Introduction to the Course

TIME SERIES ANALYSIS IN PYTHON

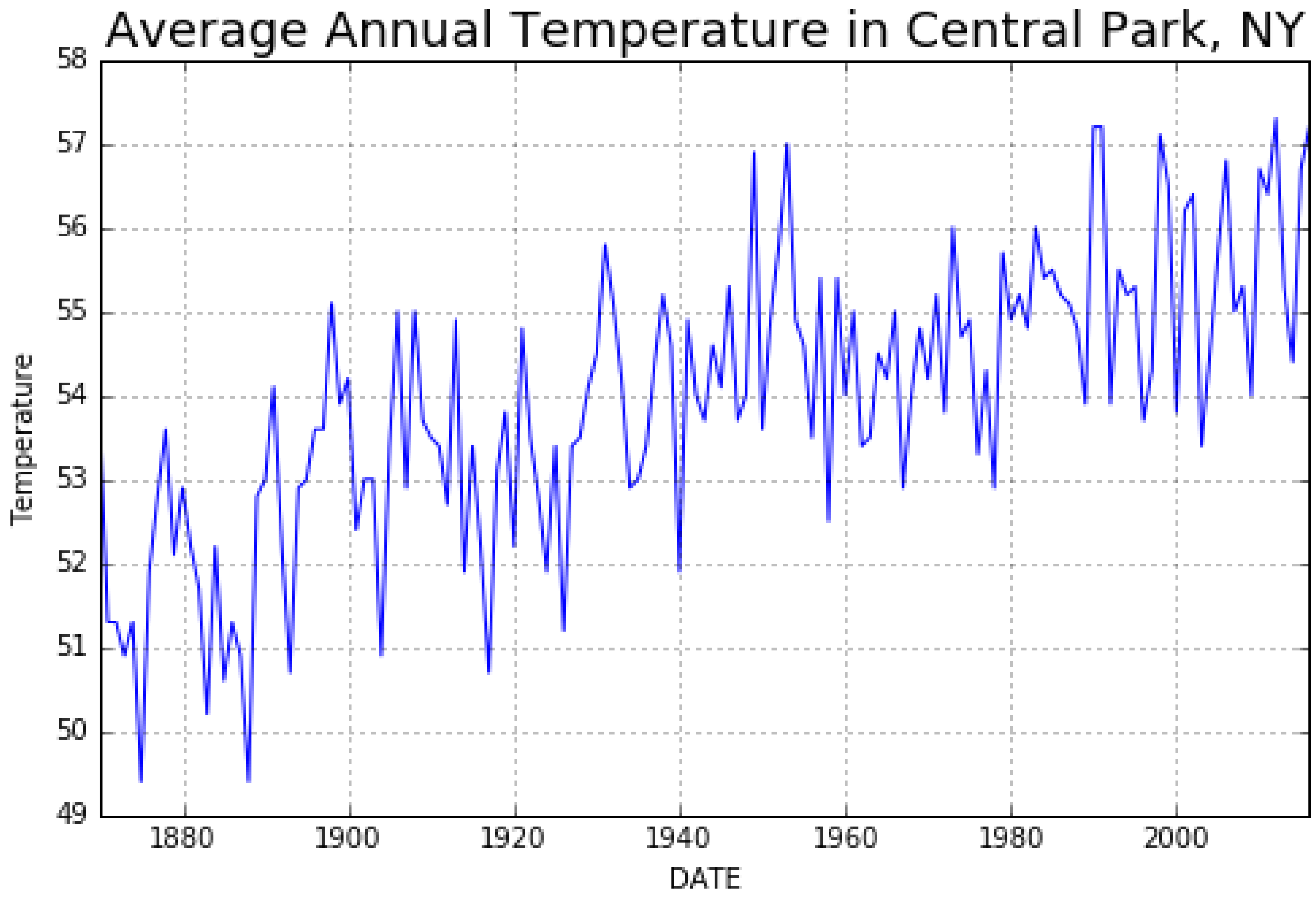
Rob Reider

Adjunct Professor, NYU-Courant
Consultant, Quantopian

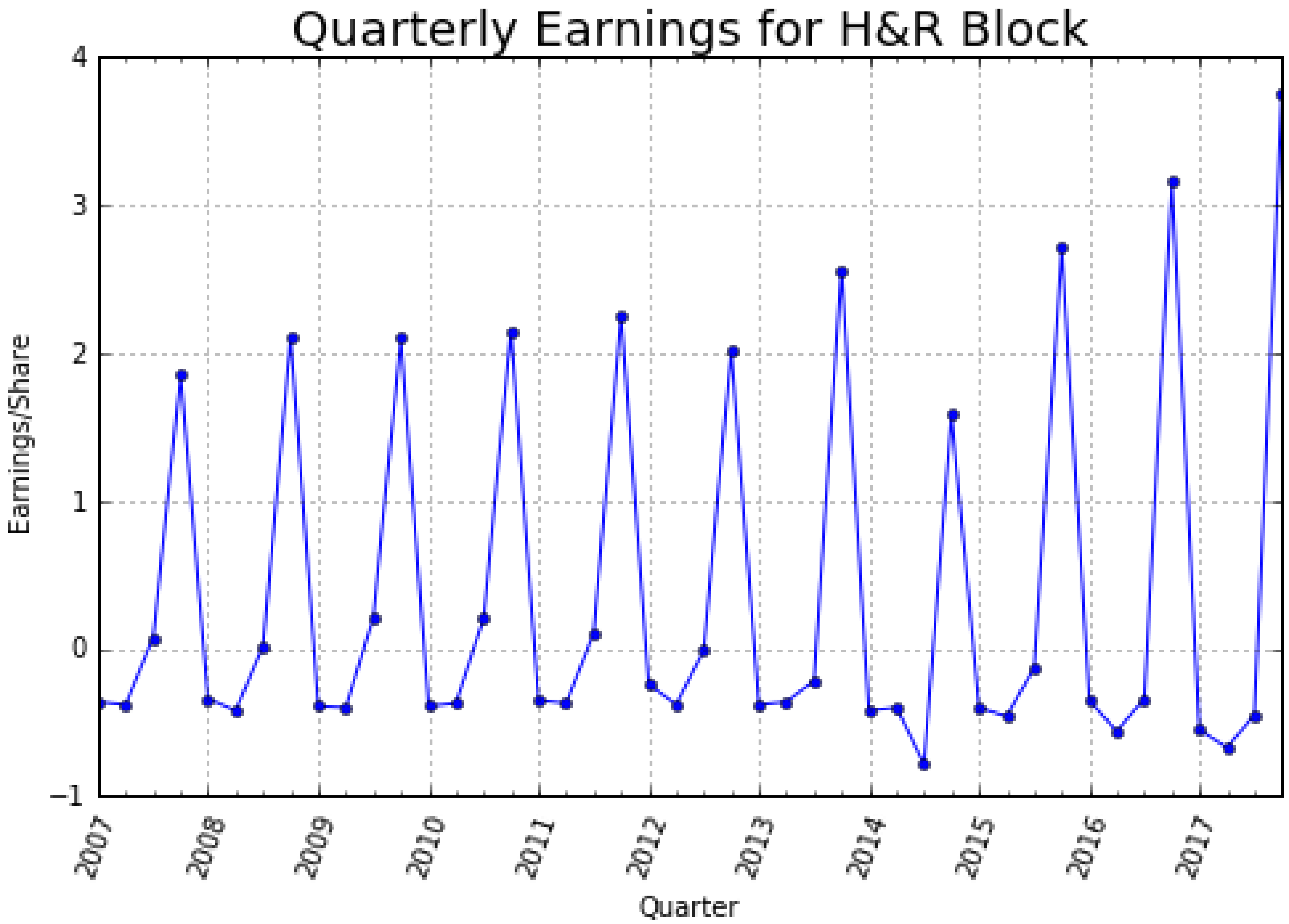
Quantopian: Business built on python for analyzing backlog of data & quantitative data strategies.
Quantopian is also a community where code is shared and questions are asked/answered.

