CSE 544 - Project

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1 Personal Info

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2 Load Data

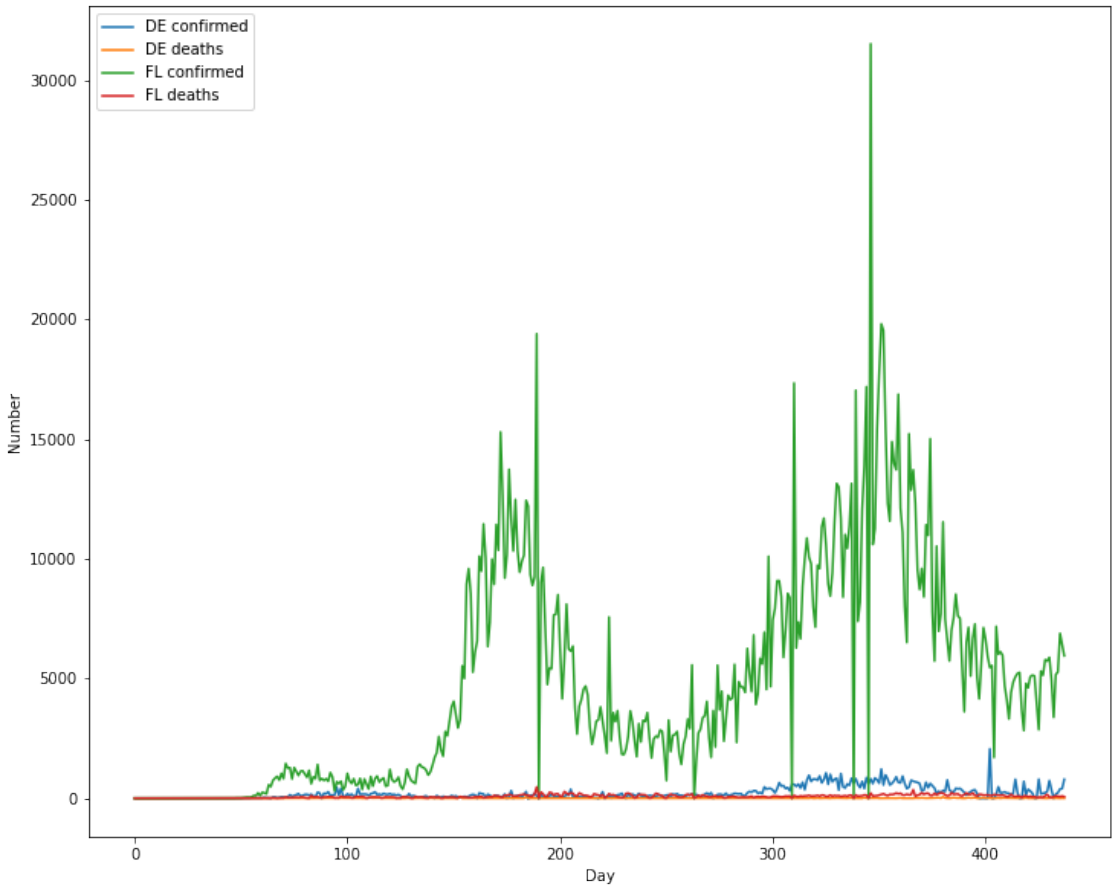
[1]:
```
import matplotlib.pyplot as plt
import numpy as np
import math
import datetime
import csv
import scipy.stats
```

[2]:
```
# Get number of days passed since 2020-01-22
def date_index(date_string):
    year = int(date_string[0:4])
    month = int(date_string[5:7])
    day = int(date_string[8:10])
    d1 = datetime.datetime(2020, 1, 22)
    d2 = datetime.datetime(year, month, day)
    return (d2 - d1).days
```

[3]:
```
de_confirmed = np.loadtxt("Datasets/States Data/5.csv", delimiter=",",␣
 ↪encoding='utf-8-sig', usecols=((1)), skiprows=1)
fl_confirmed = np.loadtxt("Datasets/States Data/5.csv", delimiter=",",␣
 ↪encoding='utf-8-sig', usecols=((2)), skiprows=1)
de_deaths = np.loadtxt("Datasets/States Data/5.csv", delimiter=",",␣
 ↪encoding='utf-8-sig', usecols=((3)), skiprows=1)
fl_deaths = np.loadtxt("Datasets/States Data/5.csv", delimiter=",",␣
 ↪encoding='utf-8-sig', usecols=((4)), skiprows=1)

date = []
csv_file=open('Datasets/States Data/5.csv')
csv_reader_lines = csv.reader(csv_file)
for one_line in csv_reader_lines:
```

```
    if one_line[0]!='Date':
        date.append(date_index(one_line[0]))
```

[4]:
```
# Get daily data
de_confirmed_daily = [0]
fl_confirmed_daily = [0]
de_deaths_daily = [0]
fl_deaths_daily = [0]
for i in range(1, len(de_confirmed)):
    de_confirmed_daily.append(de_confirmed[i] - de_confirmed[i-1])
    fl_confirmed_daily.append(fl_confirmed[i] - fl_confirmed[i-1])
    de_deaths_daily.append(de_deaths[i] - de_deaths[i-1])
    fl_deaths_daily.append(fl_deaths[i] - fl_deaths[i-1])

plt.figure(figsize=(12,10))
plt.plot(date, de_confirmed_daily, label='DE confirmed')
plt.plot(date, de_deaths_daily, label='DE deaths')
plt.plot(date, fl_confirmed_daily, label='FL confirmed')
plt.plot(date, fl_deaths_daily, label='FL deaths')
plt.xlabel('Day')
plt.ylabel('Number')
plt.legend(loc='upper left')
plt.show()
```



3 Clean Dataset

[5]:
```
def tukey_outlier(input, alpha):
    sorted_data = sorted(input)
    n = len(input)
    count = 0

    q1 = sorted_data[math.ceil(n / 4)]
    q3 = sorted_data[math.ceil((3 * n) / 4)]
    iqr = q3 - q1

    for i in range(len(input)):
        if input[i] > q3 + alpha * iqr or input[i] < q1 - alpha * iqr:
            count += 1
            if input[i] != 0: # Except 0s
                input[i] = (input[i-1] + input[i-2])/2

    return count
```

[6]:
```
outlier_alpha = 1.5
print('DE confirmed:', tukey_outlier(de_confirmed_daily, outlier_alpha),␣
 ↪'outliers detected.')
print('FL confirmed:', tukey_outlier(fl_confirmed_daily, outlier_alpha),␣
 ↪'outliers detected.')
print('DE deaths:', tukey_outlier(de_deaths_daily, outlier_alpha), 'outliers␣
 ↪detected.')
print('FL deaths:', tukey_outlier(fl_deaths_daily, outlier_alpha), 'outliers␣
 ↪detected.')
```

```
DE confirmed: 41 outliers detected.
FL confirmed: 5 outliers detected.
DE deaths: 24 outliers detected.
FL deaths: 3 outliers detected.
```

[7]:
```
def daily_to_cum(daily):
    sum = 0
    cum = []
    for x in daily:
        sum += x
        cum.append(sum)
    return cum
```

[8]:
```
de_confirmed = daily_to_cum(de_confirmed_daily)
de_deaths = daily_to_cum(de_deaths_daily)
fl_confirmed = daily_to_cum(fl_confirmed_daily)
fl_deaths = daily_to_cum(fl_deaths_daily)
```

- Result:
  - DE confirmed: 41 outliers detected.
  - FL confirmed: 5 outliers detected.
  - DE deaths: 24 outliers detected.
  - FL deaths: 3 outliers detected.
- For daily data, outliers are removed by replaced with average of the previous and next one.
- Then sum up daily data to get outlier-removed cumulative data.

4 2a: Time Series Analysis

[9]:
```
def mse(estimator, truth):
    n = len(estimator)
    sum = 0
    for i in range(n):
        sum += (truth[i] - estimator[i]) ** 2
    return sum/n
```

[10]:
```
def mape(estimator, truth):
    n = len(estimator)
```

```
    sum = 0
    for i in range(n):
        if truth[i] == 0:
            n -= 1
        else:
            sum += abs(truth[i] - estimator[i]) / truth[i]
    return (100 * sum) / n
```

4.1 EWMA

[11]:
```
def ewma(input, alpha):
    n = len(input)
    prediction = [input[0]]
    for i in range(1, n):
        last_observation = input[i-1]
        last_prediction = prediction[-1]
        prediction.append(alpha * last_observation + (1-alpha) *␣
↪last_prediction)
    return prediction
```

[12]:
```
def ewma_one_week(data, alpha):
    aug = data[date_index('2020-08-01'):date_index('2020-08-29')]
    true = data[date_index('2020-08-22'):date_index('2020-08-29')]
    predict = ewma(aug, alpha)[-7:]

    print('True value =', true)
    print('Predict value =', predict)
    print('MAPE =', mape(predict, true), '%')
    print('MSE =', mse(predict,true))
    # return predict
```

[13]:
```
# EWMA with alpha=0.5
print('EWMA with alpha=0.5')
print('\nDE confirmed: ')
ewma_one_week(de_confirmed, 0.5)
print('\nFL confirmed: ')
ewma_one_week(fl_confirmed, 0.5)
print('\nDE deaths: ')
ewma_one_week(de_deaths, 0.5)
print('\nFL deaths: ')
ewma_one_week(fl_deaths, 0.5)
```

```
EWMA with alpha=0.5

DE confirmed:
True value = [16828.0, 16895.0, 16942.0, 16962.0, 16986.0, 16976.0, 17083.0]
Predict value = [16709.58656692505, 16768.793283462524, 16831.896641731262,
16886.94832086563, 16924.474160432816, 16955.237080216408, 16965.618540108204]
```

```
MAPE = 0.5306679794392648 %
MSE = 9385.759339060727

FL confirmed:
True value = [587256.0, 590230.0, 592488.0, 595161.0, 598381.0, 601650.0,
605465.0]
Predict value = [578467.9563293457, 582861.9781646729, 586545.9890823364,
589516.9945411682, 592338.9972705841, 595359.998635292, 598504.999317646]
MAPE = 1.128672834196662 %
MSE = 46170181.76240079

DE deaths:
True value = [436.25, 436.25, 440.25, 439.25, 440.25, 440.25, 440.25]
Predict value = [433.49581146240234, 434.8729057312012, 435.5614528656006,
437.9057264328003, 438.57786321640015, 439.4139316082001, 439.83196580410004]
MAPE = 0.42609826300059556 %
MSE = 5.27732759264657

FL deaths:
True value = [9744.5, 9795.5, 9867.5, 10050.5, 10203.5, 10338.5, 10427.5]
Predict value = [9506.847492218018, 9625.673746109009, 9710.586873054504,
9789.043436527252, 9919.771718263626, 10061.635859131813, 10200.067929565907]
MAPE = 2.2862786998490954 %
MSE = 55311.68171059968
```

[14]:
```
# EWMA with alpha = 0.7
print('EWMA with alpha = 0.7')
print('\nDE confirmed: ')
ewma_one_week(de_confirmed, 0.7)
print('\nFL confirmed: ')
ewma_one_week(fl_confirmed, 0.7)
print('\nDE deaths: ')
ewma_one_week(de_deaths, 0.7)
print('\nFL deaths: ')
ewma_one_week(fl_deaths, 0.7)
```

```
EWMA with alpha = 0.7

DE confirmed:
True value = [16828.0, 16895.0, 16942.0, 16962.0, 16986.0, 16976.0, 17083.0]
Predict value = [16745.551564378715, 16803.265469313614, 16867.479640794085,
16919.643892238226, 16949.29316767147, 16974.987950301438, 16975.696385090432]
MAPE = 0.3675252945568383 %
MSE = 5060.396287771784

FL confirmed:
True value = [587256.0, 590230.0, 592488.0, 595161.0, 598381.0, 601650.0,
605465.0]
```

```
Predict value = [580976.4174998556, 585372.1252499567, 588772.637574987,
591373.3912724961, 594024.7173817488, 597074.1152145247, 600277.2345643574]
MAPE = 0.7858895058795293 %
MSE = 22572975.902908426

DE deaths:
True value = [436.25, 436.25, 440.25, 439.25, 440.25, 440.25, 440.25]
Predict value = [434.6959603637846, 435.7837881091354, 436.11013643274066,
439.0080409298222, 439.17741227894663, 439.928223683684, 440.15346710510516]
MAPE = 0.25673872763649824 %
MSE = 3.013244326023961

FL deaths:
True value = [9744.5, 9795.5, 9867.5, 10050.5, 10203.5, 10338.5, 10427.5]
Predict value = [9585.444726555805, 9696.78341796674, 9765.885025390022,
9837.015507617007, 9986.454652285101, 10138.386395685531, 10278.46591870566]
MAPE = 1.6122808928889698 %
MSE = 28615.724302200655
```

4.2 AR

[15]:
```python
def ar(data, p):
    y = []
    x = []
    for i in range(len(data)-p):
        x.append([1]+data[i:i+p])
        y.append([data[i+p]])

    beta = np.dot(np.transpose(x), x)
    beta = np.linalg.inv(beta)
    beta = np.dot(beta, np.transpose(x))
    beta = np.dot(beta, y)

    feature = [1] + data[-p:]
    result = np.dot(feature, beta)[0]

    return result
```

[16]:
```python
def ar_one_week(data,p):
    aug_first3 = data[date_index('2020-08-01'):date_index('2020-08-22')]
    true = data[date_index('2020-08-22'):date_index('2020-08-29')]
    predict = []

    predict.append(ar(aug_first3, p))
    for i in range(6):
        aug_first3 = np.append(aug_first3, [true[i]])
        predict.append(ar(aug_first3, p))
```

```
    print('True value =', true)
    print('Predict value =', predict)
    print('MAPE =', mape(predict, true), '%')
    print('MSE =', mse(predict,true))
    # return predict
```

