# Mini Project - 1

January 31, 2024

Mini Project Title: "Dynamic Filtering and State-Contingent Signal Generation for USD/EUR Trading Strategy based on Interest Rate Differentials"

Description: This project focuses on designing a trading strategy for the USD/EUR currency pair using interest rate differentials. The approach involves fitting a filter with a specified gain, computing standard deviations of filter errors, and generating state-contingent signals based on a boundary of inaction. The strategy aims to exploit market movements and adjust positions dynamically. The project further visualizes the filter and interest rate differentials, describes the trading strategy, presents the equity curve, computes annual rates of return, evaluates the Sharpe Ratio, and assesses the strategy's performance.Sensitivity analysis explores the impact of varying filter parameters on the strategy's behavior, seeking potential optimization for improved results.

[ ]:
```
import yfinance as yf
import matplotlib.pyplot as plt
import pandas as pd
import numpy as np
import datetime
import datetime
import matplotlib.lines as mlines
from fredapi import Fred
import statsmodels.formula.api as smf
import datetime
import warnings
warnings.filterwarnings("ignore")
```

[ ]:
```
data = pd.read_csv('hw1_w24_data.csv', parse_dates =  True, index_col = 0)
data.head()
```

[ ]:
```
             I_US    I_EU  ir_diff   USDEUR
date
2004-01-01  1.10  2.1463   -1.046  0.79428
2004-02-01  1.06  2.0895   -1.030  0.80205
2004-03-01  1.05  2.0706   -1.021  0.80038
2004-04-01  1.05  2.0288   -0.979  0.81215
2004-05-01  1.08  2.0488   -0.969  0.83452
```

[ ]:
```
#Set the filter gain
k = 0.62
```

```
# Fit the filter and compute standard deviation of filter errors
data['Filter'] = data['ir_diff'].ewm(alpha=k, adjust=False).mean()
data['Filter Error'] = data['ir_diff'] - data['Filter']
data['Filter Error Std'] = data['Filter Error'].ewm(alpha=k, adjust=False).
  ↪std(bias=False)
```

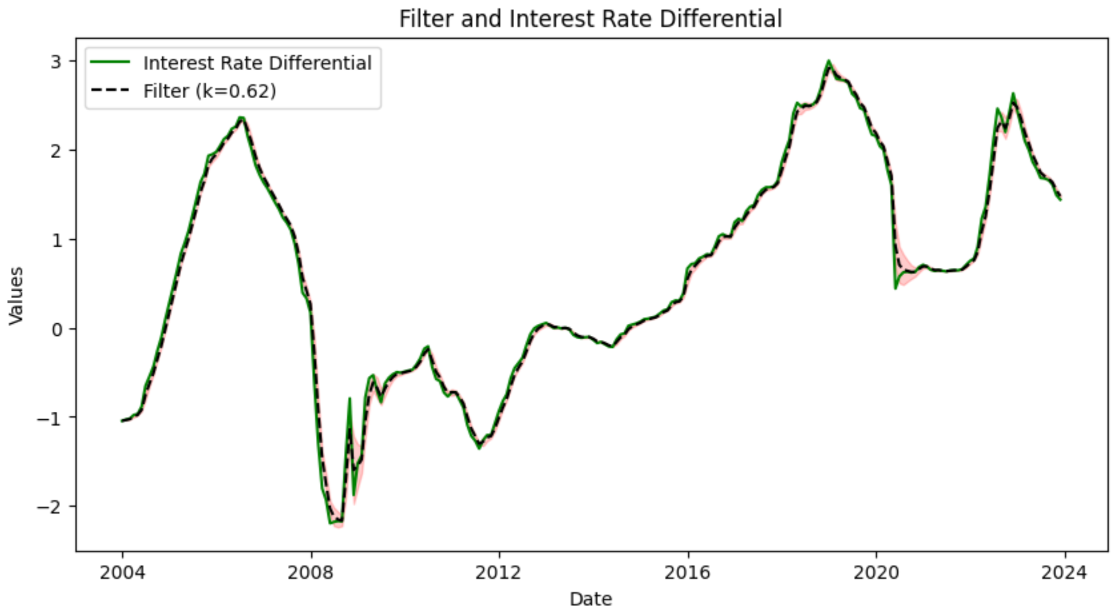
[ ]:
```
# Display the standard deviation
print("Standard Deviation of Filter Errors:")
print(data["Filter Error Std"])
```

```
Standard Deviation of Filter Errors:
date
2004-01-01         NaN
2004-02-01    0.004299
2004-03-01    0.002796
2004-04-01    0.008783
2004-05-01    0.005639
                 …
2023-08-01    0.025732
2023-09-01    0.021986
2023-10-01    0.013553
2023-11-01    0.021268
2023-12-01    0.013352
Name: Filter Error Std, Length: 240, dtype: float64
```

