993-2002	5%	18%	77%	3.4E-04	2.3E-05	14.1
1994-2003	5%	23%	72%	3.2E-04	2.4E-05	12.8
1995-2004	4%	22%	74%	3.7E-04	2.3E-05	15.7
1996-2005	5%	22%	73%	2.9E-04	2.2E-05	12.7
1997-2006	5%	21%	74%	2.9E-04	2.0E-05	14.0
1998-2007	7%	20%	73%	2.8E-04	1.9E-05	14.1
1999-2008	7%	13%	80%	2.7E-04	2.3E-05	11.3
2000-2009	8%	14%	78%	2.5E-04	2.4E-05	9.7
2001-2010	10%	17%	73%	2.4E-04	2.5E-05	9.3
1989-2010	6%	22%	72%	3.2E-04	2.2E-05	14.1