Example of Time Series: Google Trends

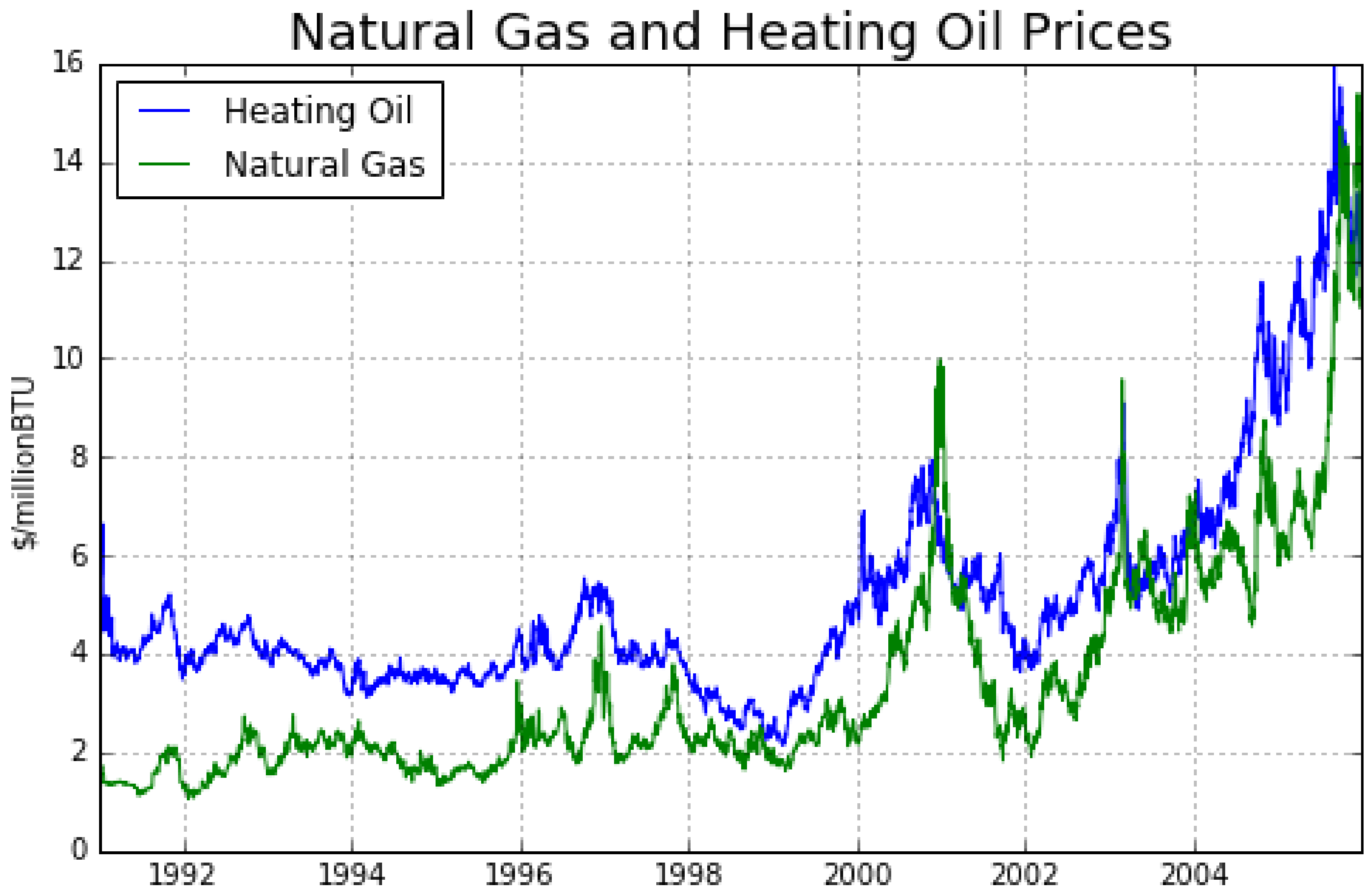
Example of Time Series: Climate Data



Example of Time Series: Quarterly Earnings Data



Example of Multiple Series: Natural Gas and Heating Oil



Goals of Course

- Learn about time series models
- Fit data to a times series model
- Use the models to make forecasts of the future
- Learn how to use the relevant statistical packages in Python
- Provide concrete examples of how these models are used

Many of the models and data will be applicable in the field of finance.