[ ]:
```
# last value of the computed standard deviation
last_std_value = data['Filter Error Std'].iloc[-1]

print(f"The standard deviation of filter errors is: {last_std_value: .6f}")
```

```
The standard deviation of filter errors is:  0.013352
```

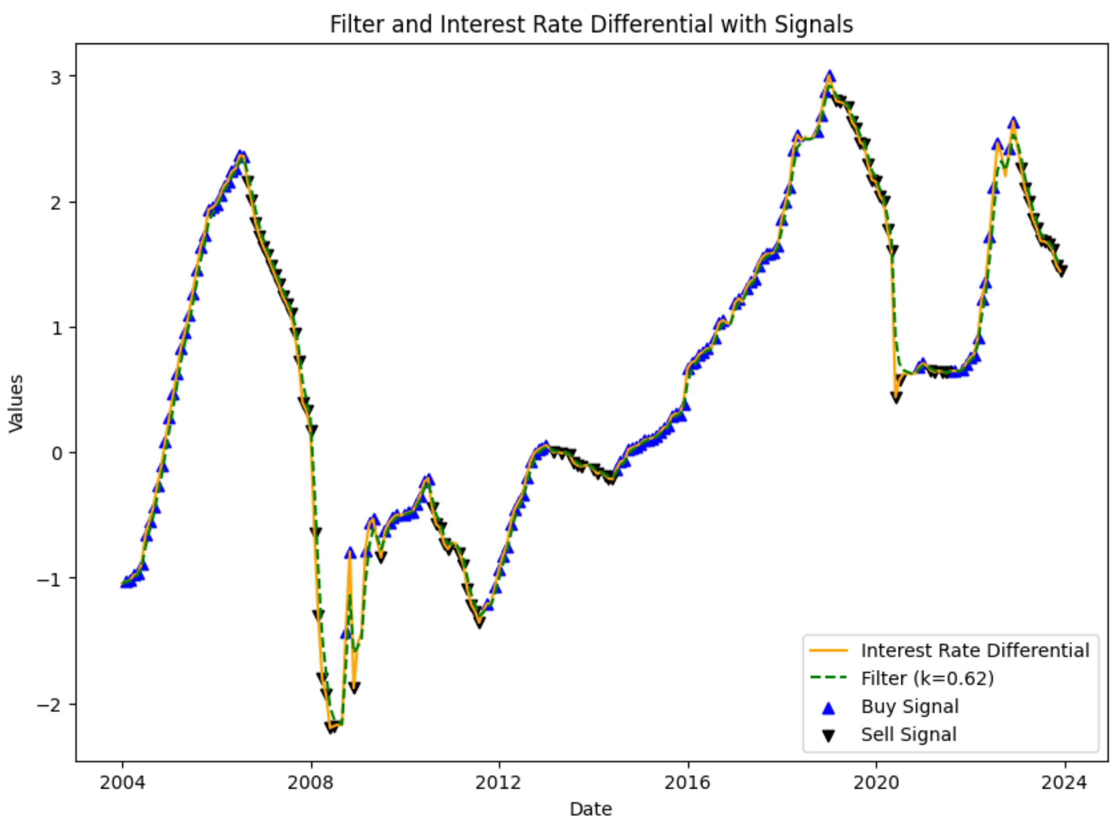
[ ]:
```
# Visualize the filter and interest rate differential on the same plot
plt.figure(figsize=(10, 5))
plt.plot(data.index, data['ir_diff'], label='Interest Rate Differential',␣
  ↪color='green')
plt.plot(data.index, data['Filter'], label=f'Filter (k={k})', color='black',␣
  ↪linestyle='dashed')
plt.fill_between(data.index, data['Filter'] - data['Filter Error Std'],␣
  ↪data['Filter'] + data['Filter Error Std'], color='red', alpha=0.2)
plt.title('Filter and Interest Rate Differential')
plt.xlabel('Date')
plt.ylabel('Values')
plt.legend()
plt.show()
```




[ ]:
```
#Generate signals when the interest rate crosses a boundary of inaction
z = 0.5
data["Upper"] = data["Filter"] + z*data["Filter Error Std"]
data["Lower"] = data["Filter"] - z*data["Filter Error Std"]

data["signal"] = np.where(data["Filter Error"].abs()>z*data["Filter Error␣
↪Std"], 1, 0) * np.sign(data["Filter Error"])

# Display the resulting DataFrame with signals
data[['ir_diff', 'Filter', 'Filter Error', 'Filter Error Std', 'signal']]
```

[ ]:
```
            ir_diff    Filter  Filter Error  Filter Error Std  signal
date
2004-01-01   -1.046 -1.046000      0.000000               NaN     0.0
2004-02-01   -1.030 -1.036080      0.006080          0.004299     1.0
2004-03-01   -1.021 -1.026730      0.005730          0.002796     1.0
2004-04-01   -0.979 -0.997138      0.018138          0.008783     1.0
2004-05-01   -0.969 -0.979692      0.010692          0.005639     1.0
…               …       …           …                …       …
2023-08-01    1.678  1.703429     -0.025429          0.025732    -1.0
2023-09-01    1.660  1.676503     -0.016503          0.021986    -1.0
2023-10-01    1.610  1.635271     -0.025271          0.013553    -1.0
2023-11-01    1.490  1.545203     -0.055203          0.021268    -1.0
2023-12-01    1.440  1.479977     -0.039977          0.013352    -1.0

[240 rows x 5 columns]
```

```
[ ]: # Plotting the signals with IRD and Filter
plt.figure(figsize=(10, 7))
plt.plot(data.index, data['ir_diff'], label='Interest Rate Differential',␣
 ↪color='orange')
plt.plot(data.index, data['Filter'], label=f'Filter (k={k})', color='green',␣
 ↪linestyle='dashed')
plt.scatter(data[data['signal'] == 1].index, data.loc[data['signal'] == 1,␣
 ↪'ir_diff'], label='Buy Signal', color='blue', marker='^')
plt.scatter(data[data['signal'] == -1].index, data.loc[data['signal'] == -1,␣
 ↪'ir_diff'], label='Sell Signal', color='black', marker='v')


plt.title("Filter and Interest Rate Differential with Signals")
plt.xlabel("Date")
plt.ylabel("Values")
plt.legend()
plt.show()
```




Description of Strategy: In constructing the filter for this trading strategy, I opted for a I opted for a filter gain (alpha) of k =0.62, leveraging an exponentially weighted moving average (EWMA). The primary goal wasto create a filter that could capture trends in the interest rate differential while smoothing out noise in the time series. This filtered output was intended to offer a more refined estimate of the underlying trend in the interest rate differential. The calculation of the filter error involved taking the difference between the observed IRD and the corresponding value of the filter. This served as a measure of how much the actual data deviated from the smoothed trend. To gauge the variability or volatility of these filter errors over time, I computed their standard deviation using the same EWMA with the filter gain (alpha) set at 0.62. Signal generation in this strategy hinged on the identification of boundary crossings around the filter. These boundaries, defined as the filter value plus or minus z times the standard deviation of the filter errors, acted as thresholds for triggering signals. If the absolute value of the filter error surpassed z times the standard deviation, a signal was initiated. The sign of the signal was then determined by the sign of the filter error. These signals were designed to be state contingent, taking into account the current state of the filter error inrelation to its historical variability. Interpreting the signals is straightforward. A triggered signal indicates a substantial deviation from the filtered trend, presenting a potential trading opportunity. A positive signal(1.0) implied a bullish stance, suggesting that the interest rate differential had significantly exceeded the upper boundary of inaction. Conversely, a negative signal (-1.0) signaled a bearish position, indicating a substantial drop in the interest rate differential below the lowerboundary of inaction. When it comes to implementing the s.trategy, traders could leverage these signals to inform their trading decisions. This might involve entering either long or short positions in market, depending on the direction of the signals. My strategy integrates filtering techniques with signal generation, relying on deviations from historical volatility to guide informed decisions made by investor.

