derek_stage4

November 6, 2024

```
[22]: import pandas as pd
      import numpy as np
      import matplotlib.pyplot as plt
      from sklearn.linear_model import LinearRegression
      from numpy.polynomial.polynomial import polyfit, polyval
      from sklearn.metrics import root_mean_squared_error
      from seaborn import regplot
      import scipy.stats as stats
```

0.0.1 Load Data

```
[23]: cases = pd.read_csv('./data/covid_cases_weekly', index_col=0)
      deaths = pd.read_csv('./data/covid_deaths_weekly', index_col=0)
```

1 First task: create linear and non-linear models to predict the number of new cases and deaths in Florida

```
[24]: state = 'FL'
```

```
[25]: florida_cases = cases[cases['State'] == state].drop(columns=['State',␣
       ↪'StateFIPS'])
      florida_deaths = deaths[deaths['State'] == state].drop(columns=['State',␣
       ↪'StateFIPS'])
      florida_cases = florida_cases.iloc[1:]
      florida_deaths = florida_deaths.iloc[1:]
```

```
[26]: florida_case_sums = florida_cases[florida_cases.columns[3:]].sum()
      florida_death_sums = florida_deaths[florida_deaths.columns[3:]].sum()
      florida_new_cases = florida_case_sums.diff()[1:]
      florida_new_deaths = florida_death_sums.diff()[1:]
```

1.0.1 Linear Model

```
[27]: x = np.arange(len(florida_new_cases)) * 7
      cases_linear = LinearRegression()
      deaths_linear = LinearRegression()
      reshape = lambda a: a.copy().reshape(-1, 1)
```

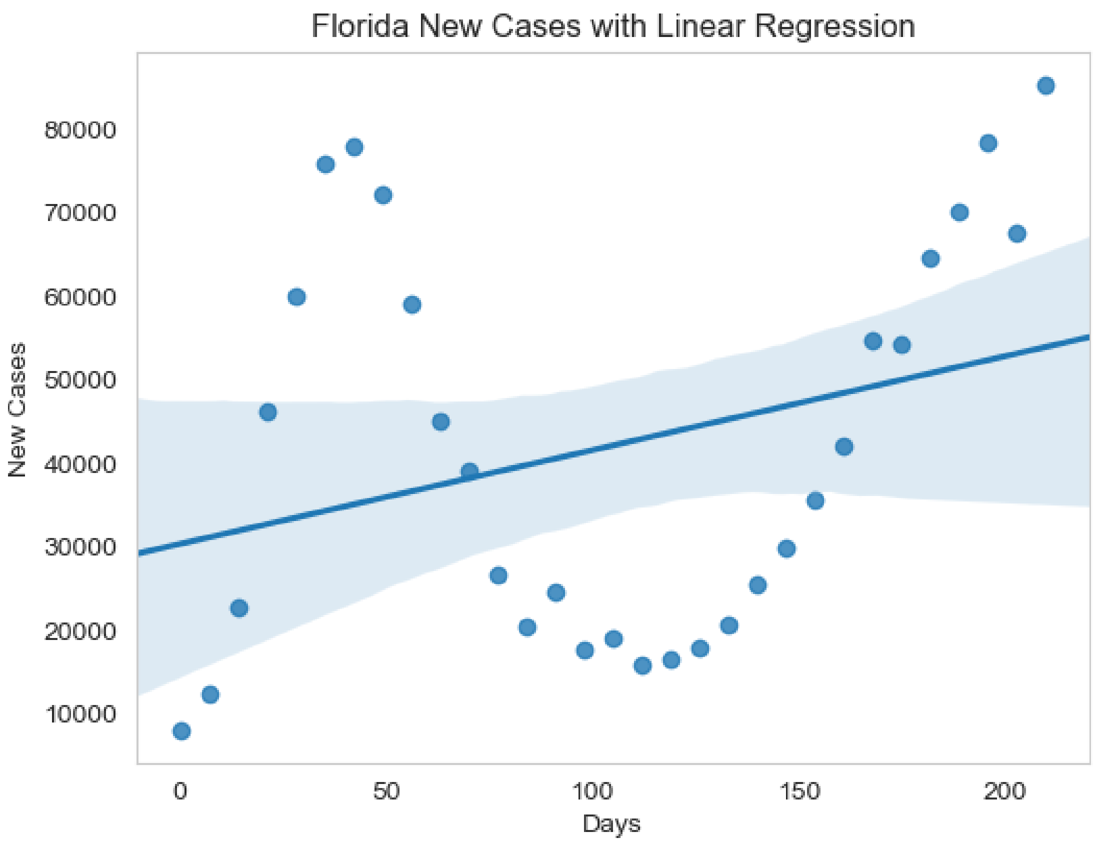
```
cases_linear.fit(reshape(x), florida_new_cases)
deaths_linear.fit(reshape(x), florida_new_deaths)
```

[27]: LinearRegression()

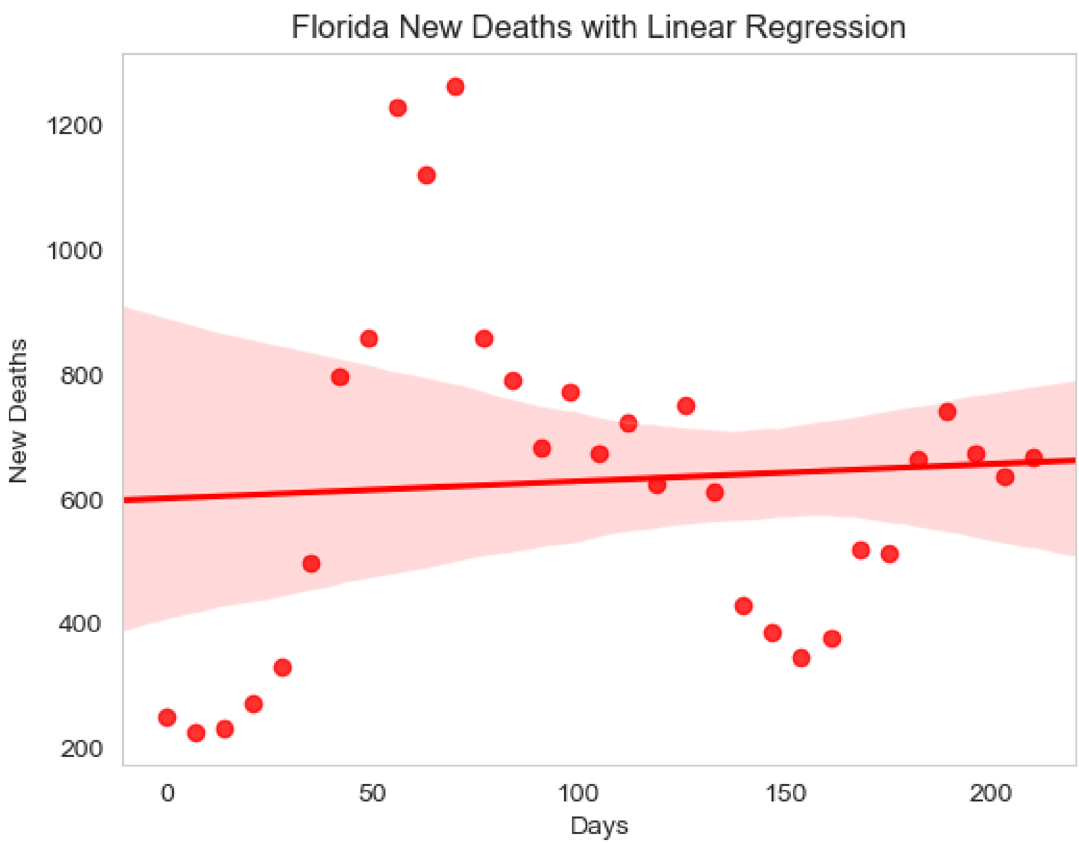
1.0.2 Get Predictions and plot with 1 week prediction into the future

