265Assng2_achsit

February 19, 2025

[4]:
```
### Import libraries
import pandas as pd
import numpy as np
import statsmodels.api as sm
from sklearn.model_selection import train_test_split
import matplotlib.pyplot as plt
import seaborn as sns
```

[5]:
```
### Create dataframe from csv file
exposure = pd.read_csv('Data for model.csv')
exposure.head()
```

[5]:

	year	Annual	ClimateZone	Precip05in	Precip1in	Snow10in	Temp90	\
0	2014	1.008715e+05	3	160	55	0.0	4.0	
1	2014	1.160158e+06	3	160	55	0.0	4.0	
2	2014	5.230030e+05	3	160	55	0.0	4.0	
3	2014	5.453961e+05	3	160	55	0.0	4.0	
4	2014	1.303617e+05	3	160	55	0.0	4.0	

	FC_Min	FC_Max	PrincArt	…	HseHldH	WalkComH	TransComH	\
0	4	7	1	…	3442.366473	166.738041	1018.284763	
1	3	3	2	…	3162.386495	158.532153	773.437362	
2	3	7	1	…	4858.992498	916.155792	1430.823715	
3	3	7	1	…	2755.337596	111.032411	383.858091	
4	3	4	1	…	1338.560970	22.904996	44.223395	

	DegreeH	NoVehH	WalkComPctH	TransComPctH	NonWhitePctH	\
0	1099.640883	947.562614	0.044633	0.272576	0.226225	
1	1590.916415	508.269792	0.036902	0.180034	0.326323	
2	2858.854956	805.819303	0.155156	0.242317	0.723288	
3	721.283123	147.926427	0.026330	0.091027	0.348611	
4	574.407818	65.102869	0.017433	0.033658	0.334453	

	DegreePctH	NoVehPctH
0	0.193205	0.275265
1	0.264586	0.160723
2	0.373215	0.165841
3	0.119821	0.053687

```
4    0.208903   0.048636

[5 rows x 80 columns]
```

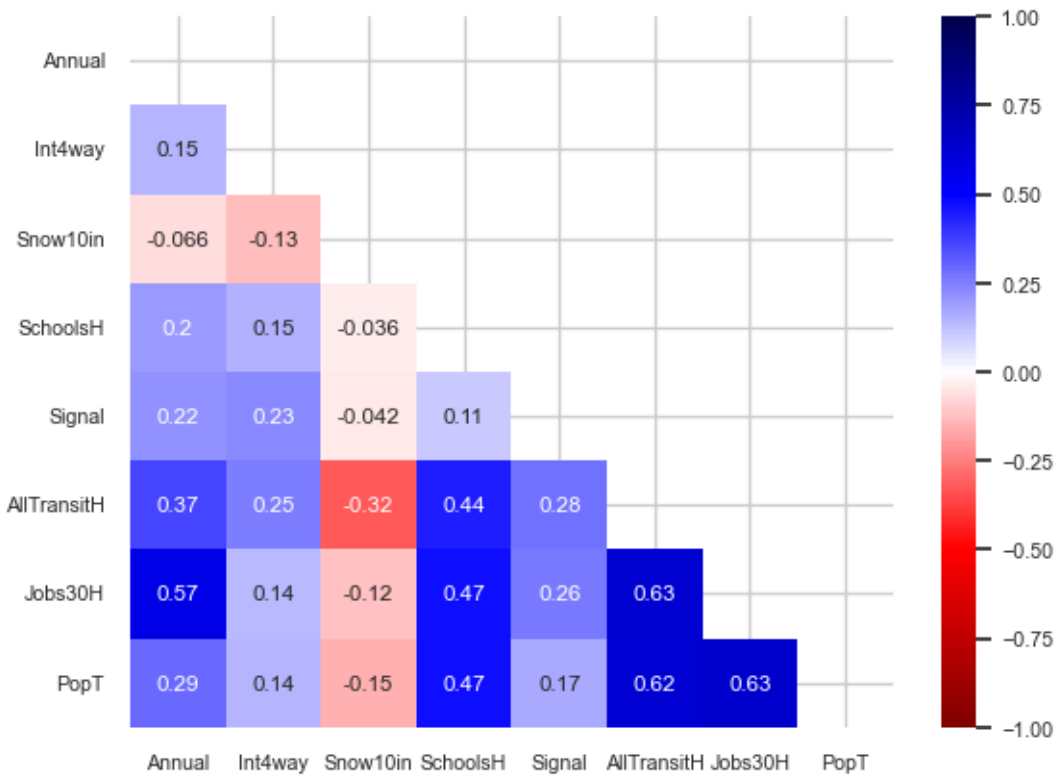
[6]:
```
### Select variables & check mean, std dev., min, & max value.
df = exposure[['Annual', 'Int4way','Snow10in', 'SchoolsH', 'Signal',␣
 ↪'AllTransitH','Jobs30H', 'PopT']]
df.describe()
```

[6]:

	Annual	Int4way	Snow10in	SchoolsH	Signal
count	1.301000e+03	1301.000000	1301.000000	1301.000000	1301.000000
mean	7.328024e+05	0.694081	0.212452	1.882398	0.490392
std	2.029549e+06	0.460973	1.013796	1.874322	0.500100
min	0.000000e+00	0.000000	0.000000	0.000000	0.000000
25%	3.550104e+04	0.000000	0.000000	0.000000	0.000000
50%	1.434238e+05	1.000000	0.000000	1.000000	0.000000
75%	5.436381e+05	1.000000	0.000000	3.000000	1.000000
max	2.579122e+07	1.000000	5.600000	9.000000	1.000000