[17]:
```
# AR(3)
print('AR(3)')
print('\nDE confirmed: ')
ar_one_week(de_confirmed, 3)
print('\nFL confirmed: ')
ar_one_week(fl_confirmed, 3)
print('\nDE deaths: ')
ar_one_week(de_deaths, 3)
print('\nFL deaths: ')
ar_one_week(fl_deaths, 3)
```

```
AR(3)

DE confirmed:
True value = [16828.0, 16895.0, 16942.0, 16962.0, 16986.0, 16976.0, 17083.0]
Predict value = [16842.71575310638, 16918.198571333596, 16984.58735446166,
17028.460501805133, 17037.558173848483, 17051.709197117965, 17027.994868342103]
MAPE = 0.2770640642409507 %
MSE = 2628.728641311562

FL confirmed:
True value = [587256.0, 590230.0, 592488.0, 595161.0, 598381.0, 601650.0,
605465.0]
Predict value = [587229.7467283518, 592065.7115944263, 593772.4800386173,
595329.5762093004, 598429.324961134, 602091.5508621987, 605294.1087547903]
MAPE = 0.09575661270329319 %
MSE = 753619.9262282973

DE deaths:
True value = [436.25, 436.25, 440.25, 439.25, 440.25, 440.25, 440.25]
Predict value = [435.6573570192732, 437.99325482631593, 437.22888391902165,
440.18906936247026, 440.3242639408007, 441.2798909393159, 441.32516846081893]
MAPE = 0.27578364430194485 %
MSE = 2.2316192047546877

FL deaths:
True value = [9744.5, 9795.5, 9867.5, 10050.5, 10203.5, 10338.5, 10427.5]
Predict value = [9789.046699993583, 9922.975561048617, 9940.531200894215,
10017.554637353758, 10250.18894853977, 10363.865000385455, 10498.353207954982]
MAPE = 0.6012627879936584 %
MSE = 4642.3998009624165
```

[18]:
```
# AR(5)
print('AR(5)')
print('\nDE confirmed: ')
ar_one_week(de_confirmed, 5)
print('\nFL confirmed: ')
ar_one_week(fl_confirmed, 5)
print('\nDE deaths: ')
ar_one_week(de_deaths, 5)
print('\nFL deaths: ')
ar_one_week(fl_deaths, 5)
```

```
AR(5)

DE confirmed:
True value = [16828.0, 16895.0, 16942.0, 16962.0, 16986.0, 16976.0, 17083.0]
Predict value = [16868.66422796663, 16928.88359570937, 16990.55933952239,
17036.258671796102, 17040.856736712125, 17053.323805394844, 17030.714846877883]
MAPE = 0.3215889427852308 %
MSE = 3199.4295666480707

FL confirmed:
True value = [587256.0, 590230.0, 592488.0, 595161.0, 598381.0, 601650.0,
605465.0]
Predict value = [587007.5452938905, 591724.9658989512, 593458.1322872348,
595301.2497318574, 598326.7197570035, 601605.201149218, 604688.5749162063]
MAPE = 0.0896643032175803 %
MSE = 552181.2306559233

DE deaths:
True value = [436.25, 436.25, 440.25, 439.25, 440.25, 440.25, 440.25]
Predict value = [434.6524291687015, 437.99313131641634, 435.43869165707054,
438.7665060157638, 440.37622665575356, 442.0522281921937, 440.35319556073074]
MAPE = 0.34716919573699884 %
MSE = 4.606828957133928

FL deaths:
True value = [9744.5, 9795.5, 9867.5, 10050.5, 10203.5, 10338.5, 10427.5]
Predict value = [9788.59023953529, 9903.781097764395, 9918.185309334462,
9984.265435772331, 10217.20849645857, 10346.40862810162, 10501.623306058864]
MAPE = 0.5217497850764912 %
MSE = 3767.0710301144645
```

4.3 Results

MAPE	AR(3)	AR(5)	EWMA $\alpha = 0.5$	EWMA $\alpha = 0.8$
DE Confirmed	0.28%	0.32%	0.53%	0.37%
DE Deaths	0.28%	0.35%	0.43%	0.26%
FL Confirmed	0.10%	0.09%	1.13%	0.79%

MAPE	AR(3)	AR(5)	EWMA $\alpha = 0.5$	EWMA $\alpha = 0.8$
FL Deaths	0.60%	0.52%	2.29%	1.61%

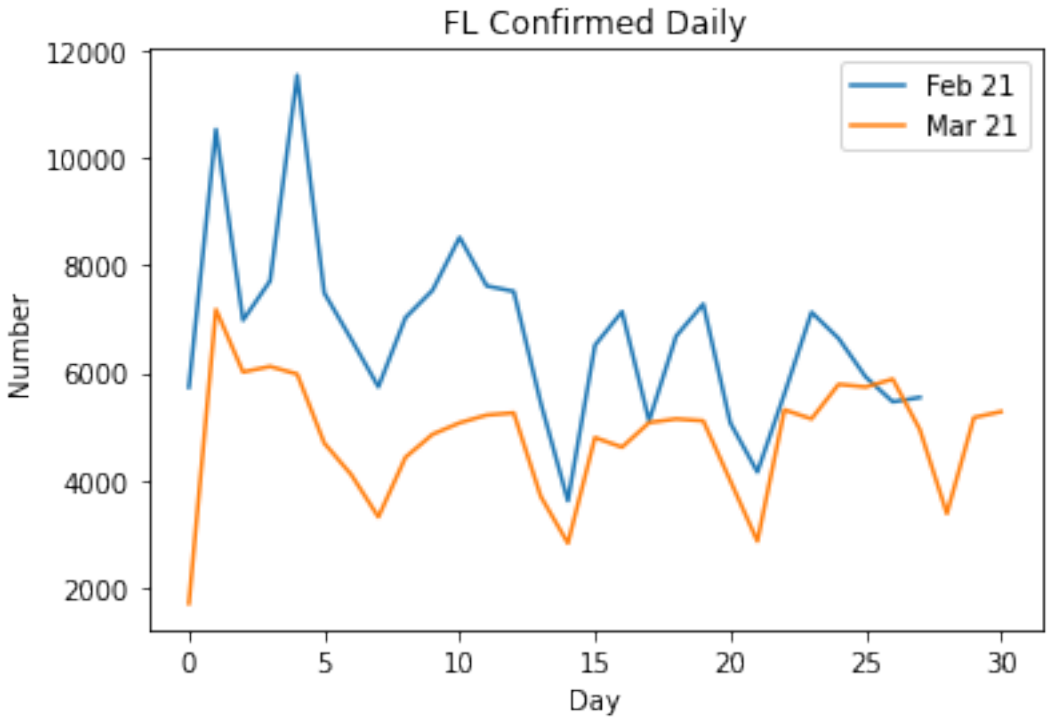
MSE	AR(3)	AR(5)	EWMA $\alpha = 0.5$	EWMA $\alpha = 0.8$
DE Confirmed	2628.73	3199.43	9385.76	5060.40
DE Deaths	2.23	4.61	5.28	3.01
FL Confirmed	753619.93	552181.23	46170181.76	22572975.90
FL Deaths	4642.40	3767.07	55311.68	28615.72