[28]:
```
x_ext = np.arange(len(florida_new_cases) + 1) * 7
cases_pred_linear = cases_linear.predict(reshape(x))
deaths_pred_linear = deaths_linear.predict(reshape(x))
```

[29]:
```
ax = regplot(florida_new_cases, x=x, y=florida_new_cases, label='Cases',␣
 ↪truncate=False)
ax.set_title('Florida New Cases with Linear Regression')
ax.set_xlabel('Days')
ax.set_ylabel('New Cases')
plt.grid()
plt.show()
```



[30]:
```
ax = regplot(florida_new_deaths, x=x, y=florida_new_deaths, label='Deaths',␣
    ↪truncate=False, color='red')
ax.set_title('Florida New Deaths with Linear Regression')
ax.set_xlabel('Days')
ax.set_ylabel('New Deaths')
plt.grid()
plt.show()
```



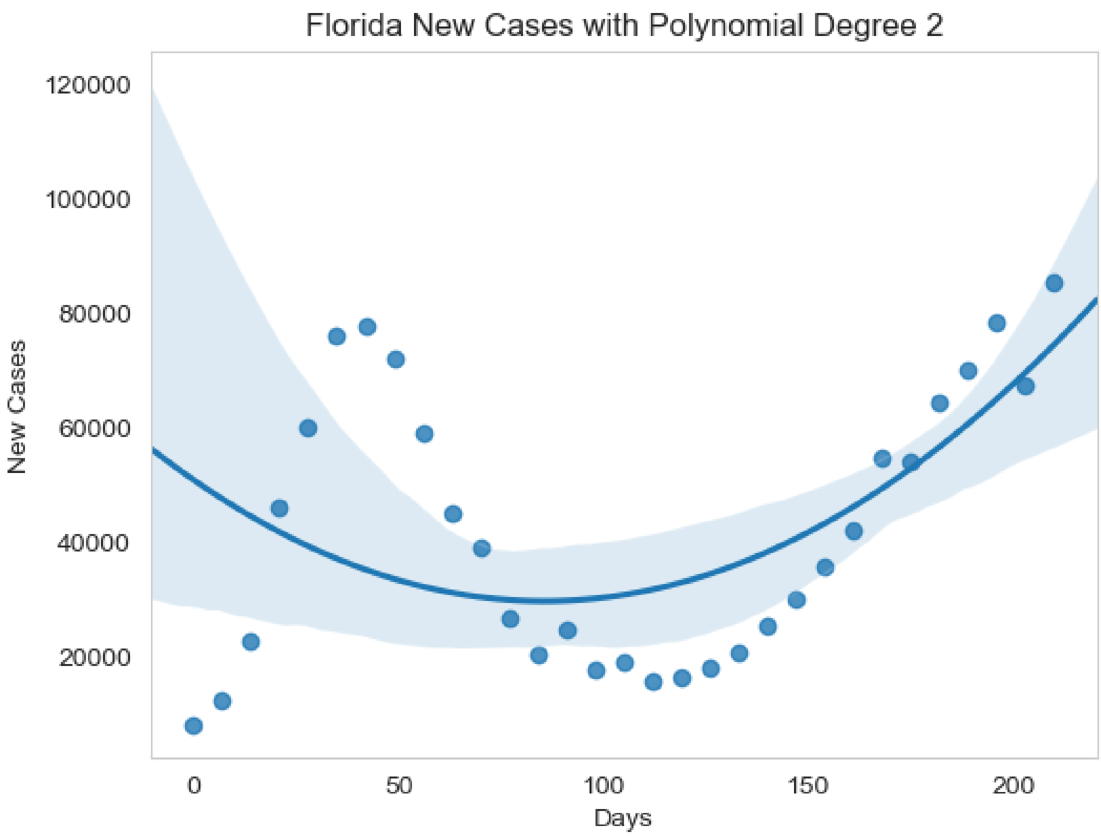
1.0.3 Non-Linear Model - Polynomial Degree 2

[31]:
```
cases_poly2 = polyfit(x, florida_new_cases, 2)
deaths_poly2 = polyfit(x, florida_new_deaths, 2)
```

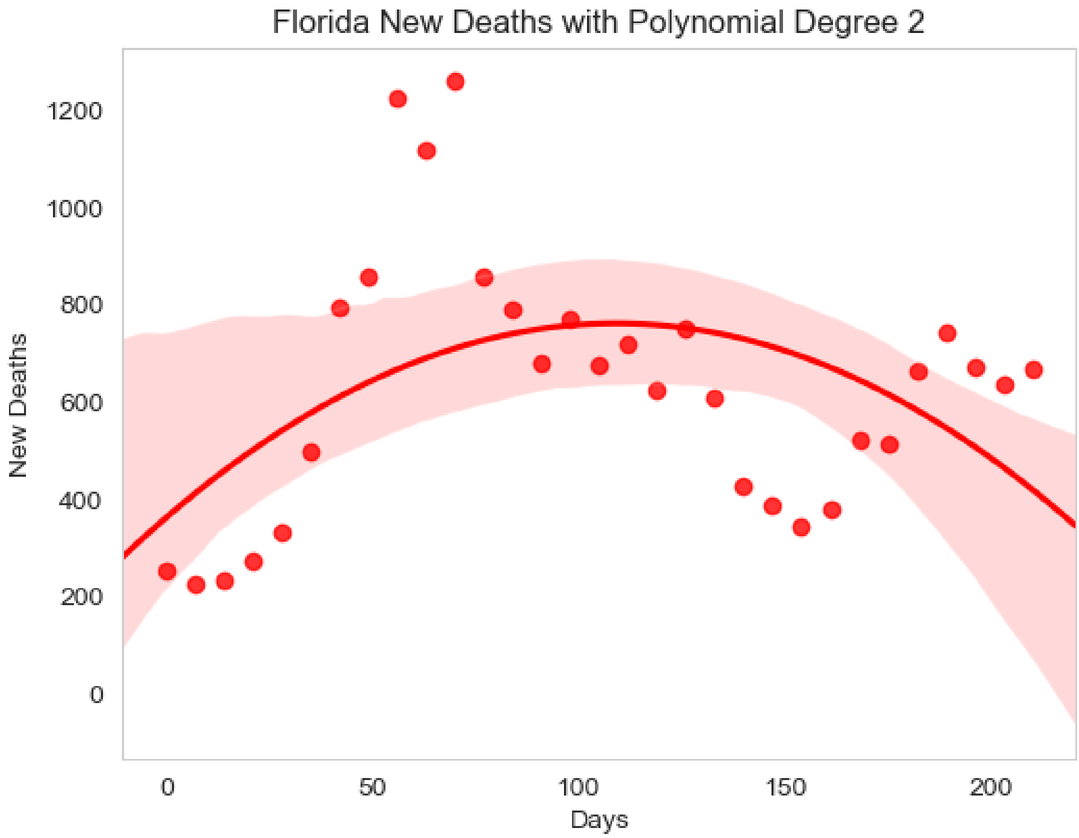
[32]:
```
cases_pred_poly2 = polyval(x, cases_poly2)
deaths_pred_poly2 = polyval(x, deaths_poly2)
```

