Tracking Error

Tracking error is a measurement used to evaluate the performance of an investment or portfolio relative to a benchmark or target. It quantifies the extent to which the returns of the investment or portfolio deviate from the returns of the benchmark.

The concept of tracking error is applicable to various investment vehicles, including mutual funds, index funds, hedge funds, and ETFs. It is used to assess how closely an investment vehicle replicates the performance of its benchmark.

Tracking error is typically calculated as the standard deviation of the difference between the investment's returns and the benchmark's returns over a specific period of time. A low tracking error indicates that the investment closely tracks the benchmark, while a high tracking error suggests a greater divergence.

Several factors contribute to tracking error. One key factor is the investment manager's ability to accurately replicate the benchmark. This involves selecting appropriate securities or assets that closely resemble the constituents of the benchmark. In the case of actively managed funds, tracking error may arise from the manager's intentional deviations from the benchmark to achieve outperformance.

Transaction costs, such as brokerage fees and bid-ask spreads, can also impact tracking error. Rebalancing the portfolio or making adjustments to holdings incurs costs that can contribute to deviations from the benchmark.

Additionally, tracking error can be influenced by differences in expenses, dividend reinvestment policies, and cash holdings between the investment and the benchmark. Corporate actions, such as stock splits or mergers, can also introduce tracking differences.

Investors and fund managers monitor tracking error to evaluate the effectiveness of an investment strategy and to assess the fund manager's ability to deliver returns in line with the benchmark. A low tracking error suggests a more accurate replication of the benchmark and may be preferred by investors seeking close alignment with the benchmark's performance.

However, tracking error should not be considered in isolation. Other factors, such as expenses, risk measures, investment style, and the fund manager's expertise, should also be evaluated when selecting an investment vehicle.

In summary, tracking error provides insights into the consistency and accuracy with which an investment vehicle replicates its benchmark. By understanding the factors that contribute to tracking error, investors can make informed decisions and assess the potential risks and returns associated with an investment relative to its benchmark.

In [104]:

```python
# library
import yfinance as yf
import numpy as np
import pandas as pd
import matplotlib.pyplot as plt
%matplotlib inline
import seaborn as sns
```

In [105]:

```
# Define the ticker symbol for VOO
ticker_symbol = "VOO"

# Historical
VOO_data = yf.download(ticker_symbol, period="4y")

# Add the Ticker
VOO_data['Ticker'] = ticker_symbol
print(VOO_data.head())
```

```
[*********************100%***********************]  1 of 1 completed
                  Open        High         Low       Close   Adj Close  \
Date
2019-06-17  265.940002  266.559998  265.619995  265.859985  248.497894
2019-06-18  267.649994  269.660004  267.299988  268.510010  250.974869
2019-06-19  268.739990  269.720001  267.760010  269.220001  251.638428
2019-06-20  271.940002  272.190002  269.730011  271.730011  253.984573
2019-06-21  271.529999  272.790009  271.170013  271.410004  253.685455

             Volume Ticker
Date
2019-06-17  1782500    VOO
2019-06-18  2340700    VOO
2019-06-19  1684500    VOO
2019-06-20  3288100    VOO
2019-06-21  2226000    VOO
```

In [106]:

```
ticker_symbol = "^GSPC"
GSPC_data = yf.download(ticker_symbol, period="4y")
GSPC_data['Ticker'] = ticker_symbol
print(GSPC_data.head())
```

```
[*********************100%***********************]  1 of 1 completed
                   Open         High          Low        Close    Adj Clos
e  \
Date
2019-06-17  2889.750000  2897.270020  2887.300049  2889.669922  2889.66992
2
2019-06-18  2906.709961  2930.790039  2905.439941  2917.750000  2917.75000
0
2019-06-19  2920.550049  2931.739990  2911.429932  2926.459961  2926.45996
1
2019-06-20  2949.600098  2958.060059  2931.500000  2954.179932  2954.17993
2
2019-06-21  2952.709961  2964.149902  2946.870117  2950.459961  2950.45996
1

                Volume Ticker
Date
2019-06-17  2828400000  ^GSPC
2019-06-18  3441540000  ^GSPC
2019-06-19  3300220000  ^GSPC
2019-06-20  3943060000  ^GSPC
2019-06-21  5003540000  ^GSPC
```

