Research phase

In [1]:
```
# importing libs
import pandas as pd
import matplotlib.pyplot as plt
import yfinance as yf
from datetime import datetime
from statsmodels.tsa.stattools import coint
import plotly.graph_objects as go
```

In [2]:
```
# List of asset candidates
assets = ["SPY", "QQQ", "XLK", "VGT", "IVV"]
```

In [3]:
```
# Download historical price data
start_date = "2020-01-01"
# Creating today date variable
end_date = str(datetime.today().date())
```

In [4]:
```
# Downlaod our data
data = yf.download(tickers=assets, start=start_date, end=end_date, interval="1d")['
# Reset the index
data.reset_index(inplace=True)
# Extracting date form date time
data["Date"] = data["Date"].apply(lambda x : x.date())
# setting Date column as our index and dropping the old one
data  = data.reset_index(drop=True).set_index("Date")
# show up the resualt
data.head()
```

```
[*********************100%***********************]  5 of 5 completed
```

Out[4]:

Ticker	IVV	QQQ	SPY	VGT	XLK
Date					
2020-01-02	326.320007	216.160004	324.869995	249.339996	93.389999
2020-01-03	323.809998	214.179993	322.410004	246.720001	92.339996
2020-01-06	325.089996	215.559998	323.640015	247.539993	92.559998
2020-01-07	324.200012	215.529999	322.730011	247.509995	92.519997
2020-01-08	325.850006	217.149994	324.450012	250.119995	93.510002

In [5]:
```
# Studying correlation matrix
corr_matrix = data.corr()
corr_matrix
```

Out[5]:

Ticker	IVV	QQQ	SPY	VGT	XLK
Ticker					
IVV	1.000000	0.977887	0.999980	0.984819	0.978188
QQQ	0.977887	1.000000	0.978017	0.994889	0.984167
SPY	0.999980	0.978017	1.000000	0.984833	0.978050
VGT	0.984819	0.994889	0.984833	1.000000	0.994947
XLK	0.978188	0.984167	0.978050	0.994947	1.000000

In [6]:

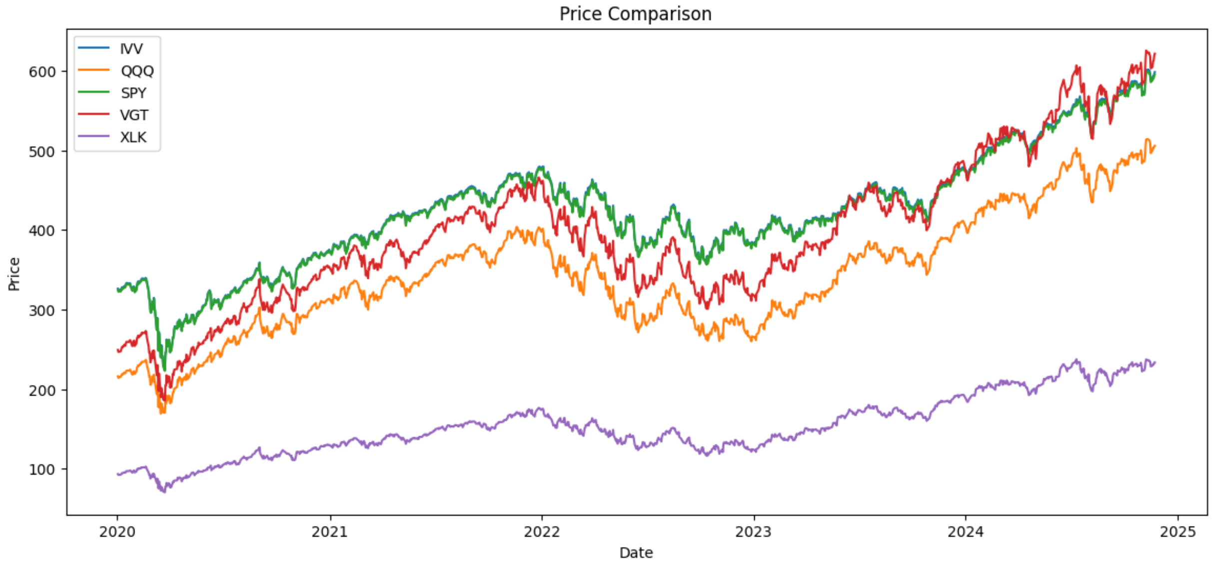
```
# Looking for the strongest correlation between assets
strong_corr = corr_matrix[(corr_matrix > 0.8) & (corr_matrix < 1)]
strong_corr
```

Out[6]:

Ticker	IVV	QQQ	SPY	VGT	XLK
Ticker					
IVV	NaN	0.977887	0.999980	0.984819	0.978188
QQQ	0.977887	NaN	0.978017	0.994889	0.984167
SPY	0.999980	0.978017	NaN	0.984833	0.978050
VGT	0.984819	0.994889	0.984833	NaN	0.994947
XLK	0.978188	0.984167	0.978050	0.994947	NaN

In [7]:

```
# plotting Price over time to make a comparison
plt.figure(figsize=(14, 6))
for i in data.columns:
    plt.plot(data[i], label=str(i))
plt.title('Price Comparison')
plt.xlabel('Date')
plt.ylabel('Price')
plt.legend()
plt.show()
```



In [8]:
```
# Initialize an empty DataFrame to store spreads
spread_df = pd.DataFrame(index=data.index)

# Loop through each pair of assets and calculate the spread
for i in range(len(assets)):
    for j in range(i+1, len(assets)):
        asset1 = assets[i]
        asset2 = assets[j]

        # Calculate the spread (difference between the two assets)
        spread_label = f"{asset1}_{asset2}"
        spread_df[spread_label] = data[asset1] - data[asset2]

# Display the first few rows of the calculated spreads
spread_df
```

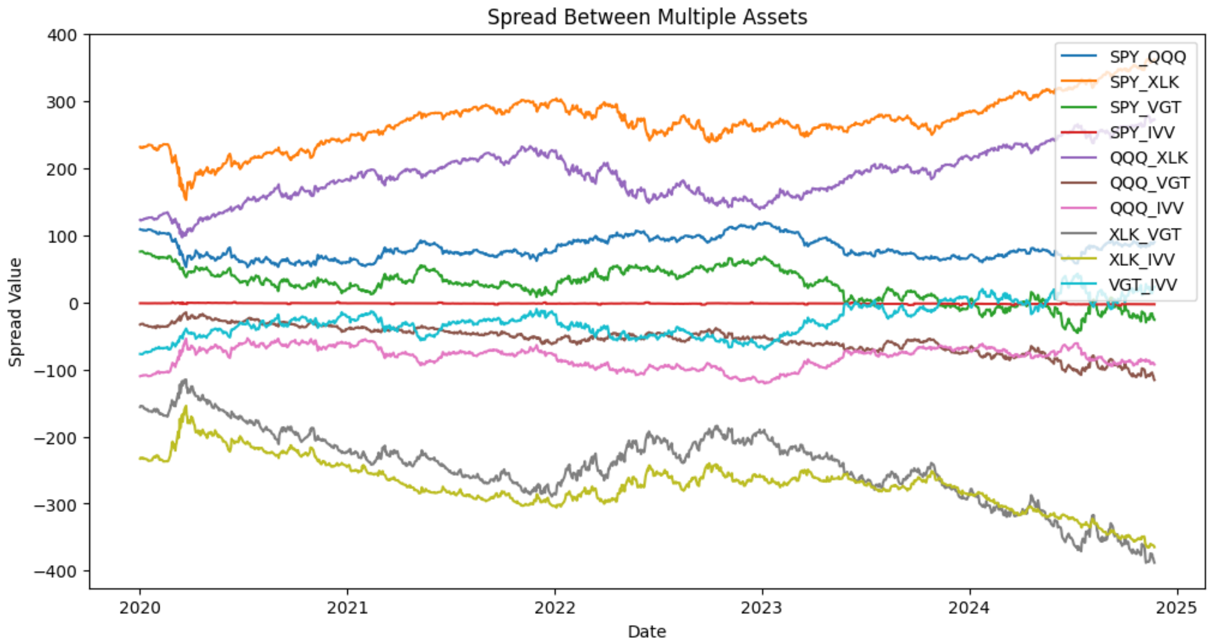
Out[8]:

Date	SPY_QQQ	SPY_XLK	SPY_VGT	SPY_IVV	QQQ_XLK	QQQ_VGT	QQC
2020-01-02	108.709991	231.479996	75.529999	-1.450012	122.770004	-33.179993	-110.16
2020-01-03	108.230011	230.070007	75.690002	-1.399994	121.839996	-32.540009	-109.63
2020-01-06	108.080017	231.080017	76.100021	-1.449982	123.000000	-31.979996	-109.52
2020-01-07	107.200012	230.210014	75.220016	-1.470001	123.010002	-31.979996	-108.67
2020-01-08	107.300018	230.940010	74.330017	-1.399994	123.639992	-32.970001	-108.70
...	...	...	...	...	...	...	
2024-11-18	88.130035	358.700027	-16.569946	-2.959961	270.569992	-104.699982	-91.08
2024-11-19	86.839996	358.969986	-21.869995	-2.869995	272.129990	-108.709991	-89.70
2024-11-20	87.329987	359.369995	-22.320007	-2.940002	272.040009	-109.649994	-90.26
2024-11-21	88.689972	360.189987	-25.610046	-2.809998	271.500015	-114.300018	-91.49
2024-11-22	89.720001	361.910004	-26.070007	-2.940002	272.190002	-115.790009	-92.66

1233 rows × 10 columns

In [9]:

```
# Plot the spreads
plt.figure(figsize=(12, 6))
for column in spread_df.columns:
    plt.plot(spread_df[column], label=column)

plt.title('Spread Between Multiple Assets')
plt.xlabel('Date')
plt.ylabel('Spread Value')
plt.legend()
plt.show()
```



In [10]:
```
# Initialize an empty dictionary, so we can store each assets with p-value
pvalue = dict()
# Looping throw corrlated assets and caluclationg the p-value for each
for i in range(len(assets)):
    for j in range(i+1, len(assets)):
        score, p_value, _ = coint(data[assets[i]], data[assets[j]])
        print(f"Cointegration Test p-value for {assets[i]} and {assets[j]}: {p_valu
        pvalue.update({f"{assets[i]} and {assets[j]}": p_value})
```

```
Cointegration Test p-value for SPY and QQQ: 0.3155661765430872
Cointegration Test p-value for SPY and XLK: 0.25960481938442675
Cointegration Test p-value for SPY and VGT: 0.08336141312415557
Cointegration Test p-value for SPY and IVV: 5.806752345023216e-10
Cointegration Test p-value for QQQ and XLK: 0.7004737757609873
Cointegration Test p-value for QQQ and VGT: 0.368603499414228
Cointegration Test p-value for QQQ and IVV: 0.23714145065723224
Cointegration Test p-value for XLK and VGT: 0.9739081572857883
Cointegration Test p-value for XLK and IVV: 0.21253649456122092
Cointegration Test p-value for VGT and IVV: 0.06911395483017198
```

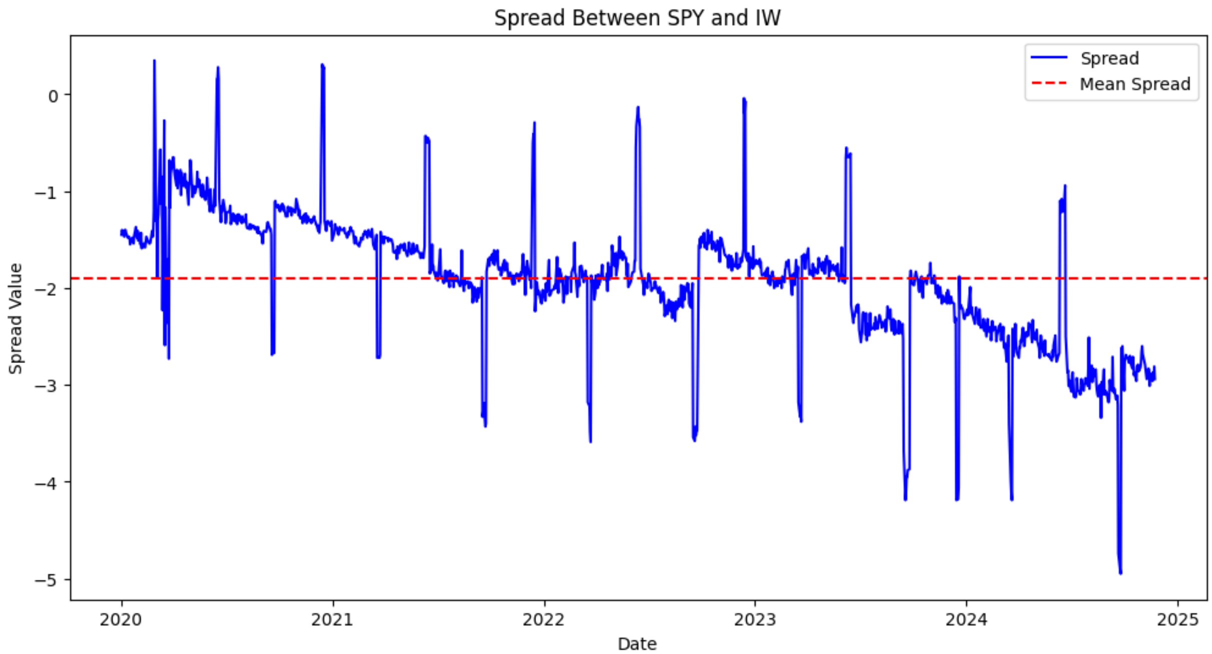
In [11]:
```
# Looping throw the p-values dict, so we can find out the co-integrated assets, wit
for i in pvalue.values():
    if i < 0.05:
        key = next((k for k, v in pvalue.items() if v == i), None)
        print(f"Spread trading opportunity: {key} thier p-value: {i} < 0.05")
```

```
Spread trading opportunity: SPY and IVV thier p-value: 5.806752345023216e-10 < 0.05
```