[33]:
```
ax = regplot(florida_new_cases, x=x, y=florida_new_cases, order=2,␣
    ↪label='Trendline', truncate=False)
ax.set_title('Florida New Cases with Polynomial Degree 2')
ax.set_xlabel('Days')
```

```
ax.set_ylabel('New Cases')
plt.grid()
plt.show()
```




```
[34]: ax = regplot(florida_new_deaths, x=x, y=florida_new_deaths, order=2,␣
       ↪label='Trendline', truncate=False, color='red')
      ax.set_title('Florida New Deaths with Polynomial Degree 2')
      ax.set_xlabel('Days')
      ax.set_ylabel('New Deaths')
      plt.grid()
      plt.show()
```

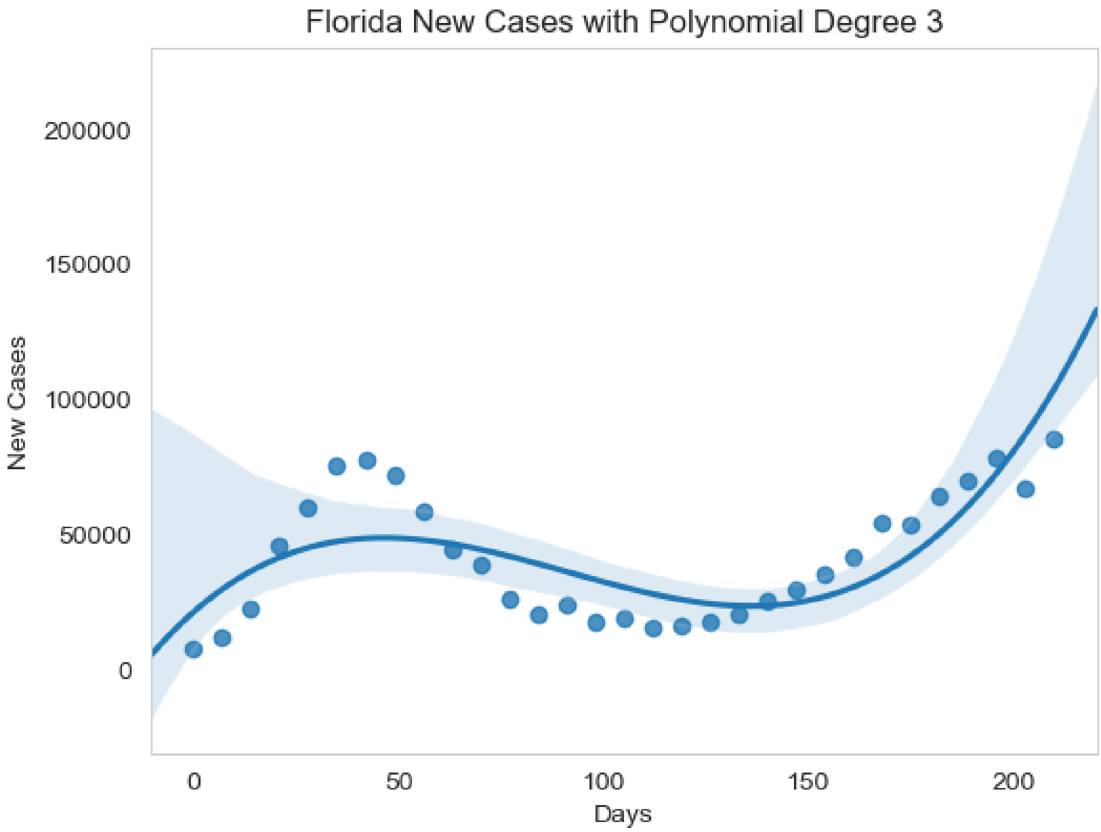


1.0.4 Non-Linear Model - Polynomial Degree 3

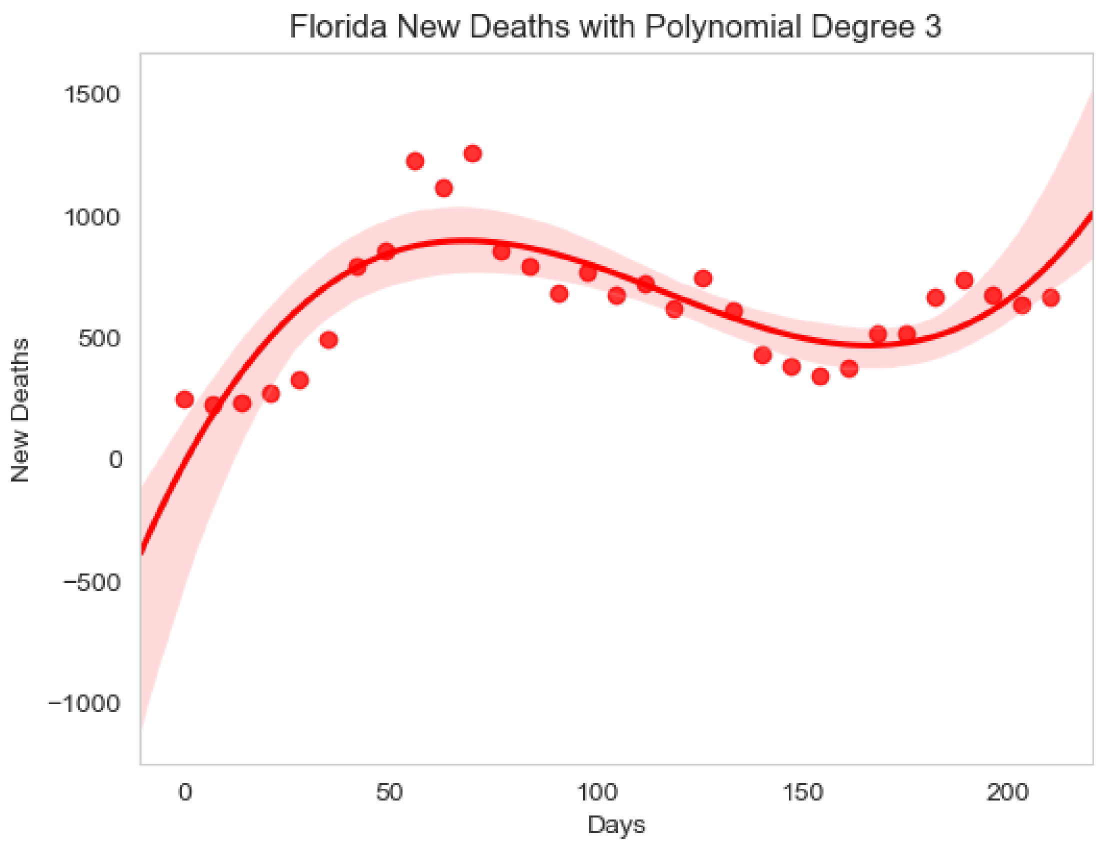
[35]:
```
cases_poly3 = polyfit(x, florida_new_cases, 3)
deaths_poly3 = polyfit(x, florida_new_deaths, 3)
```

[36]:
```
cases_pred_poly3 = polyval(x, cases_poly3)
deaths_pred_poly3 = polyval(x, deaths_poly3)
```

[37]:
```
ax = regplot(florida_new_cases, x=x, y=florida_new_cases, order=3,␣
 ↪label='Trendline', truncate=False)
ax.set_title('Florida New Cases with Polynomial Degree 3')
ax.set_xlabel('Days')
ax.set_ylabel('New Cases')
plt.grid()
plt.show()
```



[38]:
```
ax = regplot(florida_new_deaths, x=x, y=florida_new_deaths, order=3,␣
 ↪label='Trendline', truncate=False, color='red')
ax.set_title('Florida New Deaths with Polynomial Degree 3')
ax.set_xlabel('Days')
ax.set_ylabel('New Deaths')
plt.grid()
plt.show()
```



1.0.5 Root Mean Squared Error of Models

[39]:
```
# Linear
linear_cases_rmse = root_mean_squared_error(florida_new_cases,␣
 ↪cases_pred_linear)
linear_deaths_rmse = root_mean_squared_error(florida_new_deaths,␣
 ↪deaths_pred_linear)
# Polynomial degree 2
poly2_cases_rmse = root_mean_squared_error(florida_new_cases, cases_pred_poly2)
poly2_deaths_rmse = root_mean_squared_error(florida_new_deaths,␣
 ↪deaths_pred_poly2)
# Polynomial degree 3
poly3_cases_rmse = root_mean_squared_error(florida_new_cases, cases_pred_poly3)
poly3_deaths_rmse = root_mean_squared_error(florida_new_deaths,␣
 ↪deaths_pred_poly3)

data = {
    'Model': ['Linear', 'Polynomial Degree 2', 'Polynomial Degree 3'],
    'Cases RMSE': [linear_cases_rmse, poly2_cases_rmse, poly3_cases_rmse],
    'Deaths RMSE': [linear_deaths_rmse, poly2_deaths_rmse, poly3_deaths_rmse]
```

```
}

rmse_df = pd.DataFrame(data).set_index('Model')

rmse_df
```

[39]:

```
                        Cases RMSE  Deaths RMSE
Model
Linear                22187.631338   264.658561
Polynomial Degree 2   19740.446819   237.114555
Polynomial Degree 3   14433.191037   159.315881
```

2 Task 2: Find the top 5 counties in Florida with the highest risk of infection and analyze the trend of cases in those counties

I choose to define the risk of infection as the percentage of the population that has been infected. This is calculated by dividing the cumulative number of infected people by the population of the county.

[40]:

```
last_week = cases.columns[-1]
top_5_counties = florida_cases.sort_values(by=last_week, ascending=False).
    ↪set_index('County Name').drop(columns=['countyFIPS'])
top_5_counties = top_5_counties.head(5)
top_5_counties
```

[40]:

```
                    population  2020-06-01 00:00:00  2020-06-08 00:00:00  \
County Name
Miami-Dade County      2716940                18139                19756
Broward County         1952778                 7196                 7924
Palm Beach County      1496770                 6135                 7329
Hillsborough County    1471968                 2251                 2861
Orange County          1393452                 2031                 2378

                    2020-06-15 00:00:00  2020-06-22 00:00:00  \
County Name
Miami-Dade County                 22197                26239
Broward County                     9086                11327
Palm Beach County                  9015                10943
Hillsborough County                3826                 5973
Orange County                      3282                 5157

                    2020-06-29 00:00:00  2020-07-06 00:00:00  \
County Name
Miami-Dade County                 35222                48992
Broward County                    15045                21856
Palm Beach County                 13711                17242
Hillsborough County               10323                14677
```

```
Orange County                          10014                 14407

                     2020-07-13 00:00:00  2020-07-20 00:00:00  \
County Name
Miami-Dade County                      67713                 87035
Broward County                         31484                 40976
Palm Beach County                      21806                 26426
Hillsborough County                    19828                 24135
Orange County                          18937                 23584

                     2020-07-27 00:00:00  …  2020-11-02 00:00:00  \
County Name                               …
Miami-Dade County                     107315  …               187757
Broward County                         50784  …                87456
Palm Beach County                      30958  …                53151
Hillsborough County                    27483  …                48925
Orange County                          27393  …                46986

                     2020-11-09 00:00:00  2020-11-16 00:00:00  \
County Name
Miami-Dade County                     194879                203654
Broward County                         91441                 95734
Palm Beach County                      55816                 58754
Hillsborough County                    51055                 53187
Orange County                          49029                 51888

                     2020-11-23 00:00:00  2020-11-30 00:00:00  \
County Name
Miami-Dade County                     216442                229618
Broward County                        101747                107524
Palm Beach County                      62278                 65372
Hillsborough County                    55835                 58293
Orange County                          55047                 58325

                     2020-12-07 00:00:00  2020-12-14 00:00:00  \
County Name
Miami-Dade County                     245064                260138
Broward County                        114426                120840
Palm Beach County                      69331                 73079
Hillsborough County                    61599                 66041
Orange County                          60291                 64593

                     2020-12-21 00:00:00  2020-12-28 00:00:00  \
County Name
Miami-Dade County                     276414                290363
Broward County                        128157                133480
Palm Beach County                      77241                 80865
```

```
Hillsborough County                70849                74788
Orange County                      69491                73691

                     2021-01-03 00:00:00
County Name
Miami-Dade County                 305734
Broward County                    141010
Palm Beach County                  85479
Hillsborough County                80035
Orange County                      79165

[5 rows x 33 columns]
```

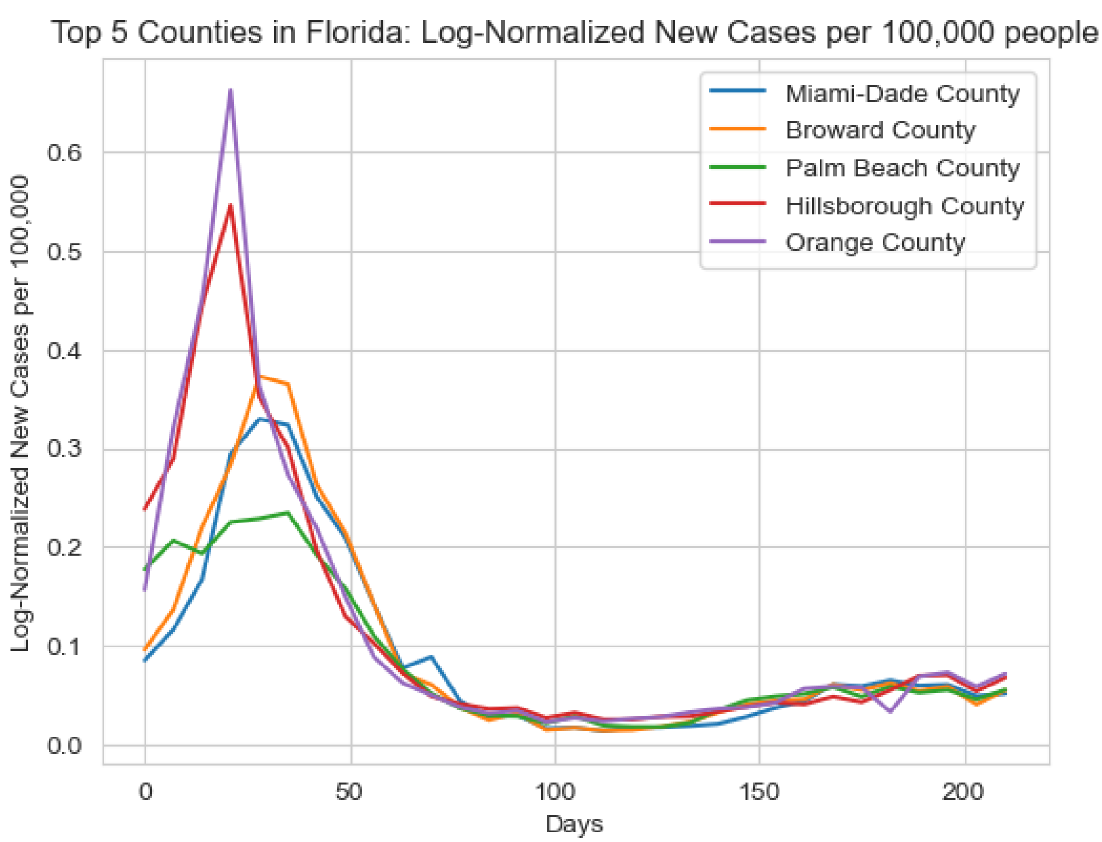
[41]:
```python
# log normalize cases per 100,000 based on population
top_5_counties_normalized = top_5_counties.copy()[top_5_counties.columns[1:]].
 ↪div(top_5_counties['population'], axis=0) * 100000
top_5_counties_normalized = np.log1p(top_5_counties_normalized)
top_5_counties_new = top_5_counties_normalized.diff(axis=1)
top_5_counties_new = top_5_counties_new.dropna(axis=1)
top_5_counties_new
```

[41]:
```
                     2020-06-08 00:00:00  2020-06-15 00:00:00  \
County Name
Miami-Dade County               0.085271             0.116349
Broward County                  0.096122             0.136524
Palm Beach County               0.177432             0.206670
Hillsborough County             0.238411             0.289357
Orange County                   0.156737             0.320587

                     2020-06-22 00:00:00  2020-06-29 00:00:00  \
County Name
Miami-Dade County               0.167101             0.294160
Broward County                  0.220030             0.283431
Palm Beach County               0.193518             0.225223
Hillsborough County             0.444051             0.546089
Orange County                   0.450364             0.662321

                     2020-07-06 00:00:00  2020-07-13 00:00:00  \
County Name
Miami-Dade County               0.329769             0.323468
Broward County                  0.373026             0.364731
Palm Beach County               0.228926             0.234655
Hillsborough County             0.351485             0.300553
Orange County                   0.363306             0.273172

                     2020-07-20 00:00:00  2020-07-27 00:00:00  \
County Name
```

```
Miami-Dade County              0.250943             0.209399
Broward County                 0.263363             0.214503
Palm Beach County              0.192043             0.158200
Hillsborough County            0.196436             0.129830
Orange County                  0.219306             0.149637

                    2020-08-03 00:00:00  2020-08-10 00:00:00  …  \
County Name                                                   …
Miami-Dade County              0.141605             0.077600  …
Broward County                 0.141924             0.071935  …
Palm Beach County              0.109726             0.076473  …
Hillsborough County            0.102466             0.072203  …
Orange County                  0.088431             0.062280  …

                    2020-11-02 00:00:00  2020-11-09 00:00:00  \
County Name
Miami-Dade County              0.028268             0.037225
Broward County                 0.040762             0.044548
Palm Beach County              0.044913             0.048910
Hillsborough County            0.038428             0.042602
Orange County                  0.037812             0.042550

                    2020-11-16 00:00:00  2020-11-23 00:00:00  \
County Name
Miami-Dade County              0.044038             0.060892
Broward County                 0.045870             0.060904
Palm Beach County              0.051285             0.058235
Hillsborough County            0.040899             0.048574
Orange County                  0.056660             0.059084

                    2020-11-30 00:00:00  2020-12-07 00:00:00  \
County Name
Miami-Dade County              0.059087             0.065095
Broward County                 0.055214             0.062203
Palm Beach County              0.048474             0.058785
Hillsborough County            0.043070             0.055150
Orange County                  0.057829             0.033144

                    2020-12-14 00:00:00  2020-12-21 00:00:00  \
County Name
Miami-Dade County              0.059686             0.060681
Broward County                 0.054530             0.058779
Palm Beach County              0.052638             0.055378
Hillsborough County            0.069614             0.070260
Orange County                  0.068908             0.073076

                    2020-12-28 00:00:00  2021-01-03 00:00:00
```

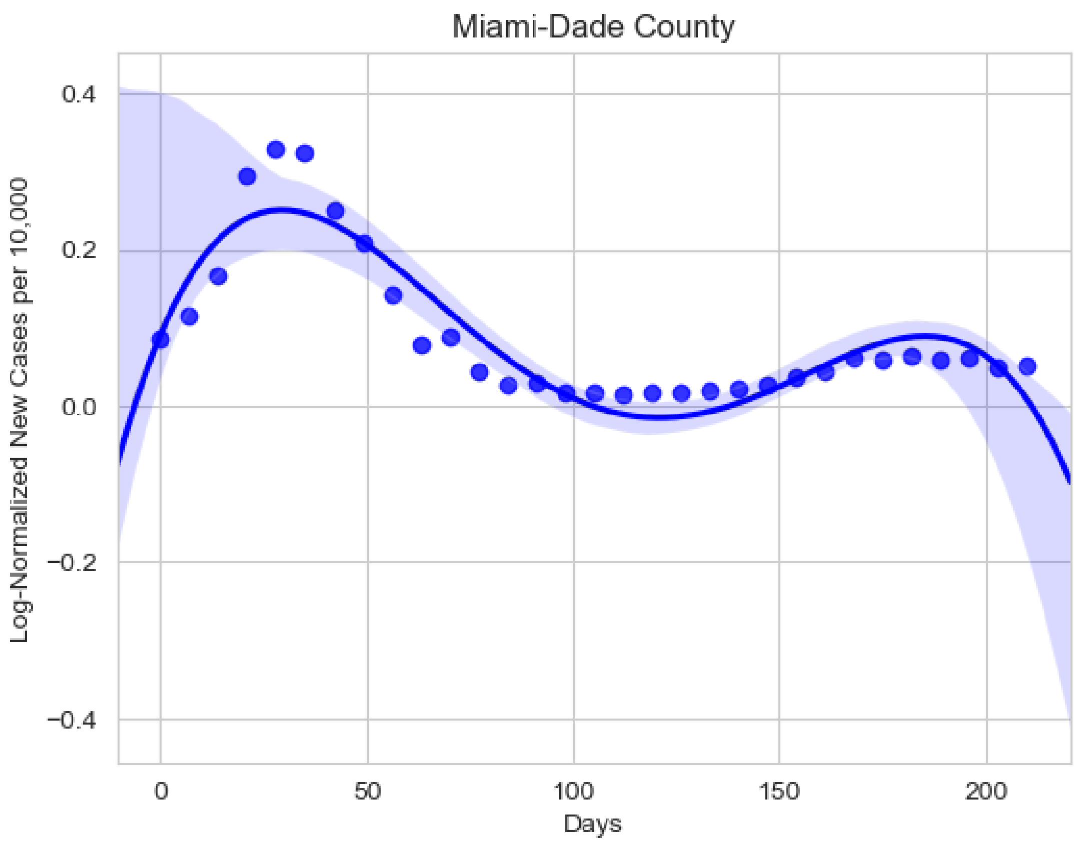
```
County Name
Miami-Dade County             0.049227         0.051579
Broward County                0.040690         0.054871
Palm Beach County             0.045842         0.055480
Hillsborough County           0.054096         0.067794
Orange County                 0.058672         0.071641

[5 rows x 31 columns]
```

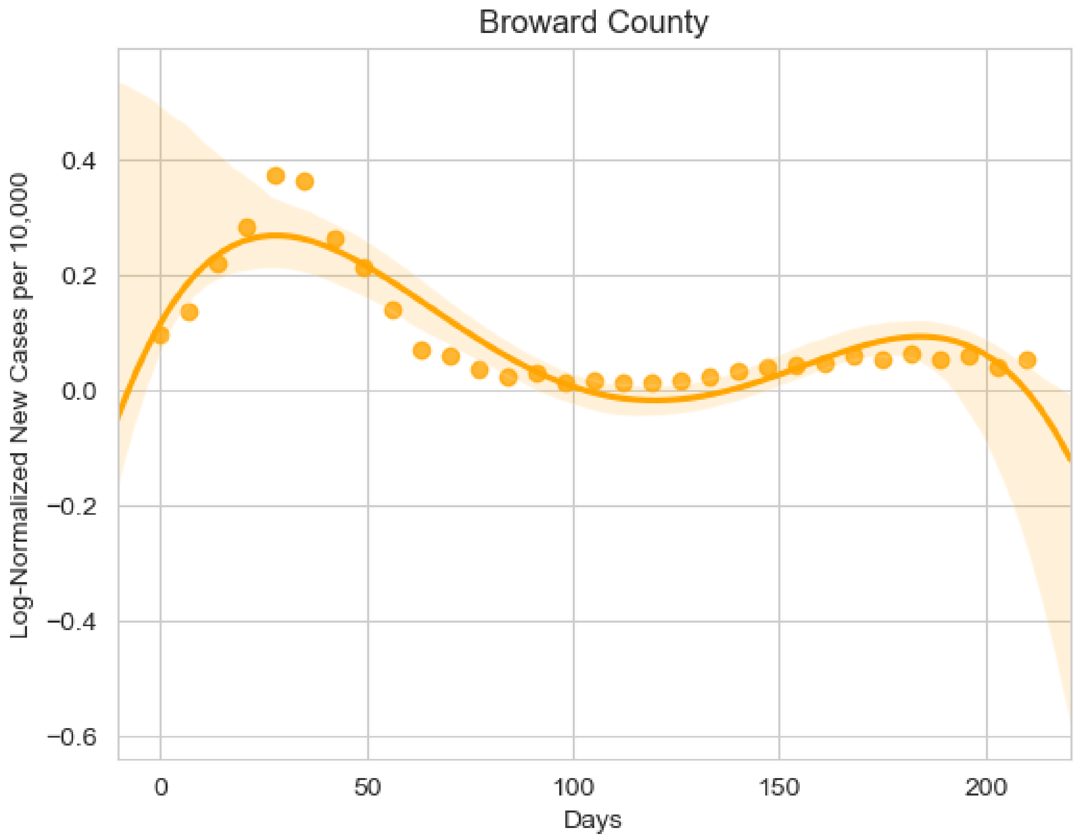
[42]:
```python
# first view the log-normalized cases per 100,000 people
plt.plot(x, top_5_counties_new.T)
plt.legend(top_5_counties.index)
plt.title('Top 5 Counties in Florida: Log-Normalized New Cases per 100,000␣
 ↪people')
plt.xlabel('Days')
plt.ylabel('Log-Normalized New Cases per 100,000')
plt.show()
```

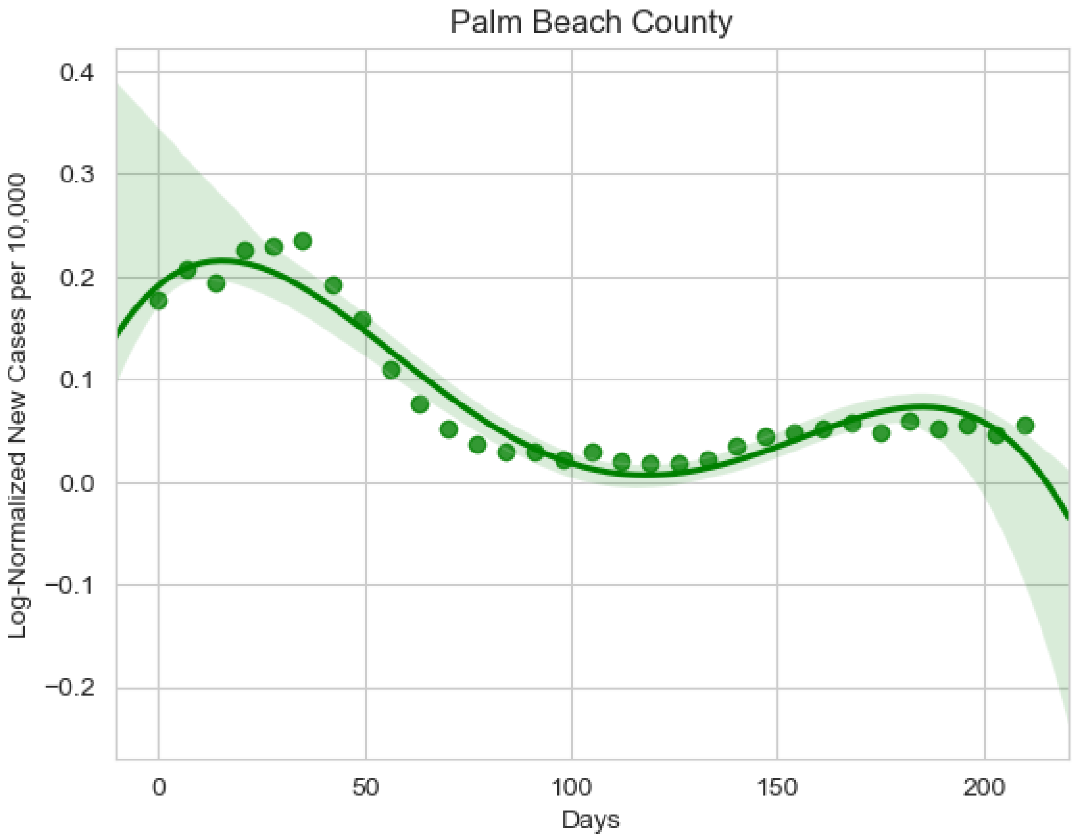


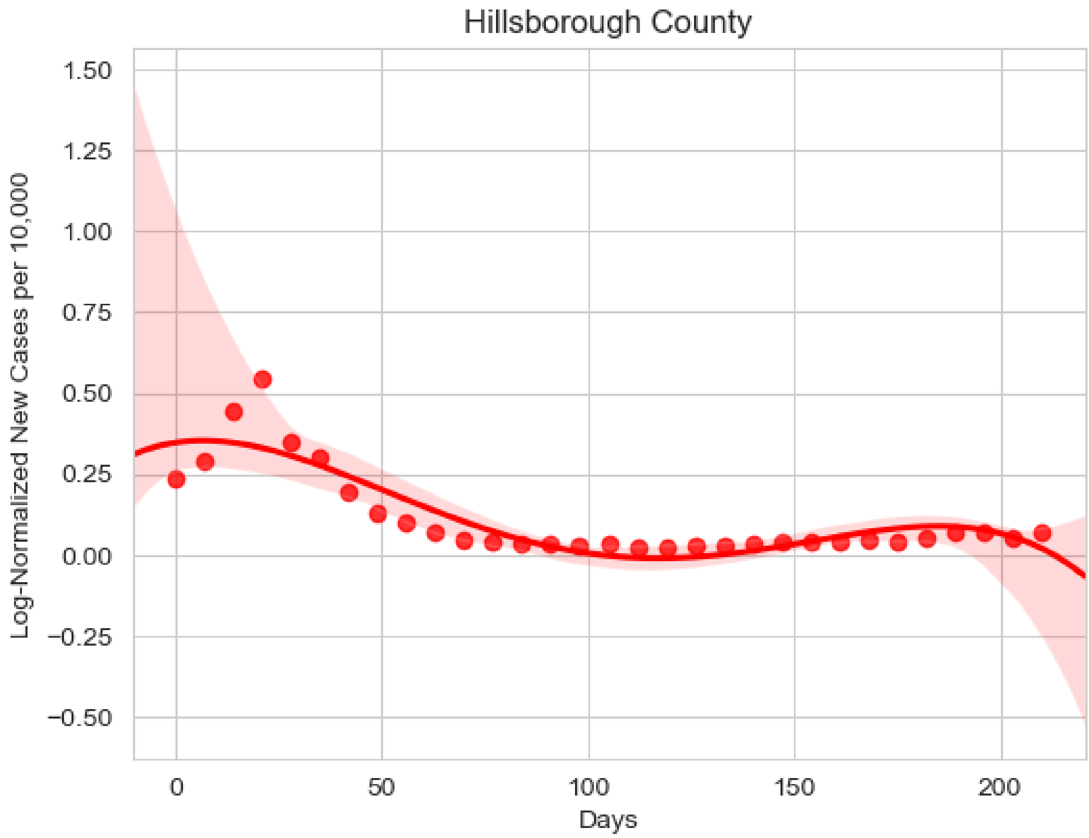
2.0.1 Polynomial Degree 3 Regression to Analyze Trends in Top 5 Counties

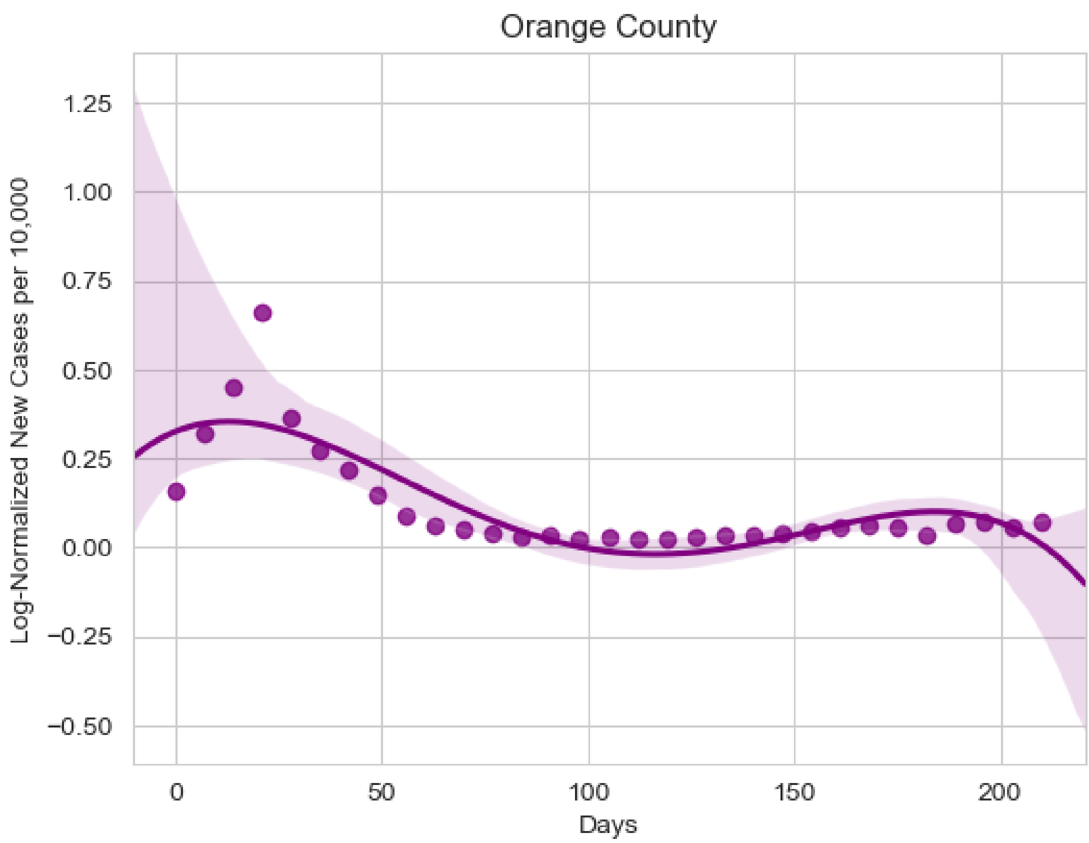
[43]:
```
colors = ['blue', 'orange', 'green', 'red', 'purple']
for county, color in zip(top_5_counties_new.index, colors):
    plt.figure()
    y = top_5_counties_new.loc[county]
    regplot(y=y, x=x, order=4, label='Trendline', truncate=False, color=color)
    plt.title(f'{county}')
    plt.xlabel('Days')
    plt.ylabel('Log-Normalized New Cases per 10,000')
    plt.show()
```




Broward County
Log-Normalized New Cases per 10,000
0.4
0.2
0.0
−0.2
−0.4
−0.6
0
50
100
150
200
Days


Palm Beach County
0.4
0.3
0.2
0.1
0.0
−0.1
−0.2
Log-Normalized New Cases per 10,000
0
50
100
150
200
Days


Hillsborough County
Log-Normalized New Cases per 10,000
1.50
1.25
1.00
0.75
0.50
0.25
0.00
−0.25
−0.50
0
50
100
150
200
Days



As we can see in the above diagrams, each county follows roughly the same trend.There is a spike at around 30 days, which would be around the 4th of July. After that, the number of new cases per 100,000 people decreases and levels off.

3 Task 3: Perform hypothesis testing between election result data and COVID-19 cases in Florida

[44]:
```
election = pd.read_csv('./data/president_county_candidate.csv')
florida_election = election[election['state'] == 'Florida']
fl_election_clean = florida_election.drop(columns=['state']).set_index('county')
```

[45]:
```
# Create a DataFrame with lots of useful information for hypothesis testing
vote_info = pd.DataFrame()
vote_info['total_votes'] = fl_election_clean.groupby('county')['total_votes'].
 ↪sum()
vote_info['dem_votes'] = fl_election_clean[fl_election_clean['party'] == 'DEM'].
 ↪groupby('county')['total_votes'].sum()
vote_info['rep_votes'] = fl_election_clean[fl_election_clean['party'] == 'REP'].
 ↪groupby('county')['total_votes'].sum()
```

```
vote_info['dem_prop'] = vote_info['dem_votes'] / vote_info['total_votes'] * 100
vote_info['rep_prop'] = vote_info['rep_votes'] / vote_info['total_votes'] * 100
vote_info['population'] = florida_cases.set_index('County Name')['population']
vote_info['turnout'] = vote_info['total_votes'] / vote_info['population'] * 100
```

[52]:
```
# Join the vote information with the COVID-19 cases
florida_cases['infected%'] = florida_cases[florida_cases.columns[-1]] /␣
↪florida_cases['population'] * 100
just_cases = florida_cases.set_index('County Name').drop(columns=['countyFIPS',␣
↪'population'])
hypothesis = vote_info.join(just_cases, how='inner')
```

3.0.1 Hypothesis 1: Counties with a higher proportion of votes for the Democratic candidate have a lower number of COVID-19 cases

3.0.2 First perform 2 sided 2 sample T-test

- Null Hypothesis: The number of COVID-19 cases in Dem-leaning counties is the same as the number of COVID-19 cases in Rep-leaning counties
- Alternative Hypothesis: The number of COVID-19 cases in counties in Dem-leaning counties is different from the number of COVID-19 cases in Rep-leaning counties

[47]:
```
dem_cases_2_sided = hypothesis[hypothesis['dem_prop'] > 50].iloc[:, -1]
rep_cases_2_sided = hypothesis[hypothesis['rep_prop'] > 50].iloc[:, -1]
_, p_val = stats.ttest_ind(dem_cases_2_sided, rep_cases_2_sided,␣
↪equal_var=False, alternative='two-sided')
print(f'P-value: {p_val}')
print(f'Reject Null Hypothesis: {p_val < 0.05}')
```

```
P-value: 0.026620782044504937
Reject Null Hypothesis: True
```

We reject the Null Hypothesis that the number of COVID-19 cases in Dem-leaning counties is the same as the number of COVID-19 cases in Rep-leaning counties. This suggests that there is a significant difference in the number of COVID-19 cases between the two groups.

3.0.3 Next, perform 1 sided 2 sample T-test

- Null Hypothesis: The number of COVID-19 cases in counties in Dem-leaning counties is less than or equal to the number of COVID-19 cases in Rep-leaning counties
- Alternative Hypothesis: The number of COVID-19 cases in counties in Dem-leaning counties is greater than the number of COVID-19 cases in Rep-leaning counties

[48]:
```
# perform 1 tail 2 sample t-test
dem_cases_1_sided = hypothesis[hypothesis['dem_prop'] > 50].iloc[:, -1]
rep_cases_1_sided = hypothesis[hypothesis['rep_prop'] > 50].iloc[:, -1]
_, p_val = stats.ttest_ind(dem_cases_1_sided, rep_cases_1_sided,␣
↪equal_var=False, alternative='greater')
print(f'P-value: {p_val}')
```

```
print(f'Reject Null Hypothesis: {p_val < 0.05}')
```

```
P-value: 0.013310391022252469
Reject Null Hypothesis: True
```

We reject the Null Hypothesis that the number of COVID-19 cases in Dem-leaning counties is less than or equal to the number of COVID-19 cases in Rep-leaning counties. This suggests that the number of COVID-19 cases is higher in Dem-leaning counties than in Rep-leaning counties.

3.0.4 Hypothesis 2: Counties with a higher voter turnout have a higher number of COVID-19 cases

3.0.5 First perform 2 sided 2 sample T-test

- Null Hypothesis: The number of COVID-19 cases in high-turnout counties is the same as the number of COVID-19 cases in low-turnout counties
- Alternative Hypothesis: The number of COVID-19 cases in high-turnout counties is different from the number of COVID-19 cases in low-turnout counties

[49]:
```
high_turnout_cases_2_sided = hypothesis[hypothesis['turnout'] > 50].iloc[:, -1]
low_turnout_cases_2_sided = hypothesis[hypothesis['turnout'] <= 50].iloc[:, -1]
_, p_val = stats.ttest_ind(high_turnout_cases_2_sided,␣
↪low_turnout_cases_2_sided, equal_var=False, alternative='two-sided')
print(f'P-value: {p_val}')
print(f'Reject Null Hypothesis: {p_val < 0.05}')
```

```
P-value: 0.39884269097381786
Reject Null Hypothesis: False
```

We accept the Null Hypothesis that the number of COVID-19 cases in high-turnout counties is the same as the number of COVID-19 cases in low-turnout counties. This suggests that there is no significant difference in the number of COVID-19 cases between the two groups.

3.0.6 Next, perform 1 sided 2 sample T-test

- Null Hypothesis: The number of COVID-19 cases in high-turnout counties is less than or equal to the number of COVID-19 cases in low-turnout counties
- Alternative Hypothesis: The number of COVID-19 cases in high-turnout counties is greater than the number of COVID-19 cases in low-turnout counties

[50]:
```
high_turnout_cases_1_sided = hypothesis[hypothesis['turnout'] > 50].iloc[:, -1]
low_turnout_cases_1_sided = hypothesis[hypothesis['turnout'] <= 50].iloc[:, -1]
_, p_val = stats.ttest_ind(high_turnout_cases_1_sided,␣
↪low_turnout_cases_1_sided, equal_var=False, alternative='greater')
print(f'P-value: {p_val}')
print(f'Reject Null Hypothesis: {p_val < 0.05}')
```

```
P-value: 0.8005786545130911
Reject Null Hypothesis: False
```

We accept the Null Hypothesis that the number of COVID-19 cases in high-turnout counties is less than or equal to the number of COVID-19 cases in low-turnout counties. This suggests that there is no significant difference in the number of COVID-19 cases between the two groups.

3.0.7 Hypothesis 3: Counties with a higher proportion of votes for the Democratic candidate have a lower infection rate

- Null Hypothesis: The infection rate in Dem-leaning counties is the same as the infection rate in Rep-leaning counties
- Alternative Hypothesis: The infection rate in counties in Dem-leaning counties is different from the infection rate in Rep-leaning counties

3.0.8 First perform 2 sided 2 sample T-test

[53]:
```
dem_infection_2_sided = hypothesis[hypothesis['dem_prop'] > 50]['infected%']
rep_infection_2_sided = hypothesis[hypothesis['rep_prop'] > 50]['infected%']
_, p_val = stats.ttest_ind(dem_infection_2_sided, rep_infection_2_sided,␣
 ↪equal_var=False, alternative='two-sided')
print(f'P-value: {p_val}')
print(f'Reject Null Hypothesis: {p_val < 0.05}')
```

```
P-value: 0.8373095955695355
Reject Null Hypothesis: False
```

We accept the Null Hypothesis that the infection rate in Dem-leaning counties is the same as the infection rate in Rep-leaning counties. This suggests that there is a no significant difference in the infection rate between the two groups.

3.0.9 Next, perform 1 sided 2 sample T-test

[54]:
```
dem_infection_1_sided = hypothesis[hypothesis['dem_prop'] > 50]['infected%']
rep_infection_1_sided = hypothesis[hypothesis['rep_prop'] > 50]['infected%']
_, p_val = stats.ttest_ind(dem_infection_1_sided, rep_infection_1_sided,␣
 ↪equal_var=False, alternative='greater')
print(f'P-value: {p_val}')
print(f'Reject Null Hypothesis: {p_val < 0.05}')
```

```
P-value: 0.4186547977847678
Reject Null Hypothesis: False
```

We accept the Null Hypothesis that the infection rate in Dem-leaning counties is less than or equal to the infection rate in Rep-leaning counties. This suggests that there is no significant difference in the infection rate between the two groups.

3.0.10 Results

- Hypothesis 1: We find, based on our tests, that the number of cases in Democratic leaning counties is higher than in Republican leaning counties.
- Hypothesis 2: We find, based on our tests, that the number of cases in high-turnout counties is the same as in low-turnout counties.

- Hypothesis 3: We find, based on our tests, that the infection rate in Democratic leaning counties is the same as in Republican leaning counties.

These results suggest that the number of cases is related to the political leaning of the county, but not to the voter turnout or the infection rate. This implies that there is another variable which is causing the difference in the number of cases between Democratic and Republican leaning counties. My guess is that this variable is the population density of the county, which is likely to be higher in Democratic leaning counties due to cities often being left-leaning compared to rural areas. This would lead to a higher number of cases in these counties.