In [107]:

```
# Calculate the percentage variation of 'Close' for 'VOO_data'
VOO_data['Percen_Diff_VOO'] = VOO_data.groupby('Ticker')['Close'].pct_change() * 100
VOO_data.dropna(subset=['Percen_Diff_VOO'], inplace=True)
print(VOO_data)
```

```
                  Open        High         Low       Close   Adj Close  \
Date
2019-06-18  267.649994  269.660004  267.299988  268.510010  250.974869
2019-06-19  268.739990  269.720001  267.760010  269.220001  251.638428
2019-06-20  271.940002  272.190002  269.730011  271.730011  253.984573
2019-06-21  271.529999  272.790009  271.170013  271.410004  253.685455
2019-06-24  271.589996  271.920013  270.899994  271.059998  253.358322
...                ...         ...         ...         ...         ...
2023-06-12  395.980011  398.690002  395.299988  398.660004  398.660004
2023-06-13  400.019989  401.850006  399.399994  401.290009  401.290009
2023-06-14  401.609985  403.440002  398.459991  401.600006  401.600006
2023-06-15  401.000000  407.929993  400.890015  406.750000  406.750000
2023-06-16  408.690002  408.739990  406.160004  406.920013  406.920013

             Volume Ticker  Percen_Diff_VOO
Date
2019-06-18  2340700    VOO         0.996774
2019-06-19  1684500    VOO         0.264419
2019-06-20  3288100    VOO         0.932327
2019-06-21  2226000    VOO        -0.117767
2019-06-24  3518400    VOO        -0.128958
...             ...    ...              ...
2023-06-12  3792700    VOO         0.918919
2023-06-13  3913100    VOO         0.659711
2023-06-14  5161300    VOO         0.077250
2023-06-15  5265600    VOO         1.282369
2023-06-16  2069340    VOO         0.041798

[1008 rows x 8 columns]
```

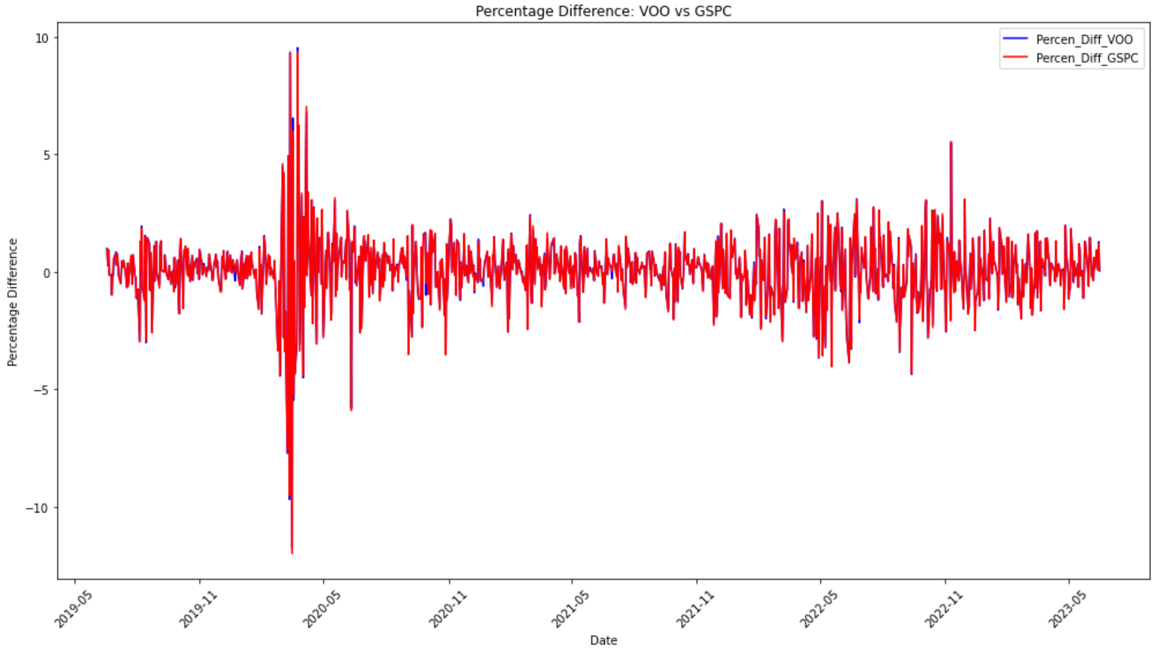
In [108]:

```
# Calculate the percentage variation of 'Close' for 'GSPC_data'
GSPC_data['Percen_Diff_GSPC'] = GSPC_data.groupby('Ticker')['Close'].pct_change() * 1
GSPC_data.dropna(subset=['Percen_Diff_GSPC'], inplace=True)
print(GSPC_data)
```

```
                   Open         High          Low        Close    Adj Clos
e  \
Date
2019-06-18  2906.709961  2930.790039  2905.439941  2917.750000  2917.75000
0
2019-06-19  2920.550049  2931.739990  2911.429932  2926.459961  2926.45996
1
2019-06-20  2949.600098  2958.060059  2931.500000  2954.179932  2954.17993
2
2019-06-21  2952.709961  2964.149902  2946.870117  2950.459961  2950.45996
1
2019-06-24  2951.419922  2954.919922  2944.050049  2945.350098  2945.35009
8
...                 ...          ...          ...          ...
...
2023-06-12  4308.319824  4340.129883  4304.370117  4338.930176  4338.93017
6
2023-06-13  4352.609863  4375.370117  4349.310059  4369.009766  4369.00976
6
2023-06-14  4366.290039  4391.819824  4337.850098  4372.589844  4372.58984
4
2023-06-15  4365.330078  4439.200195  4362.600098  4425.839844  4425.83984
4
2023-06-16  4440.950195  4448.470215  4421.160156  4428.390137  4428.39013
7

                Volume  Ticker  Percen_Diff_GSPC
Date
2019-06-18  3441540000   ^GSPC          0.971740
2019-06-19  3300220000   ^GSPC          0.298516
2019-06-20  3943060000   ^GSPC          0.947219
2019-06-21  5003540000   ^GSPC         -0.125922
2019-06-24  3136960000   ^GSPC         -0.173189
...                ...     ...               ...
2023-06-12  3945670000   ^GSPC          0.932115
2023-06-13  4275400000   ^GSPC          0.693249
2023-06-14  4252110000   ^GSPC          0.081943
2023-06-15  4176690000   ^GSPC          1.217814
2023-06-16  1225649000   ^GSPC          0.057623

[1008 rows x 8 columns]
```