Application & Backtesting phase

In [12]:
```
# Creating new dataframe with the spread of correlated assets
spread_data = spread_df['SPY_IVV'].to_frame("Spread")
# Plot the speard and the mean
```

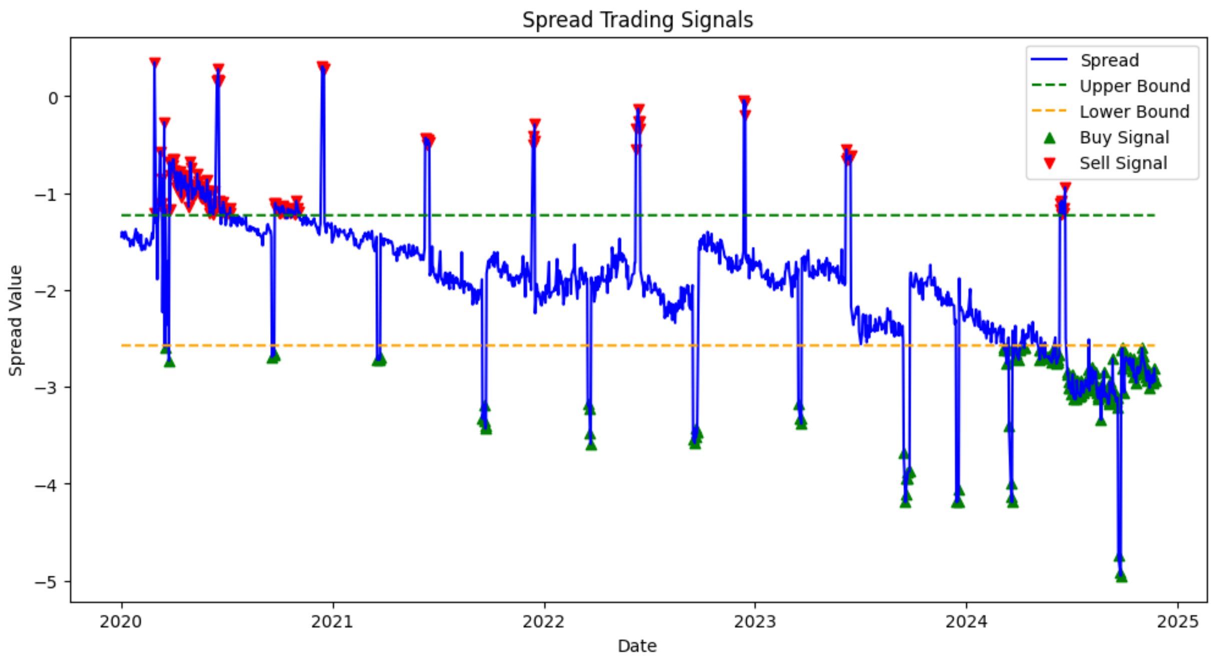
```
plt.figure(figsize=(12, 6))
plt.plot(spread_data['Spread'], label='Spread', color='blue')
plt.axhline(spread_data['Spread'].mean(), color='red', linestyle='--', label='Mean
plt.title('Spread Between SPY and IW')
plt.xlabel('Date')
plt.ylabel('Spread Value')
plt.legend()
plt.show()
```