[ ]:
```
data['returns'] = np.log(data['USDEUR']).diff()
# Before multipling the signals are shifted by one period
data['strat returns'] = data['signal'].shift()*data['returns']

# Use summation to get cumulative log returns
data['log strategy returns'] = data['strat returns'].cumsum()

# convert into simple returns
data['simple strategy returns'] = np.exp(data['log strategy returns'])-1

data.tail()
```

[ ]:
```
            I_US    I_EU  ir_diff   USDEUR    Filter  Filter Error  \
date
2023-08-01  5.35  3.6718    1.678  0.90709  1.703429     -0.025429
2023-09-01  5.44  3.7803    1.660  0.91470  1.676503     -0.016503
2023-10-01  5.49  3.8800    1.610  0.94675  1.635271     -0.025271
2023-11-01  5.46  3.9700    1.490  0.94206  1.545203     -0.055203
2023-12-01  5.41  3.9700    1.440  0.91127  1.479977     -0.039977

            Filter Error Std     Upper     Lower  signal   returns  \
date
2023-08-01          0.025732  1.716295  1.690563    -1.0 -0.014273
2023-09-01          0.021986  1.687496  1.665510    -1.0  0.008354
2023-10-01          0.013553  1.642048  1.628495    -1.0  0.034439
```

```
2023-11-01          0.021268  1.555837  1.534569    -1.0 -0.004966
2023-12-01          0.013352  1.486653  1.473301    -1.0 -0.033230

            strat returns  log strategy returns  simple strategy returns
date
2023-08-01       0.014273              0.604427                 0.830203
2023-09-01      -0.008354              0.596073                 0.814977
2023-10-01      -0.034439              0.561634                 0.753535
2023-11-01       0.004966              0.566600                 0.762265
2023-12-01       0.033230              0.599830                 0.821808
```

[ ]:
```python
plt.figure(figsize = (7, 5))
plt.plot(data['simple strategy returns'][data.index.year
 ↪<2024]*100,label='Strategy Equity Curve', color='green')
plt.title('Equity Curve')
plt.xlabel('Date')
plt.ylabel('Cumulative Returns')
plt.legend()
plt.grid()
```

CCROR stands for Continuously Compounded Rate of Return and Annual Return:

```
[ ]: data["total_returns"] = (data["simple strategy returns"] + 1)
     CCROR = np.log(data["total_returns"].iloc[-1])/(len(data)/12)
     CCROR*100
```

```
[ ]: 2.9991478541823806
```

```
[ ]: AR = (np.power(data["total_returns"] .iloc[-1],(1/(len(data)/12)))-1)
     AR*100
```

```
[ ]: 3.0445753015716503
```

```
[ ]: # Aggregate strategy returns at the monthly level
     monthly = np.exp(data['simple strategy returns'].resample('M').sum()) - 1

     monthly
```

```
[ ]: date
     2004-01-31    0.000000
     2004-02-29    0.000000
     2004-03-31   -0.002080
     2004-04-30    0.012672
     2004-05-31    0.041314
                     …
     2023-08-31    1.293785
     2023-09-30    1.259123
     2023-10-31    1.124497
     2023-11-30    1.143125
     2023-12-31    1.274609
     Freq: M, Name: simple strategy returns, Length: 240, dtype: float64
```

Annual risk free rate: assumed to be fixed at 2%

```
[ ]: rf= 0.02
     excess = monthly - rf
     sharpe= excess.mean()/excess.std()*np.sqrt(12)
     sharpe
```

```
[ ]: 4.961068403459206
```

```
[ ]: # Aggregate strategy returns at the Yearly level
     Yearly = np.exp(data['simple strategy returns'].resample('Y').sum()) - 1

     Yearly
```

```
[ ]: date
     2004-12-31        0.075517
     2005-12-31       -0.036184
```