In [109]:

```python
# Select the desired date range (4-year period)
start_date = '2019-06-18'
end_date = '2023-06-16'
voo_data_range = VOO_data.loc[start_date:end_date]
gspc_data_range = GSPC_data.loc[start_date:end_date]

# Line chart size
plt.figure(figsize=(14, 8))

# Plot the Percen_Diff_VOO
plt.plot(voo_data_range.index, voo_data_range['Percen_Diff_VOO'], label='Percen_Diff_

# Plot the Percen_Diff_GSPC
plt.plot(gspc_data_range.index, gspc_data_range['Percen_Diff_GSPC'], label='Percen_Di

# Set the X-axis tick labels to show every 6 months
plt.xticks(rotation=45)
plt.gca().xaxis.set_major_locator(plt.matplotlib.dates.MonthLocator(interval=6))
plt.gca().xaxis.set_major_formatter(plt.matplotlib.dates.DateFormatter('%Y-%m'))

# Title
plt.title('Percentage Difference: VOO vs GSPC')
plt.xlabel('Date')
plt.ylabel('Percentage Difference')
plt.legend()
plt.tight_layout()
plt.show()
```



This close in volatility is expected as the aim of the fund Vanguard is to replicate the S&P500 index. We will use the tracking error now to check how much the fund's returns deviate from the benchmark.

The formula to calculate the tracking error is as follows:

Tracking Error = Standard Deviation(Returns of the Fund - Returns of the Benchmark)

Here's a step-by-step breakdown of the formula:

1 - Calculate the returns of the fund by taking the percentage change in its value over a specific period. Fund Returns = (Fund Price at End - Fund Price at Start) / Fund Price at Start

2 - Calculate the returns of the benchmark index using the same period. Benchmark Returns = (Benchmark Price at End - Benchmark Price at Start) / Benchmark Price at Start

3 - Calculate the difference between the fund returns and benchmark returns. Difference = Fund Returns - Benchmark Returns