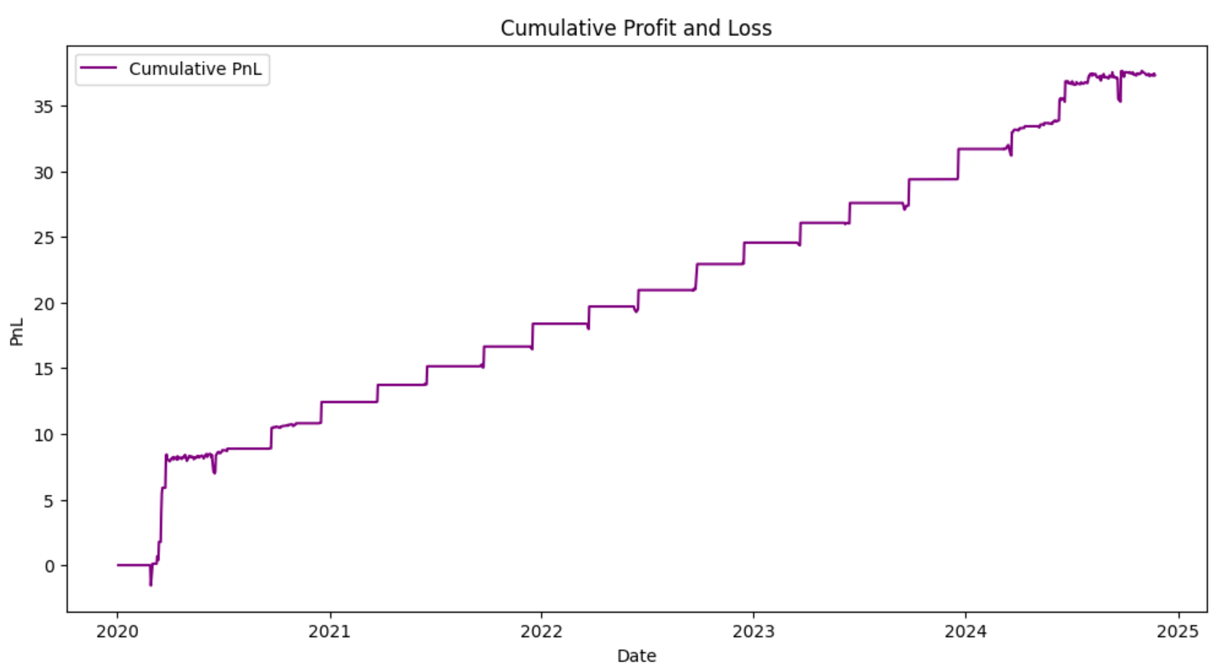
In [13]:
```
# Calculate mean and standard deviation
mean_spread = spread_df['SPY_IVV'].mean()
std_spread = spread_df['SPY_IVV'].std()

# Calculate upper and lower bounds
spread_data['Upper Bound'] = mean_spread + std_spread
spread_data['Lower Bound'] = mean_spread - std_spread
```

In [14]:
```
# Create our signals
spread_data['Signal'] = 0
# Short opportunity
spread_data.loc[spread_data['Spread'] > spread_data['Upper Bound'], 'Signal'] = -1
# Long portunity
spread_data.loc[spread_data['Spread'] < spread_data['Lower Bound'], 'Signal'] = 1

# Visualize signals on the spread
plt.figure(figsize=(12, 6))
plt.plot(spread_data['Spread'], label='Spread', color='blue')
plt.plot(spread_data['Upper Bound'], label='Upper Bound', color='green', linestyle=
plt.plot(spread_data['Lower Bound'], label='Lower Bound', color='orange', linestyle
plt.scatter(spread_data['Spread'][spread_data['Signal']== 1].index, spread_data['Sp
plt.scatter(spread_data['Spread'][spread_data['Signal']== -1].index, spread_data['S
plt.title('Spread Trading Signals')
plt.xlabel('Date')
plt.ylabel('Spread Value')
plt.legend()
```

```
plt.show()
```



In [15]:
```
# Backtesting
spread_data['PnL'] = spread_data['Signal'].shift(1) * (spread_data['Spread'].diff()
spread_data['Cumulative PnL'] = spread_data['PnL'].cumsum()

# Plot cumulative profit and loss
plt.figure(figsize=(12, 6))
plt.plot(spread_data['Cumulative PnL'], label='Cumulative PnL', color='purple')
plt.title('Cumulative Profit and Loss')
plt.xlabel('Date')
plt.ylabel('PnL')
plt.legend()
plt.show()
```