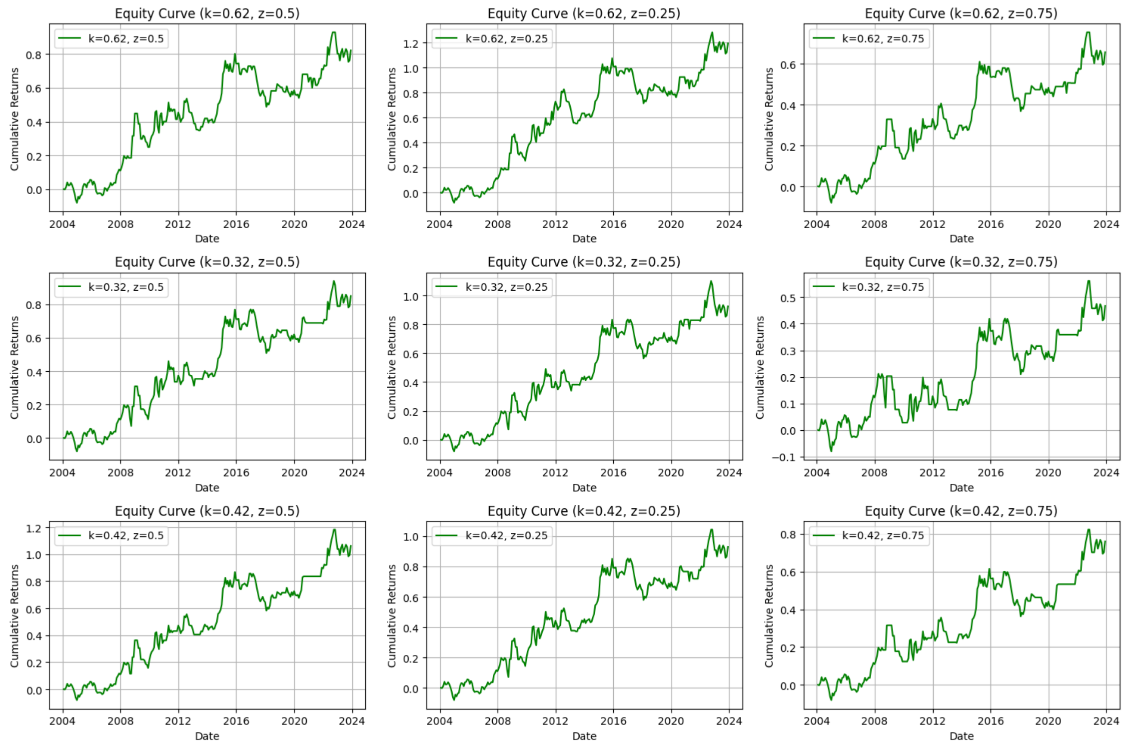
```
2006-12-31       -0.022532
2007-12-31        0.612616
2008-12-31        9.396490
2009-12-31       62.196995
2010-12-31       81.649165
2011-12-31      203.824944
2012-12-31      260.353887
2013-12-31       95.983864
2014-12-31      188.698953
2015-12-31     5094.189973
2016-12-31     5330.191408
2017-12-31     2178.462142
2018-12-31      823.784708
2019-12-31     1081.306827
2020-12-31     1576.291094
2021-12-31     2311.009545
2022-12-31    20665.096485
2023-12-31    14401.565349
Freq: A-DEC, Name: simple strategy returns, dtype: float64
```

[ ]:
```
rf= 0.02
excess = Yearly - rf
sharpe= excess.mean()/excess.std()*np.sqrt(12)
print('The Sharpe ratio is', sharpe.round(3),'%')
```

```
The Sharpe ratio is 1.741 %
```

[ ]:
```
# Initial parameters
k_values = [0.62, 0.32, 0.42]
z_values = [0.5, 0.25, 0.75]
rf = 0.02  # Constant annual risk-free rate

plt.figure(figsize=(15, 10))

# Calculate Sharpe ratios for each combination
sharpe_ratios = []

for i in range(3):
    k = k_values[i]

    for j in range(3):
        z = z_values[j]

        # Set the filter gain
        data['Filter'] = data['ir_diff'].ewm(alpha=k, adjust=False).mean()
        data['Filter Error'] = data['ir_diff'] - data['Filter']
        data['Filter Error Std'] = data['Filter Error'].ewm(alpha=k,␣
 ↪adjust=False).std(bias=False)
```

```
        # Generate signals based on filter and z
        data["signal"] = np.where(data["Filter Error"].abs() > z * data["Filter Error Std"], 1, 0) * np.sign(data["Filter Error"])

        # Calculate strategy returns
        data['Returns'] = np.log(data['USDEUR']).diff()
        data['Strategy Returns'] = data['signal'].shift(1) * data['returns']
        data['log strategy returns'] = data['Strategy Returns'].cumsum()
        data['simple strategy returns'] = np.exp(data['log strategy returns']) - 1

        # Calculate Sharpe ratio
        monthly = np.exp(data['simple strategy returns'].resample('Y').sum()) - 1
        rf = 0.02
        excess = monthly - rf
        sharpe = excess.mean() / excess.std() * np.sqrt(12)
        sharpe_ratios.append((k, z, sharpe))

        # Plot equity curve
        plt.subplot(3, 3, i * 3 + j + 1)
        plt.plot(data['simple strategy returns'], label=f'k={k}, z={z}', color='green')
        plt.title(f'Equity Curve (k={k}, z={z})')
        plt.xlabel('Date')
        plt.ylabel('Cumulative Returns')
        plt.legend()
        plt.grid()

plt.tight_layout()
plt.show()

# Print Sharpe ratios for each combination
for k, z, sharpe in sharpe_ratios:
    print(f'Sharpe Ratio (k={k}, z={z}): {sharpe}')
```




```
Sharpe Ratio (k=0.62, z=0.5): 1.7412506975722526
Sharpe Ratio (k=0.62, z=0.25): 1.333429485743395
Sharpe Ratio (k=0.62, z=0.75): 1.908728499735542
Sharpe Ratio (k=0.32, z=0.5): 1.811754038790672
Sharpe Ratio (k=0.32, z=0.25): 1.4994431670901984
Sharpe Ratio (k=0.32, z=0.75): 2.115988670153232
Sharpe Ratio (k=0.42, z=0.5): 1.306745598571725
Sharpe Ratio (k=0.42, z=0.25): 1.67462760643206
Sharpe Ratio (k=0.42, z=0.75): 1.4547848561100503
```