Some Useful Pandas Tools

- Changing an index to datetime

```
df.index = pd.to_datetime(df.index)
```

- Plotting data

```
df.plot()
```

- Slicing data

```
df['2012']
```

Some Useful Pandas Tools

- Join two DataFrames Say, if one dataframe contains stock prices while another one contains bond prices.

```
df1.join(df2)
```

- Resample data (e.g. from daily to weekly)

```
df = df.resample(rule='W', how='last')
```

More pandas Functions

- Computing percent changes and differences of a time series

```
df['col'].pct_change()
df['col'].diff()
```

Say, if you wanted to convert prices to returns.

- `pandas` correlation method of Series

```
df['ABC'].corr(df['XYZ'])
```

- `pandas` autocorrelation

```
df['ABC'].autocorr()
```

```
# From previous step
diet.index = pd.to_datetime(diet.index)

# Slice the dataset to keep only 2012
diet2012 = diet['2012']

# Plot 2012 data
diet2012.plot(grid = True)
plt.show()
```

```
# Import pandas
import pandas as pd

# Convert the stock index and bond index into sets
set_stock_dates = set(stocks.index)
set_bond_dates = set(bonds.index)

# Take the difference between the sets and print
print(set_stock_dates - set_bond_dates)

# Merge stocks and bonds DataFrames using join()
stocks_and_bonds = stocks.join(bonds, how = 'inner')
```

Let's practice!