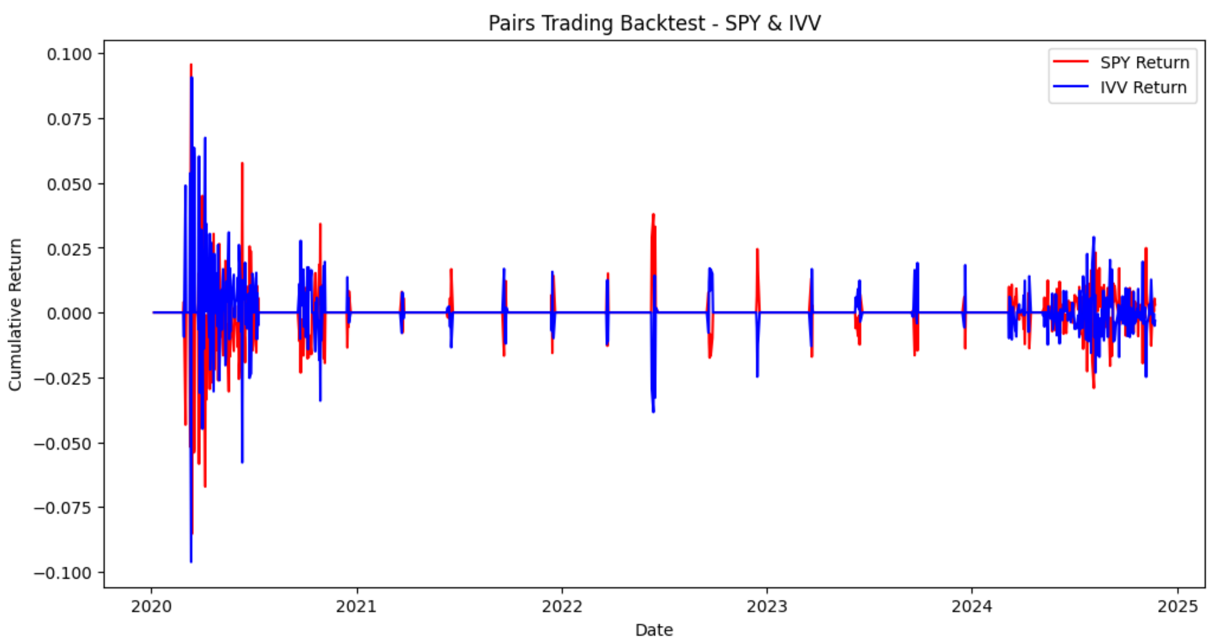


In [16]:
```python
# Calculate sharpe ratio
sharpe_ratio = spread_data['PnL'].mean() / spread_data['PnL'].std() * (252**0.5)
print(f"Sharpe Ratio: {sharpe_ratio:.2f}")
```

```
Sharpe Ratio: 1.86
```

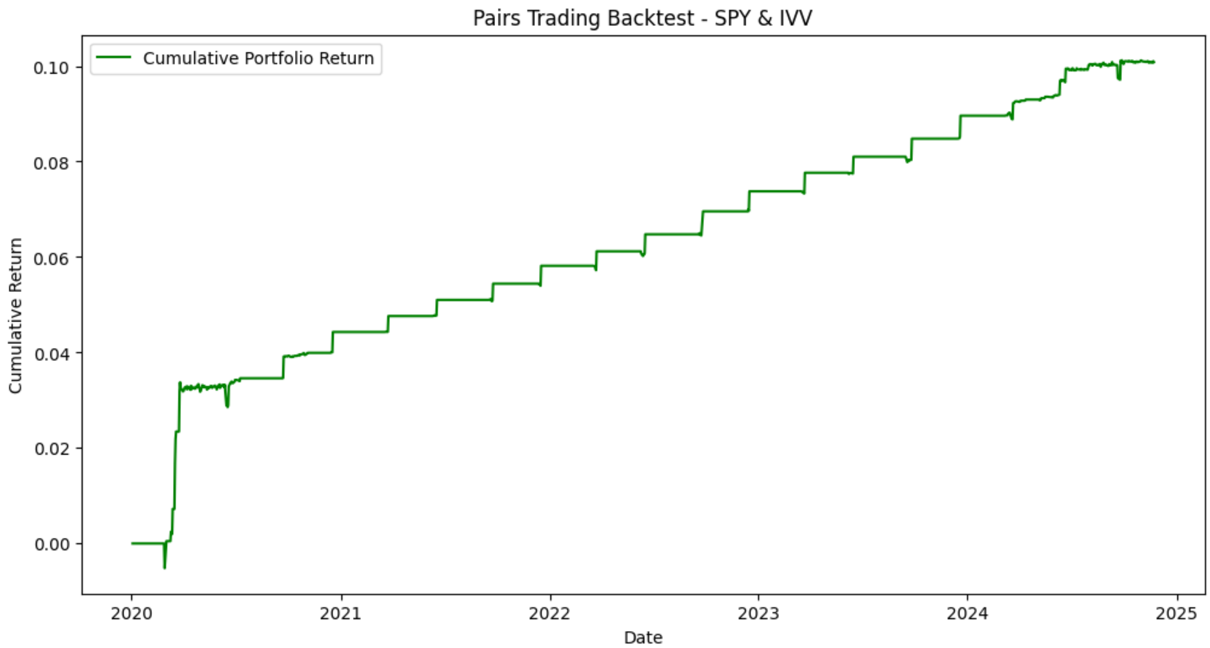
In [17]:
```python
# Create new portfolio df for backtesting
portfolio = pd.DataFrame(index=data.index)
# Calculate the opposite positions for each asset
# If SPY long IVV short and vice versa
portfolio['SPY_Position'] = spread_data['Signal']
portfolio['IVV_Position'] = spread_data['Signal'] * -1

# Calculate the returns for each asset
portfolio['SPY_Return'] = data['SPY'].pct_change() * portfolio['SPY_Position'].shif
portfolio['IVV_Return'] = data['IVV'].pct_change() * portfolio['IVV_Position'].shif
# Total Reurn
portfolio['Total_Return'] = portfolio['SPY_Return'] + portfolio['IVV_Return']
# Cumulative return
portfolio['Cumulative_Return'] = portfolio['Total_Return'].cumsum()
portfolio.dropna(inplace=True)
```

In [18]:
```python
# Plot the resualt of our backtest
plt.figure(figsize=(12, 6))
plt.plot(data['SPY'].pct_change() * portfolio['SPY_Position'].shift(1), label="SPY
plt.plot(data['IVV'].pct_change() * portfolio['IVV_Position'].shift(1), label="IVV
plt.title("Pairs Trading Backtest - SPY & IVV")
plt.xlabel("Date")
plt.ylabel("Cumulative Return")
plt.legend()
plt.show()
```

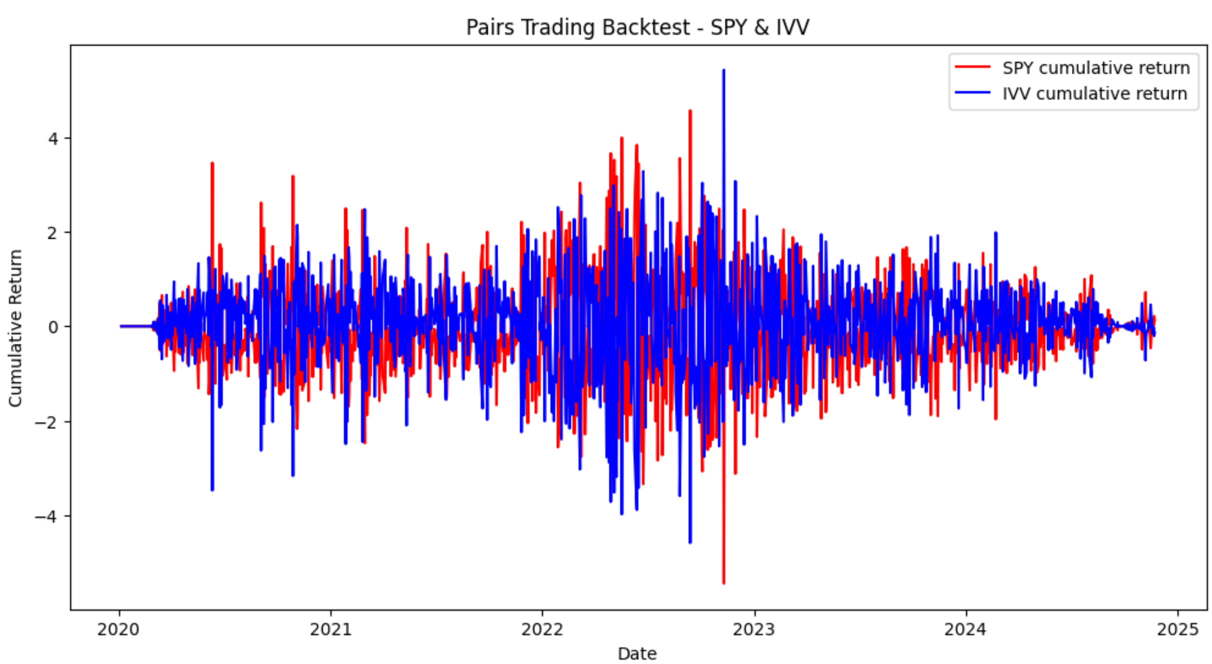


In [19]:
```python
# Plot the resualt of our backtest
plt.figure(figsize=(12, 6))
plt.plot(portfolio['Cumulative_Return'], label="Cumulative Portfolio Return", color
plt.title("Pairs Trading Backtest - SPY & IVV")
```

```
plt.xlabel("Date")
plt.ylabel("Cumulative Return")
plt.legend()
plt.show()
```

