Metadata

```
Course:   DS 5100
Module:   05 Numpy HW
Topic:    Capital Asset Pricing Model (CAPM)
Author:   R.C. Alvarado (revised)
Date:     7 July 2023
```

Student Info

- Name: Hilde Younce
- Net ID: ksg8xy
- URL of this file in GitHub: https://github.com/hyounce/DS5100-ksg8xy/blob/main/lessons/M05/hw05.ipynb

Instructions

In your **private course repo on Rivanna**, use this Jupyter notebook and the data file `capm_market_data.csv` to write code that performs the tasks below. The data file is in the HW directory of this module in the course repo.

Save your notebook in the `M05` directory.

Remember to add and commit these files to your repo.

Then push your commits to your repo on GitHib.

Be sure to fill out the **Student Info** block above.

To submit your homework, save the notebook as a PDF and upload it to GradeScope, following the instructions.

TOTAL POINTS: 10

Overview

In finance, a capital asset pricing model (CAPM) is a single-factor regression model used to explain and predict excess stock returns.

There are better, more accurate models, but CAPM has its uses.

For example, the **market beta** β_i a useful output.

Here is the formula for calculating the expected excess return:

$$E[R_i] - R_f = \beta_i(E[R_m] - R_f)$$

where:

- ER_i: expected return of stock i
- R_f: risk-free rate
- β_i: market beta of the stock
- $ER_m - R_f$: market risk premium

Review the instructions below to complete the requested tasks.

TOTAL POINTS: 10

Setting Up

Import NumPy

In [ ]:
```
import numpy as np
```

Define Risk-free Treasury rate. You will use this constant below.

In [ ]:
```
R_f = 0.0175 / 252
```

Prepare the Data

We import the data and convert it into usable Numby arrays.

Read in the market data

The values are closing prices, adjusted for splits and dividends.

The prefixes of the second two columns are based on the following codes:

- SPY is an ETF for the S&P 500 (i.e. the stock market as whole)
- AAPL stands for Apple

In [ ]:
```
data_file = "capm_market_data-2.csv"
```

In [ ]:
```
data_2D = np.array([row.strip().split(',') for row in open(data_file, 'r').r
```

Separete columns from the data

In [ ]:
```
COLS = np.str_(data_2D[0])
```

In [ ]:
```
COLS
```

Out[ ]:
```
"['date' 'spy_adj_close' 'aapl_adj_close']"
```

Separate columns by data types

Numpy wants everything to in a data structure to be of the same type.

In [ ]:
```
DATES = data_2D[1:, 0]
```

In [ ]:
```
RETURNS = data_2D[1:, 1:].astype('float')
```

Task 1

(1 PT)

Print the first 5 rows of the `RETURNS` table.

In [ ]:
```
RETURNS[:5]
```

Out[ ]:
```
array([[321.55578613, 298.82995605],
       [319.12091064, 295.92471313],
       [320.33837891, 298.28271484],
       [319.43765259, 296.87988281],
       [321.1401062 , 301.6555481 ]])
```

Task 2

(1 PT)

Print the first five values from the SPY column in `RETURNS`.

Then do the same for the AAPL column.

Use one cell for each operation.

In [ ]:
```
spy = RETURNS[:, :1]
aapl = RETURNS[:, 1:]
print(spy[:5], "\n")
print(aapl[:5])
```

```
[[321.55578613]
 [319.12091064]
 [320.33837891]
 [319.43765259]
 [321.1401062 ]]

[[298.82995605]
 [295.92471313]
 [298.28271484]
 [296.87988281]
 [301.6555481 ]]
```

Task 3

(1 PT)

Compute the excess returns by subtracting the constant `R_f` from `RETURNS`.

Save the result as numpy 2D array (i.e. a table) named `EXCESS`.

Print the LAST five rows from the new table.

In [ ]:
```
EXCESS = RETURNS - R_f
EXCESS[-5:]
```

Out[ ]:
```
array([[314.37993544, 383.00994032],
       [317.58992689, 383.67992323],
       [314.83992689, 381.90993422],
       [318.91994398, 388.22994154],
       [321.84993666, 390.89992445]])
```

Task 4

(1 PT)

Make a simple scatterplot using Matplotlib with SPY excess returns on the x-axis, AAPL excess returns on the y-axis.