	AllTransitH	Jobs30H	PopT
count	1301.000000	1.301000e+03	1301.000000
mean	5.669776	9.730359e+05	237.709650
std	3.105202	1.733345e+06	259.902302
min	0.000000	0.000000e+00	0.000000
25%	3.099828	6.017384e+03	66.095605
50%	6.498840	1.591286e+05	167.359809
75%	8.408637	1.064683e+06	334.644143
max	9.986393	1.050488e+07	3799.904870

[7]:
```
#Create heatmap of correlations among the variables
sns.set(context='notebook', style='whitegrid', font_scale=0.7)
upper = np.triu(df.corr())  # Here, we are looking at the upper triangle.␣
 ↪Optionally, you can just look at the lower triangle.
sns.heatmap(df.corr(), cmap="seismic_r", annot=True, vmin=-1, vmax=1,␣
 ↪mask=upper);
plt.savefig('heatmap.png')
```



[8]:
```
#Splitting into training & test data
X_train, X_test, y_train, y_test = train_test_split(df[['Int4way','Snow10in',␣
↪'SchoolsH', 'Signal', 'AllTransitH','Jobs30H', 'PopT']], df['Annual'],␣
↪test_size=0.2, random_state=20)
```

[9]:
```
### Fit a linear regression model using statsmodels

import statsmodels.api as sm

# List of all explanatory variables in the order you'd like to add them:
predictors = ['Int4way', 'Snow10in', 'SchoolsH', 'Signal', 'AllTransitH',␣
↪'PopT', 'Jobs30H']

# Fit models adding one predictor at a time
for i in range(1, len(predictors) + 1):
    current_vars = predictors[:i]
    X_curr = sm.add_constant(X_train[current_vars])
    model = sm.OLS(y_train, X_curr).fit()
    print(f"\nModel with predictors: {current_vars}")
    print(model.summary())
```

```
Model with predictors: ['Int4way']
                            OLS Regression Results
==============================================================================
Dep. Variable:                 Annual   R-squared:                       0.021
Model:                            OLS   Adj. R-squared:                  0.020
Method:                 Least Squares   F-statistic:                     22.43
Date:                Wed, 19 Feb 2025   Prob (F-statistic):           2.48e-06
Time:                        17:03:27   Log-Likelihood:                -16620.
No. Observations:                1040   AIC:                         3.324e+04
Df Residuals:                    1038   BIC:                         3.325e+04
Df Model:                           1
Covariance Type:            nonrobust
==============================================================================
                 coef    std err          t      P>|t|      [0.025      0.975]
------------------------------------------------------------------------------
const       2.754e+05   1.17e+05      2.347      0.019    4.52e+04    5.06e+05
Int4way     6.697e+05   1.41e+05      4.736      0.000    3.92e+05    9.47e+05
==============================================================================
Omnibus:                     1314.896   Durbin-Watson:                   2.041
Prob(Omnibus):                  0.000   Jarque-Bera (JB):           144842.697
Skew:                           6.715   Prob(JB):                         0.00
Kurtosis:                      59.233   Cond. No.                         3.35
==============================================================================

Notes:
[1] Standard Errors assume that the covariance matrix of the errors is correctly
specified.

Model with predictors: ['Int4way', 'Snow10in']
                            OLS Regression Results
==============================================================================
Dep. Variable:                 Annual   R-squared:                       0.023
Model:                            OLS   Adj. R-squared:                  0.021
Method:                 Least Squares   F-statistic:                     12.37
Date:                Wed, 19 Feb 2025   Prob (F-statistic):           4.93e-06
Time:                        17:03:27   Log-Likelihood:                -16619.
No. Observations:                1040   AIC:                         3.324e+04
Df Residuals:                    1037   BIC:                         3.326e+04
Df Model:                           2
Covariance Type:            nonrobust
==============================================================================
                 coef    std err          t      P>|t|      [0.025      0.975]
------------------------------------------------------------------------------
const       3.172e+05    1.2e+05      2.633      0.009    8.08e+04    5.54e+05
Int4way     6.406e+05   1.43e+05      4.492      0.000    3.61e+05     9.2e+05
Snow10in   -9.472e+04   6.28e+04     -1.508      0.132   -2.18e+05    2.85e+04
==============================================================================
Omnibus:                     1315.226   Durbin-Watson:                   2.037
```

Prob(Omnibus):	0.000	Jarque-Bera (JB):	145197.158
Skew:	6.717	Prob(JB):	0.00
Kurtosis:	59.305	Cond. No.	3.53

Notes:
[1] Standard Errors assume that the covariance matrix of the errors is correctly specified.

Model with predictors: ['Int4way', 'Snow10in', 'SchoolsH']

OLS Regression Results

Dep. Variable:	Annual	R-squared:	0.046
Model:	OLS	Adj. R-squared:	0.043
Method:	Least Squares	F-statistic:	16.55
Date:	Wed, 19 Feb 2025	Prob (F-statistic):	1.65e-10
Time:	17:03:27	Log-Likelihood:	-16607.
No. Observations:	1040	AIC:	3.322e+04
Df Residuals:	1036	BIC:	3.324e+04
Df Model:	3		
Covariance Type:	nonrobust		

	coef	std err	t	P>|t|	[0.025	0.975]
const	7.182e+04	1.29e+05	0.556	0.578	-1.82e+05	3.25e+05
Int4way	5.299e+05	1.43e+05	3.710	0.000	2.5e+05	8.1e+05
Snow10in	-8.823e+04	6.21e+04	-1.420	0.156	-2.1e+05	3.37e+04
SchoolsH	1.693e+05	3.43e+04	4.935	0.000	1.02e+05	2.37e+05

Omnibus:	1343.359	Durbin-Watson:	2.043
Prob(Omnibus):	0.000	Jarque-Bera (JB):	164983.631
Skew:	6.938	Prob(JB):	0.00
Kurtosis:	63.123	Cond. No.	7.84

Notes:
[1] Standard Errors assume that the covariance matrix of the errors is correctly specified.

Model with predictors: ['Int4way', 'Snow10in', 'SchoolsH', 'Signal']

OLS Regression Results

Dep. Variable:	Annual	R-squared:	0.075
Model:	OLS	Adj. R-squared:	0.072
Method:	Least Squares	F-statistic:	21.07
Date:	Wed, 19 Feb 2025	Prob (F-statistic):	1.02e-16
Time:	17:03:27	Log-Likelihood:	-16591.
No. Observations:	1040	AIC:	3.319e+04

```
Df Residuals:                     1035   BIC:                         3.322e+04
Df Model:                            4
Covariance Type:            nonrobust
==============================================================================
                 coef    std err          t      P>|t|      [0.025      0.975]
------------------------------------------------------------------------------
const      -1.374e+05   1.32e+05     -1.039      0.299   -3.97e+05    1.22e+05
Int4way     3.441e+05   1.44e+05      2.384      0.017    6.09e+04    6.27e+05
Snow10in   -9.021e+04   6.12e+04     -1.474      0.141    -2.1e+05    2.99e+04
SchoolsH    1.561e+05   3.39e+04      4.609      0.000    8.96e+04    2.23e+05
Signal      7.574e+05   1.32e+05      5.752      0.000    4.99e+05    1.02e+06
==============================================================================
Omnibus:                     1338.389   Durbin-Watson:                   2.057
Prob(Omnibus):                  0.000   Jarque-Bera (JB):           165260.557
Skew:                           6.886   Prob(JB):                         0.00
Kurtosis:                      63.200   Cond. No.                         7.92
==============================================================================

Notes:
[1] Standard Errors assume that the covariance matrix of the errors is correctly
specified.

Model with predictors: ['Int4way', 'Snow10in', 'SchoolsH', 'Signal',
'AllTransitH']
                            OLS Regression Results
==============================================================================
Dep. Variable:                  Annual   R-squared:                       0.146
Model:                             OLS   Adj. R-squared:                  0.142
Method:                  Least Squares   F-statistic:                     35.43
Date:                 Wed, 19 Feb 2025   Prob (F-statistic):           1.59e-33
Time:                         17:03:27   Log-Likelihood:                -16549.
No. Observations:                1040   AIC:                         3.311e+04
Df Residuals:                    1034   BIC:                         3.314e+04
Df Model:                           5
Covariance Type:            nonrobust
==============================================================================
                 coef    std err          t      P>|t|      [0.025      0.975]
------------------------------------------------------------------------------
const      -9.189e+05   1.53e+05     -6.024      0.000   -1.22e+06    -6.2e+05
Int4way     1.703e+05    1.4e+05      1.217      0.224   -1.04e+05    4.45e+05
Snow10in    1.054e+05   6.25e+04      1.686      0.092   -1.73e+04    2.28e+05
SchoolsH    1.257e+04   3.61e+04      0.349      0.727   -5.82e+04    8.33e+04
Signal      4.818e+05    1.3e+05      3.705      0.000    2.27e+05    7.37e+05
AllTransitH 2.256e+05   2.43e+04      9.270      0.000    1.78e+05    2.73e+05
==============================================================================
Omnibus:                     1320.390   Durbin-Watson:                   2.024
Prob(Omnibus):                  0.000   Jarque-Bera (JB):           159240.947
Skew:                           6.721   Prob(JB):                         0.00
```

```
Kurtosis:                       62.111   Cond. No.                         19.7
==============================================================================

Notes:
[1] Standard Errors assume that the covariance matrix of the errors is correctly
specified.

Model with predictors: ['Int4way', 'Snow10in', 'SchoolsH', 'Signal',
'AllTransitH', 'PopT']
                            OLS Regression Results
==============================================================================
Dep. Variable:                 Annual   R-squared:                       0.151
Model:                            OLS   Adj. R-squared:                  0.146
Method:                 Least Squares   F-statistic:                     30.58
Date:                Wed, 19 Feb 2025   Prob (F-statistic):           6.67e-34
Time:                        17:03:27   Log-Likelihood:                -16546.
No. Observations:                1040   AIC:                          3.311e+04
Df Residuals:                    1033   BIC:                          3.314e+04
Df Model:                           6
Covariance Type:            nonrobust
==============================================================================
                 coef    std err          t      P>|t|      [0.025      0.975]
------------------------------------------------------------------------------
const       -8.702e+05   1.54e+05     -5.665      0.000   -1.17e+06   -5.69e+05
Int4way      1.846e+05    1.4e+05      1.320      0.187   -8.98e+04    4.59e+05
Snow10in     1.007e+05   6.24e+04      1.614      0.107   -2.17e+04    2.23e+05
SchoolsH    -1.414e+04   3.77e+04     -0.375      0.708   -8.82e+04    5.99e+04
Signal       4.802e+05    1.3e+05      3.701      0.000    2.26e+05    7.35e+05
AllTransitH  1.894e+05   2.87e+04      6.592      0.000    1.33e+05    2.46e+05
PopT          848.7418    360.276      2.356      0.019     141.785    1555.699
==============================================================================
Omnibus:                     1330.467   Durbin-Watson:                   2.027
Prob(Omnibus):                  0.000   Jarque-Bera (JB):           165807.784
Skew:                           6.802   Prob(JB):                         0.00
Kurtosis:                      63.343   Cond. No.                         952.
==============================================================================

Notes:
[1] Standard Errors assume that the covariance matrix of the errors is correctly
specified.

Model with predictors: ['Int4way', 'Snow10in', 'SchoolsH', 'Signal',
'AllTransitH', 'PopT', 'Jobs30H']
                            OLS Regression Results
==============================================================================
Dep. Variable:                 Annual   R-squared:                       0.341
Model:                            OLS   Adj. R-squared:                  0.336
Method:                 Least Squares   F-statistic:                     76.25
```

```
Date:                Wed, 19 Feb 2025   Prob (F-statistic):           4.78e-89
Time:                        17:03:27   Log-Likelihood:                -16415.
No. Observations:                1040   AIC:                         3.285e+04
Df Residuals:                    1032   BIC:                         3.288e+04
Df Model:                           7
Covariance Type:            nonrobust
==============================================================================
                 coef    std err          t      P>|t|      [0.025      0.975]
------------------------------------------------------------------------------
const      -9.771e+04   1.43e+05     -0.685      0.493   -3.78e+05    1.82e+05
Int4way     2.924e+05   1.23e+05      2.369      0.018    5.02e+04    5.35e+05
Snow10in    3.436e+04   5.51e+04      0.623      0.533   -7.38e+04    1.43e+05
SchoolsH   -1.188e+05   3.38e+04     -3.517      0.000   -1.85e+05   -5.25e+04
Signal      2.265e+05   1.15e+05      1.965      0.050     287.366    4.53e+05
AllTransitH 4.018e+04   2.68e+04      1.501      0.134   -1.23e+04    9.27e+04
PopT        -922.8168    333.747     -2.765      0.006   -1577.717    -267.917
Jobs30H        0.7747      0.045     17.252      0.000       0.687       0.863
==============================================================================
Omnibus:                     1252.630   Durbin-Watson:                   1.974
Prob(Omnibus):                  0.000   Jarque-Bera (JB):           152403.939
Skew:                           6.074   Prob(JB):                         0.00
Kurtosis:                      61.047   Cond. No.                     5.73e+06
==============================================================================

Notes:
[1] Standard Errors assume that the covariance matrix of the errors is correctly
specified.
[2] The condition number is large, 5.73e+06. This might indicate that there are
strong multicollinearity or other numerical problems.
```

[10]:
```python
### Fit a Poisson regression model using statsmodels

import statsmodels.api as sm

# List of explanatory variables in the order you'd like to add them:
predictors = ['Int4way', 'Snow10in', 'SchoolsH', 'Signal', 'AllTransitH',␣
 ↪'PopT', 'Jobs30H']

# Iteratively build Poisson regression models
for i in range(1, len(predictors) + 1):
    current_vars = predictors[:i]
    X_curr = sm.add_constant(X_train[current_vars])
    poisson_model = sm.GLM(y_train, X_curr, family=sm.families.Poisson()).fit()
    print(f"\nPoisson Model with predictors: {current_vars}")
    print(poisson_model.summary())
```

```
Poisson Model with predictors: ['Int4way']
```

```
                 Generalized Linear Model Regression Results
==============================================================================
Dep. Variable:                 Annual   No. Observations:                 1040
Model:                            GLM   Df Residuals:                     1038
Model Family:                 Poisson   Df Model:                            1
Link Function:                    Log   Scale:                          1.0000
Method:                          IRLS   Log-Likelihood:           -1.0230e+09
Date:                Wed, 19 Feb 2025   Deviance:                  2.0459e+09
Time:                        17:03:27   Pearson chi2:                5.88e+09
No. Iterations:                     9   Pseudo R-squ. (CS):             1.000
Covariance Type:            nonrobust
==============================================================================
                 coef    std err          z      P>|z|      [0.025      0.975]
------------------------------------------------------------------------------
const         12.5260      0.000   1.18e+05      0.000      12.526      12.526
Int4way        1.2331      0.000   1.09e+04      0.000       1.233       1.233
==============================================================================

Poisson Model with predictors: ['Int4way', 'Snow10in']
                 Generalized Linear Model Regression Results
==============================================================================
Dep. Variable:                 Annual   No. Observations:                 1040
Model:                            GLM   Df Residuals:                     1037
Model Family:                 Poisson   Df Model:                            2
Link Function:                    Log   Scale:                          1.0000
Method:                          IRLS   Log-Likelihood:           -1.0069e+09
Date:                Wed, 19 Feb 2025   Deviance:                  2.0138e+09
Time:                        17:03:27   Pearson chi2:                5.67e+09
No. Iterations:                     7   Pseudo R-squ. (CS):             1.000
Covariance Type:            nonrobust
==============================================================================
                 coef    std err          z      P>|z|      [0.025      0.975]
------------------------------------------------------------------------------
const         12.6099      0.000   1.19e+05      0.000      12.610      12.610
Int4way        1.1784      0.000   1.05e+04      0.000       1.178       1.179
Snow10in      -0.4851      0.000  -3432.865      0.000      -0.485      -0.485
==============================================================================

Poisson Model with predictors: ['Int4way', 'Snow10in', 'SchoolsH']
                 Generalized Linear Model Regression Results
==============================================================================
Dep. Variable:                 Annual   No. Observations:                 1040
Model:                            GLM   Df Residuals:                     1036
Model Family:                 Poisson   Df Model:                            3
Link Function:                    Log   Scale:                          1.0000
Method:                          IRLS   Log-Likelihood:           -9.4573e+08
Date:                Wed, 19 Feb 2025   Deviance:                  1.8915e+09
Time:                        17:03:27   Pearson chi2:                5.81e+09
```

```
No. Iterations:                     7   Pseudo R-squ. (CS):              1.000
Covariance Type:            nonrobust
==============================================================================
                 coef    std err          z      P>|z|      [0.025      0.975]
------------------------------------------------------------------------------
const         12.2790      0.000    1.1e+05      0.000      12.279      12.279
Int4way        1.0531      0.000   9303.296      0.000       1.053       1.053
Snow10in      -0.4814      0.000  -3385.736      0.000      -0.482      -0.481
SchoolsH       0.1833   1.56e-05   1.17e+04      0.000       0.183       0.183
==============================================================================

Poisson Model with predictors: ['Int4way', 'Snow10in', 'SchoolsH', 'Signal']
                 Generalized Linear Model Regression Results
==============================================================================
Dep. Variable:                  Annual   No. Observations:                 1040
Model:                             GLM   Df Residuals:                     1035
Model Family:                  Poisson   Df Model:                            4
Link Function:                     Log   Scale:                          1.0000
Method:                           IRLS   Log-Likelihood:           -8.4457e+08
Date:                Wed, 19 Feb 2025   Deviance:                  1.6891e+09
Time:                        17:03:27   Pearson chi2:                4.57e+09
No. Iterations:                     8   Pseudo R-squ. (CS):              1.000
Covariance Type:            nonrobust
==============================================================================
                 coef    std err          z      P>|z|      [0.025      0.975]
------------------------------------------------------------------------------
const         11.7815      0.000   9.54e+04      0.000      11.781      11.782
Int4way        0.7907      0.000   6908.594      0.000       0.790       0.791
Snow10in      -0.4831      0.000  -3355.068      0.000      -0.483      -0.483
SchoolsH       0.1663   1.57e-05   1.06e+04      0.000       0.166       0.166
Signal         1.1608   8.91e-05    1.3e+04      0.000       1.161       1.161
==============================================================================

Poisson Model with predictors: ['Int4way', 'Snow10in', 'SchoolsH', 'Signal',
'AllTransitH']
                 Generalized Linear Model Regression Results
==============================================================================
Dep. Variable:                  Annual   No. Observations:                 1040
Model:                             GLM   Df Residuals:                     1034
Model Family:                  Poisson   Df Model:                            5
Link Function:                     Log   Scale:                          1.0000
Method:                           IRLS   Log-Likelihood:           -4.8185e+08
Date:                Wed, 19 Feb 2025   Deviance:                  9.6368e+08
Time:                        17:03:27   Pearson chi2:                1.69e+09
No. Iterations:                    10   Pseudo R-squ. (CS):              1.000
Covariance Type:            nonrobust
==============================================================================
                 coef    std err          z      P>|z|      [0.025      0.975]
```

```
------------------------------------------------------------------------------
const          8.0254      0.000   3.06e+04      0.000       8.025       8.026
Int4way        0.4822      0.000   4220.666      0.000       0.482       0.482
Snow10in       0.4411      0.000   4401.196      0.000       0.441       0.441
SchoolsH      -0.0622   1.85e-05  -3360.128      0.000      -0.062      -0.062
Signal         0.6083   9.12e-05   6666.429      0.000       0.608       0.608
AllTransitH    0.6295   3.06e-05   2.06e+04      0.000       0.629       0.630
==============================================================================

Poisson Model with predictors: ['Int4way', 'Snow10in', 'SchoolsH', 'Signal',
'AllTransitH', 'PopT']
                 Generalized Linear Model Regression Results
==============================================================================
Dep. Variable:                 Annual   No. Observations:                 1040
Model:                            GLM   Df Residuals:                     1033
Model Family:                 Poisson   Df Model:                            6
Link Function:                    Log   Scale:                          1.0000
Method:                          IRLS   Log-Likelihood:            -4.7869e+08
Date:                Wed, 19 Feb 2025   Deviance:                   9.5736e+08
Time:                        17:03:27   Pearson chi2:                 1.68e+09
No. Iterations:                     9   Pseudo R-squ. (CS):              1.000
Covariance Type:            nonrobust
==============================================================================
                 coef    std err          z      P>|z|      [0.025      0.975]
------------------------------------------------------------------------------
const          8.0438      0.000   3.05e+04      0.000       8.043       8.044
Int4way        0.5192      0.000   4506.366      0.000       0.519       0.519
Snow10in       0.4399      0.000   4386.472      0.000       0.440       0.440
SchoolsH      -0.0757   1.94e-05  -3903.966      0.000      -0.076      -0.076
Signal         0.5991   9.14e-05   6552.787      0.000       0.599       0.599
AllTransitH    0.6137   3.13e-05   1.96e+04      0.000       0.614       0.614
PopT           0.0003   1.25e-07   2589.512      0.000       0.000       0.000
==============================================================================

Poisson Model with predictors: ['Int4way', 'Snow10in', 'SchoolsH', 'Signal',
'AllTransitH', 'PopT', 'Jobs30H']
                 Generalized Linear Model Regression Results
==============================================================================
Dep. Variable:                 Annual   No. Observations:                 1040
Model:                            GLM   Df Residuals:                     1032
Model Family:                 Poisson   Df Model:                            7
Link Function:                    Log   Scale:                          1.0000
Method:                          IRLS   Log-Likelihood:            -3.9097e+08
Date:                Wed, 19 Feb 2025   Deviance:                   7.8192e+08
Time:                        17:03:27   Pearson chi2:                 1.14e+09
No. Iterations:                     8   Pseudo R-squ. (CS):              1.000
Covariance Type:            nonrobust
==============================================================================
```

```
                 coef    std err          z      P>|z|      [0.025      0.975]
------------------------------------------------------------------------------
const          9.9901      0.000   4.11e+04      0.000       9.990       9.991
Int4way        0.5506      0.000   4717.431      0.000       0.550       0.551
Snow10in       0.1675      0.000   1656.381      0.000       0.167       0.168
SchoolsH      -0.1360   2.12e-05  -6421.272      0.000      -0.136      -0.136
Signal         0.4607   9.29e-05   4960.822      0.000       0.461       0.461
AllTransitH    0.3369   3.11e-05   1.08e+04      0.000       0.337       0.337
PopT          -0.0002   1.17e-07  -1337.542      0.000      -0.000      -0.000
Jobs30H    2.897e-07   2.16e-11   1.34e+04      0.000     2.9e-07     2.9e-07
==============================================================================
```