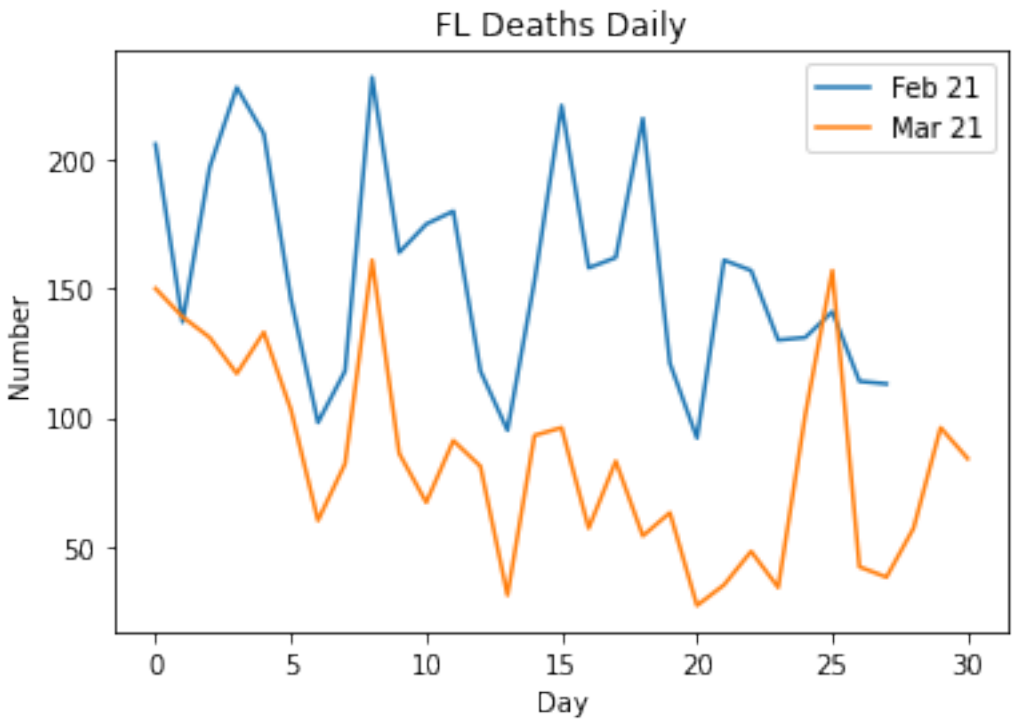
5 2b: Hypothesis Testing

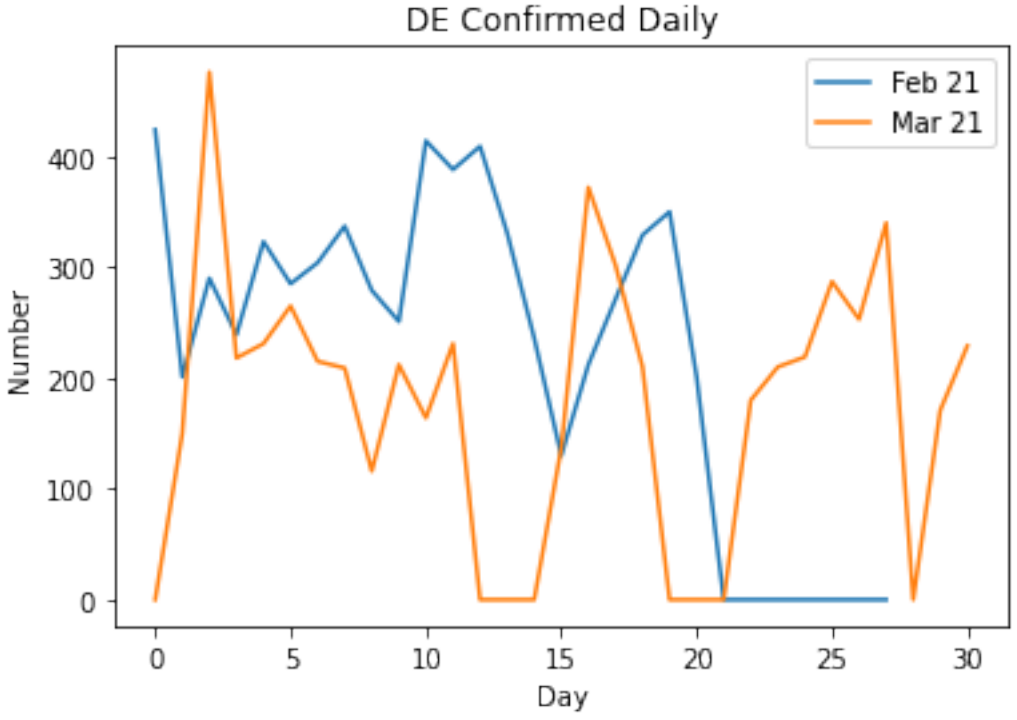
5.1 Data

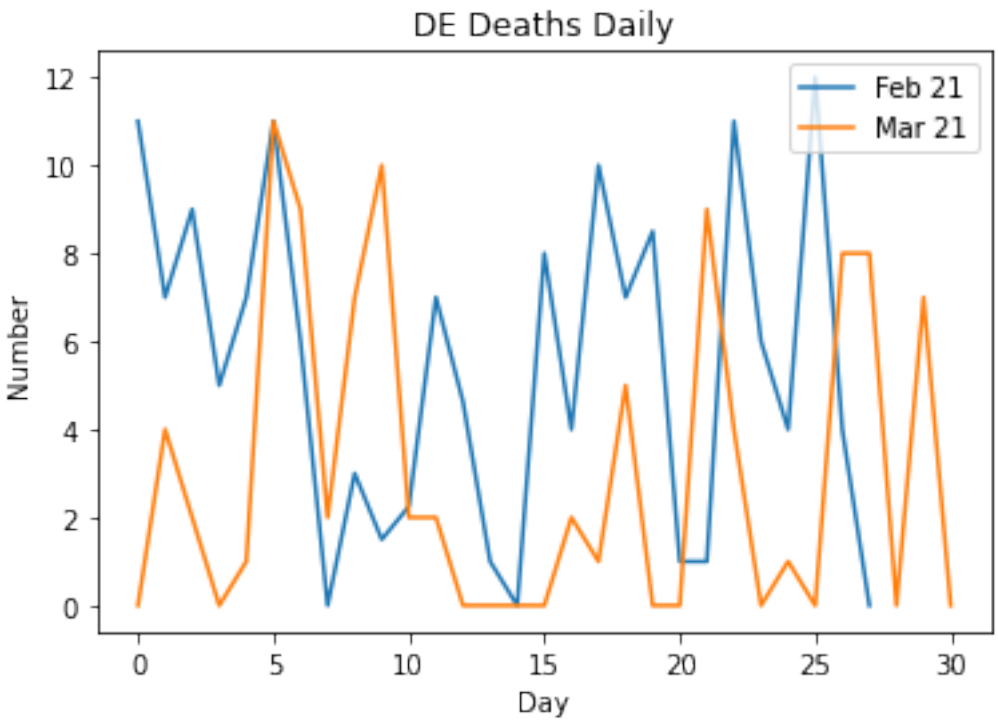
[19]:
```
fl_confirmed_daily_feb21 = fl_confirmed_daily[date_index('2021-02-01'):
 ↪date_index('2021-03-01')]
fl_confirmed_daily_mar21 = fl_confirmed_daily[date_index('2021-03-01'):
 ↪date_index('2021-04-01')]
fl_deaths_daily_feb21 = fl_deaths_daily[date_index('2021-02-01'):
 ↪date_index('2021-03-01')]
fl_deaths_daily_mar21 = fl_deaths_daily[date_index('2021-03-01'):
 ↪date_index('2021-04-01')]

de_confirmed_daily_feb21 = de_confirmed_daily[date_index('2021-02-01'):
 ↪date_index('2021-03-01')]
de_confirmed_daily_mar21 = de_confirmed_daily[date_index('2021-03-01'):
 ↪date_index('2021-04-01')]
de_deaths_daily_feb21 = de_deaths_daily[date_index('2021-02-01'):
 ↪date_index('2021-03-01')]
de_deaths_daily_mar21 = de_deaths_daily[date_index('2021-03-01'):
 ↪date_index('2021-04-01')]

plt.figure()
plt.plot(range(28), fl_confirmed_daily_feb21, label='Feb 21')
plt.plot(range(31), fl_confirmed_daily_mar21, label='Mar 21')
plt.title('FL Confirmed Daily')
plt.xlabel('Day')
plt.ylabel('Number')
plt.legend(loc='upper right')
plt.show()

plt.figure()
plt.plot(range(28), fl_deaths_daily_feb21, label='Feb 21')
plt.plot(range(31), fl_deaths_daily_mar21, label='Mar 21')
plt.title('FL Deaths Daily')
```

```
plt.xlabel('Day')
plt.ylabel('Number')
plt.legend(loc='upper right')
plt.show()

plt.figure()
plt.plot(range(28), de_confirmed_daily_feb21, label='Feb 21')
plt.plot(range(31), de_confirmed_daily_mar21, label='Mar 21')
plt.title('DE Confirmed Daily')
plt.xlabel('Day')
plt.ylabel('Number')
plt.legend(loc='upper right')
plt.show()

plt.figure()
plt.plot(range(28), de_deaths_daily_feb21, label='Feb 21')
plt.plot(range(31), de_deaths_daily_mar21, label='Mar 21')
plt.title('DE Deaths Daily')
plt.xlabel('Day')
plt.ylabel('Number')
plt.legend(loc='upper right')
plt.show()
```




FL Deaths Daily
Feb 21
Mar 21
Number
Day
200
150
100
50
0
5
10
15
20
25
30


DE Confirmed Daily
Feb 21
Mar 21
Number
Day
400
300
200
100
0
0
5
10
15
20
25
30



[20]:
```
def get_corrected_std(data):
    n = len(data)
    sum = 0
    mean = np.mean(data)
    for x in data:
        sum += (x - mean) ** 2
    return np.sqrt(sum/(n-1))
```

[21]:
```
def get_uncorrected_std(data):
    n = len(data)
    sum = 0
    mean = np.mean(data)
    for x in data:
        sum += (x - mean) ** 2
    return np.sqrt(sum/n)
```

5.2 One Sample Wald's Test

[22]:
```
def walds_test_1(data, theta0, threshold):
    mean = np.mean(data)
    n = len(data)
    w = mean - theta0
    w = w / np.sqrt(mean/n)
```

```
    w = abs(w)

    if w > threshold:
        # reject H0: theta = theta0
        print('|W| =', w, '>', threshold, ', thus reject H0, theta != theta0')
    else:
        # accept H0: theta != theta0
        print('|W| =', w, '<=', threshold, ', thus accept H0, theta = theta0')
```

[23]:
```
print('\nFL Confirmed Daily')
walds_test_1(fl_confirmed_daily_mar21, np.mean(fl_confirmed_daily_feb21), 1.96)

print('\nFL Deaths Daily')
walds_test_1(fl_deaths_daily_mar21, np.mean(fl_deaths_daily_feb21), 1.96)

print('\nDE Confirmed Daily')
walds_test_1(de_confirmed_daily_mar21, np.mean(de_confirmed_daily_feb21), 1.96)

print('\nDE Deaths Daily')
walds_test_1(de_deaths_daily_mar21, np.mean(de_deaths_daily_feb21), 1.96)
```

```
FL Confirmed Daily
|W| = 154.00699922906583 > 1.96 , thus reject H0, theta != theta0

FL Deaths Daily
|W| = 44.066109897784024 > 1.96 , thus reject H0, theta != theta0

DE Confirmed Daily
|W| = 20.033060218514848 > 1.96 , thus reject H0, theta != theta0

DE Deaths Daily
|W| = 7.504756829872881 > 1.96 , thus reject H0, theta != theta0
```

Applicability: - $\hat{\theta}$ is AN, since we use MLE for Wald's test as the estimator. - Thus the test is applicable.

5.3 One Sample Z-test

[24]:
```
def z_test_1(data, u0, sigma, threshold):
    mean = np.mean(data)
    n = len(data)

    z = mean - u0
    z = z / (sigma / np.sqrt(n))
    z = abs(z)

    if z > threshold:
```

```
        # reject H0: mu = mu0
        print('|Z| =', z, '>', threshold, ', thus reject H0, mu != mu0')
    else:
        # accept H0: mu != mu0
        print('|Z| =', z, '<=', threshold, ', thus accept H0, mu = mu0')
```

[25]:
```
print('\nFL Confirmed Daily')
z_test_1(fl_confirmed_daily_mar21, np.mean(fl_confirmed_daily_feb21),␣
 ↪get_corrected_std(fl_confirmed_daily), 1.96)

print('\nFL Deaths Daily')
z_test_1(fl_deaths_daily_mar21, np.mean(fl_deaths_daily_feb21),␣
 ↪get_corrected_std(fl_deaths_daily), 1.96)

print('\nDE Confirmed Daily')
z_test_1(de_confirmed_daily_mar21, np.mean(de_confirmed_daily_feb21),␣
 ↪get_corrected_std(de_confirmed_daily), 1.96)

print('\nDE Deaths Daily')
z_test_1(de_deaths_daily_mar21, np.mean(de_deaths_daily_feb21),␣
 ↪get_corrected_std(de_deaths_daily), 1.96)
```

```
FL Confirmed Daily
|Z| = 2.517436185080843 > 1.96 , thus reject H0, mu != mu0

FL Deaths Daily
|Z| = 6.538899043920793 > 1.96 , thus reject H0, mu != mu0

DE Confirmed Daily
|Z| = 1.4461925149404402 <= 1.96 , thus accept H0, mu = mu0

DE Deaths Daily
|Z| = 4.119543506529116 > 1.96 , thus reject H0, mu != mu0
```

Applicability: - Z-test is applicable when n is large. But in this case n=31, we cannot say it large enough. - Thus the test is not applicable.

5.4 One Sample T-test

[26]:
```
def t_test_1(data, u0, threshold):
    mean = np.mean(data)
    n = len(data)

    t = mean - u0
    t = t / (get_corrected_std(data) / np.sqrt(n))
    t = abs(t)
```

```
    if t > threshold:
        # reject H0: mu = mu0
        print('|T| =', t, '>', threshold, ', thus reject H0, mu != mu0')
    else:
        # accept H0: mu != mu0
        print('|T| =', t, '<=', threshold, ', thus accept H0, mu = mu0')
```

[27]:
```
# t(30, 0.05/2) ~= 2.04

print('\nFL Confirmed Daily')
t_test_1(fl_confirmed_daily_mar21, np.mean(fl_confirmed_daily_feb21), 2.04)

print('\nFL Deaths Daily')
t_test_1(fl_deaths_daily_mar21, np.mean(fl_deaths_daily_feb21), 2.04)

print('\nDE Confirmed Daily')
t_test_1(de_confirmed_daily_mar21, np.mean(de_confirmed_daily_feb21), 2.04)

print('\nDE Deaths Daily')
t_test_1(de_deaths_daily_mar21, np.mean(de_deaths_daily_feb21), 2.04)
```

```
FL Confirmed Daily
|T| = 9.378422030507105 > 2.04 , thus reject H0, mu != mu0

FL Deaths Daily
|T| = 10.388393069005474 > 2.04 , thus reject H0, mu != mu0

DE Confirmed Daily
|T| = 2.1124218843871345 > 2.04 , thus reject H0, mu != mu0

DE Deaths Daily
|T| = 3.6075061712377248 > 2.04 , thus reject H0, mu != mu0
```

Applicability: - T-test is applicable when data are normally distributed. It is not in this case. - Thus this test is not applicable.

5.5 Two Sample Wald's Test

[28]:
```
def walds_test_2(x, y, threshold):
    n = len(x)
    m = len(y)
    x_mean = np.mean(x)
    y_mean = np.mean(y)

    w = x_mean - y_mean
    w = w / np.sqrt(x_mean/n + y_mean/m)
    w = abs(w)
```

```
    if w > threshold:
        # reject H0: theta0 = theta1
        print('|W| =', w, '>', threshold, ', thus reject H0, theta0 != theta1')
    else:
        # accept H0: theta0 != theta1
        print('|W| =', w, '<=', threshold, ', thus accept H0, theta0 = theta1')
```

[29]:
```
print('\nFL Confirmed Daily')
walds_test_2(fl_confirmed_daily_mar21, fl_confirmed_daily_feb21, 1.96)

print('\nFL Deaths Daily')
walds_test_2(fl_deaths_daily_mar21, fl_deaths_daily_feb21, 1.96)

print('\nDE Confirmed Daily')
walds_test_2(de_confirmed_daily_mar21, de_confirmed_daily_feb21, 1.96)

print('\nDE Deaths Daily')
walds_test_2(de_deaths_daily_mar21, de_deaths_daily_feb21, 1.96)
```

```
FL Confirmed Daily
|W| = 96.45320339102717 > 1.96 , thus reject H0, theta0 != theta1

FL Deaths Daily
|W| = 25.17243031843485 > 1.96 , thus reject H0, theta0 != theta1

DE Confirmed Daily
|W| = 12.906970106995074 > 1.96 , thus reject H0, theta0 != theta1

DE Deaths Daily
|W| = 4.362337488195578 > 1.96 , thus reject H0, theta0 != theta1
```

Applicability: - Two populated Wald's test is applicable when two datas are independent. In this case we can say it fits. - Thus the test is applicable.

5.6 Two Sample Unpaired T-test

[30]:
```
def t_test_2(x, y, threshold):
    n = len(x)
    m = len(y)
    x_mean = np.mean(x)
    y_mean = np.mean(y)
    x_s2 = get_corrected_std(x) ** 2
    y_s2 = get_corrected_std(y) ** 2

    t = x_mean - y_mean
    t = t / np.sqrt(x_s2/n + y_s2/m)
```

```
    t = abs(t)

    if t > threshold:
        # reject H0: mu0 = mu1
        print('|T| =', t, '>', threshold, ', thus reject H0, mu0 != mu1')
    else:
        # accept H0: mu0 != mu1
        print('|T| =', t, '<=', threshold, ', thus accept H0, mu0 = mu1')
```

[31]:
```
# t(30, 0.05/2) ~= 2.04

print('\nFL Confirmed Daily')
t_test_2(fl_confirmed_daily_mar21, fl_confirmed_daily_feb21, 2.04)

print('\nFL Deaths Daily')
t_test_2(fl_deaths_daily_mar21, fl_deaths_daily_feb21, 2.04)

print('\nDE Confirmed Daily')
t_test_2(de_confirmed_daily_mar21, de_confirmed_daily_feb21, 2.04)

print('\nDE Deaths Daily')
t_test_2(de_deaths_daily_mar21, de_deaths_daily_feb21, 2.04)
```

```
FL Confirmed Daily
|T| = 5.086801893689198 > 2.04 , thus reject H0, mu0 != mu1

FL Deaths Daily
|T| = 6.847398048523643 > 2.04 , thus reject H0, mu0 != mu1

DE Confirmed Daily
|T| = 1.330939688448386 <= 2.04 , thus accept H0, mu0 = mu1

DE Deaths Daily
|T| = 2.4424131597900365 > 2.04 , thus reject H0, mu0 != mu1
```

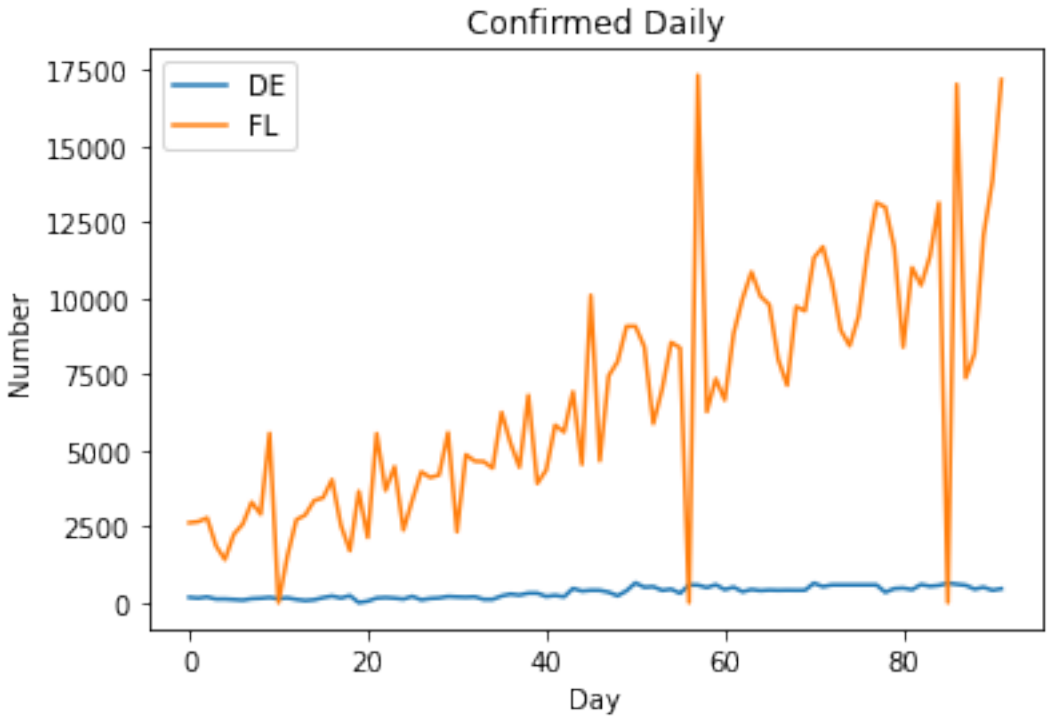
Applicability: - Two-sample unpaired T-test is applicable when 2 datas are normally distributed. It is not in this case. - Thus the test is not applicable.