Hint: Use the following code:

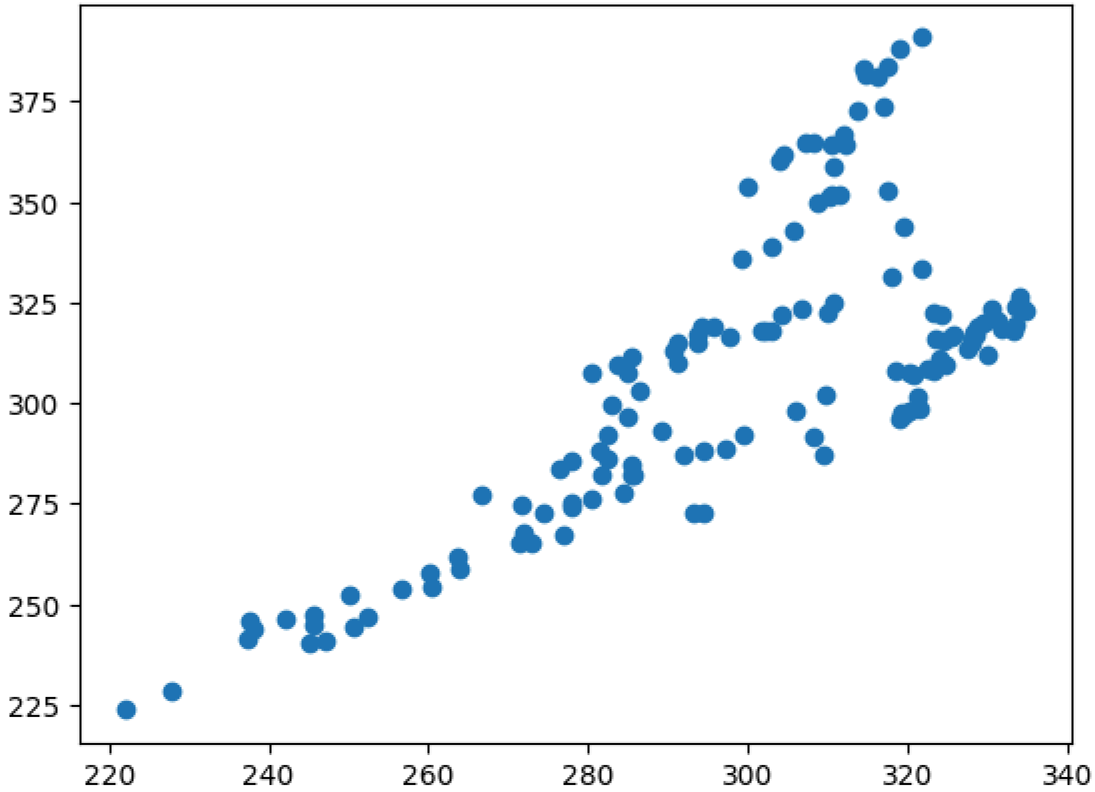
```
from matplotlib.pyplot import scatter

scatter(<x>, <y>)
```

Replace `<x>` and `<y>` with the appropriate vectors.

You may want to save the vectors for the SPY and AAPL columns as `x` and `y` respectively. This will make it visually easier to perform Task 6.

In [ ]:
```
from matplotlib.pyplot import scatter
x = spy
y = aapl
scatter(x, y)
```

Out[ ]: <matplotlib.collections.PathCollection at 0x12dda1790>



Taks 5

(3 PTS)

Use the **normal equation**, listed below, to compute the Regression Coefficient Estimate of the data plotted above, $\hat{\beta}_i$.

Note that x^T denotes the transpose of x.

$$\hat{\beta}_i = (x^T x)^{-1} x^T y$$

Use the Numpy functions for matrix to do this — multiplication, transpose, and inverse.

Note, however, that since x in this case a single column matrix, i.e. a vector, the result of $x'x$ will be a scalar, which is not invertable. So you can just invert the result by division, i.e.

$$\hat{\beta}_i = \frac{1}{x^T x}(x^T y)$$

Be sure to review what these operations do, and how they work, if you're a bit rusty.

You should find that $\hat{\beta}_i > 1$.

This means that the risk of AAPL stock, given the data, and according to this particular (flawed) model, is higher relative to the risk of the S&P 500.

In [ ]:
```
beta = np.multiply(1 / np.matmul(np.transpose(x), x), np.matmul(np.transpose
beta[0][0]
```

Out[ ]: 1.0299802873008543

Task 6

(3 PTS)

Measuring Beta Sensitivity to Dropping Observations (Jackknifing)

Let's understand how sensitive the beta is to each data point.
We want to drop each data point (one at a time), compute $\hat{\beta}_i$ using our formula from above, and save each measurement.

Write a function called `beta_sensitivity()` with these specs:

- Take numpy arrays x and y as inputs.
- For each observation i, compute the beta without the current observation. You can use a `lambda` function for this.
- Return a list of tuples each containing the observation row dropped and the beta estimate, i.e. something like `(i, beta_est)`, depending how you've named your variables.

Hint: `np.delete(x, i)` will delete observation i from array x.

Call `beta_sensitivity()` and print the first five tuples of output.

In [ ]:
```
def beta_sensitivity(x,y):
    betas = []
    i = 0
    while len(x) > 1:
        x = np.delete(x, i)
        y = np.delete(y, i)
        get_beta = lambda x,y: np.multiply(1 / np.matmul(np.transpose(x), x)
        betas.append((i, get_beta(x,y)))
        i += i
    return betas
print(beta_sensitivity(x,y)[:5])
```

```
[(0, 1.030847723014743), (0, 1.0317340452064), (0, 1.0326092429162974), (0,
1.0335101728366376), (0, 1.0343483557452924)]
```