Miller_HW5

July 14, 2021

0.0.1 Package import

[1]:
```
import pandas as pd
import statsmodels.api as sm
import matplotlib.pyplot as plt
from math import ceil, floor
```

0.0.2 Set alpha

[2]:
```
alpha = 0.05
```

1 Problem 1

1.0.1 Data setup and dataframe creation.

[3]:
```
data = {'Temp': [7, 5, 7, 7, 6, 6, 5, 6, 5, 6, 5, 7, 6, 6, 6],
        'Oil': [4, 3, 3, 2, 4, 3, 3, 2, 4, 2, 2, 3, 3, 3, 4],
        'Time': [90, 105, 105, 90, 105, 90, 75, 105, 90, 75, 90, 75, 90, 90,␣
 ↪75],
        'y': [24, 28, 40, 42, 11, 16, 126, 34, 32, 32, 34, 17, 30, 17, 50]}

df = pd.DataFrame(data)
df = sm.add_constant(df)
df.head()
```

[3]:

	const	Temp	Oil	Time	y
0	1.0	7	4	90	24
1	1.0	5	3	105	28
2	1.0	7	3	105	40
3	1.0	7	2	90	42
4	1.0	6	4	105	11

1.1 Problem 1a

[4]:
```
df_exog = df[['const', 'Temp', 'Oil', 'Time']]
df_exog = pd.concat([df_exog,
                     df_exog['Temp'] * df_exog['Oil'],
                     df_exog['Temp'] * df_exog['Time'],
```

```
                      df_exog['Oil'] * df_exog['Time']], axis = 1)
df_exog = df_exog.rename(columns = {0: 'Temp * Oil',
                                    1: 'Temp * Time',
                                    2: 'Oil * Time'})
df_endog = df['y']
```

1.1.1 Full Poisson, *log* link function

[5]:
```
model_poisson = sm.GLM(df_endog, df_exog,
                       family = sm.families.Poisson(sm.families.links.log()),
                       alpha = 0.05)
res_poisson = model_poisson.fit()
res_poisson.summary2()
```

[5]:
```
<class 'statsmodels.iolib.summary2.Summary'>
"""
               Results: Generalized linear model
=================================================================
Model:              GLM              AIC:            129.2872
Link Function:      log              BIC:            15.0506
Dependent Variable: y                Log-Likelihood: -57.644
Date:               2021-07-14 09:36 LL-Null:        -146.01
No. Observations:   15               Deviance:       36.715
Df Model:           6                Pearson chi2:   38.9
Df Residuals:       8                Scale:          1.0000
Method:             IRLS
-----------------------------------------------------------------
               Coef.  Std.Err.    z    P>|z|   [0.025  0.975]
-----------------------------------------------------------------
const         24.9964   3.6530  6.8427 0.0000 17.8367 32.1561
Temp          -4.2817   0.5679 -7.5389 0.0000 -5.3948 -3.1685
Oil            2.9898   0.7655  3.9060 0.0001  1.4896  4.4901
Time          -0.2517   0.0373 -6.7444 0.0000 -0.3249 -0.1786
Temp * Oil    -0.1634   0.0903 -1.8089 0.0705 -0.3404  0.0136
Temp * Time    0.0505   0.0057  8.8684 0.0000  0.0393  0.0617
Oil * Time    -0.0242   0.0060 -4.0614 0.0000 -0.0359 -0.0125
=================================================================

"""
```

Remove any variables where CI includes 0 and p $>$ 0.05, i.e. “Temp * Oil”

1.1.2 Reduced Poisson, *log* link function

[6]:
```
df_exog_2 = df_exog[[i for i in df_exog.columns if i != 'Temp * Oil']]
model_reduced = sm.GLM(df_endog, df_exog_2,
                       family = sm.families.Poisson(sm.families.links.log()),
                       alpha = 0.05)
```

```
res_reduced = model_reduced.fit()
res_reduced.summary2()
```

[6]:
```
<class 'statsmodels.iolib.summary2.Summary'>
"""
               Results: Generalized linear model
=============================================================
Model:              GLM              AIC:            130.5569
Link Function:      log              BIC:            15.6123
Dependent Variable: y                Log-Likelihood: -59.278
Date:               2021-07-14 09:36 LL-Null:        -146.01
No. Observations:   15               Deviance:       39.985
Df Model:           5                Pearson chi2:   42.5
Df Residuals:       9                Scale:          1.0000
Method:             IRLS
-------------------------------------------------------------
               Coef.  Std.Err.    z    P>|z|   [0.025  0.975]
-------------------------------------------------------------
const         27.9918   3.2634  8.5775 0.0000 21.5957 34.3880
Temp          -4.7708   0.5019 -9.5053 0.0000 -5.7545 -3.7870
Oil            1.9909   0.5249  3.7931 0.0001  0.9621  3.0196
Time          -0.2537   0.0372 -6.8230 0.0000 -0.3265 -0.1808
Temp * Time    0.0506   0.0057  8.9154 0.0000  0.0395  0.0618
Oil * Time    -0.0238   0.0059 -4.0022 0.0001 -0.0355 -0.0121
=============================================================

"""
```

Remaining variables all show significant impact.

1.2 Problem 1b

[7]:
```
disp = res_reduced.deviance / res_reduced.df_model
print('Dispersion (D / df) = {}'.format(round(disp, 2)))
```

```
Dispersion (D / df) = 8.0
```

Likely overdispersion.

1.3 Problem 1c

1.3.1 Reduced Poisson, *identity* link function

[8]:
```
model_poi_id = sm.GLM(df_endog, df_exog_2,
                      family = sm.families.Poisson(sm.families.links.
 ↪identity()),
                      alpha = 0.05)
res_poi_id = model_poi_id.fit()
res_poi_id.summary2()
```

```
/Users/jmiller/opt/anaconda3/lib/python3.8/site-
packages/statsmodels/genmod/generalized_linear_model.py:293: DomainWarning: The
identity link function does not respect the domain of the Poisson family.
  warnings.warn((f"The {type(family.link).__name__} link function "
/Users/jmiller/opt/anaconda3/lib/python3.8/site-
packages/statsmodels/genmod/generalized_linear_model.py:293: DomainWarning: The
identity link function does not respect the domain of the Poisson family.
  warnings.warn((f"The {type(family.link).__name__} link function "
```

[8]:
```
<class 'statsmodels.iolib.summary2.Summary'>
"""
                Results: Generalized linear model
=================================================================
Model:               GLM               AIC:            168.7367
Link Function:       identity          BIC:            53.7920
Dependent Variable:  y                 Log-Likelihood: -78.368
Date:                2021-07-14 09:36  LL-Null:        -146.01
No. Observations:    15                Deviance:       78.164
Df Model:            5                 Pearson chi2:   80.1
Df Residuals:        9                 Scale:          1.0000
Method:              IRLS
-----------------------------------------------------------------
              Coef.   Std.Err.    z    P>|z|    [0.025   0.975]
-----------------------------------------------------------------
const        679.9396 111.2702  6.1107 0.0000  461.8540 898.0251
Temp        -128.2427  16.0021 -8.0141 0.0000 -159.6062 -96.8792
Oil           60.6622  17.1033  3.5468 0.0004   27.1404  94.1839
Time          -6.3492   1.1955 -5.3111 0.0000   -8.6922  -4.0061
Temp * Time    1.3111   0.1734  7.5611 0.0000    0.9712   1.6509
Oil * Time    -0.7166   0.1832 -3.9124 0.0001   -1.0756  -0.3576
=================================================================

"""
```

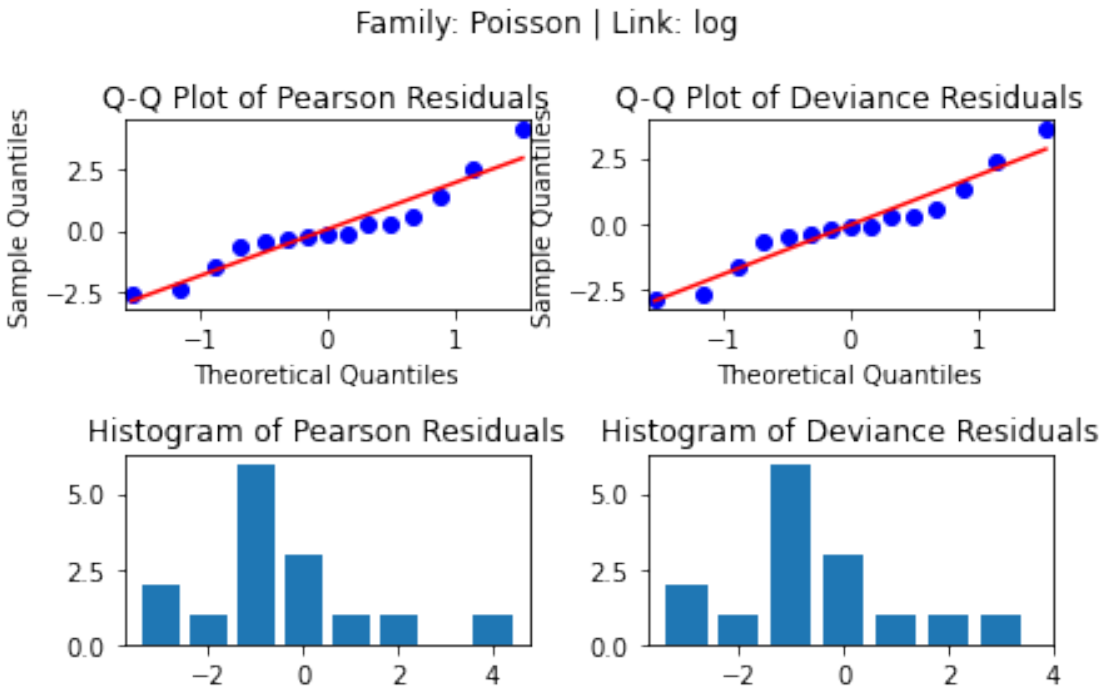
AIC and BIC are lower for log link, therefore use that.

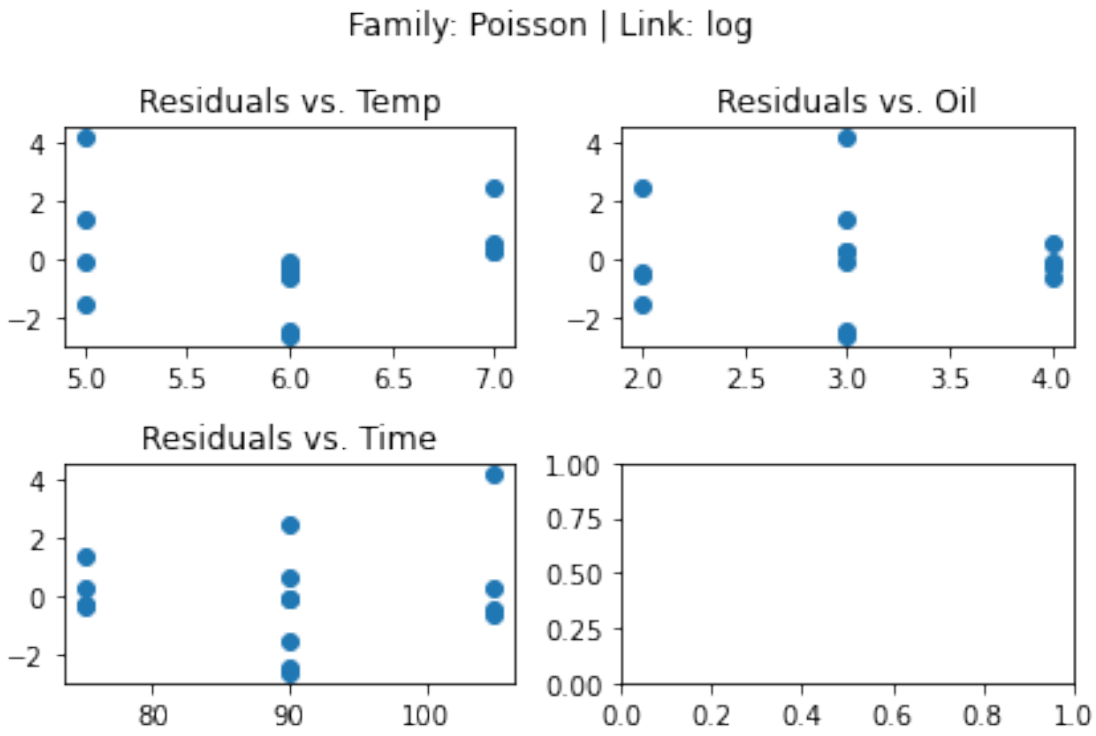
1.3.2 Q-Q, histogram, residual plots

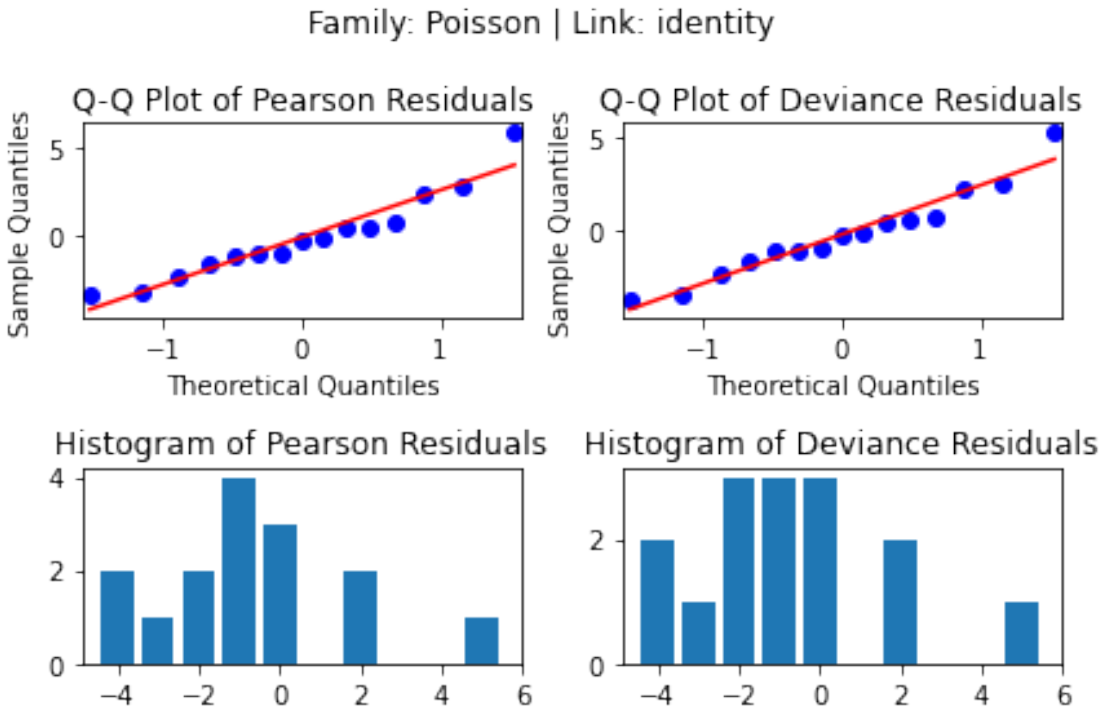
[9]:
```
for model in [res_reduced, res_poi_id]:
    model_family = str(model.model.family).split('.')[-1].split(' ')[0]
    model_link = str(model.model.family.link).split('.')[-1].split(' ')[0]

    ############################
    # Q-Q AND HISTOGRAM PLOTS #
    ############################
    fig, ax = plt.subplots(2, 2)

    sm.qqplot(model.resid_pearson, line = 'r', ax = ax[0, 0])
```

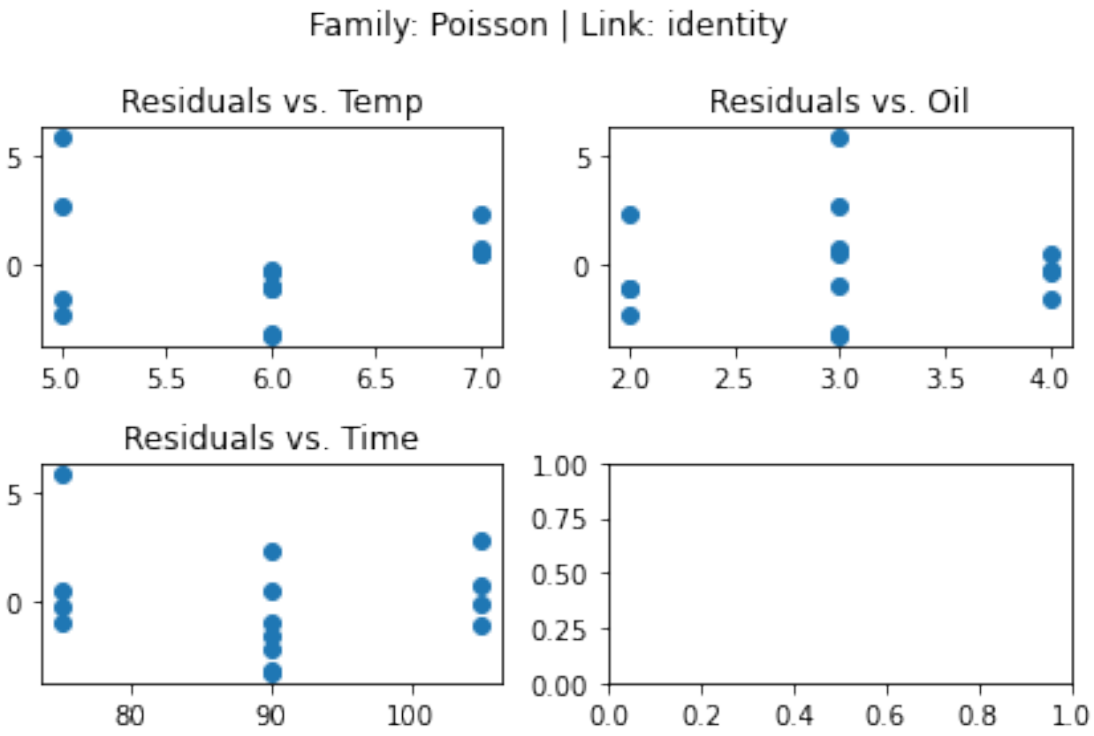
```
ax[0, 0].set_title('Q-Q Plot of Pearson Residuals')

sm.qqplot(model.resid_deviance, line = 'r', ax = ax[0, 1])
ax[0, 1].set_title('Q-Q Plot of Deviance Residuals')

pearson_min_bin = floor(min(model.resid_pearson))
pearson_max_bin = ceil(max(model.resid_pearson)) + 1
ax[1, 0].hist(model.resid_pearson,
              bins = range(pearson_min_bin, pearson_max_bin),
              rwidth = 0.8,
              align = 'left')
ax[1, 0].set_xticks([i for i in range(pearson_min_bin, pearson_max_bin)
                     if i % 2 == 0])
ax[1, 0].set_title('Histogram of Pearson Residuals')

deviance_min_bin = floor(min(model.resid_deviance))
deviance_max_bin = ceil(max(model.resid_deviance)) + 1
ax[1, 1].hist(model.resid_deviance,
              bins = range(deviance_min_bin, deviance_max_bin),
              rwidth = 0.8,
              align = 'left')
ax[1, 1].set_xticks([i for i in range(deviance_min_bin, deviance_max_bin)
                     if i % 2 == 0])
ax[1, 1].set_title('Histogram of Deviance Residuals')

fig_title = 'Family: {} | Link: {}'.format(model_family, model_link)
fig.suptitle(fig_title)
plt.tight_layout()
plt.show()

##########################
# RESIDUALS VS VARIABLES #
##########################
fig, ax = plt.subplots(2, 2)

sorted_temp = sorted(list(zip(df['Temp'], model.resid_pearson)))
sorted_temp_x = [i[0] for i in sorted_temp]
sorted_temp_y = [i[1] for i in sorted_temp]

ax[0, 0].scatter(sorted_temp_x, sorted_temp_y)
ax[0, 0].set_title('Residuals vs. Temp')

sorted_oil = sorted(list(zip(df['Oil'], model.resid_pearson)))
sorted_oil_x = [i[0] for i in sorted_oil]
sorted_oil_y = [i[1] for i in sorted_oil]

ax[0, 1].scatter(sorted_oil_x, sorted_oil_y)
```

```
    ax[0, 1].set_title('Residuals vs. Oil')

    sorted_time = sorted(list(zip(df['Time'], model.resid_pearson)))
    sorted_time_x = [i[0] for i in sorted_time]
    sorted_time_y = [i[1] for i in sorted_time]

    ax[1, 0].scatter(sorted_time_x, sorted_time_y)
    ax[1, 0].set_title('Residuals vs. Time')

    fig_title = 'Family: {} | Link: {}'.format(model_family, model_link)
    fig.suptitle(fig_title)
    plt.tight_layout()
    plt.show()
```




Family: Poisson | Link: log
Residuals vs. Temp
Residuals vs. Oil
Residuals vs. Time


Family: Poisson | Link: identity
Q-Q Plot of Pearson Residuals
Q-Q Plot of Deviance Residuals
Sample Quantiles
Theoretical Quantiles
Histogram of Pearson Residuals
Histogram of Deviance Residuals



Nothing stands out as abnormal in any of these plots, therefore either model likely ok to use for this analysis.

2 Problem 2

Data setup and dataframe creation.

[10]:
```
data = {'bath_temperature': [248, 248, 248, 248, 248, 248, 248, 248, 248,
                             252, 252, 252, 252, 252, 252, 252, 252, 252],
        'wave_height': [4.38, 4.38, 4.38, 4.4, 4.4, 4.4, 4.42, 4.42, 4.42,
                        4.38, 4.38, 4.38, 4.4, 4.4, 4.4, 4.42, 4.42, 4.42],
        'overhead_preheater': [340, 360, 380, 340, 360, 380, 360, 380, 380,
                               340, 360, 380, 340, 360, 380, 340, 360, 380],
        'preheater_1': [340, 360, 380, 360, 380, 340, 340, 360, 340,
                        380, 340, 360, 360, 380, 340, 380, 340, 360],
        'preheater_2': [340, 360, 380, 360, 380, 340, 340, 360, 380,
                        380, 340, 360, 380, 340, 360, 360, 380, 340],
        'air_knife': [0, 3, 6, 3, 6, 0, 6, 0, 3, 3, 6, 0, 0, 3, 6, 6, 0, 3],
        'overhead_vibration': [0, 2, 4, 4, 0, 2, 2, 4, 0,
                               2, 4, 0, 4, 0, 2, 0, 2, 4],
        'y': [4, 2, 1, 2, 6, 15, 9, 5, 8, 5, 4, 11, 10, 15, 4, 12, 6, 7]}

df = pd.DataFrame(data)
```

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

[10]:

	const	bath_temperature	wave_height	overhead_preheater	preheater_1	preheater_2	air_knife	overhead_vibration	y
0	1.0	248	4.38	340	340	340	0	0	4
1	1.0	248	4.38	360	360	360	3	2	2
2	1.0	248	4.38	380	380	380	6	4	1
3	1.0	248	4.40	340	360	360	3	4	2
4	1.0	248	4.40	360	380	380	6	0	6

2.1 Problem 2a

[11]:
```
df_exog = df[['const', 'bath_temperature', 'wave_height', 'overhead_preheater',
              'preheater_1', 'preheater_2', 'air_knife', 'overhead_vibration']]
df_endog = df['y']
```

2.1.1 Normal, identity link function

[12]:
```
model_glm = sm.GLM(df_endog, df_exog,
                   family = sm.families.Gaussian(sm.families.links.identity()),
                   alpha = 0.05)
res_glm = model_glm.fit()
res_glm.summary2()
```

[12]:
```
<class 'statsmodels.iolib.summary2.Summary'>
"""
                  Results: Generalized linear model
================================================================================
Model:                    GLM                 AIC:                101.4445
Link Function:            identity            BIC:                92.5351
Dependent Variable:       y                   Log-Likelihood:     -42.722
Date:                     2021-07-14 09:36    LL-Null:            -51.611
No. Observations:         18                  Deviance:           121.44
Df Model:                 7                   Pearson chi2:       121.
Df Residuals:             10                  Scale:              12.144
Method:                   IRLS
--------------------------------------------------------------------------------
                     Coef.   Std.Err.     z     P>|z|     [0.025     0.975]
--------------------------------------------------------------------------------
const              -527.4145 247.9185 -2.1274 0.0334 -1013.3259 -41.5031
```

```
bath_temperature      0.5667   0.4184  1.3546 0.1756    -0.2533   1.3868
wave_height          89.9889  51.7073  1.7404 0.0818   -11.3555 191.3333
overhead_preheater    0.0287   0.0533  0.5380 0.5905    -0.0758   0.1331
preheater_1           0.0686   0.0589  1.1653 0.2439    -0.0468   0.1840
preheater_2          -0.0955   0.0539 -1.7720 0.0764    -0.2011   0.0101
air_knife            -0.5310   0.3494 -1.5198 0.1286    -1.2158   0.1538
overhead_vibration   -1.0917   0.5065 -2.1552 0.0311    -2.0845  -0.0989
================================================================================

"""
```

2.1.2 Full Poisson, identity link function

[13]:
```
model_poisson = sm.GLM(df_endog, df_exog,
                       family = sm.families.Poisson(sm.families.links.
 ↪identity()),
                       alpha = 0.05)
res_poisson = model_poisson.fit()
res_poisson.summary2()
```

```
/Users/jmiller/opt/anaconda3/lib/python3.8/site-
packages/statsmodels/genmod/generalized_linear_model.py:293: DomainWarning: The
identity link function does not respect the domain of the Poisson family.
  warnings.warn((f"The {type(family.link).__name__} link function "
/Users/jmiller/opt/anaconda3/lib/python3.8/site-
packages/statsmodels/genmod/generalized_linear_model.py:293: DomainWarning: The
identity link function does not respect the domain of the Poisson family.
  warnings.warn((f"The {type(family.link).__name__} link function "
```

[13]:
```
<class 'statsmodels.iolib.summary2.Summary'>
"""
                  Results: Generalized linear model
================================================================================
Model:                    GLM                 AIC:                97.1260
Link Function:            identity            BIC:                -12.7365
Dependent Variable:       y                   Log-Likelihood:     -40.563
Date:                     2021-07-14 09:36    LL-Null:            -54.793
No. Observations:         18                  Deviance:           16.167
Df Model:                 7                   Pearson chi2:       16.9
Df Residuals:             10                  Scale:              1.0000
Method:                   IRLS
--------------------------------------------------------------------------------
                     Coef.   Std.Err.     z     P>|z|     [0.025     0.975]
--------------------------------------------------------------------------------
const              -610.2714 183.0321 -3.3342 0.0009 -969.0077 -251.5351
bath_temperature      0.6998   0.2888  2.4230 0.0154    0.1337    1.2659
wave_height          99.3022  37.2052  2.6690 0.0076   26.3814  172.2231
```

```
overhead_preheater    0.0400   0.0352  1.1376 0.2553   -0.0290    0.1090
preheater_1           0.0682   0.0461  1.4795 0.1390   -0.0221    0.1585
preheater_2          -0.0838   0.0434 -1.9316 0.0534   -0.1689    0.0012
air_knife            -0.5059   0.2562 -1.9749 0.0483   -1.0080   -0.0038
overhead_vibration   -0.9059   0.3521 -2.5728 0.0101   -1.5960   -0.2158
=================================================================================

"""
```

Remove any variables where CI includes 0 and p > 0.05, i.e. overhead_preheater, preheater_1, preheater_2

2.1.3 Reduced Poisson, identity link function

[14]:
```
df_exog_reduced = df_exog[['const', 'bath_temperature', 'wave_height',
                           'air_knife', 'overhead_vibration']]
model_poi_reduced = sm.GLM(df_endog, df_exog_reduced,
                           family = sm.families.Poisson(
                               sm.families.links.identity()),
                           alpha = 0.05)
res_poi_reduced = model_poi_reduced.fit()
res_poi_reduced.summary2()
```

```
/Users/jmiller/opt/anaconda3/lib/python3.8/site-
packages/statsmodels/genmod/generalized_linear_model.py:293: DomainWarning: The
identity link function does not respect the domain of the Poisson family.
  warnings.warn((f"The {type(family.link).__name__} link function "
/Users/jmiller/opt/anaconda3/lib/python3.8/site-
packages/statsmodels/genmod/generalized_linear_model.py:293: DomainWarning: The
identity link function does not respect the domain of the Poisson family.
  warnings.warn((f"The {type(family.link).__name__} link function "
```

[14]:
```
<class 'statsmodels.iolib.summary2.Summary'>
"""
                  Results: Generalized linear model
================================================================================
Model:                    GLM                AIC:               95.8069
Link Function:            identity           BIC:               -16.7267
Dependent Variable:       y                  Log-Likelihood:    -42.903
Date:                     2021-07-14 09:36   LL-Null:           -54.793
No. Observations:         18                 Deviance:          20.848
Df Model:                 4                  Pearson chi2:      22.3
Df Residuals:             13                 Scale:             1.0000
Method:                   IRLS
--------------------------------------------------------------------------------
                      Coef.   Std.Err.     z     P>|z|     [0.025     0.975]
--------------------------------------------------------------------------------
const               -543.6999 164.2827 -3.3095 0.0009 -865.6880 -221.7117
```

```
bath_temperature      0.6333   0.2787  2.2724 0.0231    0.0871    1.1796
wave_height          89.8949  35.3360  2.5440 0.0110   20.6376  159.1522
air_knife            -0.3881   0.2358 -1.6456 0.0998   -0.8503    0.0741
overhead_vibration   -1.0025   0.3546 -2.8270 0.0047   -1.6976   -0.3075
==============================================================================

"""
```

Both Poisson are similar in AIC/BIC, with reduced Poisson being slightly better performance. Normal distribution much larger.

2.2 Problem 2b

[15]:
```
for i in [res_glm, res_poisson, res_poi_reduced]:
    if i == res_glm:
        family = 'GLM'
    elif i == res_poisson:
        family = 'Poisson'
    elif i == res_poi_reduced:
        family = 'Reduced Poisson'

    param = round(i.params['wave_height'], 2)
    conf_int_lo = round(i.conf_int().loc['wave_height'][0], 2)
    conf_int_hi = round(i.conf_int().loc['wave_height'][1], 2)
    p_val = round(i.pvalues['wave_height'], 5)
    print('-- {} --\nParam: {} | C Int: [{} {}] | p: {}'.
          format(family,
                 param,
                 conf_int_lo,
                 conf_int_hi,
                 p_val))
    if (conf_int_lo < 0 and conf_int_hi > 0) or p_val > alpha:
        sig = 'Not Significant'
    else:
        sig = 'Significant'
    print('"b" value is: {}\n'.format(sig))
```

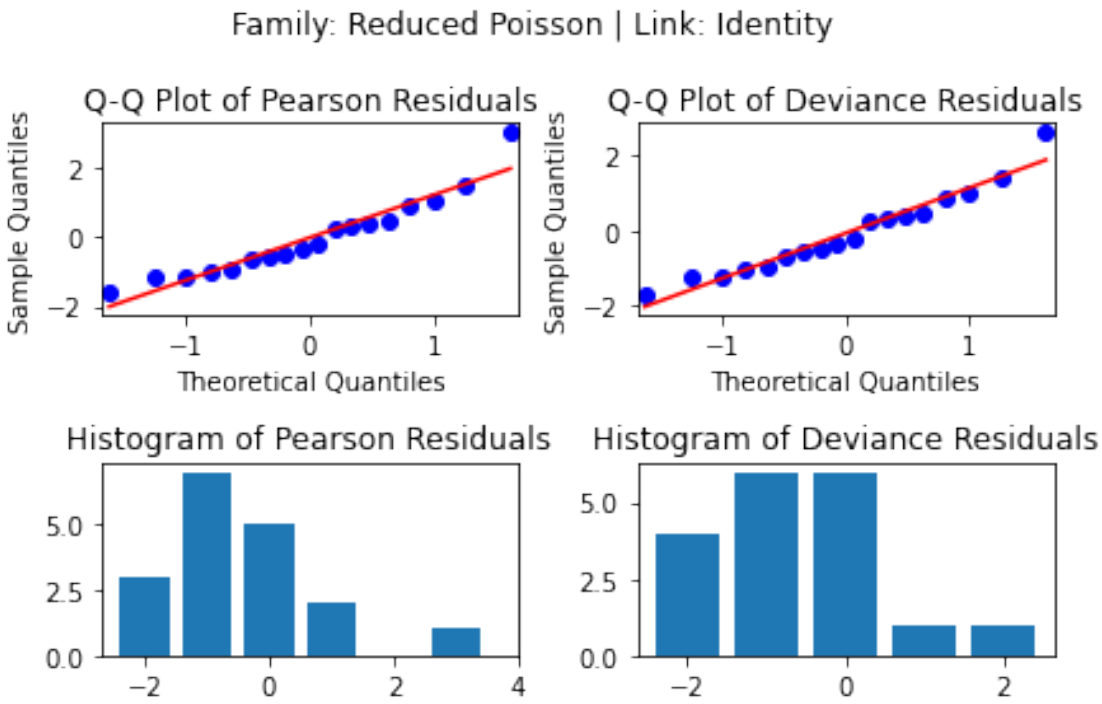
```
-- GLM --
Param: 89.99 | C Int: [-11.36 191.33] | p: 0.0818
"b" value is: Not Significant

-- Poisson --
Param: 99.3 | C Int: [26.38 172.22] | p: 0.00761
"b" value is: Significant

-- Reduced Poisson --
Param: 89.89 | C Int: [20.64 159.15] | p: 0.01096
"b" value is: Significant
```

2.3 Problem 2c

[16]:
```
model_family = 'Reduced Poisson'
model_link = 'Identity'
```

2.3.1 Q-Q, histogram plots

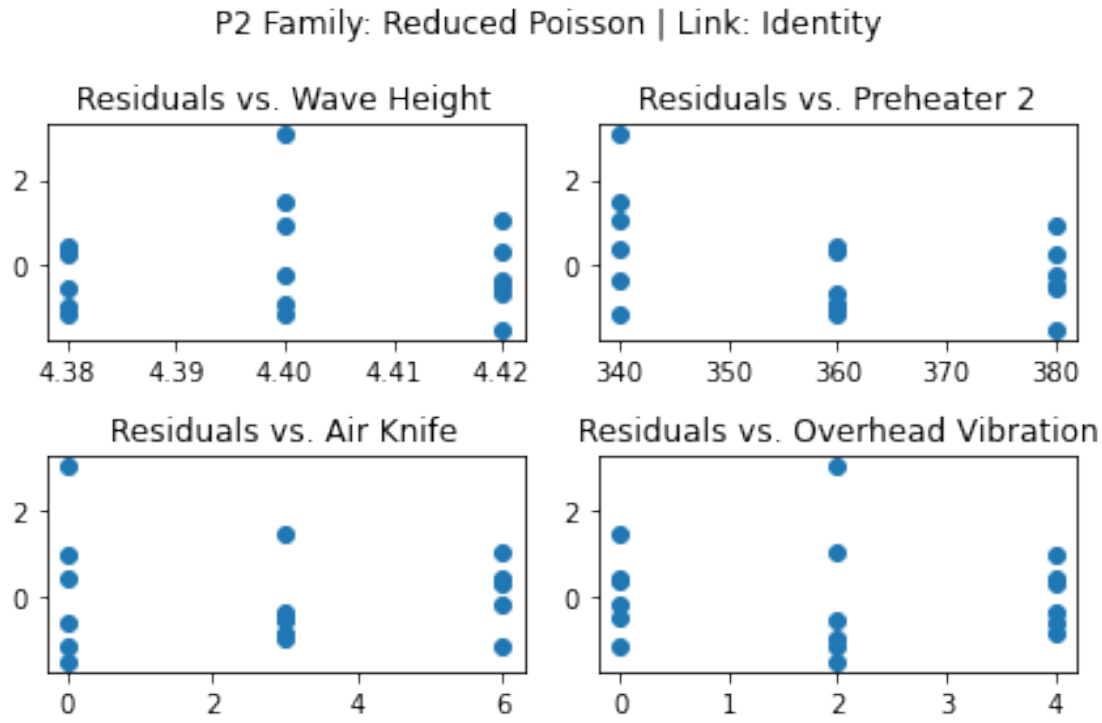
[17]:
```
fig, ax = plt.subplots(2, 2)

sm.qqplot(res_poi_reduced.resid_pearson, line = 'r', ax = ax[0, 0])
ax[0, 0].set_title('Q-Q Plot of Pearson Residuals')

sm.qqplot(res_poi_reduced.resid_deviance, line = 'r', ax = ax[0, 1])
ax[0, 1].set_title('Q-Q Plot of Deviance Residuals')

pearson_min_bin = floor(min(res_poi_reduced.resid_pearson))
pearson_max_bin = ceil(max(res_poi_reduced.resid_pearson)) + 1
ax[1, 0].hist(res_poi_reduced.resid_pearson,
              bins = range(pearson_min_bin, pearson_max_bin),
              rwidth = 0.8,
              align = 'left')
ax[1, 0].set_xticks([i for i in range(pearson_min_bin, pearson_max_bin)
                     if i % 2 == 0])
ax[1, 0].set_title('Histogram of Pearson Residuals')

deviance_min_bin = floor(min(res_poi_reduced.resid_deviance))
deviance_max_bin = ceil(max(res_poi_reduced.resid_deviance)) + 1
ax[1, 1].hist(res_poi_reduced.resid_deviance,
              bins = range(deviance_min_bin, deviance_max_bin),
              rwidth = 0.8,
              align = 'left')
ax[1, 1].set_xticks([i for i in range(deviance_min_bin, deviance_max_bin)
                     if i % 2 == 0])
ax[1, 1].set_title('Histogram of Deviance Residuals')

fig_title = 'Family: {} | Link: {}'.format(model_family, model_link)
fig.suptitle(fig_title)
plt.tight_layout()
plt.show()
```



2.3.2 Residual plots

[18]:
```
fig, ax = plt.subplots(2, 2)

sorted_wave_height = sorted(list(zip(df['wave_height'],
                                     res_poi_reduced.resid_pearson)))
sorted_wave_height_x = [i[0] for i in sorted_wave_height]
sorted_wave_height_y = [i[1] for i in sorted_wave_height]

ax[0, 0].scatter(sorted_wave_height_x, sorted_wave_height_y)
ax[0, 0].set_title('Residuals vs. Wave Height')

sorted_preheater_2 = sorted(list(zip(df['preheater_2'],
                                     res_poi_reduced.resid_pearson)))
sorted_preheater_2_x = [i[0] for i in sorted_preheater_2]
sorted_preheater_2_y = [i[1] for i in sorted_preheater_2]

ax[0, 1].scatter(sorted_preheater_2_x, sorted_preheater_2_y)
ax[0, 1].set_title('Residuals vs. Preheater 2')

sorted_air_knife = sorted(list(zip(df['air_knife'],
                                   res_poi_reduced.resid_pearson)))
sorted_air_knife_x = [i[0] for i in sorted_air_knife]
sorted_air_knife_y = [i[1] for i in sorted_air_knife]
```

```
ax[1, 0].scatter(sorted_air_knife_x, sorted_air_knife_y)
ax[1, 0].set_title('Residuals vs. Air Knife')

sorted_overhead_vibration = sorted(list(zip(df['overhead_vibration'],
                                            res_poi_reduced.resid_pearson)))
sorted_overhead_vibration_x = [i[0] for i in sorted_overhead_vibration]
sorted_overhead_vibration_y = [i[1] for i in sorted_overhead_vibration]

ax[1, 1].scatter(sorted_overhead_vibration_x, sorted_overhead_vibration_y)
ax[1, 1].set_title('Residuals vs. Overhead Vibration')

fig_title = 'P2 Family: {} | Link: {}'.format(model_family, model_link)
fig.suptitle(fig_title)
plt.tight_layout()
plt.show()
```



2.3.3 Parameter value to minimize response

[19]:
```
for i in df.columns:
    if i in ['const', 'y']:
        continue
    means = df.groupby([i]).mean()['y']
```

```
    print('-- {} --\nMinimize at: {}\n'.format(i, means.idxmin()))
```

```
-- bath_temperature --
Minimize at: 248

-- wave_height --
Minimize at: 4.38

-- overhead_preheater --
Minimize at: 340

-- preheater_1 --
Minimize at: 360

-- preheater_2 --
Minimize at: 360

-- air_knife --
Minimize at: 6

-- overhead_vibration --
Minimize at: 4
```