[11]:
```
### Fit a Negative Binomial regression model using statsmodels

import statsmodels.api as sm

# List of explanatory variables in the order you'd like to add them
predictors = ['Int4way', 'Snow10in', 'SchoolsH', 'Signal', 'AllTransitH',␣
 ↪'PopT', 'Jobs30H']

# Iteratively build Negative Binomial models
for i in range(1, len(predictors) + 1):
    current_vars = predictors[:i]
    X_curr = sm.add_constant(X_train[current_vars])
    nb_model = sm.GLM(y_train, X_curr, family=sm.families.
 ↪NegativeBinomial(alpha=1)).fit()
    print(f"\nNegative Binomial Model with predictors: {current_vars}")
    print(nb_model.summary())
```

```
Negative Binomial Model with predictors: ['Int4way']
                 Generalized Linear Model Regression Results
==============================================================================
Dep. Variable:                 Annual   No. Observations:                 1040
Model:                            GLM   Df Residuals:                     1038
Model Family:        NegativeBinomial   Df Model:                            1
Link Function:                    Log   Scale:                          1.0000
Method:                          IRLS   Log-Likelihood:                -14950.
Date:                Wed, 19 Feb 2025   Deviance:                       3844.4
Time:                        17:03:27   Pearson chi2:                 9.81e+03
No. Iterations:                     7   Pseudo R-squ. (CS):             0.2362
Covariance Type:            nonrobust
==============================================================================
                 coef    std err          z      P>|z|      [0.025      0.975]
------------------------------------------------------------------------------
const         12.5260      0.056    225.467      0.000      12.417      12.635
Int4way        1.2331      0.067     18.416      0.000       1.102       1.364
==============================================================================
```

```
Negative Binomial Model with predictors: ['Int4way', 'Snow10in']
                 Generalized Linear Model Regression Results
==============================================================================
Dep. Variable:                 Annual   No. Observations:                 1040
Model:                            GLM   Df Residuals:                     1037
Model Family:        NegativeBinomial   Df Model:                            2
Link Function:                    Log   Scale:                          1.0000
Method:                          IRLS   Log-Likelihood:                -14920.
Date:                Wed, 19 Feb 2025   Deviance:                       3785.1
Time:                        17:03:27   Pearson chi2:                 9.08e+03
No. Iterations:                     8   Pseudo R-squ. (CS):             0.2785
Covariance Type:            nonrobust
==============================================================================
                 coef    std err          z      P>|z|      [0.025      0.975]
------------------------------------------------------------------------------
const         12.6149      0.057    220.982      0.000      12.503      12.727
Int4way        1.1526      0.068     17.056      0.000       1.020       1.285
Snow10in      -0.2700      0.030     -9.070      0.000      -0.328      -0.212
==============================================================================

Negative Binomial Model with predictors: ['Int4way', 'Snow10in', 'SchoolsH']
                 Generalized Linear Model Regression Results
==============================================================================
Dep. Variable:                 Annual   No. Observations:                 1040
Model:                            GLM   Df Residuals:                     1036
Model Family:        NegativeBinomial   Df Model:                            3
Link Function:                    Log   Scale:                          1.0000
Method:                          IRLS   Log-Likelihood:                -14792.
Date:                Wed, 19 Feb 2025   Deviance:                       3529.3
Time:                        17:03:27   Pearson chi2:                 1.05e+04
No. Iterations:                    12   Pseudo R-squ. (CS):             0.4358
Covariance Type:            nonrobust
==============================================================================
                 coef    std err          z      P>|z|      [0.025      0.975]
------------------------------------------------------------------------------
const         11.9479      0.062    193.158      0.000      11.827      12.069
Int4way        1.2412      0.068     18.139      0.000       1.107       1.375
Snow10in      -0.2473      0.030     -8.306      0.000      -0.306      -0.189
SchoolsH       0.2528      0.016     15.377      0.000       0.221       0.285
==============================================================================

Negative Binomial Model with predictors: ['Int4way', 'Snow10in', 'SchoolsH',
'Signal']
                 Generalized Linear Model Regression Results
==============================================================================
Dep. Variable:                 Annual   No. Observations:                 1040
Model:                            GLM   Df Residuals:                     1035
```

Model Family:	NegativeBinomial	Df Model:	4
Link Function:	Log	Scale:	1.0000
Method:	IRLS	Log-Likelihood:	-14584.
Date:	Wed, 19 Feb 2025	Deviance:	3112.0
Time:	17:03:27	Pearson chi2:	7.97e+03
No. Iterations:	14	Pseudo R-squ. (CS):	0.6223
Covariance Type:	nonrobust		

	coef	std err	z	P>|z|	[0.025	0.975]
const	11.1935	0.064	173.981	0.000	11.067	11.320
Int4way	1.0236	0.070	14.580	0.000	0.886	1.161
Snow10in	-0.2014	0.030	-6.766	0.000	-0.260	-0.143
SchoolsH	0.2828	0.016	17.165	0.000	0.251	0.315
Signal	1.3286	0.064	20.743	0.000	1.203	1.454

Negative Binomial Model with predictors: ['Int4way', 'Snow10in', 'SchoolsH', 'Signal', 'AllTransitH']

Generalized Linear Model Regression Results

Dep. Variable:	Annual	No. Observations:	1040
Model:	GLM	Df Residuals:	1034
Model Family:	NegativeBinomial	Df Model:	5
Link Function:	Log	Scale:	1.0000
Method:	IRLS	Log-Likelihood:	-14172.
Date:	Wed, 19 Feb 2025	Deviance:	2288.1
Time:	17:03:27	Pearson chi2:	2.96e+03
No. Iterations:	21	Pseudo R-squ. (CS):	0.8290
Covariance Type:	nonrobust		

	coef	std err	z	P>|z|	[0.025	0.975]
const	9.7753	0.077	126.631	0.000	9.624	9.927
Int4way	0.6805	0.071	9.605	0.000	0.542	0.819
Snow10in	0.1434	0.032	4.532	0.000	0.081	0.205
SchoolsH	0.0824	0.018	4.515	0.000	0.047	0.118
Signal	0.6310	0.066	9.591	0.000	0.502	0.760
AllTransitH	0.3389	0.012	27.522	0.000	0.315	0.363

Negative Binomial Model with predictors: ['Int4way', 'Snow10in', 'SchoolsH', 'Signal', 'AllTransitH', 'PopT']

Generalized Linear Model Regression Results

Dep. Variable:	Annual	No. Observations:	1040
Model:	GLM	Df Residuals:	1033
Model Family:	NegativeBinomial	Df Model:	6

Link Function:	Log	Scale:	1.0000
Method:	IRLS	Log-Likelihood:	-14163.
Date:	Wed, 19 Feb 2025	Deviance:	2269.9
Time:	17:03:27	Pearson chi2:	3.07e+03
No. Iterations:	22	Pseudo R-squ. (CS):	0.8319
Covariance Type:	nonrobust		

	coef	std err	z	P>|z|	[0.025	0.975]
const	9.7852	0.078	125.607	0.000	9.633	9.938
Int4way	0.7318	0.071	10.320	0.000	0.593	0.871
Snow10in	0.1466	0.032	4.633	0.000	0.085	0.209
SchoolsH	0.0603	0.019	3.152	0.002	0.023	0.098
Signal	0.6123	0.066	9.306	0.000	0.483	0.741
AllTransitH	0.3115	0.015	21.374	0.000	0.283	0.340
PopT	0.0006	0.000	3.542	0.000	0.000	0.001

Negative Binomial Model with predictors: ['Int4way', 'Snow10in', 'SchoolsH', 'Signal', 'AllTransitH', 'PopT', 'Jobs30H']

Generalized Linear Model Regression Results

Dep. Variable:	Annual	No. Observations:	1040
Model:	GLM	Df Residuals:	1032
Model Family:	NegativeBinomial	Df Model:	7
Link Function:	Log	Scale:	1.0000
Method:	IRLS	Log-Likelihood:	-14072.
Date:	Wed, 19 Feb 2025	Deviance:	2087.9
Time:	17:03:27	Pearson chi2:	2.28e+03
No. Iterations:	13	Pseudo R-squ. (CS):	0.8589
Covariance Type:	nonrobust		

	coef	std err	z	P>|z|	[0.025	0.975]
const	10.1444	0.082	123.633	0.000	9.984	10.305
Int4way	0.7381	0.071	10.395	0.000	0.599	0.877
Snow10in	0.1114	0.032	3.511	0.000	0.049	0.174
SchoolsH	0.0353	0.019	1.816	0.069	-0.003	0.073
Signal	0.5260	0.066	7.929	0.000	0.396	0.656
AllTransitH	0.2055	0.015	13.348	0.000	0.175	0.236
PopT	0.0004	0.000	2.002	0.045	8.16e-06	0.001
Jobs30H	3.158e-07	2.58e-08	12.221	0.000	2.65e-07	3.66e-07

Negative Binomial Model with predictors: ['Int4way', 'Snow10in', 'SchoolsH', 'Signal', 'AllTransitH', 'PopT', 'Jobs30H']