Lower values of k make the filter more responsive to recent changes, while higher values make it smoother. Different values of z impact the sensitivity of signal generation to filter errors.

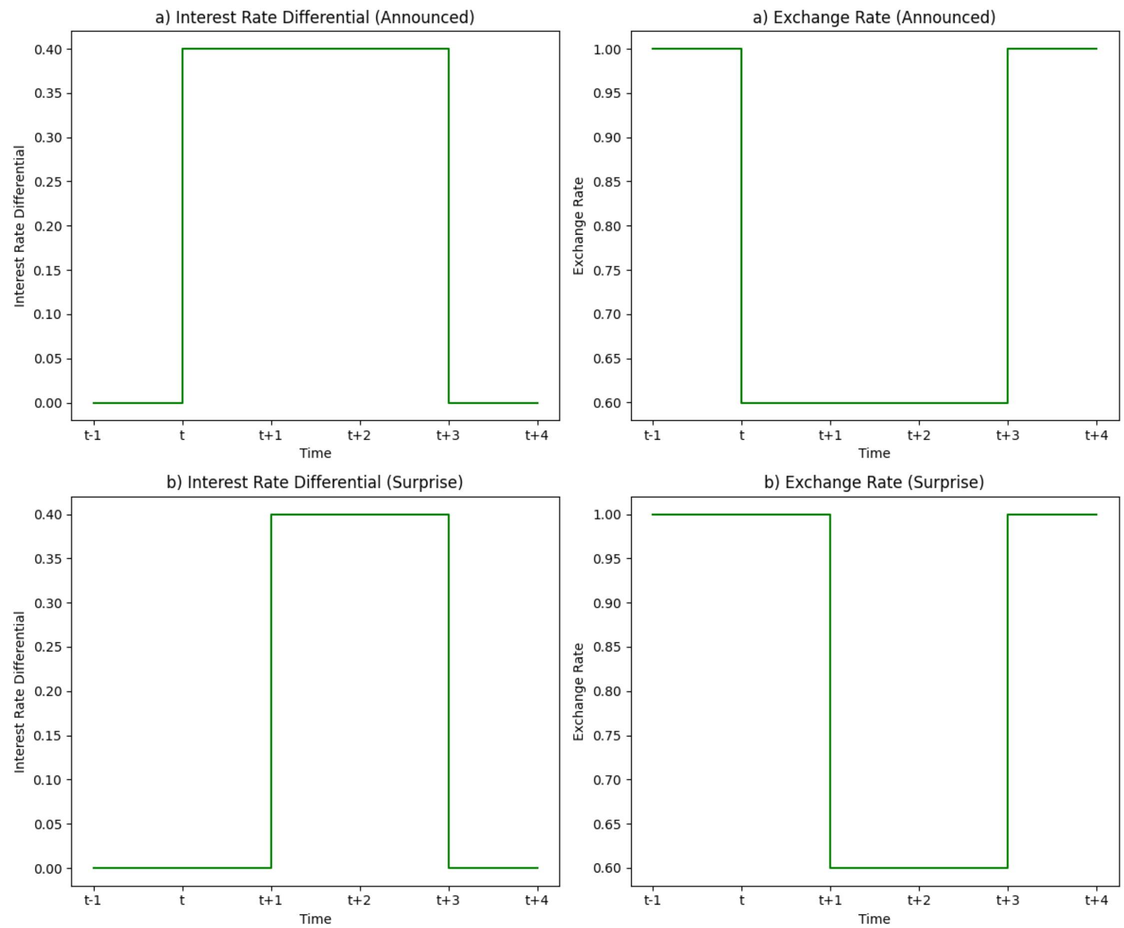
A higher Sharpe ratio generally indicates a better risk-adjusted performance. Sharpe Ratio (k=0.62, z=0.75): 1.909%. Therefore, the strategy with parameters k=0.62 and z=0.75 is considered better based on the Sharpe ratio among the provided combinations.