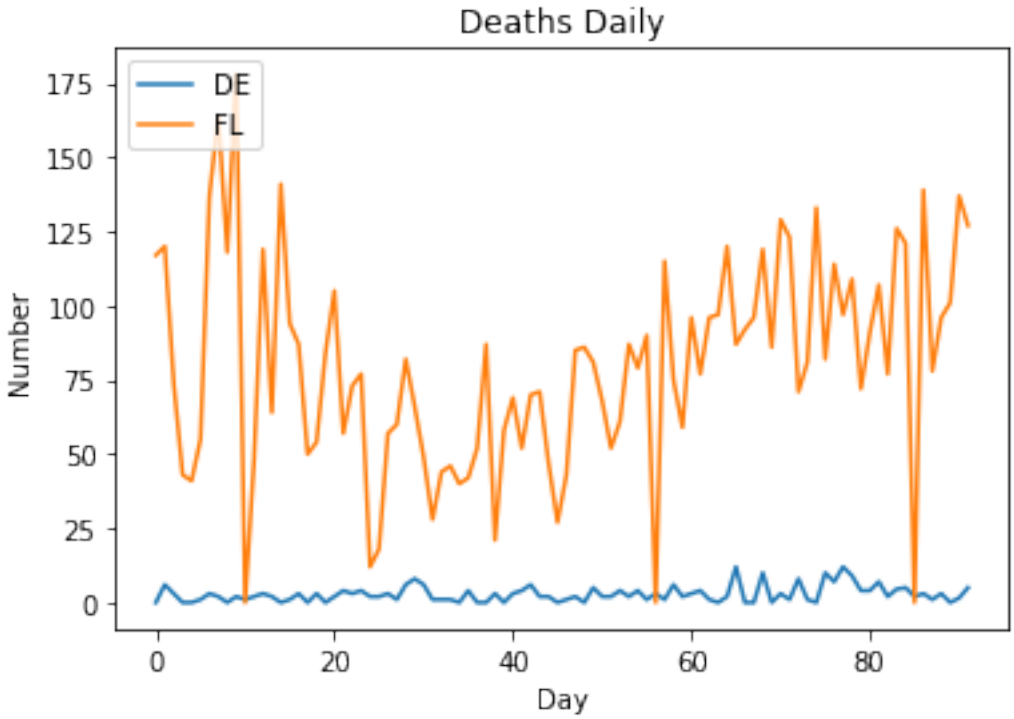
6 2c: Inference of Equality

6.1 Data

[32]:
```
fl_confirmed_daily_3month = fl_confirmed_daily[date_index('2020-10-01'):␣
↪date_index('2021-01-01')]
fl_deaths_daily_3month = fl_deaths_daily[date_index('2020-10-01'):␣
↪date_index('2021-01-01')]
```

```
de_confirmed_daily_3month = de_confirmed_daily[date_index('2020-10-01'):␣
 ↪date_index('2021-01-01')]
de_deaths_daily_3month = de_deaths_daily[date_index('2020-10-01'):␣
 ↪date_index('2021-01-01')]

plt.figure()
plt.plot(range(len(de_confirmed_daily_3month)), de_confirmed_daily_3month,␣
 ↪label='DE')
plt.plot(range(len(fl_confirmed_daily_3month)), fl_confirmed_daily_3month,␣
 ↪label='FL')
plt.title('Confirmed Daily')
plt.xlabel('Day')
plt.ylabel('Number')
plt.legend(loc='upper left')
plt.show()

plt.figure()
plt.plot(range(len(de_deaths_daily_3month)), de_deaths_daily_3month, label='DE')
plt.plot(range(len(fl_deaths_daily_3month)), fl_deaths_daily_3month, label='FL')
plt.title('Deaths Daily')
plt.xlabel('Day')
plt.ylabel('Number')
plt.legend(loc='upper left')
plt.show()
```





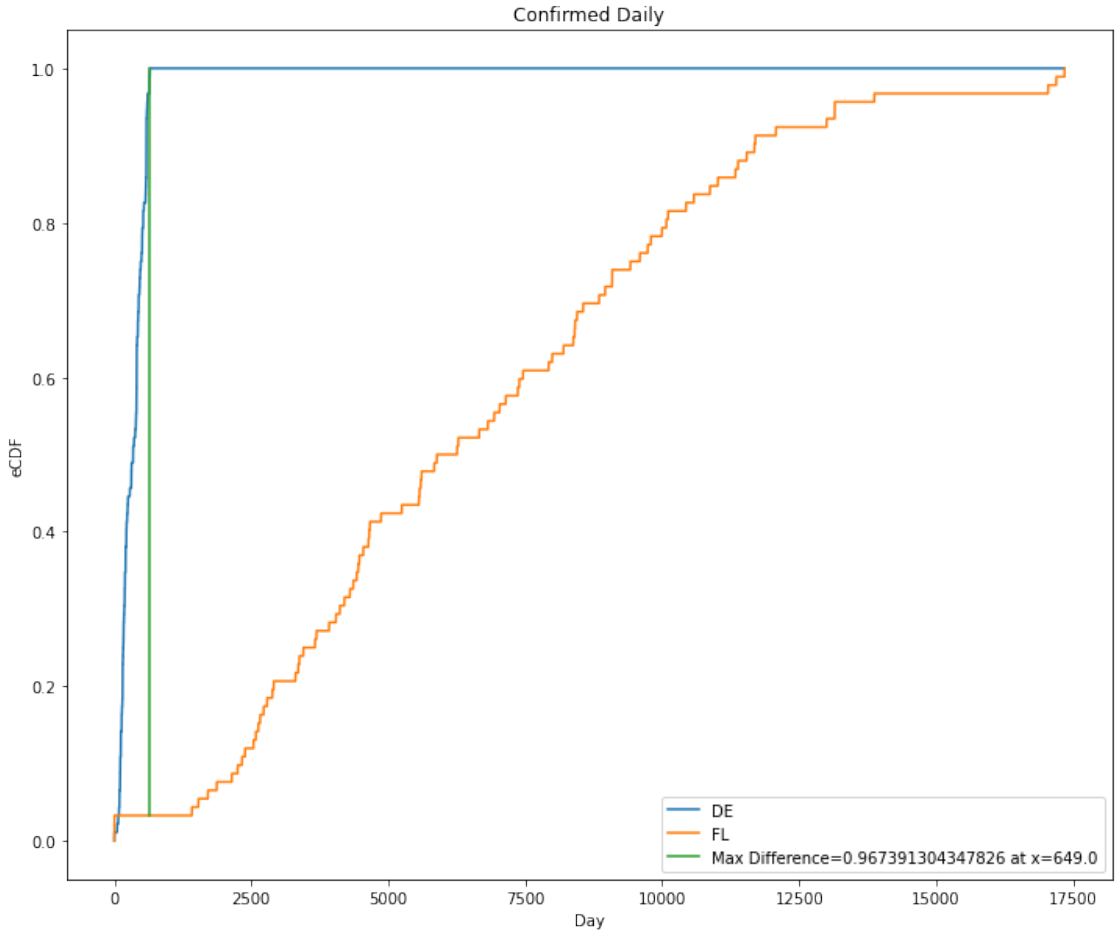
6.2 2-Sample K-S Test

[33]:
```
def get_eCDF(sample, x):
    n = len(sample)
    count = 0
    for d in sample:
        if d <= x:
            count += 1
    return count/n
```

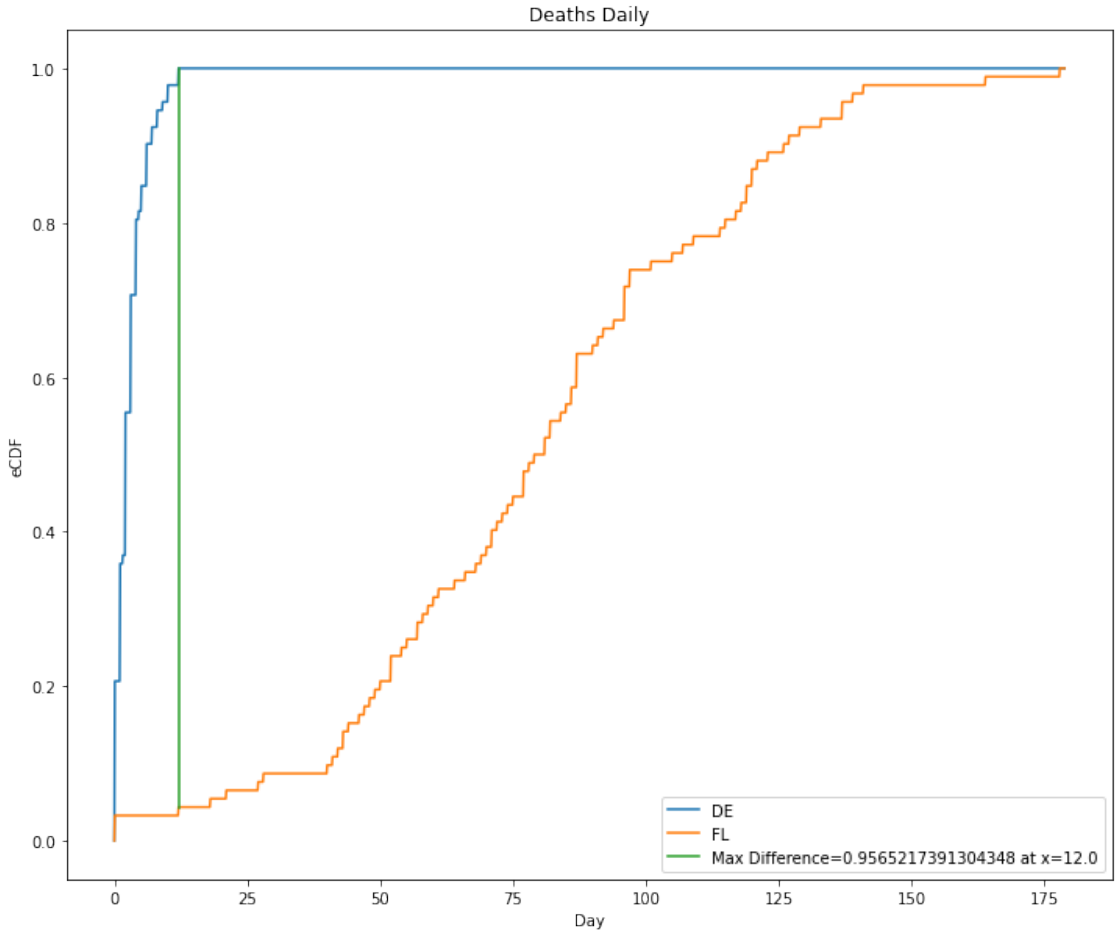
[34]:
```
def ks_test_2(data1, data2, plt_title, threshold):
    x = []
    for i in range(-1, int(np.max(data1+data2)) * 10 + 10):
        x.append(i/10)

    y1 = []
    y2 = []
    max_dif = 0
    max_dif_x = 0
    max_dif_y1 = 0
    max_dif_y2 = 0
```

```
    for xi in x:
        eCDF_1 = get_eCDF(data1, xi)
        eCDF_2 = get_eCDF(data2, xi)
        dif = abs(eCDF_1 - eCDF_2)
        if (dif > max_dif):
            max_dif = dif
            max_dif_x = xi
            max_dif_y1 = eCDF_1
            max_dif_y2 = eCDF_2
        y1.append(eCDF_1)
        y2.append(eCDF_2)

    plt.figure(figsize=(12,10))
    plt.plot(x, y1, label='DE')
    plt.plot(x, y2, label='FL')
    plt.plot([max_dif_x, max_dif_x], [max_dif_y1, max_dif_y2], label='Max␣
↪Difference='+str(max_dif)+' at x='+str(max_dif_x))
    plt.xlabel('Day')
    plt.ylabel('eCDF')
    plt.title(plt_title)
    plt.legend()
    plt.show()

    if max_dif > threshold:
        # reject H0: F_x != F_y
        print('d =', max_dif, '>', threshold, ', thus reject H0, F_x != F_y\n')
    else:
        # accept H0: F_x = F_y
        print('d =', max_dif, '<=', threshold, ', thus accept H0, F_x = F_y\n')
```