TIME SERIES ANALYSIS IN PYTHON

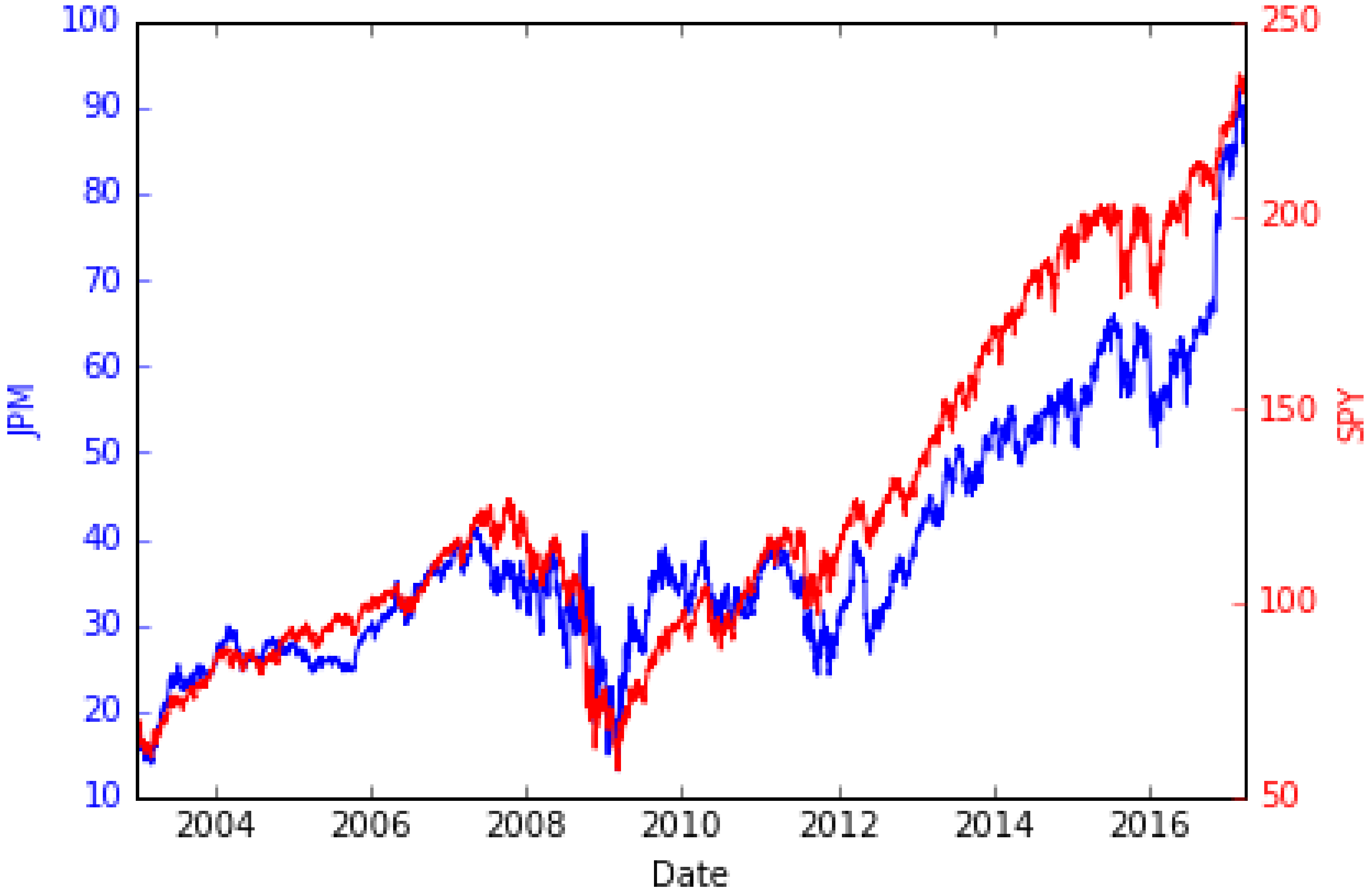
Correlation of Two Time Series

TIME SERIES ANALYSIS IN PYTHON

Rob Reider
Adjunct Professor, NYU-Courant
Consultant, Quantopian

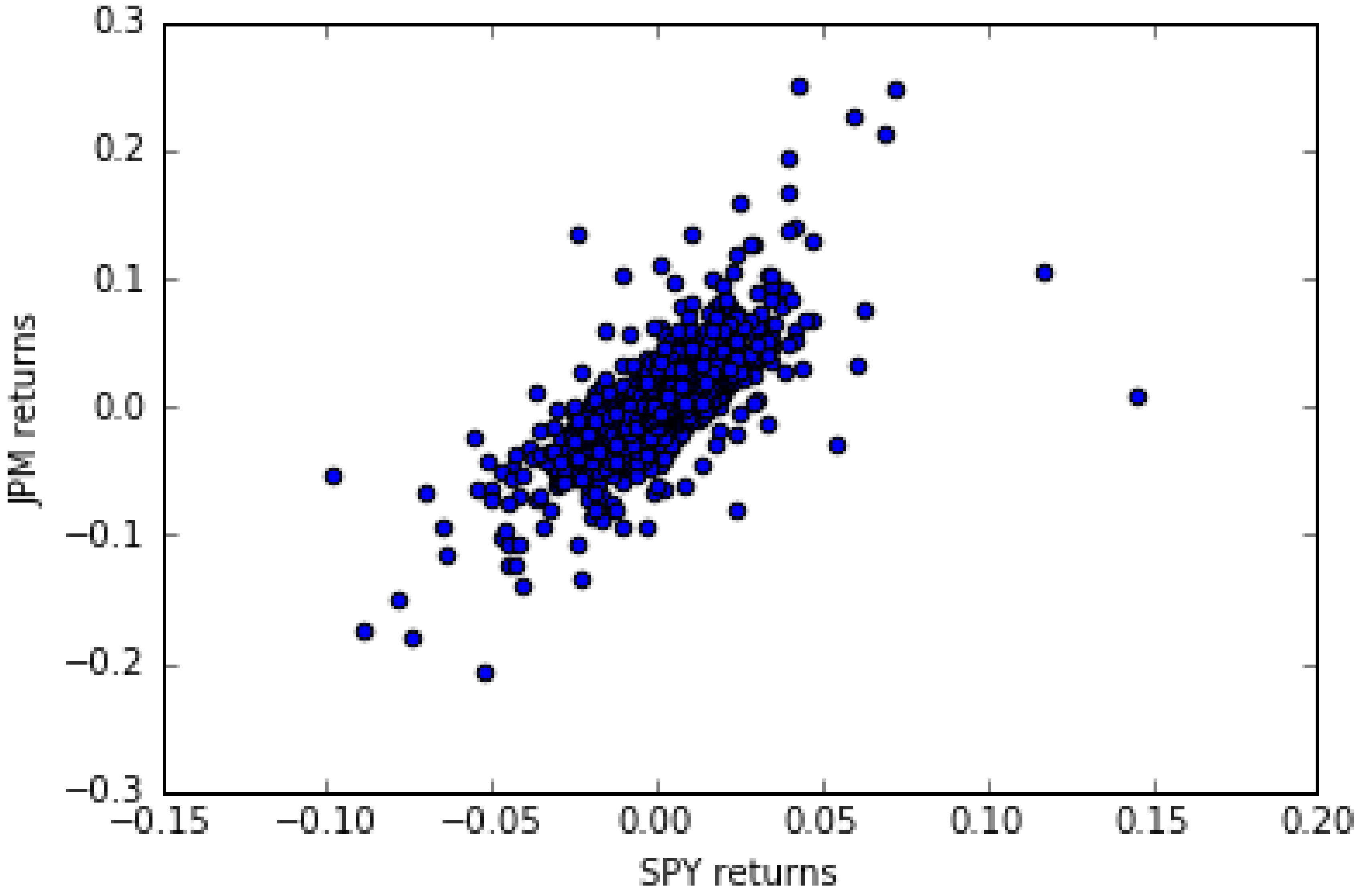
Correlation of Two Time Series

- Plot of S&P500 and JPMorgan stock



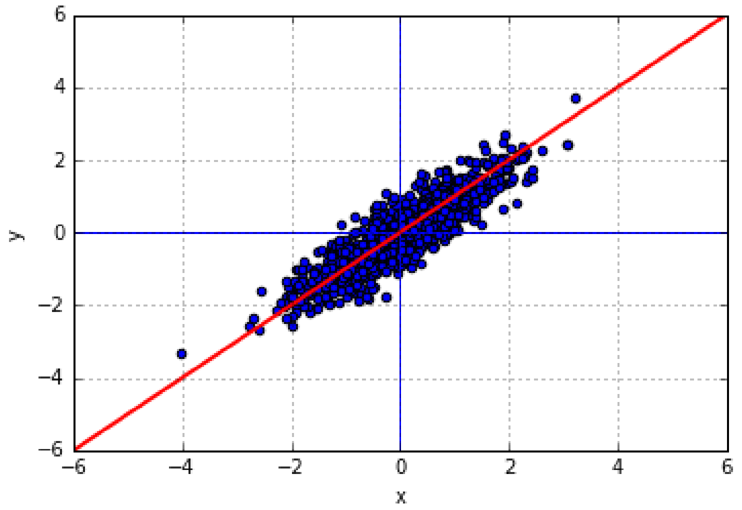
Correlation of Two Time Series

- Scatter plot of S&P500 and JP Morgan returns