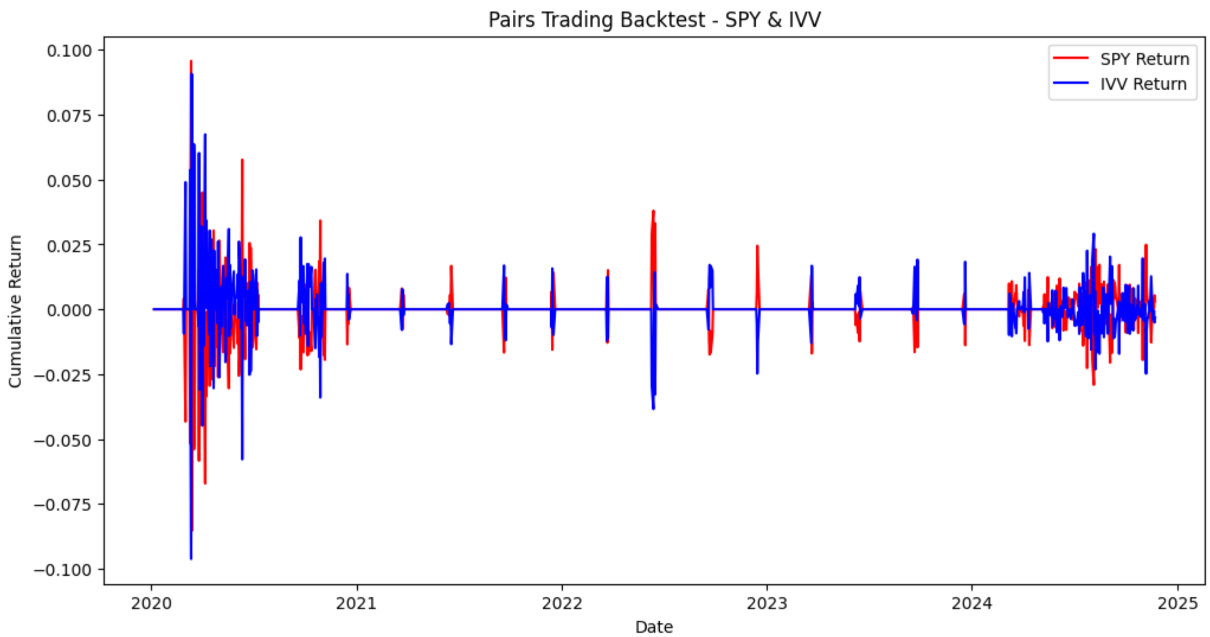


In [20]:
```
# Plot the resualt of our cumulative return for each asset
plt.figure(figsize=(12, 6))
plt.plot(data['SPY'].pct_change() * portfolio['SPY_Position'].shift(1).cumsum(), la
plt.plot(data['IVV'].pct_change() * portfolio['IVV_Position'].shift(1).cumsum(), la
plt.title("Pairs Trading Backtest - SPY & IVV")
plt.xlabel("Date")
plt.ylabel("Cumulative Return")
plt.legend()
plt.show()
```



In [21]:

```python
# Plot the resualt of our return for each asset
plt.figure(figsize=(12, 6))
plt.plot(data['SPY'].pct_change() * portfolio['SPY_Position'].shift(1), label="SPY
plt.plot(data['IVV'].pct_change() * portfolio['IVV_Position'].shift(1), label="IVV
plt.title("Pairs Trading Backtest - SPY & IVV")
plt.xlabel("Date")
plt.ylabel("Cumulative Return")
plt.legend()
plt.show()
```



In [22]:

```python
# Preparing data for plotting
x = portfolio.index
SPY_CumReturn = data['SPY'].pct_change() * portfolio['SPY_Position'].shift(1).cumsu
IVV_CumReturn = data['IVV'].pct_change() * portfolio['IVV_Position'].shift(1).cumsu
SPY_Return = data['SPY'].pct_change() * portfolio['SPY_Position'].shift(1)
IVV_Return = data['IVV'].pct_change() * portfolio['IVV_Position'].shift(1)

# Create a figure
fig = go.Figure()

# Create traces
fig.add_traces([
    go.Scatter(x=x, y=portfolio['Cumulative_Return'], mode='lines', name='Total cum
    go.Scatter(x=x, y=SPY_CumReturn, mode='lines', name='SPY cumulative return', li
    go.Scatter(x=x, y=IVV_CumReturn, mode='lines', name='IVV cumulative return', li
    go.Scatter(x=x, y=SPY_Return, mode='lines+markers', name='SPY return', line=dic
    go.Scatter(x=x, y=IVV_Return, mode='lines+markers', name='IVV return', line=dic
])

# Update layout
fig.update_layout(
    title="Pairs Trading Backtest - Interactive Plot",
    xaxis_title="Date",
    yaxis_title="Cumulative Return",
    hovermode="x unified",
    template="plotly_dark",
```

```
    width=1000,
    height=600,
)

# Show the plot
fig.show()
```