[35]:
```
ks_test_2(de_confirmed_daily_3month, fl_confirmed_daily_3month, 'Confirmed␣
↪Daily', 0.05)
ks_test_2(de_deaths_daily_3month, fl_deaths_daily_3month, 'Deaths Daily', 0.05)
```




```
d = 0.967391304347826 > 0.05 , thus reject H0, F_x != F_y
```




```
d = 0.9565217391304348 > 0.05 , thus reject H0, F_x != F_y
```

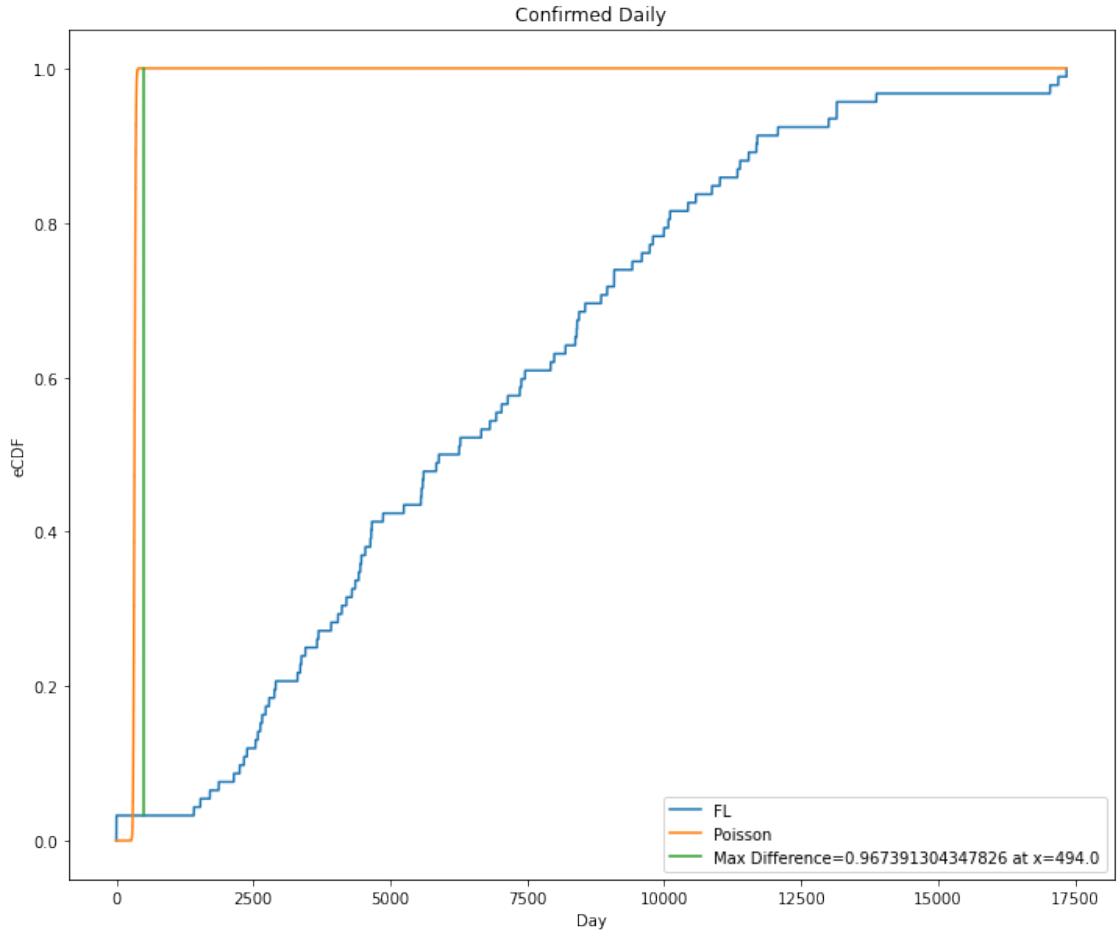
6.3 1-Sample K-S Test: Poisson

- $\hat{\lambda}_{MME} = \bar{X}$

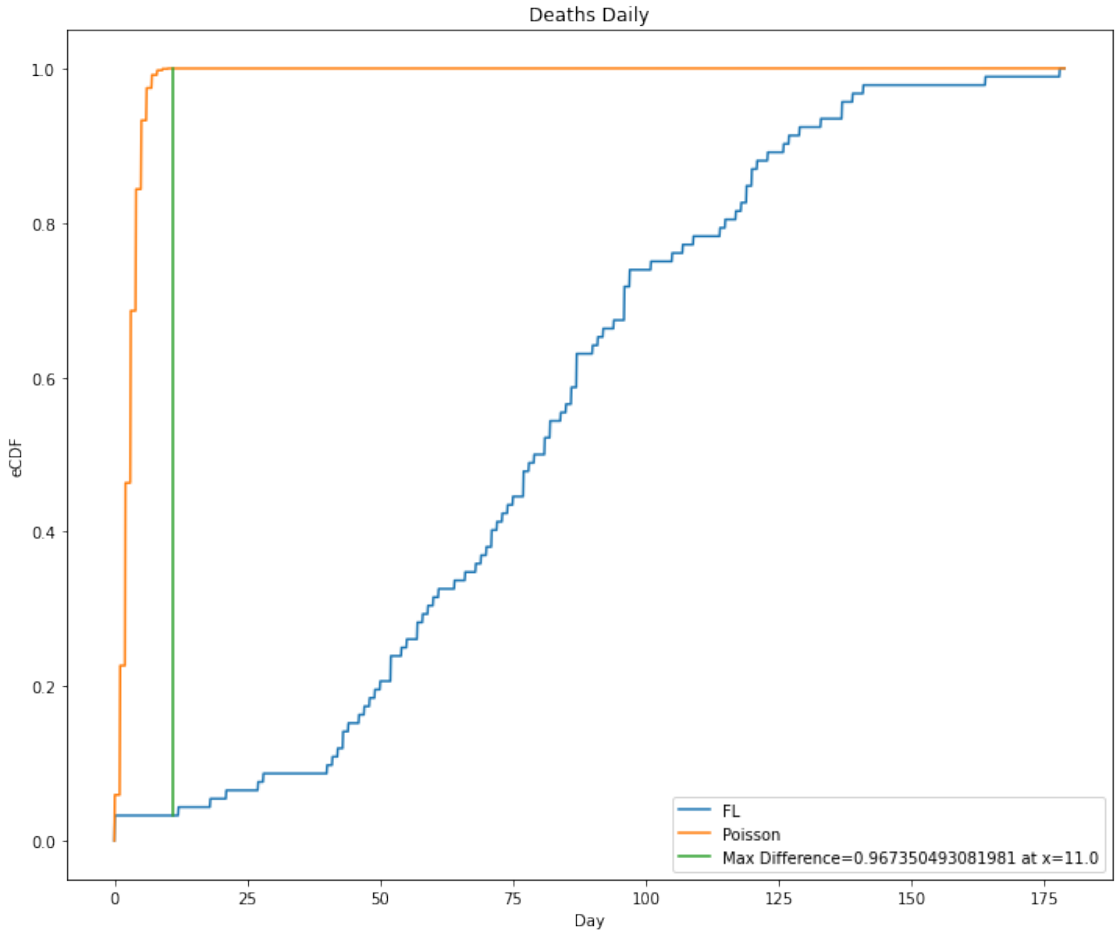
[36]:
```
def ks_test_poisson(data, lam, plt_title, threshold):
    x = []
    for i in range(-1, int(np.max(data)) * 10 + 10):
        x.append(i/10)

    y1 = []
    y2 = []
    max_dif = 0
    max_dif_x = 0
    max_dif_y1 = 0
    max_dif_y2 = 0
```

```
    for xi in x:
        eCDF_1 = get_eCDF(data, xi)
        eCDF_2 = scipy.stats.poisson.cdf(xi, lam)
        dif = abs(eCDF_1 - eCDF_2)
        if (dif > max_dif):
            max_dif = dif
            max_dif_x = xi
            max_dif_y1 = eCDF_1
            max_dif_y2 = eCDF_2
        y1.append(eCDF_1)
        y2.append(eCDF_2)

    plt.figure(figsize=(12,10))
    plt.plot(x, y1, label='FL')
    plt.plot(x, y2, label='Poisson')
    plt.plot([max_dif_x, max_dif_x], [max_dif_y1, max_dif_y2], label='Max␣
↪Difference='+str(max_dif)+' at x='+str(max_dif_x))
    plt.xlabel('Day')
    plt.ylabel('eCDF')
    plt.title(plt_title)
    plt.legend()
    plt.show()

    if max_dif > threshold:
        # reject H0: F_x != F_y
        print('d =', max_dif, '>', threshold, ', thus reject H0, F_x !=␣
↪Poisson(' + str(lam) + ')\n')
    else:
        # accept H0: F_x = F_y
        print('d =', max_dif, '<=', threshold, ', thus accept H0, F_x =␣
↪Poisson(' + str(lam) + ')\n')
```

[37]:
```
ks_test_poisson(fl_confirmed_daily_3month, np.mean(de_confirmed_daily_3month),␣
↪'Confirmed Daily', 0.05)
ks_test_poisson(fl_deaths_daily_3month, np.mean(de_deaths_daily_3month),␣
↪'Deaths Daily', 0.05)
```



d = 0.967391304347826 > 0.05 , thus reject H0, F_x != Poisson(331.9381103515625)




```
d = 0.967350493081981 > 0.05 , thus reject H0, F_x !=
Poisson(2.8260869565217392)
```