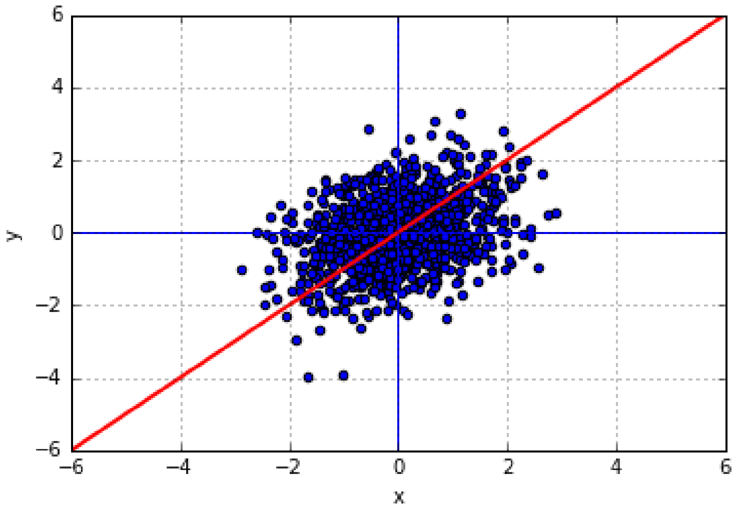


More Scatter Plots

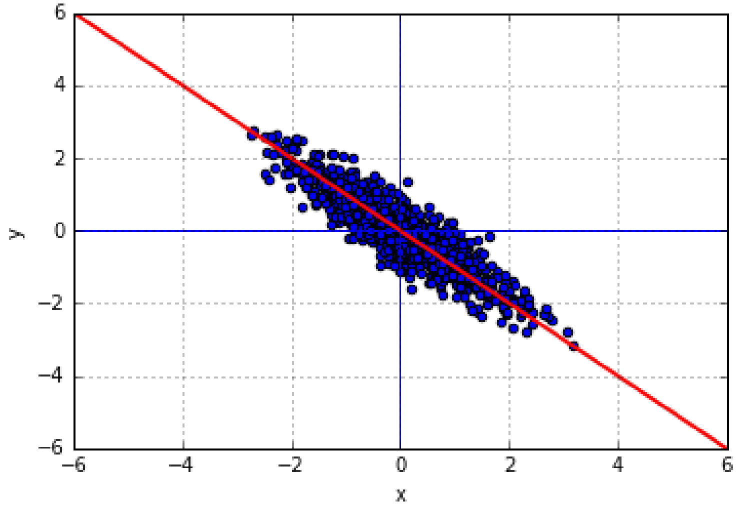
- Correlation = 0.9



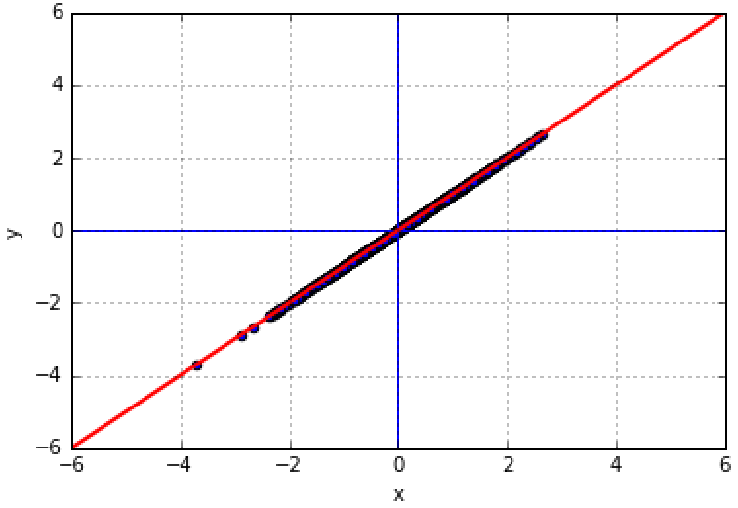
- Correlation = 0.4



- Correlation = -0.9



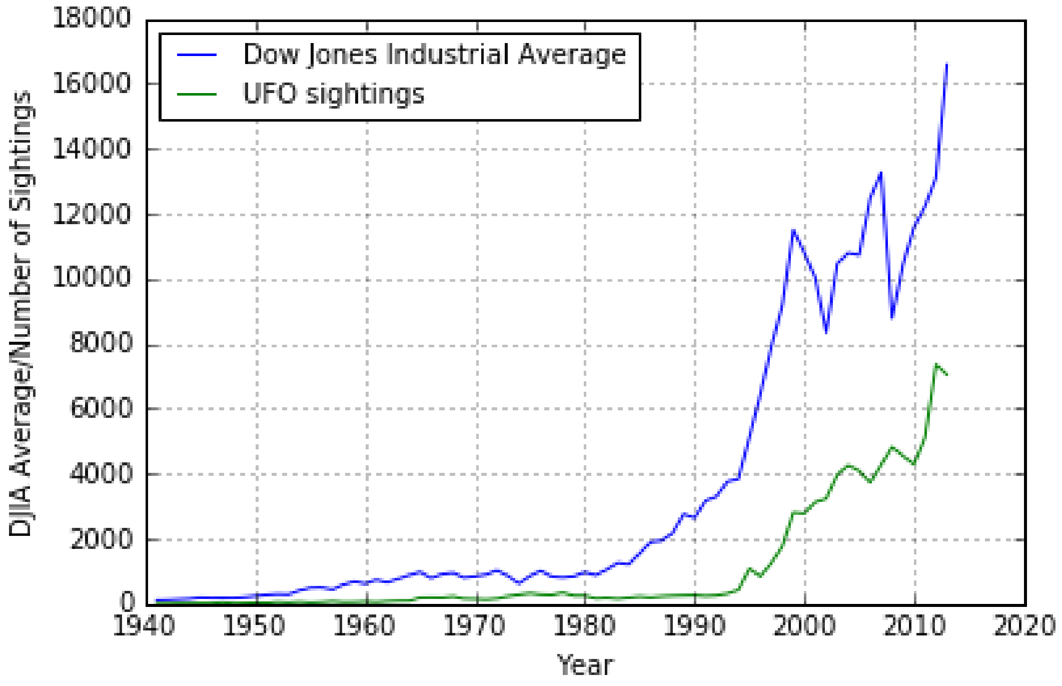
- Corelation = 1.0



Common Mistake: Correlation of Two Trending Series

- Dow Jones Industrial Average and UFO Sightings

(www.nuforc.org)



- Correlation of levels: 0.94

Example: Correlation of Large Cap and Small Cap Stocks

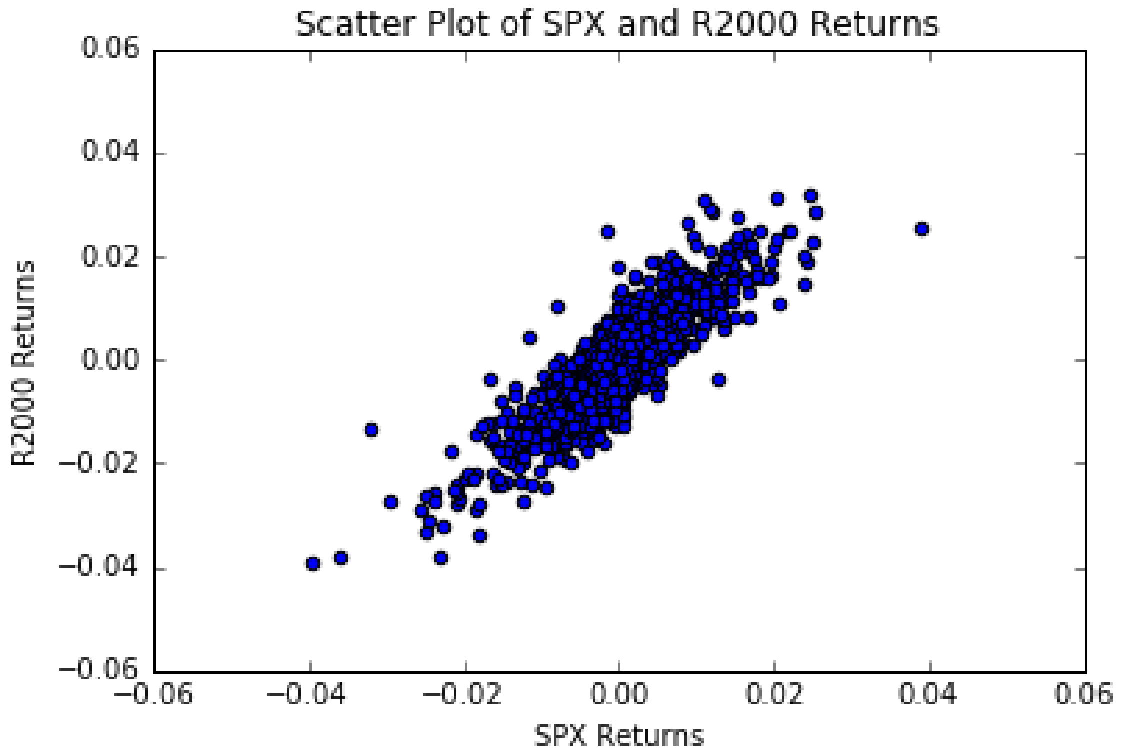
- Start with stock prices of SPX (large cap) and R2000 (small cap)
- First step: Compute percentage changes of both series

```
df['SPX_Ret'] = df['SPX_Prices'].pct_change()
df['R2000_Ret'] = df['R2000_Prices'].pct_change()
```

Example: Correlation of Large Cap and Small Cap Stocks

- Visualize correlation with scattter plot

```
plt.scatter(df['SPX_Ret'], df['R2000_Ret'])
plt.show()
```



Example: Correlation of Large Cap and Small Cap Stocks

- Use pandas correlation method for Series

```
correlation = df['SPX_Ret'].corr(df['R2000_Ret'])
print("Correlation is: ", correlation)
```

```
Correlation is: 0.868
```

Let's practice!

TIME SERIES ANALYSIS IN PYTHON

Simple Linear Regressions

TIME SERIES ANALYSIS IN PYTHON

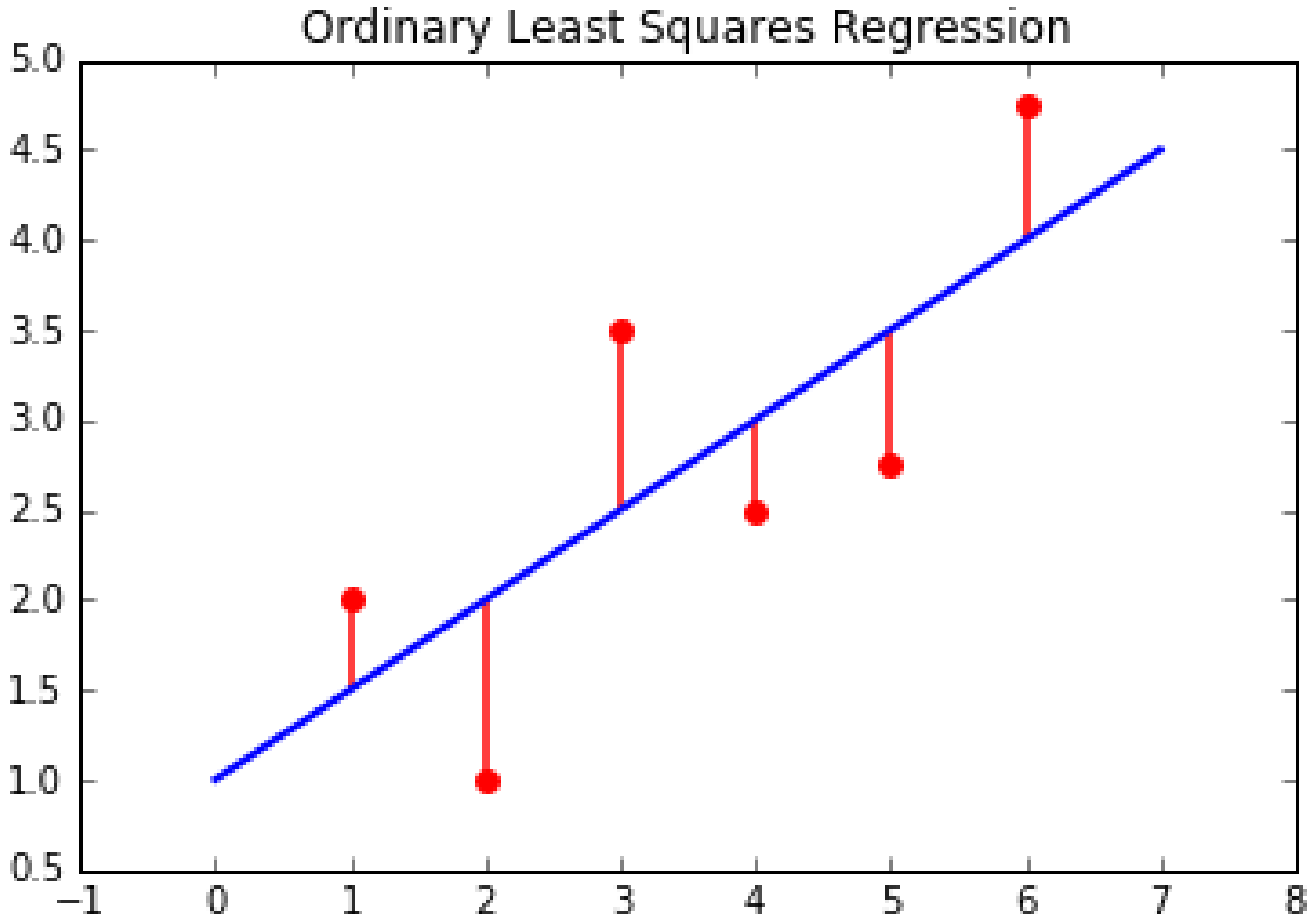
Rob Reider
Adjunct Professor, NYU-Courant
Consultant, Quantopian

What is a Regression?

- Simple linear regression: $y_t = \alpha + \beta x_t + \epsilon_t$

What is a Regression?

- Ordinary Least Squares (OLS)



Python Packages to Perform Regressions

- In statsmodels:

```
import statsmodels.api as sm
sm.OLS(y, x).fit()
```

- In numpy:

```
np.polyfit(x, y, deg=1)
```

- In pandas:

```
pd.ols(y, x)
```

- In scipy:

```
from scipy import stats
stats.linregress(x, y)
```

Warning: the order of `x` and `y` is not consistent across packages

Example: Regression of Small Cap Returns on Large Cap

- Import the statsmodels module

```
import statsmodels.api as sm
```

- As before, compute percentage changes in both series

```
df['SPX_Ret'] = df['SPX_Prices'].pct_change()
df['R2000_Ret'] = df['R2000_Prices'].pct_change()
```

- Add a constant to the DataFrame for the regression intercept

```
df = sm.add_constant(df)
```

Regression Example (continued)

- Notice that the first row of returns is NaN

```
             SPX_Price  R2000_Price   SPX_Ret  R2000_Ret
Date
2012-11-01  1427.589966   827.849976       NaN        NaN
2012-11-02  1414.199951   814.369995 -0.009379  -0.016283
```

- Delete the row of NaN

```
df = df.dropna()
```

- Run the regression

```
results = sm.OLS(df['R2000_Ret'],df[['const','SPX_Ret']]).fit()
print(results.summary())
```

Regression Example (continued)

- Regression output

```
                            OLS Regression Results
==============================================================================
Dep. Variable:              R2000_Ret   R-squared:                       0.753
Model:                            OLS   Adj. R-squared:                  0.753
Method:                 Least Squares   F-statistic:                     3829.
Date:                Fri, 26 Jan 2018   Prob (F-statistic):               0.00
Time:                        13:29:55   Log-Likelihood:                 4882.4
No. Observations:                1257   AIC:                            -9761.
Df Residuals:                    1255   BIC:                            -9751.
Df Model:                           1
Covariance Type:            nonrobust
==============================================================================
                 coef    std err          t      P>|t|      [95.0% Conf. Int.]
------------------------------------------------------------------------------
const      -4.964e-05      0.000     -0.353      0.724        -0.000     0.000
SPX_Ret        1.1412      0.018     61.877      0.000         1.105     1.177
==============================================================================
Omnibus:                       61.950   Durbin-Watson:                   1.991
Prob(Omnibus):                  0.000   Jarque-Bera (JB):              148.100
Skew:                           0.266   Prob(JB):                     6.93e-33
Kurtosis:                       4.595   Cond. No.                         131.
==============================================================================
```

- Intercept in `results.params[0]`
- Slope in `results.params[1]`

Regression Example (continued)

- Regression output

```
                            OLS Regression Results
==============================================================================
Dep. Variable:              R2000_Ret   R-squared:                       0.753
Model:                            OLS   Adj. R-squared:                  0.753
Method:                 Least Squares   F-statistic:                     3829.
Date:                Fri, 26 Jan 2018   Prob (F-statistic):               0.00
Time:                        13:29:55   Log-Likelihood:                 4882.4
No. Observations:                1257   AIC:                            -9761.
Df Residuals:                    1255   BIC:                            -9751.
Df Model:                           1
Covariance Type:            nonrobust
==============================================================================
                 coef    std err          t      P>|t|      [95.0% Conf. Int.]
------------------------------------------------------------------------------
const      -4.964e-05      0.000     -0.353      0.724        -0.000     0.000
SPX_Ret        1.1412      0.018     61.877      0.000         1.105     1.177
==============================================================================
Omnibus:                       61.950   Durbin-Watson:                   1.991
Prob(Omnibus):                  0.000   Jarque-Bera (JB):              148.100
Skew:                           0.266   Prob(JB):                     6.93e-33
Kurtosis:                       4.595   Cond. No.                         131.
==============================================================================
```

Relationship Between R-Squared and Correlation

- $[\text{corr}(x,y)]^2 = R^2$ (or R-squared)
- $\text{sign}(\text{corr}) = \text{sign}(\text{regression slope})$
- In last example:
  - R-Squared = 0.753
  - Slope is positive
  - correlation = $+\sqrt{0.753} = 0.868$

Let's practice!

TIME SERIES ANALYSIS IN PYTHON

Autocorrelation

TIME SERIES ANALYSIS IN PYTHON

Rob Reider
Adjunct Professor, NYU-Courant
Consultant, Quantopian

What is Autocorrelation?

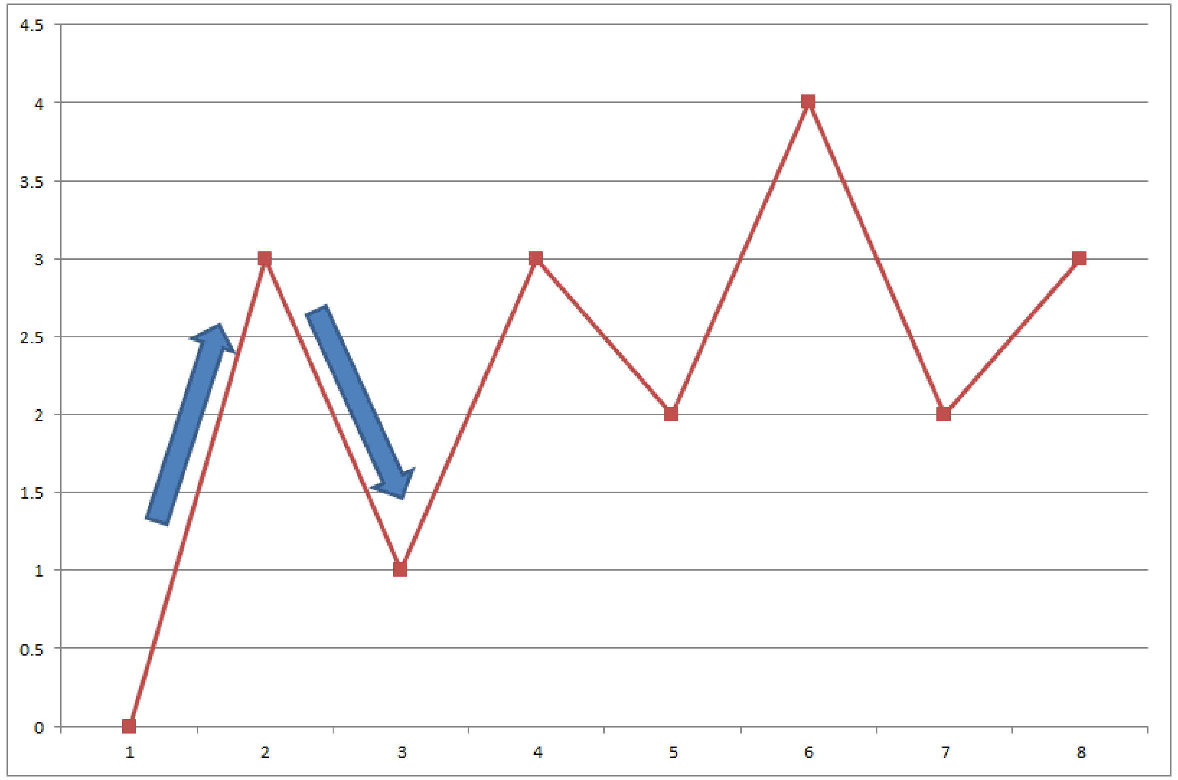
- Correlation of a time series with a lagged copy of itself