Generalized Linear Model Regression Results

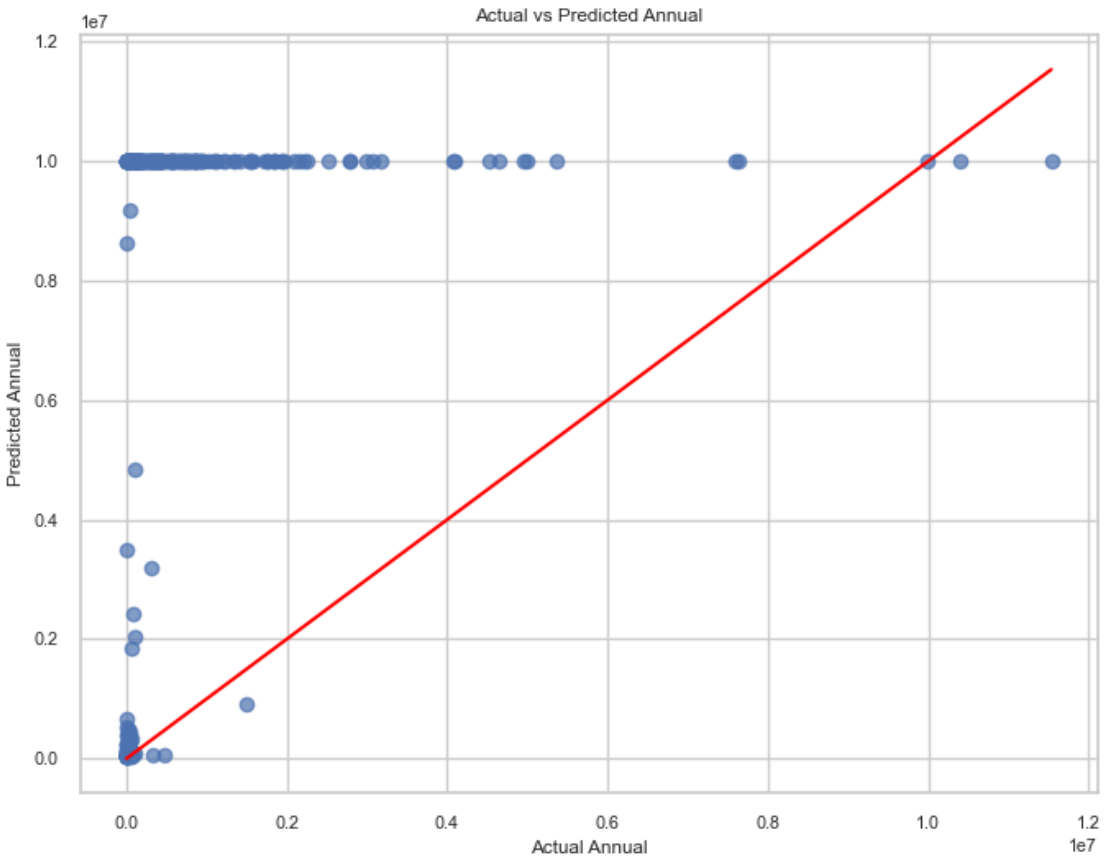
```
Dep. Variable:                 Annual   No. Observations:                 1040
Model:                            GLM   Df Residuals:                     1032
Model Family:        NegativeBinomial   Df Model:                            7
Link Function:                    Log   Scale:                          1.0000
Method:                          IRLS   Log-Likelihood:                -14072.
Date:                Wed, 19 Feb 2025   Deviance:                       2087.9
Time:                        17:03:27   Pearson chi2:                 2.28e+03
No. Iterations:                    13   Pseudo R-squ. (CS):             0.8589
Covariance Type:            nonrobust
==============================================================================
                 coef    std err          z      P>|z|      [0.025      0.975]
------------------------------------------------------------------------------
const         10.1444      0.082    123.633      0.000       9.984      10.305
Int4way        0.7381      0.071     10.395      0.000       0.599       0.877
Snow10in       0.1114      0.032      3.511      0.000       0.049       0.174
SchoolsH       0.0353      0.019      1.816      0.069      -0.003       0.073
Signal         0.5260      0.066      7.929      0.000       0.396       0.656
AllTransitH    0.2055      0.015     13.348      0.000       0.175       0.236
PopT           0.0004      0.000      2.002      0.045    8.16e-06       0.001
Jobs30H     3.158e-07   2.58e-08     12.221      0.000    2.65e-07    3.66e-07
==============================================================================
```

[12]:
```python
### Evaluate the Negative Binomial model on test data

import numpy as np
import matplotlib.pyplot as plt
from sklearn.metrics import mean_squared_error, mean_absolute_error, r2_score
import statsmodels.api as sm
from sklearn.model_selection import train_test_split

# Splitting data
predictors = ['Int4way', 'Snow10in', 'SchoolsH', 'Signal', 'AllTransitH',␣
 ↪'Jobs30H', 'PopT']
X_train, X_test, y_train, y_test = train_test_split(
    df[predictors], df['Annual'], test_size=0.2, random_state=20
)

# Note: nb_model should be your final Negative Binomial model trained using␣
 ↪X_train and y_train.
# Prepare test set by adding a constant to X_test (using the same predictors)
X_test_const = sm.add_constant(X_test)
y_pred = nb_model.predict(X_test_const)

# Check for non-finite values in predictions
if not np.all(np.isfinite(y_pred)):
    print("Non-finite values found in y_pred!")
    print("max:", np.max(y_pred[np.isfinite(y_pred)]))
```

```
    print("min:", np.min(y_pred[np.isfinite(y_pred)]))

# Clip predictions to avoid extreme values (example limits, adjust as necessary)
y_pred_clipped = np.clip(y_pred, a_min=None, a_max=1e7)  # set a realistic␣
 ↪maximum

# Then compute performance metrics on clipped predictions
mse = mean_squared_error(y_test, y_pred_clipped)
rmse = np.sqrt(mse)
mae = mean_absolute_error(y_test, y_pred_clipped)
r2  = r2_score(y_test, y_pred_clipped)

print(f"MSE: {mse}")
print(f"RMSE: {rmse}")
print(f"MAE: {mae}")
print(f"R^2: {r2}")

# Plot actual vs predicted values
plt.figure(figsize=(8, 6))
plt.scatter(y_test, y_pred_clipped, alpha=0.7)
plt.xlabel("Actual Annual")
plt.ylabel("Predicted Annual")
plt.title("Actual vs Predicted Annual")
plt.plot([min(y_test), max(y_test)], [min(y_test), max(y_test)], color="red")
plt.show()
```

```
Non-finite values found in y_pred!
max: 1.2150073969165267e+308
min: 28080.9556408886
MSE: 65909906125183.47
RMSE: 8118491.6163769895
MAE: 7104500.208496759
R^2: -26.5163803448109
```

```
C:\Users\Anson\AppData\Local\Packages\PythonSoftwareFoundation.Python.3.12_qbz5n
2kfra8p0\LocalCache\local-packages\Python312\site-
packages\statsmodels\genmod\families\links.py:527: RuntimeWarning: overflow
encountered in exp
  return np.exp(z)
```


Actual vs Predicted Annual
1e7
1.2
1.0
0.8
0.6
0.4
0.2
0.0
Predicted Annual
0.0
0.2
0.4
0.6
0.8
1.0
1.2
1e7
Actual Annual