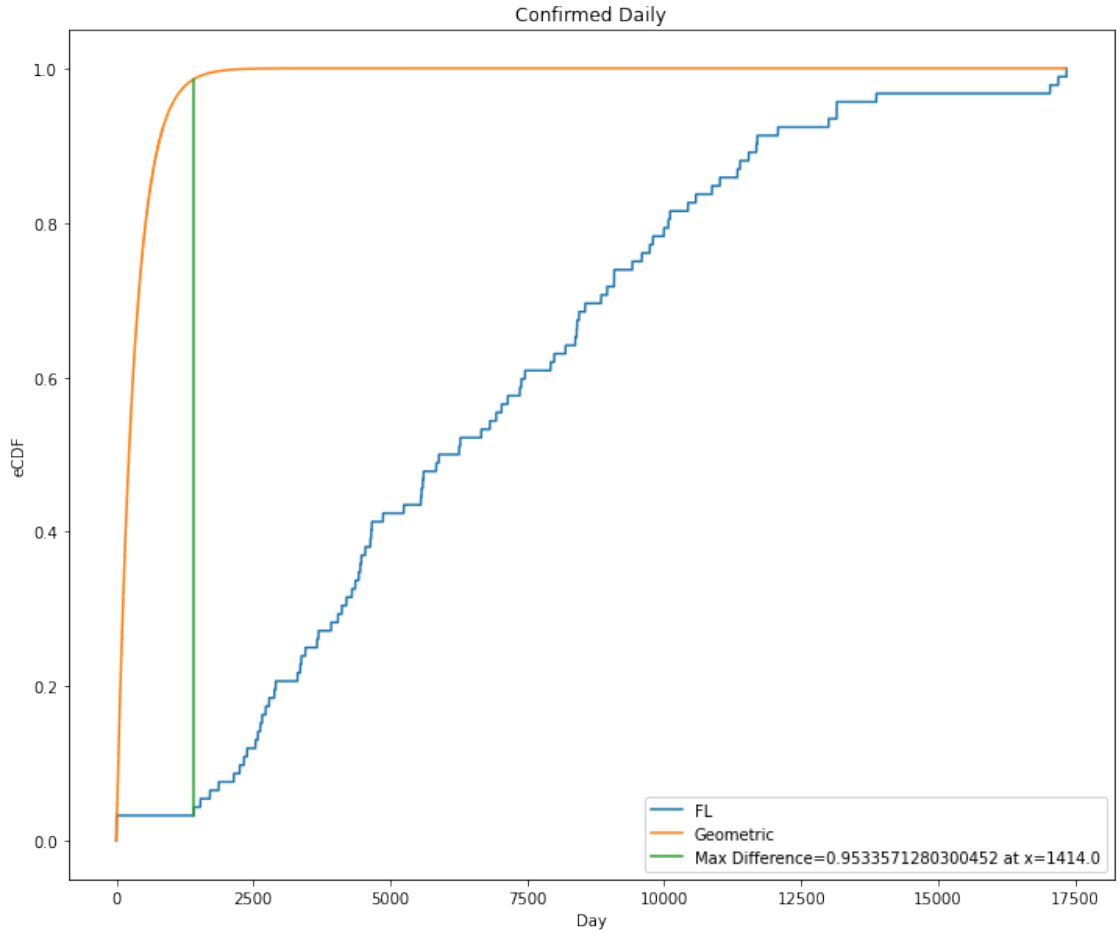
6.4 1-Sample K-S Test: Geometric

- $\hat{p}_{MME} = \frac{1}{\bar{X}}$

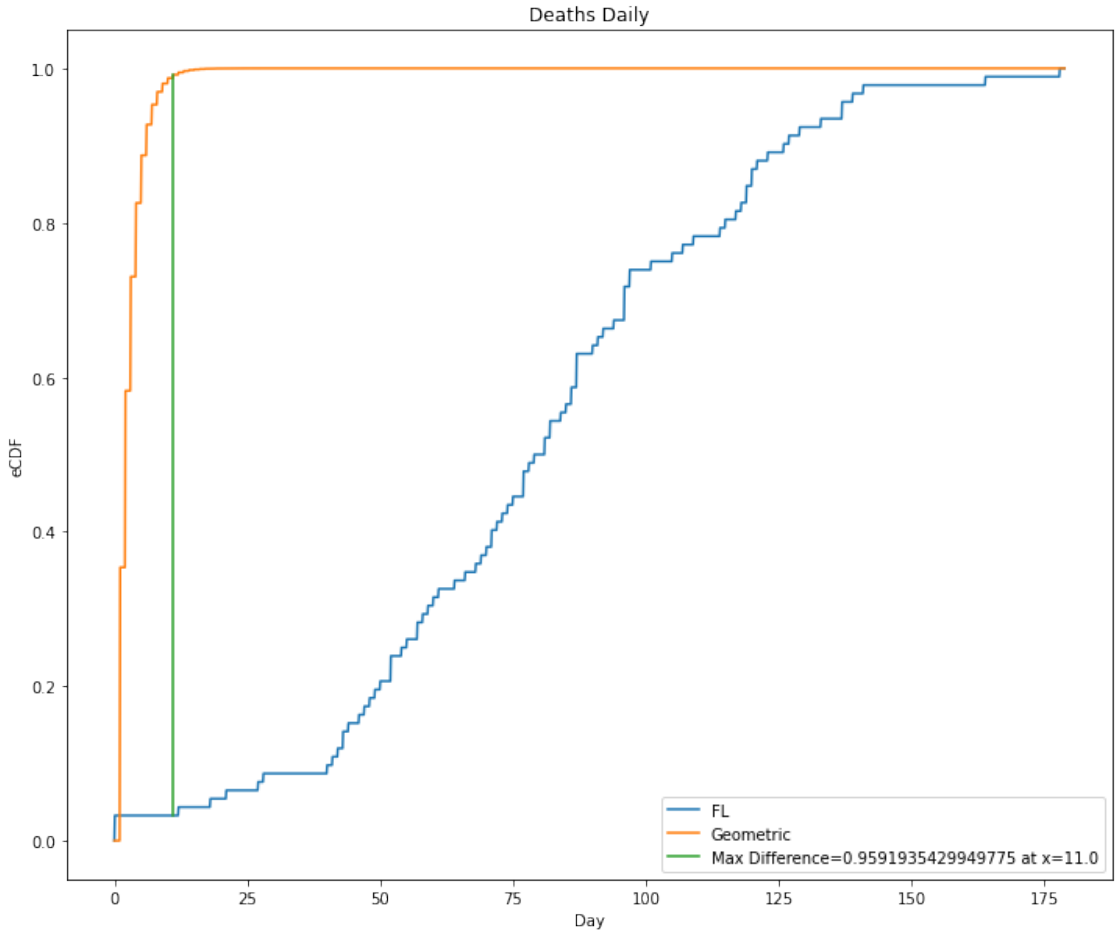
[38]:
```
def ks_test_geometric(data, p, plt_title, threshold):
    x = []
    for i in range(-1, int(np.max(data)) * 10 + 10):
        x.append(i/10)

    y1 = []
    y2 = []
    max_dif = 0
    max_dif_x = 0
    max_dif_y1 = 0
```

```
    max_dif_y2 = 0

    for xi in x:
        eCDF_1 = get_eCDF(data, xi)
        eCDF_2 = scipy.stats.geom.cdf(xi, p)
        dif = abs(eCDF_1 - eCDF_2)
        if (dif > max_dif):
            max_dif = dif
            max_dif_x = xi
            max_dif_y1 = eCDF_1
            max_dif_y2 = eCDF_2
        y1.append(eCDF_1)
        y2.append(eCDF_2)

    plt.figure(figsize=(12,10))
    plt.plot(x, y1, label='FL')
    plt.plot(x, y2, label='Geometric')
    plt.plot([max_dif_x, max_dif_x], [max_dif_y1, max_dif_y2], label='Max␣
↪Difference='+str(max_dif)+' at x='+str(max_dif_x))
    plt.xlabel('Day')
    plt.ylabel('eCDF')
    plt.title(plt_title)
    plt.legend()
    plt.show()

    if max_dif > threshold:
        # reject H0: F_x != F_y
        print('d =', max_dif, '>', threshold, ', thus reject H0, F_x !=␣
↪Geometric(' + str(p) + ')\n')
    else:
        # accept H0: F_x = F_y
        print('d =', max_dif, '<=', threshold, ', thus accept H0, F_x =␣
↪Geometric(' + str(p) + ')\n')
```

[39]:
```
ks_test_geometric(fl_confirmed_daily_3month, 1/np.
↪mean(de_confirmed_daily_3month), 'Confirmed Daily', 0.05)
ks_test_geometric(fl_deaths_daily_3month, 1/np.mean(de_deaths_daily_3month),␣
↪'Deaths Daily', 0.05)
```



d = 0.9533571280300452 > 0.05 , thus reject H0, F_x != Geometric(0.003012609787230756)




```
d = 0.9591935429949775 > 0.05 , thus reject H0, F_x !=
Geometric(0.3538461538461538)
```

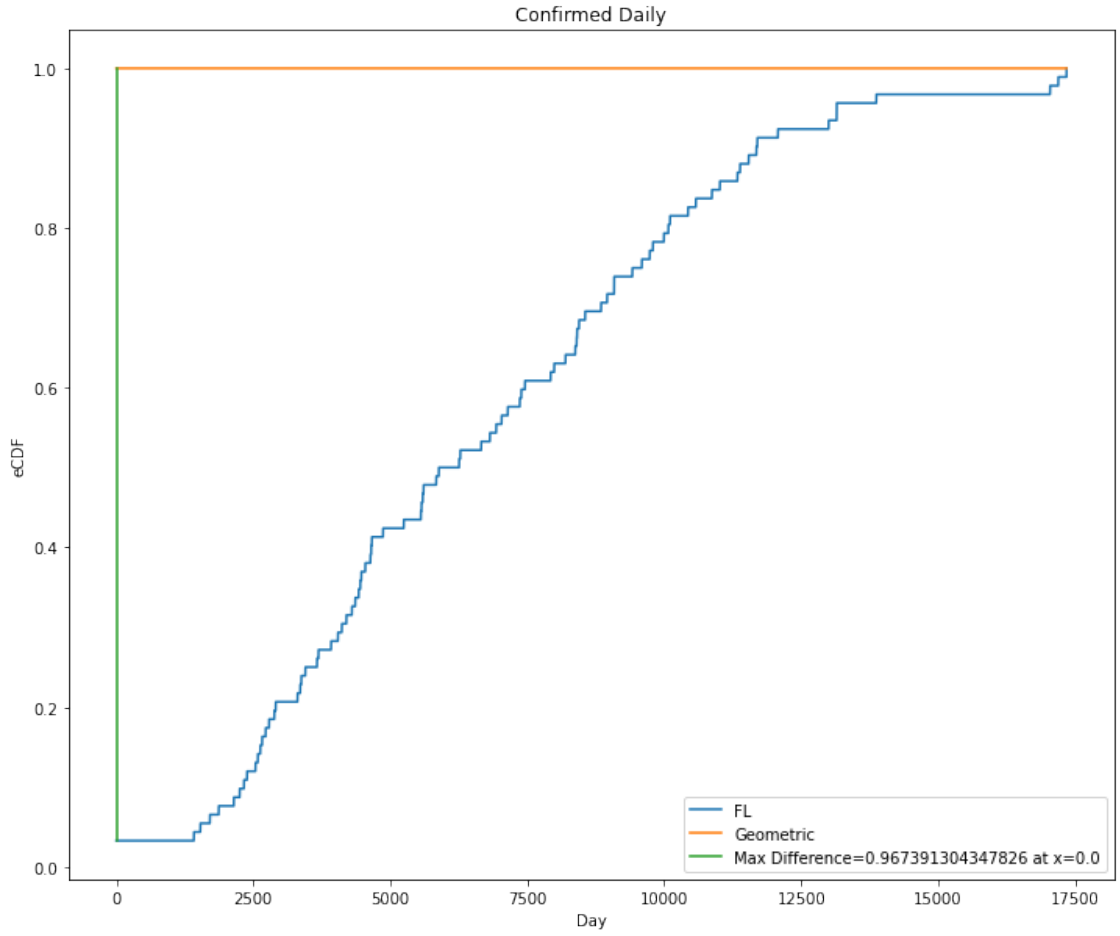
6.5 1-sample K-S Test: Binomial

- $\hat{p}_{MME} = 1 - \frac{s^2}{\bar{X}}$
- $\hat{n}_{MME} = \frac{\bar{X}^2}{\bar{X} - s^2} = \frac{\bar{X}}{p_{MME}}$

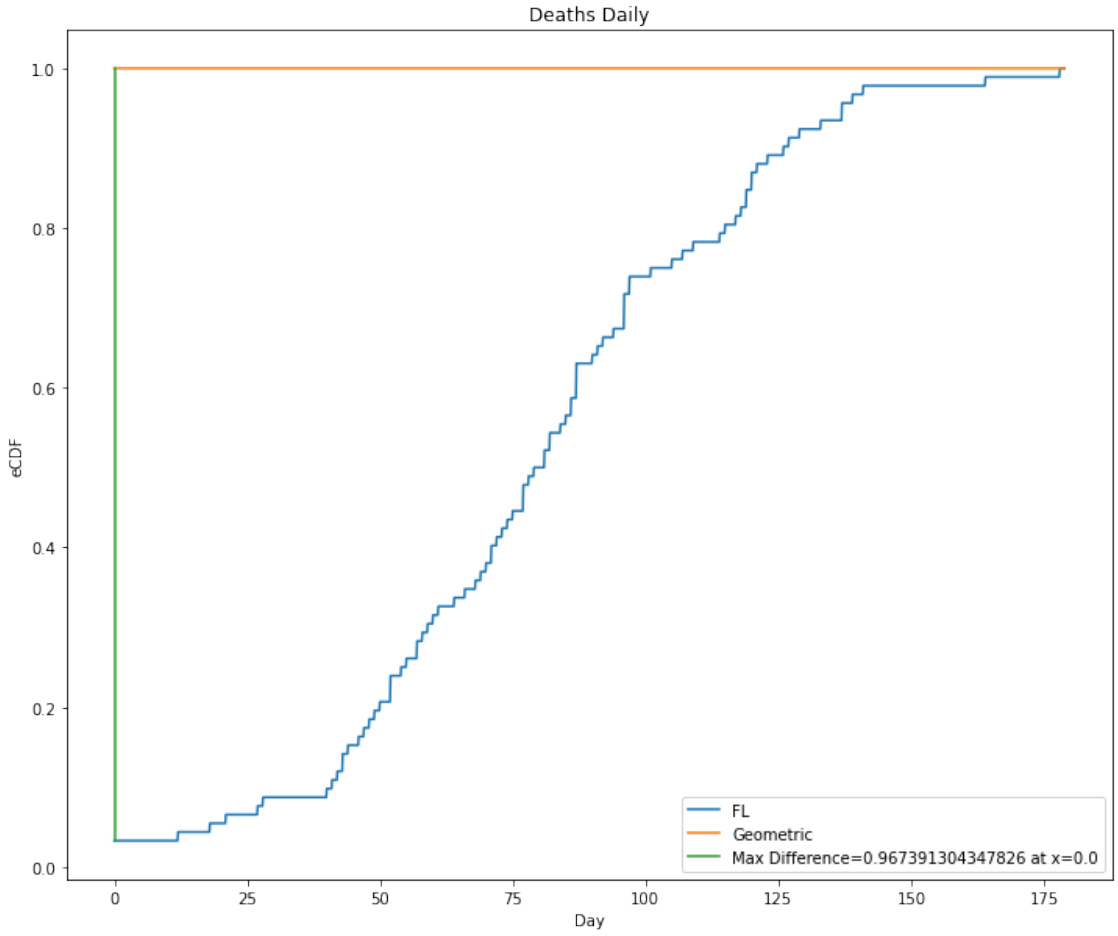
[40]:
```
def ks_test_binomial(data, data2, plt_title, threshold):
    x_bar = np.mean(data2)
    s2 = np.var(data2)
    n = (x_bar ** 2) / (x_bar - s2)
    p = 1 - (s2 / x_bar)

    x = []
    for i in range(int(np.max(data)) * 10 + 10):
        x.append(i/10)
```

```
    y1 = []
    y2 = []
    max_dif = 0
    max_dif_x = 0
    max_dif_y1 = 0
    max_dif_y2 = 0

    for xi in x:
        eCDF_1 = get_eCDF(data, xi)
        eCDF_2 = scipy.stats.binom.cdf(xi, n, p)
        dif = abs(eCDF_1 - eCDF_2)
        if (dif > max_dif):
            max_dif = dif
            max_dif_x = xi
            max_dif_y1 = eCDF_1
            max_dif_y2 = eCDF_2
        y1.append(eCDF_1)
        y2.append(eCDF_2)

    plt.figure(figsize=(12,10))
    plt.plot(x, y1, label='FL')
    plt.plot(x, y2, label='Geometric')
    plt.plot([max_dif_x, max_dif_x], [max_dif_y1, max_dif_y2], label='Max␣
↪Difference='+str(max_dif)+' at x='+str(max_dif_x))
    plt.xlabel('Day')
    plt.ylabel('eCDF')
    plt.title(plt_title)
    plt.legend()
    plt.show()

    if max_dif > threshold:
        # reject H0: F_x != F_y
        print('d =', max_dif, '>', threshold, ', thus reject H0, F_x !=␣
↪Binomial(' + str(n) + ',' + str(p) + ')\n')
    else:
        # accept H0: F_x = F_y
        print('d =', max_dif, '<=', threshold, ', thus accept H0, F_x =␣
↪Binomial(' + str(n) + ',' + str(p) + ')\n')
```

[41]:
```
ks_test_binomial(fl_confirmed_daily_3month, de_confirmed_daily_3month,␣
↪'Confirmed Daily', 0.05)
ks_test_binomial(fl_deaths_daily_3month, de_deaths_daily_3month, 'Deaths␣
↪Daily', 0.05)
```




```
d = 0.967391304347826 > 0.05 , thus reject H0, F_x !=
Binomial(-3.4167112951461887,-97.15134867353787)
```




```
d = 0.967391304347826 > 0.05 , thus reject H0, F_x !=
Binomial(-1.709920574695199,-1.6527591973244151)
```

