Metadata

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Course:   DS 5100
Module:   05 Numpy HW
Topic:    Capital Asset Pricing Model (CAPM)
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Date:     7 July 2023
```

Student Info

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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 [7]:
```
import numpy as np
```

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

In [9]:
```
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 [12]:
```
data_file = "capm_market_data-2.csv"
```

In [13]:
```
data_2D = np.array([row.strip().split(',') for row in open(data_file, 'r').r
```

Separete columns from the data

In [15]:
```
COLS = np.str_(data_2D[0])
```

In [16]:
```
COLS
```

Out[16]:
```
"['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 [18]:
```
DATES = data_2D[1:, 0]
```

In [19]:
```
RETURNS = data_2D[1:, 1:].astype('float')
```

Task 1

(1 PT)

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

In [21]:
```
# CODE HERE
print(RETURNS[:5,])
```

```
[[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 [23]:
```
# CODE HERE
print(RETURNS[:5, 0]) # Print SPY Column
```

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

In [24]:
```
print(RETURNS[:5, 1]) # Print AAPL column
```

```
[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 [26]:
```
# CODE HERE
EXCESS = RETURNS - R_f
EXCESS[-5:,:]
```

Out[26]:
```
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

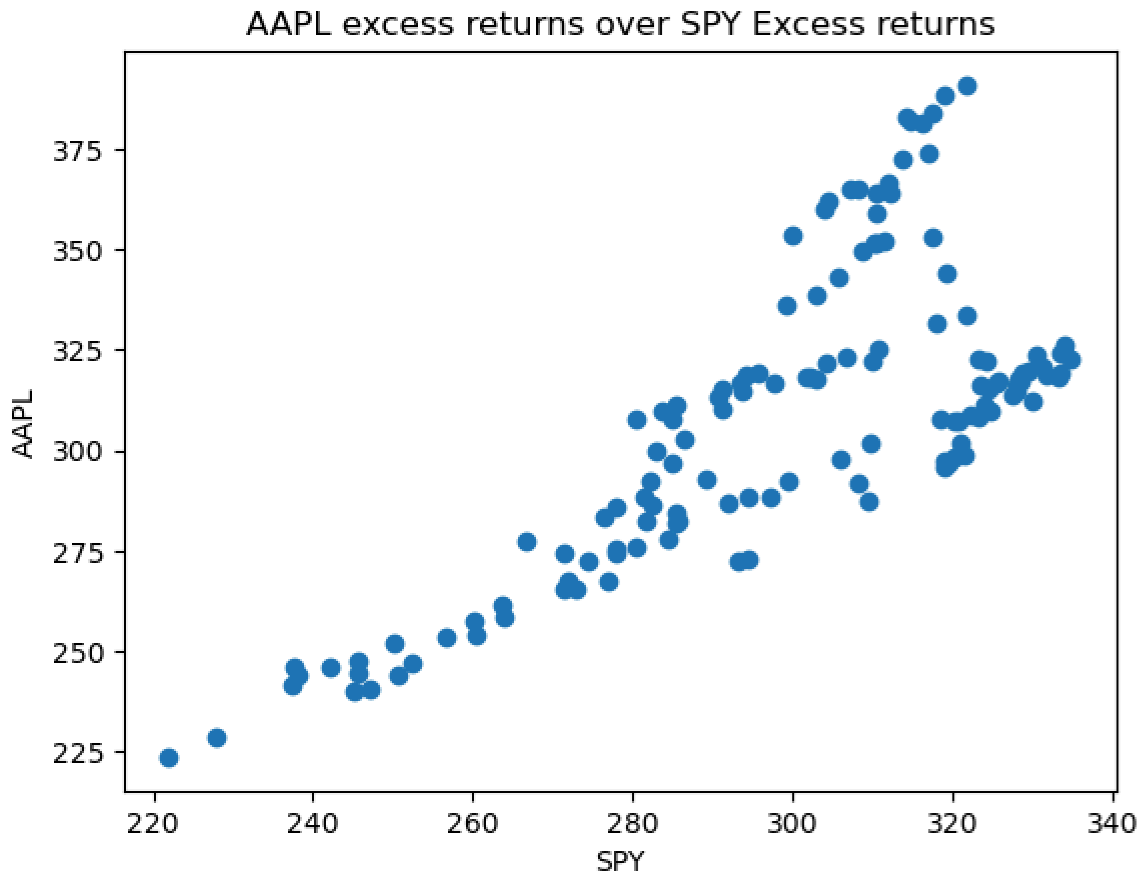
scatter(<x>, <y>)
```

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 [28]:
```
# CODE HERE
# Use matplotlib to plot AAPL over SPY
import matplotlib.pyplot as plt
x = EXCESS[:, 0]
y = EXCESS[:, 1]
plt.scatter(x, y)
plt.xlabel("SPY")
plt.ylabel("AAPL")
plt.title("AAPL excess returns over SPY Excess returns")
```

Out[28]:
```
Text(0.5, 1.0, 'AAPL excess returns over SPY Excess returns')
```



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.

$\begin{aligned} \hat\beta_i=(x^Tx)^{-1}x^Ty \end{aligned}$

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.

$\hat\beta_i = \large\frac{1}{x^Tx} \small(x^Ty)$

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 [31]:
```
# CODE HERE
# Find the Regression Coefficient Esitmate
reg_coefficient = (np.dot(np.transpose(x), y))/(np.dot(np.transpose(x), x))
reg_coefficient
```

Out[31]:
```
1.029980294240815
```

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 [48]:
```
# CODE HERE
def beta_sensitivity(x, y):
    """ For Each obsv. compute beta w/o current obsv.
        use np.delete(x, i) to delete i from array x)
        Return a list of tups w/ (i, beta_est)
    Args:
        x: (array) numpy array for EXCESS SPY returns
        y: (array) numpy array for EXCESS AAPL returns
    Returns:
        betas: (list) list of tuples containing (i, beta_est)
    """
    betas = list()

    for i, val in enumerate(x):
        x_current = np.delete(x, i)
        y_current = np.delete(y, i)
```

```
        beta_est = (np.dot(np.transpose(x_current), y_current))/(np.dot(np.t
        betas.append((i, beta_est))

    return betas

output_tuples = beta_sensitivity(x, y)
print(output_tuples[:5])
```

```
[(0, 1.030847730172396), (1, 1.0308516176393125), (2, 1.0308255236222597),
(3, 1.0308357542837525), (4, 1.030759501843587)]
```

In [ ]: