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Professor Eric Jondeau

FIN-429

Portfolio allocation on

“Energy firms with available scope 1 to 3 emissions.”

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Market foundation:

In this assignment we explore the behavior of the energy sector including portfolio volatilities, returns and tradeoffs among them.  Before diving into a detailed analysis, we need to understand the characteristics of energy stocks. The energy sector covers firms that produce and/or distribute energy. It spans from the exploration, drilling, and refining of fossil fuels to the development of renewable sources. Energy stocks are quite volatile because they largely depend on the supply and demand of energy commodities and the resulting prices, which, in turn, tend to be cyclical and highly sensitive to political events.

As such, the energy sector is directly linked to economic and political developments, resulting in a cyclical nature with extreme ups and downs. Current events such as the Ukrainian war and the pandemic have shown how sensitive the global supply and trade of energy is, which is partly due to countries being highly interdependent. Finally, future regulatory policies in terms of the renewable energy transition are another pillar that highly distinguishes energy stocks from other stocks.

Question 1

*Compute and report the* ***annualized average return*** *and* ***annualized volatility*** *for all individual assets over the period 2005-2020. Compute the correlation between individual average returns and volatility and comment on the observed correlation. (10 points)*

The mean annualized average return of all assets is ~11.45%, while the mean volatility lies at ~44% for a time span of 15 years. This results in a correlation rate of 0.106. Return and volatility have a weak positive correlation, suggesting that with the increasing risk taken by the investor, the return on the stock increases as well. The numbers show that an investor who is investing in a portfolio of energy stocks faces high risk due to large fluctuations in a short period of time, which is possibly caused by economic, political, and legal developments. The correlation rate shows a positive but weak correlation between volatility and risk.

Graph: Volatility and Return

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The blue line is the confidence interval / change x-y

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*Fig 1: Annualized Average Return of individual energy stocks from 2005 until 2020*

*Fig 2: Volatility of individual energy stocks from 2005 until 2020*

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Question 2

*Form an equally-weighted and value-weighted portfolio with monthly rebalancing over the period 2005-2020. Report the following statistics for both portfolios: annualized average return, annualized volatility, minimum return, maximum return, and Sharpe ratio. Plot the time series of returns for both portfolios. (15 points)*

Note that we use a 3.5% risk-free rate, based on the 10-year U.S. Treasury Rate on 16.03.2023.

|  |  |  |
| --- | --- | --- |
| **Portfolio** | **Value—weighted portfolio** | **Equally—weighted portfolio** |
| Annualized average return | 6.779% | 11.45% |
| Annualized volatility | 22.612% | 46.614% |
| Minimum return | -45.433% | -60.125% |
| Maximum return | 50.262% | 76.213% |
| Sharpe Ratio | 0.145 | 0.171 |

*Figure 2: Portfolio characteristics.*

The value-weighted portfolio has an annualized average return of 6.78% and an annualized volatility of 22.61%. In comparison, the equally-weighted portfolio has an annualized average return of 11.45% and an annualized volatility of 46.61%. The Sharpe ratio, which measures the excess return per unit of risk, is 0.145 for the value-weighted portfolio and 0.171 for the equally-weighted portfolio. The higher average return of the equally-weighted portfolio can be explained by the fact that it includes smaller companies with potentially higher returns than larger, more established firms. This is consistent with the size premium, where smaller stocks tend to outperform larger stocks over the long-term. Additionally, the equally-weighted portfolio may be more exposed to certain factors that have historically generated higher returns, such as value or momentum.

Moreover, the higher volatility of the equally-weighted portfolio can be explained by its lack of diversification compared to the value-weighted portfolio. The value-weighted portfolio assigns more weight to larger, more established companies, as previously stated, which tend to be less volatile than smaller, less established firms. Following this logic, the equally-weighted portfolio may be more sensitive to market movements, as small changes in the prices of individual stocks can have a more significant impact on the overall portfolio. In contrast, the value-weighted portfolio may be more resilient to such movements due to its constituents of larger, more stable stocks. This is consistent with the efficient market hypothesis, which states that in a well-functioning market, investors will demand higher returns to compensate for higher risk. The Sharpe ratio, which measures the excess return per unit of risk, is higher for the equally-weighted portfolio. This suggests that the equally-weighted portfolio provided a higher return per unit of risk compared to the value-weighted portfolio.

Regarding the dip in annual returns for both portfolios in 2007-2009, it is due to a combination of macroeconomic factors such as the global financial crisis, which led to a significant decline in energy prices and demand, punishing energy firms. This is consistent with the concept of systematic risk. Additionally, former president Barack Obama’s promise meet the global environmental challenges during his 2008 election may have caused regulatory and political uncertainty causing a decline in returns for energy firms during this period.

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Automatisk generert beskrivelse *Figure 3: Annual Portfolio Return 2005-2020.*

The value-weighted portfolio exhibits a lower annualized average return. This portfolio construction method suffers from a common bias in behavioral economics: the failure to account for regression to the mean. As Daniel Kahneman, one of the fathers of behavioral economics, argued in his 2011 book *Thinking, Fast and Slow*, investors and decision-makers fail to account for regression to the mean. Regression to the mean describes that if a variable is extreme at the time of measurement, it will be closer to an average trend at the time of the subsequent measurement. The upward and downward movements of objects that have intrinsic volatility, like stocks, tend to go back to a mean value or trend. With the value-weighted portfolio, we are favoring stocks whose capitalization increases (winners) and punishing stocks whose valuation decreases (losers). Due to regression to the mean, the deviations will likely resort back to a less extreme value. “Winner” stocks’ valuation may then (due to statistical probability) decrease after a spike, resulting in smaller returns for the value-weighted investor. Conversely, “loser” stocks’ returns may increase with a probable capitalization increase after a momentary fall – but these returns will not be fully captured since the monthly rebalancing will have decreased the weight given to losers.

Question 3

*For this question, limit your set of firms to 100 randomly selected firms. Pay a particular attention to the construction of the covariance matrix. Build an optimal portfolio with minimum variance with monthly rebalancing over the period 2005-2020. Report the following statistics: annualized average return, annualized volatility, minimum return, maximum return, and Sharpe ratio. Comment on the reported statistics in comparison with the equally-weighted and value-weighted portfolio. (20 points)*

To compute the minimum variance portfolio, we used the formula provided in class, which states that the optimal weights for minimal variance are given by:

𝛼∗=Σ−1ee′Σ−1e

However, we found negative weights by simply applying this formula. The sum of the weights for a given month was still equal to 1, but negative weights mean that our portfolio shorts some assets. While this isn’t technically wrong, we tried to assume that there was no shorting and that weights all had to be bound between [0, 1]. To do so, we used the scipy library to solve an optimization problem to minimize the variance of the portfolio through the following formula (also from the class) as an objective (with sum=1 and non-negativity as constraints):

min𝛼⁡𝜎p2 = 𝛼′Σ𝛼

Since the weights 𝛼  are rebalanced monthly, each month necessitates its own covariance matrix Σ . Otherwise, the weights would have been the same for all months since the only way that changes in returns are captured is through the covariance matrix. So, to get the weights that apply to January 2015, we use the covariance matrix of returns in the 120 preceding months – the same applies for February 2015, and so on until December 2020.

Here are the statistics we observed by implementing this portfolio:

|  |  |
| --- | --- |
| **AAR:** | 4.735% |
| **Annualized volatility:** | 6.517% |
| **Min yearly return:** | 1.861% |
| **Max yearly return:** | 7.906% |
| **Sharpe ratio:** | 0.014 |

*Figure 4: Key characteristics.*

The volatility has indeed decreased significantly compared to our value-weighted and equally-weighted portfolios. Accordingly, the spread between the minimum and maximum yearly returns has also decreased. Interestingly, the minimum yearly return (1.86%) remained positive. Even though the timeframe was only 6 years (2015-2020), this may be attractive to risk-averse investors. However, William Sharpe would disapprove of the portfolio, as his ratio is low. This suggests that the amount of returns that investors can expect is unattractive compared to the volatility they will suffer, even though it is minimized. Of course, this assumes a risk-free rate of 3.5%. One would prefer a portfolio returning 3.5% for negligible volatility than another portfolio returning 4.73% for 6.5% volatility.

Further comparison among the three portfolios is offered in our answer to question 5.

Question 4

*For this question, keep the same randomly selected firms from the previous point. Build an optimal portfolios with various target portfolio returns (e.g., from 2% to 16% with 2% increments). Plot the efficient frontier as well as the individual assets. Which portfolio is the most efficient in terms of Sharpe ratio? (15 points)*

Question 5

*Choose an appropriate benchmark, which corresponds to the region of your dataset. Compare the performance of your portfolios (equally-weighted, value-weighted, and minimum variance) with the benchmark. Comment on the differences. (10 points)*

As suggested by Prof. Jondeau, we will use our own value-weighted portfolio as the benchmark as it is a good proxy. First, the figure below plots the annual returns of each portfolio for the years 2015 to 2020.

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Automatisk generert beskrivelse *Figure ?: Portfolio performance 2015-2020*

The value-weighted portfolio, our benchmark, shows annual returns spanning from –5% to 10% with a decreasing trend from 2016 onwards. As expected, the graph shows a much more stable line for the minimum variance portfolio than for the two other portfolios over the 2015-2020 period. Its trend is relatively flat, with annual returns remaining around 5%. This portfolio also has an attractive quality in that over the timeframe studied, its annual return was always positive. Conversely, the equally-weighted portfolio is extremely volatile, as expressed by its annualized volatility of 47.318% (see table below). Over this timeframe, it may however have been more attractive to investors with a larger risk appetite, as the volatility is compensated for by a significantly higher annualized average return.

|  |  |  |  |
| --- | --- | --- | --- |
| **Portfolio** | **Value—weighted portfolio** | **Equally—weighted portfolio** | **Minimum variance portfolio** |
| Annualized average return | 2.648% | 11.45% | 4.735% |
| Annualized volatility | 13.013% | 47.318% | 6.517% |
| Minimum return | -4.293% | -11.891% | 1.861% |
| Maximum return | 9.849% | 16.21% | 7.906% |
| Sharpe Ratio | -0.126 | 0.157 | 0.014 |

Figure 6: Key *characteristics*.

When evaluating the tradeoff between returns and volatility with the Sharpe Ratio, both the equally-weighted and the minimum variance portfolios beat the value-weighted portfolio, our benchmark. Even though the volatility of the equally-weighted portfolio is substantial, the annualized average returns beat both other portfolios by a large margin, rewarding its Sharpe Ratio. All Sharpe Ratios however remain low relative to what can typically be expected on markets. This is probably due to the volatility associated with the energy sector and with the limited timeframe analyzed for this exercise.

Question 6

*Compute and comment on the simple correlation between returns, volatility, size. (10 points)*

The Figure … shows the weak negative correlation between annualized average return and Capitalization. This suggests that when the stock decreases,…???

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Question 7

*For this question, take the same 100 selected firms. You now create a minimum variance portfolio with monthly rebalancing with an additional constraint: you exclude the smallest firms (bottom tercile of the distribution of the firms’ market capitalization in month t − 1). Report summary statistics on the performance of this portfolio and comment on the differences with the minimum variance from point 3. (20 points)*