6.6 Permutation Test

[42]:
```
def get_permutation(data0, data1):
    data = data0 + data1
    data = np.random.permutation(data)
    n = len(data0)
    x = data[:n]
    y = data[n:]
    return (x,y)
```

[43]:
```
def permutation_test(a1, a2, s, threshold):
    t_obs = abs(np.mean(a1) - np.mean(a2))
    count = 0
    for i in range(s):
```

```
        (x, y) = get_permutation(a1, a2)
        t = abs(np.mean(x) - np.mean(y))
        if t > t_obs:
            count += 1
    p_value = count/s
    if p_value <= threshold:
        # reject H0: F_x != F_y
        print('p-value =', p_value, '<=', threshold, ', thus reject H0, F_x !=␣
↪F_y')
    else:
        # accept H0: F_x = F_y
        print('p-value =', p_value, '>', threshold, ', thus accept H0, F_x =␣
↪F_y')
```

[44]:
```
print('\nConfirmd Daily')
permutation_test(fl_confirmed_daily_3month, de_confirmed_daily_3month, 1000, 0.
↪05)
print('\nDeaths Daily')
permutation_test(fl_deaths_daily_3month, de_deaths_daily_3month, 1000, 0.05)
```

```
Confirmd Daily
p-value = 0.0 <= 0.05 , thus reject H0, F_x != F_y

Deaths Daily
p-value = 0.0 <= 0.05 , thus reject H0, F_x != F_y
```

7 2d: Bayesian Inference

- We can treat $Exp(\lambda)$ as $Gamma(1, \lambda)$
- The Poisson and Gamma families of distributions are a conjugate pair
- Thus, posterior of $\lambda \sim Gamma(\alpha^*, \beta^*)$, where $\alpha^* = \alpha + \sum X_i, \beta^* = \frac{\beta}{1+n\beta} = \frac{\bar{X}}{1+n\bar{X}}$

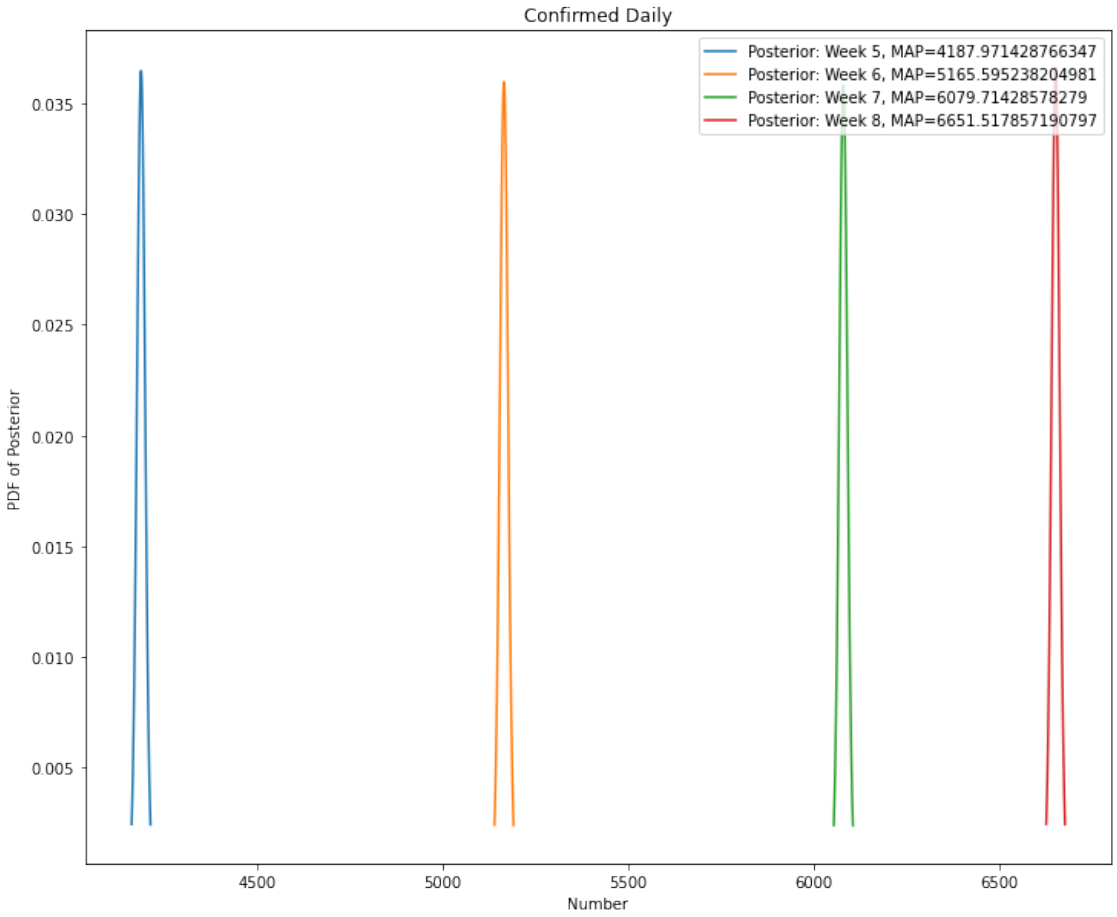
[45]:
```
def plot_gamma(alpha, beta, plt_label):
    x = np.linspace(scipy.stats.gamma.ppf(0.01, alpha, scale=beta),scipy.stats.
↪gamma.ppf(0.99, alpha, scale=beta), 100)
    y = scipy.stats.gamma.pdf(x, alpha, scale=beta)
    map = (alpha - 1) * beta
    plt.plot(x,y, label=plt_label+', MAP='+ str(map))
```

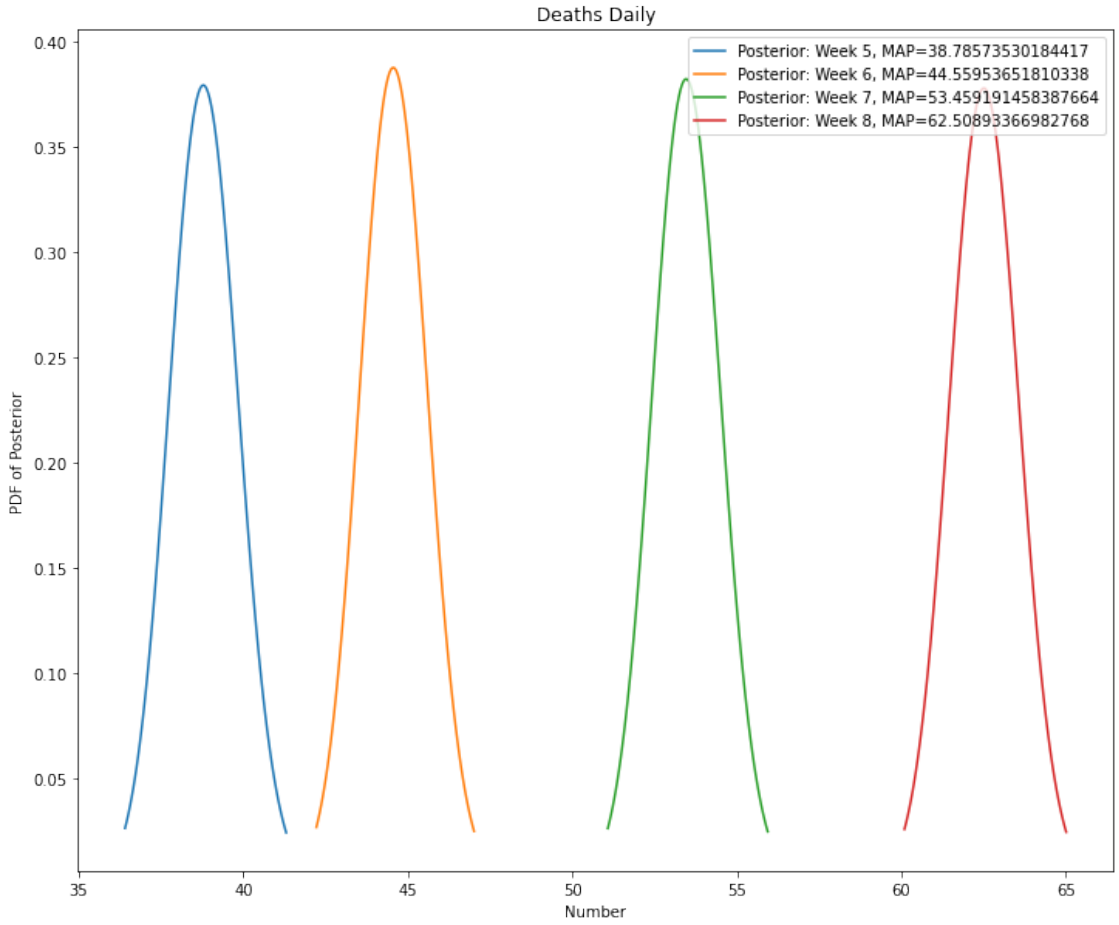
[46]:
```
def beyasian_inference(data0, data1, plt_title):
    alpha = 1
    beta = np.mean(data0)

    plt.figure(figsize=(12,10))
    # plot_gamma(alpha, beta, 'Prior: Week 1-4')
    for i in range(len(data1)):
```

```
        data0 = np.append(data0, data1[i])

        sum = np.sum(data0)
        n = len(data0)
        mean = sum / n

        alpha = 1 + sum
        beta = mean / (1 + n*mean)
        plot_gamma(alpha, beta, 'Posterior: Week '+str(5+i))
    plt.xlabel('Number')
    plt.ylabel('PDF of Posterior')
    plt.title(plt_title)
    plt.legend(loc='upper right')
    plt.show()
```

[47]:
```
confirmed_week14 = np.add(de_confirmed_daily[date_index('2020-06-01'):␣
↪date_index('2020-06-29')], fl_confirmed_daily[date_index('2020-06-01'):␣
↪date_index('2020-06-29')])
confirmed_week58 = []
for i in range(4):
    confirmed_week58.append(np.
↪add(de_confirmed_daily[date_index('2020-06-29')+7*i:␣
↪date_index('2020-07-06')+7*i],␣
↪fl_confirmed_daily[date_index('2020-06-29')+7*i:␣
↪date_index('2020-07-06')+7*i]))

deaths_week14 = np.add(de_deaths_daily[date_index('2020-06-01'):␣
↪date_index('2020-06-29')], fl_deaths_daily[date_index('2020-06-01'):␣
↪date_index('2020-06-29')])
deaths_week58 = []
for i in range(4):
    deaths_week58.append(np.add(de_deaths_daily[date_index('2020-06-29')+7*i:␣
↪date_index('2020-07-06')+7*i], fl_deaths_daily[date_index('2020-06-29')+7*i:␣
↪date_index('2020-07-06')+7*i]))
```

[48]:
```
beyasian_inference(confirmed_week14, confirmed_week58, 'Confirmed Daily')
beyasian_inference(deaths_week14, deaths_week58, 'Deaths Daily')
```


Confirmed Daily
Posterior: Week 5, MAP=4187.971428766347
Posterior: Week 6, MAP=5165.595238204981
Posterior: Week 7, MAP=6079.71428578279
Posterior: Week 8, MAP=6651.517857190797
PDF of Posterior
0.035
0.030
0.025
0.020
0.015
0.010
0.005
4500
5000
5500
6000
6500
Number



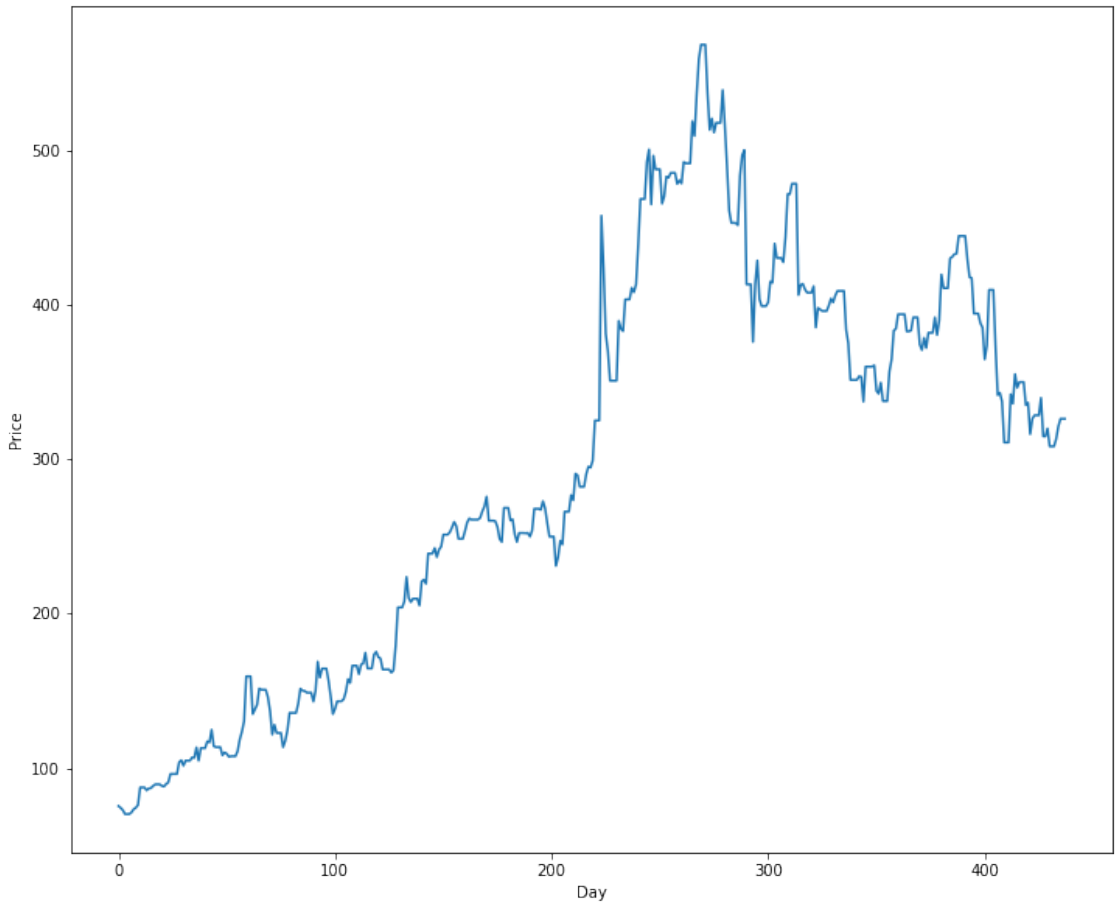
8 3a: Does X-data Impacted

[49]:
```
def date_index_slash(date_string):
    date = date_string.split('/')
    month = int(date[0])
    day = int(date[1])
    year = int(date[2])
    d1 = datetime.datetime(2020, 1, 22)
    d2 = datetime.datetime(year, month, day)
    return (d2 - d1).days

# Since the stock market closed for weekends and vacations, we need to fill␣
 ↪those days with latest available price.
def fill_stock(date, price_without_weekends):
    price = []
    latest_date = -1
    for i in range(len(date)):
```

```
        d = date[i]
        for j in range(d - latest_date):
            price.append(price_without_weekends[i])
        latest_date = d
    return price
```

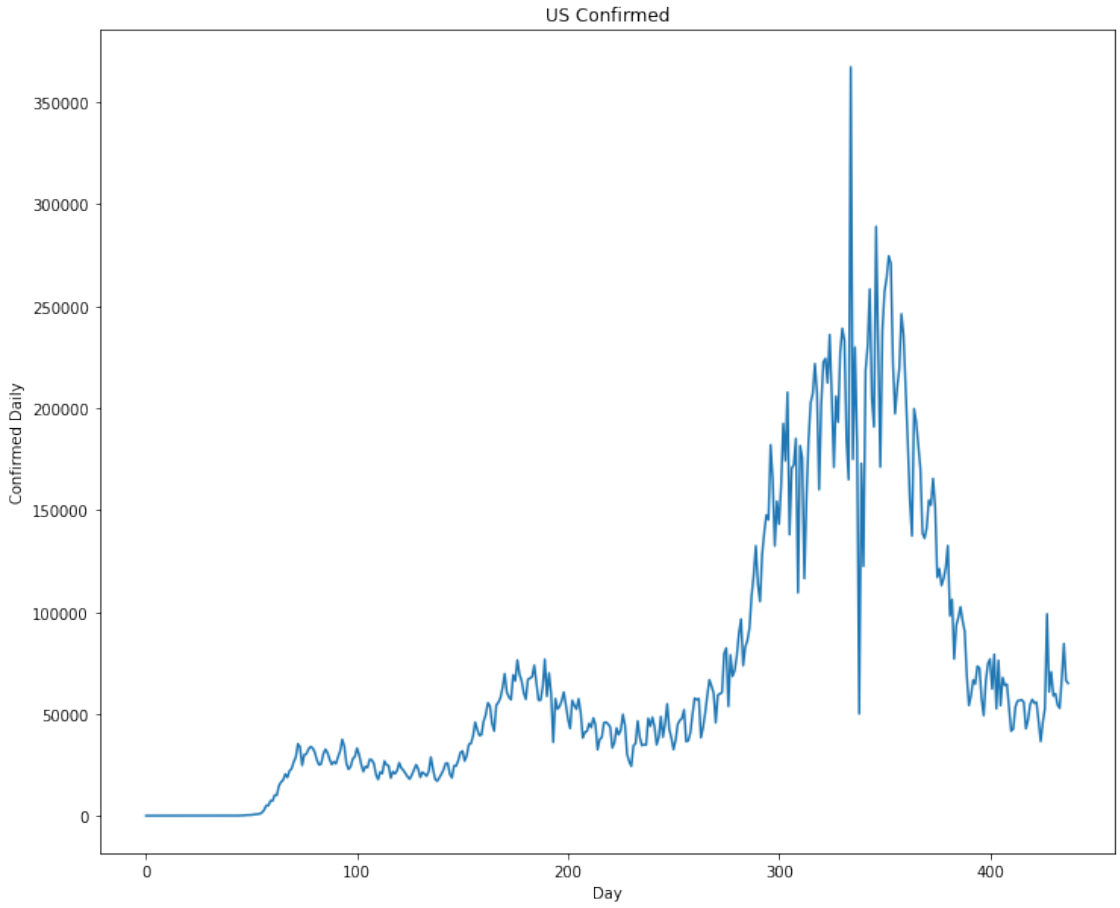
[50]:
```
zoom_price_without_weekends = []
stock_date = []
csv_file=open('Datasets/X-dataset/Zoom Price.csv')
csv_reader_lines = csv.reader(csv_file)
for one_line in csv_reader_lines:
    if one_line[0]!='Date':
        stock_date.append(date_index_slash(one_line[0]))
        zoom_price_without_weekends.append(float(one_line[4]))

zoom_price = fill_stock(stock_date, zoom_price_without_weekends)
zoom_price.append(zoom_price[-1])
zoom_price.append(zoom_price[-1])
```

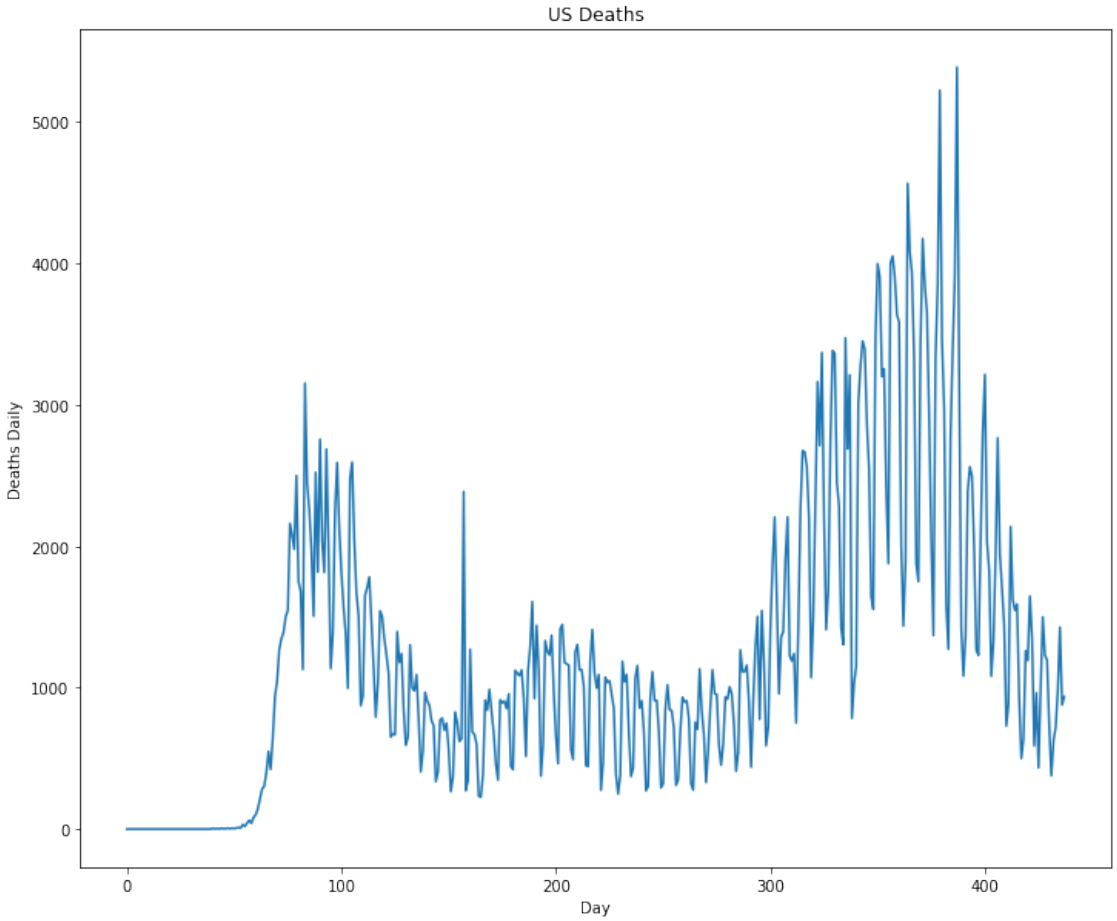
[51]:
```
plt.figure(figsize=(12,10))
plt.plot(range(len(zoom_price)), zoom_price)
plt.xlabel('Day')
plt.ylabel('Price')
plt.show()
```



[52]:
```
us_confirmed = [0]*(date_index('2021-04-03') - date_index('2020-01-22') + 1)
csv_file=open('Datasets/US-all/US_confirmed.csv')
csv_reader_lines = csv.reader(csv_file)
for one_line in csv_reader_lines:
    if one_line[0]!='State':
        for i in range(1, len(one_line)):
            us_confirmed[i-1] += int(one_line[i])

us_deaths = [0]*(date_index('2021-04-03') - date_index('2020-01-22') + 1)
csv_file=open('Datasets/US-all/US_deaths.csv')
csv_reader_lines = csv.reader(csv_file)
for one_line in csv_reader_lines:
    if one_line[0]!='State':
        for i in range(1, len(one_line)):
            us_deaths[i-1] += int(one_line[i])

us_confirmed_daily = [0]
us_deaths_daily = [0]
```

```
for i in range(1, len(us_confirmed)):
    us_confirmed_daily.append(us_confirmed[i] - us_confirmed[i-1])
    us_deaths_daily.append(us_deaths[i] - us_deaths[i-1])

plt.figure(figsize=(12,10))
plt.plot(range(len(us_confirmed_daily)), us_confirmed_daily)
plt.title('US Confirmed')
plt.xlabel('Day')
plt.ylabel('Confirmed Daily')
plt.show()

plt.figure(figsize=(12,10))
plt.plot(range(len(us_deaths_daily)), us_deaths_daily)
plt.title('US Deaths')
plt.xlabel('Day')
plt.ylabel('Deaths Daily')
plt.show()
```





[53]:
```python
def pearsons_correlation_coefficient(x, y):
    x_mean = np.mean(x)
    y_mean = np.mean(y)
    sum0 = 0
    sum1 = 0
    sum2 = 0
    for i in range(len(x)):
        sum0 += (x[i] - x_mean) * (y[i] - y_mean)
        sum1 += (x[i] - x_mean) ** 2
        sum2 += (y[i] - y_mean) ** 2
    pho = sum0 / (np.sqrt(sum1 * sum2))
    return pho
```

[54]:
```python
def pearsons_test(x, y, threshold):
    pho = pearsons_correlation_coefficient(x,y)

    if abs(pho) > threshold:
        # reject H0
```

```
        if pho > 0.5:
            print('Pho =', pho, '>', threshold, ', thus reject H0, X and Y are␣
↪positive linear correlated.')
        else:
            print('Pho =', pho, '<', -threshold, ', thus reject H0, X and Y are␣
↪positive linear correlated.')
    else:
        # accept H1
        print('|Pho| =', pho, '<=', threshold, ', thus accept H0, X and Y are␣
↪not linear correlated.')
```

[55]:
```
print('\nUS Confirmed Daily')
pearsons_test(zoom_price, us_confirmed_daily, 0.5)
print('\nUS Deaths Daily')
pearsons_test(zoom_price, us_deaths_daily, 0.5)
```

```
US Confirmed Daily
Pho = 0.571872419240749 > 0.5 , thus reject H0, X and Y are positive linear
correlated.

US Deaths Daily
|Pho| = 0.33489946915500635 <= 0.5 , thus accept H0, X and Y are not linear
correlated.
```

- H0: Zoom stock price and US #confirmed/deaths are not linear correlated.
- H1: Zoom stock price and US #confirmed/deaths are linear correlated.
- We use a threshold of 0.5 here.
- Results: we can say zoom stock price are positive linear correlated with US #confirmed but not linear correlated with US #deaths.

9 3b. If COVID19 Data Changed after Local Events

- Here we chose two events:
  - Lockdown, started since April 2020
  - Vaccine, started since Feb 2021

[56]:
```
def walds_test_2_split(data, split_date, threshold):
    split = date_index(split_date)
    data0 = data[:split]
    data1 = data[split:]

    walds_test_2(data0, data1, 1.96)
```

[57]:
```
print('\nUS Confirmed Daily')
walds_test_2_split(us_confirmed_daily, '2020-04-01', 1.96)

print('\nUS Deaths Daily')
```

```
walds_test_2_split(us_deaths_daily, '2020-04-01', 1.96)
```

```
US Confirmed Daily
|W| = 4883.045921168658 > 1.96 , thus reject H0, theta0 != theta1

US Deaths Daily
|W| = 637.0462969355976 > 1.96 , thus reject H0, theta0 != theta1
```

[58]:
```
print('\nUS Confirmed Daily')
walds_test_2_split(us_confirmed_daily, '2021-02-01', 1.96)

print('\nUS Deaths Daily')
walds_test_2_split(us_deaths_daily, '2021-02-01', 1.96)
```

```
US Confirmed Daily
|W| = 29.551043251091972 > 1.96 , thus reject H0, theta0 != theta1

US Deaths Daily
|W| = 113.46029567063303 > 1.96 , thus reject H0, theta0 != theta1
```

- H0: mean of US #confirmed/deaths before the event = mean of US #confirmed/deaths after the event
- H1: mean of US #confirmed/deaths before the event != mean of US #confirmed/deaths after the event
- We chose 2-populated Wald's test.
- The result is that means are different as lockdown and vaccine started, which means they are useful.