4 - Calculate the standard deviation of the difference to determine the tracking error. Tracking Error = Standard Deviation(Difference)

The tracking error is typically expressed as a percentage or a decimal value. It provides an indication of how closely the fund or portfolio follows the benchmark. A lower tracking error suggests a better alignment with

In [110]:

```python
# Percentages of missing values if there is any
VOO_data.isna().sum().sort_values(ascending=False)
```

Out[110]:

```
Open                 0
High                 0
Low                  0
Close                0
Adj Close            0
Volume               0
Ticker               0
Percen_Diff_VOO      0
dtype: int64
```

In [111]:

```python
# Percentages of missing values if there is any
GSPC_data.isna().sum().sort_values(ascending=False)
```

Out[111]:

```
Open                  0
High                  0
Low                   0
Close                 0
Adj Close             0
Volume                0
Ticker                0
Percen_Diff_GSPC      0
dtype: int64
```

In [112]:

```
# Calculating the funds returns (VOO_data)
# Get the Fund Price at End
fund_price_end = VOO_data['Close'].iloc[-1]
# Get the Fund Price at Start
fund_price_start = VOO_data['Close'].iloc[0]

fund_returns = (fund_price_end - fund_price_start) / fund_price_start
print('Fund Returns:', fund_returns)
```

```
Fund Returns: 0.5154742789027629
```

In [113]:

```
# Calculating the Benchmark returns (GSPC_data)
# Get the benchmark Price at End
benchmark_price_end = GSPC_data['Close'].iloc[-1]
# Get the benchmark Price at Start
benchmark_price_start = GSPC_data['Close'].iloc[0]

bench_returns = (benchmark_price_end - benchmark_price_start) / benchmark_price_start
print('Fund Returns:', bench_returns)
```

```
Fund Returns: 0.5177414571909005
```

In [114]:

```
# Difference
difference = fund_returns - bench_returns
print('Difference:', difference)
```

```
Difference: -0.0022671782881376057
```

In [116]:

```
Diff_returns = VOO_data['Percen_Diff_VOO'] - GSPC_data['Percen_Diff_GSPC']

tracking_error = np.std(Diff_returns)

print("Tracking Error:", tracking_error)
```

```
Tracking Error: 0.07502161541678053
```

The tracking error of the Vanguard fund is 0.075, which is very low. It basically means that one can expect the fund to deviate from its benchmark around 0.075 for more or less.

The tracking error is an important measure in evaluating the performance and effectiveness of an investment fund or portfolio in relation to its benchmark. Here are some key reasons why tracking error is important:

1 - Performance Evaluation: Tracking error allows investors to assess how closely a fund's returns track or deviate from its benchmark. It provides a quantitative measure of the fund manager's ability to replicate the performance of the benchmark. A low tracking error indicates a higher level of consistency in tracking the benchmark, while a high tracking error suggests greater divergence.

2 - Benchmark Comparison: Tracking error helps investors compare different funds that track the same benchmark. It provides a basis for evaluating which fund is more successful in closely replicating the benchmark's returns. Investors can use tracking error as a criterion to select funds that align with their investment objectives.

3 - Risk Assessment: Tracking error is a useful tool in assessing the risk associated with an investment fund. A higher tracking error indicates higher deviation from the benchmark, which implies increased active management and potential for divergent performance. This can be desirable for investors seeking actively managed funds but may introduce additional risk and uncertainty.

4 - Performance Attribution: Tracking error analysis enables investors to understand the sources of a fund's outperformance or underperformance relative to the benchmark. By decomposing the tracking error, investors can identify whether the deviations are due to stock selection, sector allocation, or other factors. This information is valuable in understanding the fund manager's investment decisions and style.

5 - Fund Selection and Monitoring: Tracking error is a critical metric when selecting and monitoring investment funds. It helps investors determine the degree of risk they are exposed to by investing in a particular fund. Additionally, ongoing monitoring of tracking error allows investors to evaluate whether the fund is consistently delivering the desired level of benchmark replication over time.

Overall, tracking error provides insight into the fund manager's ability to generate returns consistent with the benchmark and helps investors make informed decisions about fund selection, performance evaluation, and risk assessment. However, it is important to consider tracking error in conjunction with other factors such as fund expenses, investment strategy, and risk tolerance to gain a comprehensive understanding of a fund's performance and suitability.