Using hypothetical interest rate and shock impact ( to visualize the graph of IRD and Exchange rate in 2 cases

[ ]:
```
import matplotlib.pyplot as plt
import numpy as np

# Parameters
T= 6
```

```python
x = [1,2,3,4,5,6]
shock_size = 0.4

# Scenario (a): The t+1 shock is announced at time t
IRD_announced = np.zeros(T)
IRD_announced[1:4] = shock_size

ER_announced = np.ones(T)
ER_announced[1:4] -= shock_size

# Scenario (b): The t+1 shock is not announced at time t but it is a surprise
IRD_surprise = np.zeros(T)
IRD_surprise[2:4] = shock_size

ER_surprise = np.ones(T)
ER_surprise[2:4] -= shock_size

# Plotting
plt.figure(figsize=(12, 10))

# Graph 1: Interest rate differential (Announced)
plt.subplot(2, 2, 1)
plt.step(x, IRD_announced, where='post', color = 'g')
plt.xticks(x, ['t-1', 't', 't+1', 't+2', 't+3','t+4'])
plt.title('a) Interest Rate Differential (Announced)')
plt.xlabel('Time')
plt.ylabel('Interest Rate Differential')


# Graph 2: Exchange rate (Announced)
plt.subplot(2, 2, 2)
plt.step(x, ER_announced, where='post', color = 'g')
plt.xticks(x, ['t-1', 't', 't+1', 't+2', 't+3','t+4'])
plt.title('a) Exchange Rate (Announced)')
plt.xlabel('Time')
plt.ylabel('Exchange Rate')


# Graph 3: Interest rate differential (Surprise)
plt.subplot(2, 2, 3)
plt.step(x, IRD_surprise, where='post', color = 'g')
plt.xticks(x, ['t-1', 't', 't+1', 't+2', 't+3','t+4'])
plt.title('b) Interest Rate Differential (Surprise)')
plt.xlabel('Time')
plt.ylabel('Interest Rate Differential')
```

```
# Graph 4: Exchange rate (Surprise)
plt.subplot(2, 2, 4)
plt.step(x, ER_surprise, where='post',color = 'g')
plt.xticks(x, ['t-1', 't', 't+1', 't+2', 't+3','t+4'])
plt.title('b) Exchange Rate (Surprise)')
plt.xlabel('Time')
plt.ylabel('Exchange Rate')


plt.tight_layout()
plt.show()
```