Series	Lagged Series
5	
10	5
15	10
20	15
25	20
⋮	⋮

- Lag-one autocorrelation
- Also called **serial correlation**

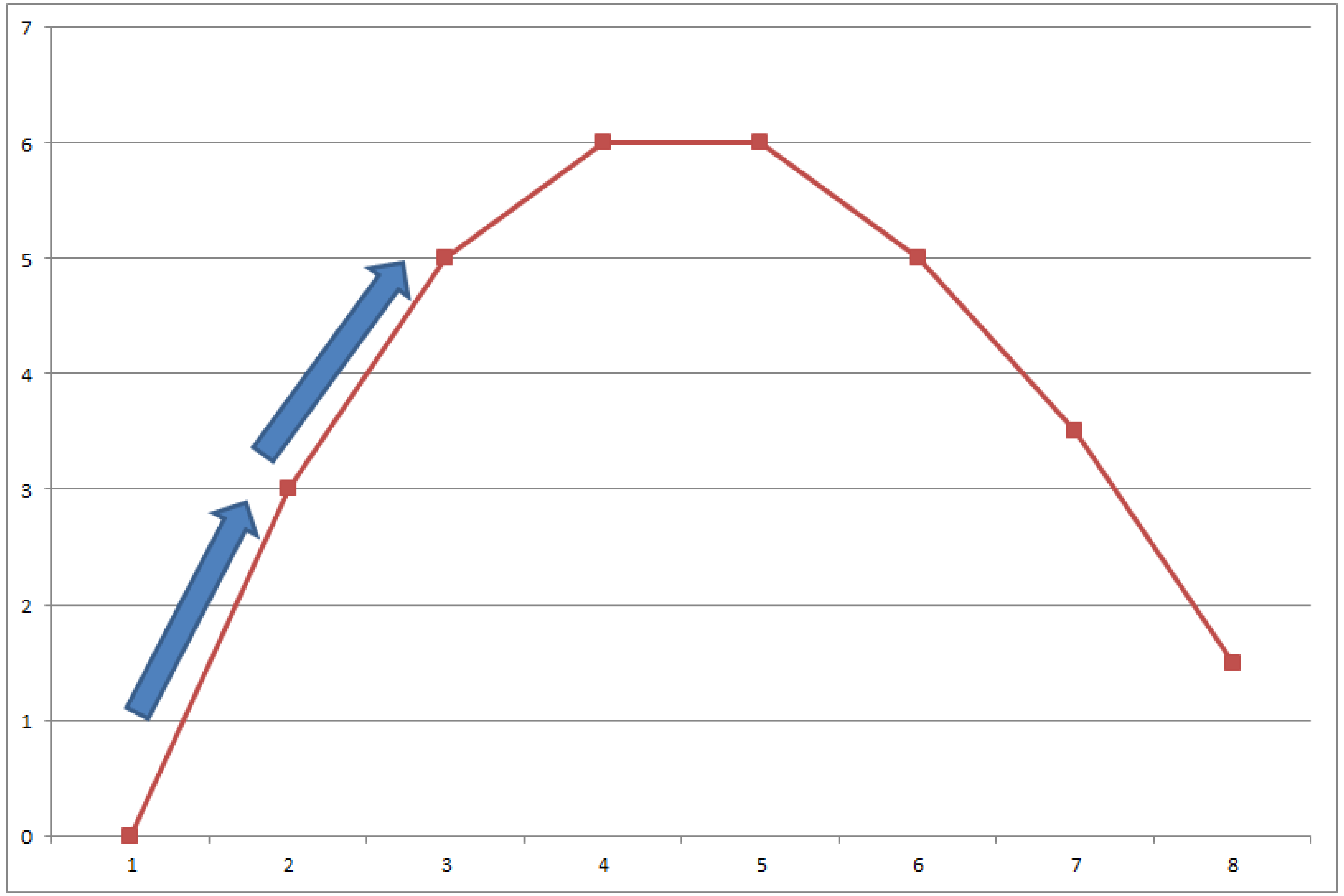
Interpretation of Autocorrelation

- **Mean Reversion** - Negative autocorrelation



Interpretation of Autocorrelation

- **Momentum**, or **Trend Following** - Positive autocorrelation



Traders Use Autocorrelation to Make Money

- Individual stocks
  - Historically have negative autocorrelation
  - Measured over short horizons (days)
  - Trading strategy: Buy losers and sell winners
- Commodities and currencies
  - Historically have positive autocorrelation
  - Measured over longer horizons (months)
  - Trading strategy: Buy winners and sell losers

Example of Positive Autocorrelation: Exchange Rates

- Use daily ¥/$ exchange rates in DataFrame `df` from **FRED**
- Convert index to datetime

```
# Convert index to datetime
df.index = pd.to_datetime(df.index)
# Downsample from daily to monthly data
df = df.resample(rule='M', how='last')
# Compute returns from prices
df['Return'] = df['Price'].pct_change()
# Compute autocorrelation
autocorrelation = df['Return'].autocorr()
print("The autocorrelation is: ",autocorrelation)
```

```
The autocorrelation is: 0.0567
```

Let's practice!

TIME SERIES ANALYSIS IN PYTHON