[ ]:
```
pip install nbconvert PyPDF2
```

```
Requirement already satisfied: nbconvert in c:\users\nishc\anaconda3\lib\site-
packages (6.5.4)
Collecting PyPDF2
  Downloading pypdf2-3.0.1-py3-none-any.whl (232 kB)
```

```
     ---------------------------------------- 0.0/232.6 kB ? eta -:--:--
     ---------------------------------- ---- 204.8/232.6 kB 6.1 MB/s eta 0:00:01
     ---------------------------------------- 232.6/232.6 kB 4.7 MB/s eta 0:00:00
Requirement already satisfied: lxml in c:\users\nishc\anaconda3\lib\site-
packages (from nbconvert) (4.9.2)
Requirement already satisfied: beautifulsoup4 in
c:\users\nishc\anaconda3\lib\site-packages (from nbconvert) (4.12.2)
Requirement already satisfied: bleach in c:\users\nishc\anaconda3\lib\site-
packages (from nbconvert) (4.1.0)
Requirement already satisfied: defusedxml in c:\users\nishc\anaconda3\lib\site-
packages (from nbconvert) (0.7.1)
Requirement already satisfied: entrypoints>=0.2.2 in
c:\users\nishc\anaconda3\lib\site-packages (from nbconvert) (0.4)
Requirement already satisfied: jinja2>=3.0 in c:\users\nishc\anaconda3\lib\site-
packages (from nbconvert) (3.1.2)
Requirement already satisfied: jupyter-core>=4.7 in
c:\users\nishc\anaconda3\lib\site-packages (from nbconvert) (5.3.0)
Requirement already satisfied: jupyterlab-pygments in
c:\users\nishc\anaconda3\lib\site-packages (from nbconvert) (0.1.2)
Requirement already satisfied: MarkupSafe>=2.0 in
c:\users\nishc\anaconda3\lib\site-packages (from nbconvert) (2.1.1)
Requirement already satisfied: mistune<2,>=0.8.1 in
c:\users\nishc\anaconda3\lib\site-packages (from nbconvert) (0.8.4)
Requirement already satisfied: nbclient>=0.5.0 in
c:\users\nishc\anaconda3\lib\site-packages (from nbconvert) (0.5.13)
Requirement already satisfied: nbformat>=5.1 in
c:\users\nishc\anaconda3\lib\site-packages (from nbconvert) (5.7.0)
Requirement already satisfied: packaging in c:\users\nishc\anaconda3\lib\site-
packages (from nbconvert) (23.0)
Requirement already satisfied: pandocfilters>=1.4.1 in
c:\users\nishc\anaconda3\lib\site-packages (from nbconvert) (1.5.0)
Requirement already satisfied: pygments>=2.4.1 in
c:\users\nishc\anaconda3\lib\site-packages (from nbconvert) (2.15.1)
Requirement already satisfied: tinycss2 in c:\users\nishc\anaconda3\lib\site-
packages (from nbconvert) (1.2.1)
Requirement already satisfied: traitlets>=5.0 in
c:\users\nishc\anaconda3\lib\site-packages (from nbconvert) (5.7.1)
Requirement already satisfied: platformdirs>=2.5 in
c:\users\nishc\anaconda3\lib\site-packages (from jupyter-core>=4.7->nbconvert)
(2.5.2)
Requirement already satisfied: pywin32>=300 in
c:\users\nishc\anaconda3\lib\site-packages (from jupyter-core>=4.7->nbconvert)
(305.1)
Requirement already satisfied: jupyter-client>=6.1.5 in
c:\users\nishc\anaconda3\lib\site-packages (from nbclient>=0.5.0->nbconvert)
(7.4.9)
Requirement already satisfied: nest-asyncio in
c:\users\nishc\anaconda3\lib\site-packages (from nbclient>=0.5.0->nbconvert)
```

```
(1.5.6)
Requirement already satisfied: fastjsonschema in
c:\users\nishc\anaconda3\lib\site-packages (from nbformat>=5.1->nbconvert)
(2.16.2)
Requirement already satisfied: jsonschema>=2.6 in
c:\users\nishc\anaconda3\lib\site-packages (from nbformat>=5.1->nbconvert)
(4.17.3)
Requirement already satisfied: soupsieve>1.2 in
c:\users\nishc\anaconda3\lib\site-packages (from beautifulsoup4->nbconvert)
(2.4)
Requirement already satisfied: six>=1.9.0 in c:\users\nishc\anaconda3\lib\site-
packages (from bleach->nbconvert) (1.16.0)
Requirement already satisfied: webencodings in
c:\users\nishc\anaconda3\lib\site-packages (from bleach->nbconvert) (0.5.1)
Requirement already satisfied: attrs>=17.4.0 in
c:\users\nishc\anaconda3\lib\site-packages (from
jsonschema>=2.6->nbformat>=5.1->nbconvert) (22.1.0)
Requirement already satisfied: pyrsistent!=0.17.0,!=0.17.1,!=0.17.2,>=0.14.0 in
c:\users\nishc\anaconda3\lib\site-packages (from
jsonschema>=2.6->nbformat>=5.1->nbconvert) (0.18.0)
Requirement already satisfied: python-dateutil>=2.8.2 in
c:\users\nishc\anaconda3\lib\site-packages (from jupyter-
client>=6.1.5->nbclient>=0.5.0->nbconvert) (2.8.2)
Requirement already satisfied: pyzmq>=23.0 in c:\users\nishc\anaconda3\lib\site-
packages (from jupyter-client>=6.1.5->nbclient>=0.5.0->nbconvert) (23.2.0)
Requirement already satisfied: tornado>=6.2 in
c:\users\nishc\anaconda3\lib\site-packages (from jupyter-
client>=6.1.5->nbclient>=0.5.0->nbconvert) (6.3.2)
Installing collected packages: PyPDF2
Successfully installed PyPDF2-3.0.1
Note: you may need to restart the kernel to use updated packages.
```

[ ]: