

Part2_spatial_interaction

May 2, 2022

1 Part 2: Spatial Interaction models

1.1 III.1 Models and calibration

```
[80]: %matplotlib inline
import numpy as np
import math
from matplotlib import pyplot as plt
from numpy import random
import pandas as pd
import geopandas as gpd
import seaborn as sns
import folium
import statsmodels.api as sm
import statsmodels.formula.api as smf
import scipy.stats
from math import sqrt
```

```
[81]: def CalcRSquared(observed, estimated):
    """Calculate the  $r^2$  from a series of observed and estimated target values
    inputs:
    Observed: Series of actual observed values
    estimated: Series of predicted values"""

    r, p = scipy.stats.pearsonr(observed, estimated)
    R2 = r **2

    return R2
```

```
[82]: def CalcRMSE(observed, estimated):
    """Calculate Root Mean Square Error between a series of observed and
    estimated values
    inputs:
    Observed: Series of actual observed values
    estimated: Series of predicted values"""

    res = (observed - estimated)**2
    RMSE = round(sqrt(res.mean()), 3)
```

```
return RMSE
```

```
[83]: #read in your London Commuting Data
cdata = pd.read_csv("https://raw.githubusercontent.com/Hannahzhu1/CASA0002/main/
↳london_flows.csv")
```

```
[84]: #Take a look
cdata.head(5)
```

```
[84]:  station_origin station_destination  flows  population  jobs  distance
0      Abbey Road  Bank and Monument      0         599  78549  8131.525097
1      Abbey Road      Beckton            1         599   442  8510.121774
2      Abbey Road    Blackwall            3         599   665  3775.448872
3      Abbey Road    Canary Wharf        1         599  58772  5086.514220
4      Abbey Road    Canning Town       37         599  15428  2228.923167
```

```
[85]: #rename
cdata.rename(columns={"population":"Oi_pop","jobs":"Dj_job","distance":
↳"Dist"},inplace = True)
cdata.head(5)
```

```
[85]:  station_origin station_destination  flows  Oi_pop  Dj_job  Dist
0      Abbey Road  Bank and Monument      0     599   78549  8131.525097
1      Abbey Road      Beckton            1     599    442  8510.121774
2      Abbey Road    Blackwall            3     599    665  3775.448872
3      Abbey Road    Canary Wharf        1     599  58772  5086.514220
4      Abbey Road    Canning Town       37     599  15428  2228.923167
```

```
[86]: #now we can create a pivot table to turn paired list into a matrix, and compute
↳the margin as well
cdamat = pd.pivot_table(cdata, values ="flows", index="station_origin",
↳columns = "station_destination",
                                aggfunc=np.sum, margins=True)
cdamat
```

```
[86]: station_destination  Abbey Road  Acton Central  Acton Town  Aldgate  \
station_origin
Abbey Road              NaN              NaN              NaN      NaN
Acton Central           NaN              NaN              NaN      NaN
Acton Town              NaN              NaN              NaN      3.0
Aldgate                 NaN              NaN              0.0      NaN
Aldgate East           NaN              NaN              2.0      0.0
...                    ...              ...              ...      ...
Woodford                NaN              NaN              2.0      5.0
Woodgrange Park         NaN              0.0              NaN      NaN
Woodside Park           NaN              NaN              1.0     26.0
```

Woolwich Arsenal	20.0	NaN	NaN	NaN
All	345.0	750.0	2202.0	7782.0

station_destination	Aldgate East	All Saints	Alpertton	Amersham	Anerley \
station_origin					
Abbey Road	NaN	NaN	NaN	NaN	NaN
Acton Central	NaN	NaN	NaN	NaN	NaN
Acton Town	17.0	NaN	35.0	0.0	NaN
Aldgate	0.0	NaN	NaN	0.0	NaN
Aldgate East	NaN	NaN	0.0	0.0	NaN
...
Woodford	47.0	NaN	NaN	NaN	NaN
Woodgrange Park	NaN	NaN	NaN	NaN	NaN
Woodside Park	11.0	NaN	0.0	NaN	NaN
Woolwich Arsenal	NaN	7.0	NaN	NaN	NaN
All	7932.0	444.0	741.0	256.0	173.0

station_destination	Angel ...	Wimbledon	Wimbledon Park	Wood Green \
station_origin	...			
Abbey Road	NaN ...	NaN	NaN	NaN
Acton Central	NaN ...	NaN	NaN	NaN
Acton Town	11.0 ...	77.0	3.0	6.0
Aldgate	17.0 ...	0.0	NaN	4.0
Aldgate East	20.0 ...	24.0	0.0	0.0
...
Woodford	22.0 ...	2.0	NaN	1.0
Woodgrange Park	NaN ...	NaN	NaN	NaN
Woodside Park	59.0 ...	0.0	NaN	0.0
Woolwich Arsenal	NaN ...	NaN	NaN	NaN
All	8103.0 ...	6295.0	596.0	2146.0

station_destination	Wood Lane	Wood Street	Woodford	Woodgrange Park \
station_origin				
Abbey Road	NaN	NaN	NaN	NaN
Acton Central	NaN	NaN	NaN	0.0
Acton Town	9.0	NaN	0.0	NaN
Aldgate	8.0	NaN	0.0	NaN
Aldgate East	12.0	NaN	1.0	NaN
...
Woodford	NaN	NaN	NaN	NaN
Woodgrange Park	NaN	NaN	NaN	NaN
Woodside Park	NaN	NaN	NaN	NaN
Woolwich Arsenal	NaN	NaN	NaN	NaN
All	1578.0	404.0	706.0	242.0

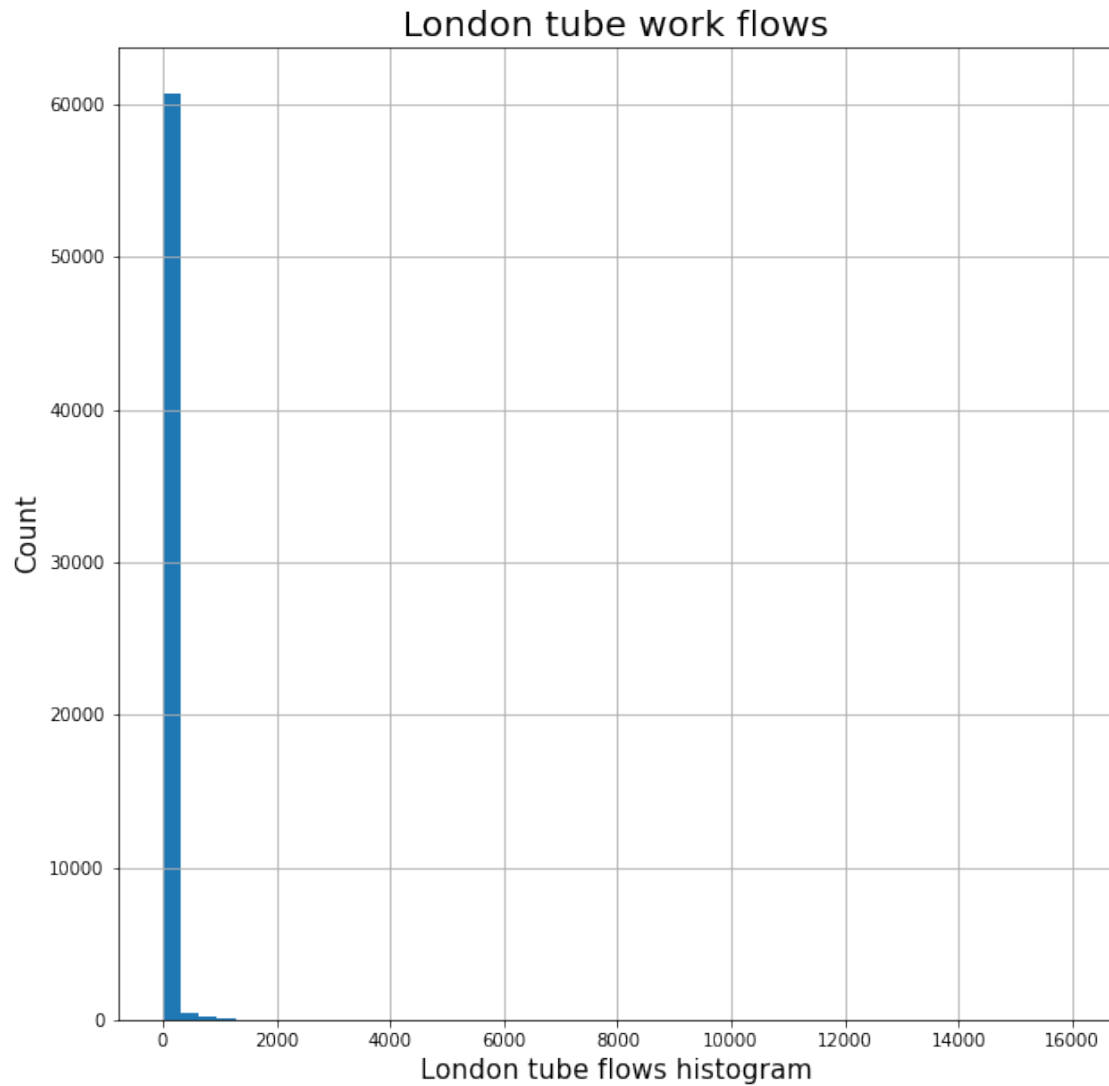
station_destination	Woodside Park	Woolwich Arsenal	All
station_origin			

Abbey Road	NaN	32.0	599
Acton Central	NaN	NaN	1224
Acton Town	0.0	NaN	3745
Aldgate	0.0	NaN	2886
Aldgate East	1.0	NaN	3172
...
Woodford	NaN	NaN	4868
Woodgrange Park	NaN	NaN	530
Woodside Park	NaN	NaN	3093
Woolwich Arsenal	NaN	NaN	7892
All	745.0	4428.0	1542391

[400 rows x 400 columns]

```
[87]: plt.subplots(figsize=(10,10))

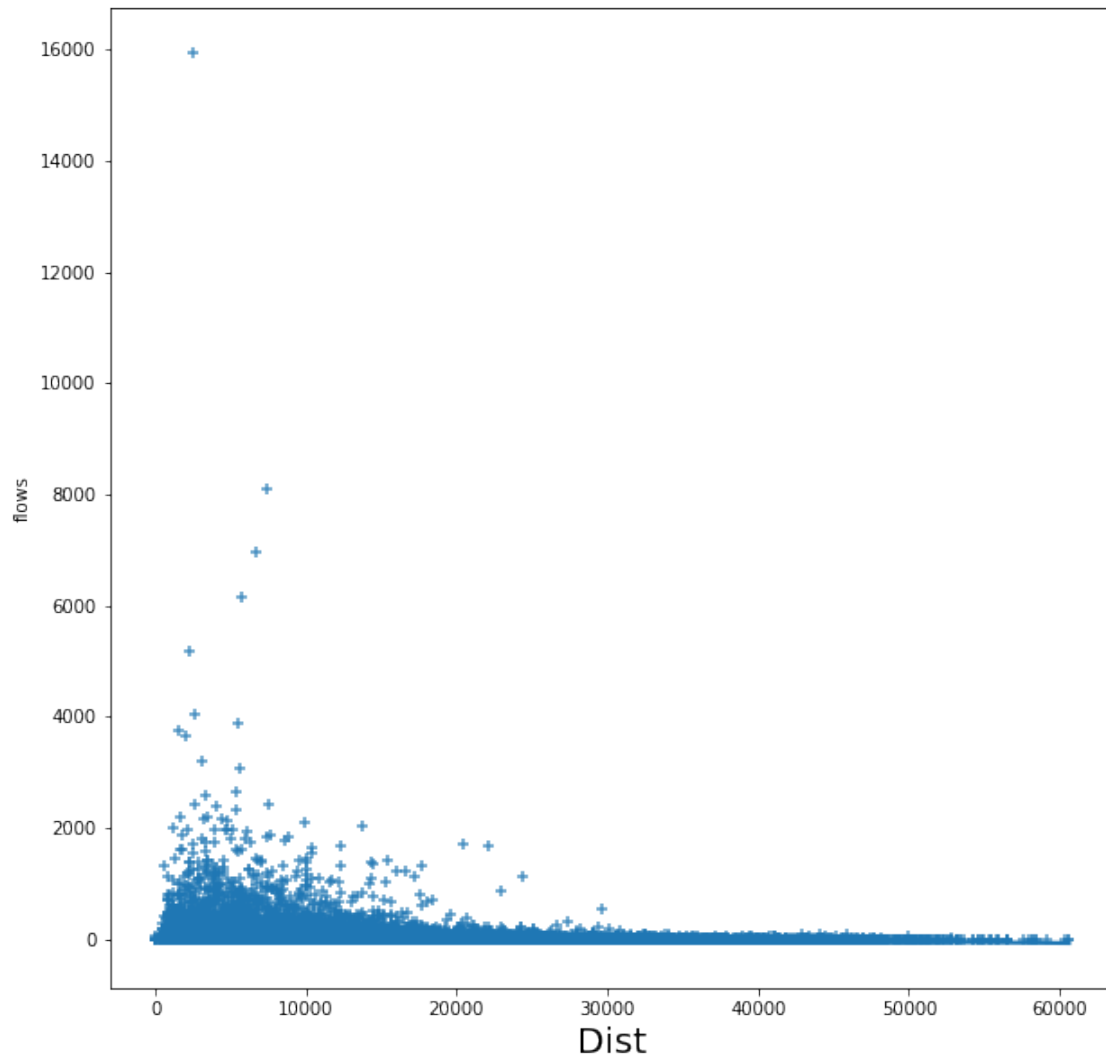
plt.hist(cdata["flows"], histtype="stepfilled" , bins = 50)
plt.xlabel("London tube flows histogram", fontsize = 15)
plt.ylabel("Count", fontsize= 15)
plt.title("London tube work flows", fontsize = 20)
plt.grid(True)
```



```
[88]: #before taking log
x = cdata["Dist"]
y = cdata["flows"]

#create the subplot
fig, ax = plt.subplots(figsize = (10,10))
#plot the results along with the line of best fit
sns.regplot(x=x, y=y, marker="+", ax=ax)
ax.set_xlabel("Dist", fontsize = 20)
```

```
[88]: Text(0.5, 0, 'Dist')
```



```
[89]: #quiet poissony, there for we decide to log the equation

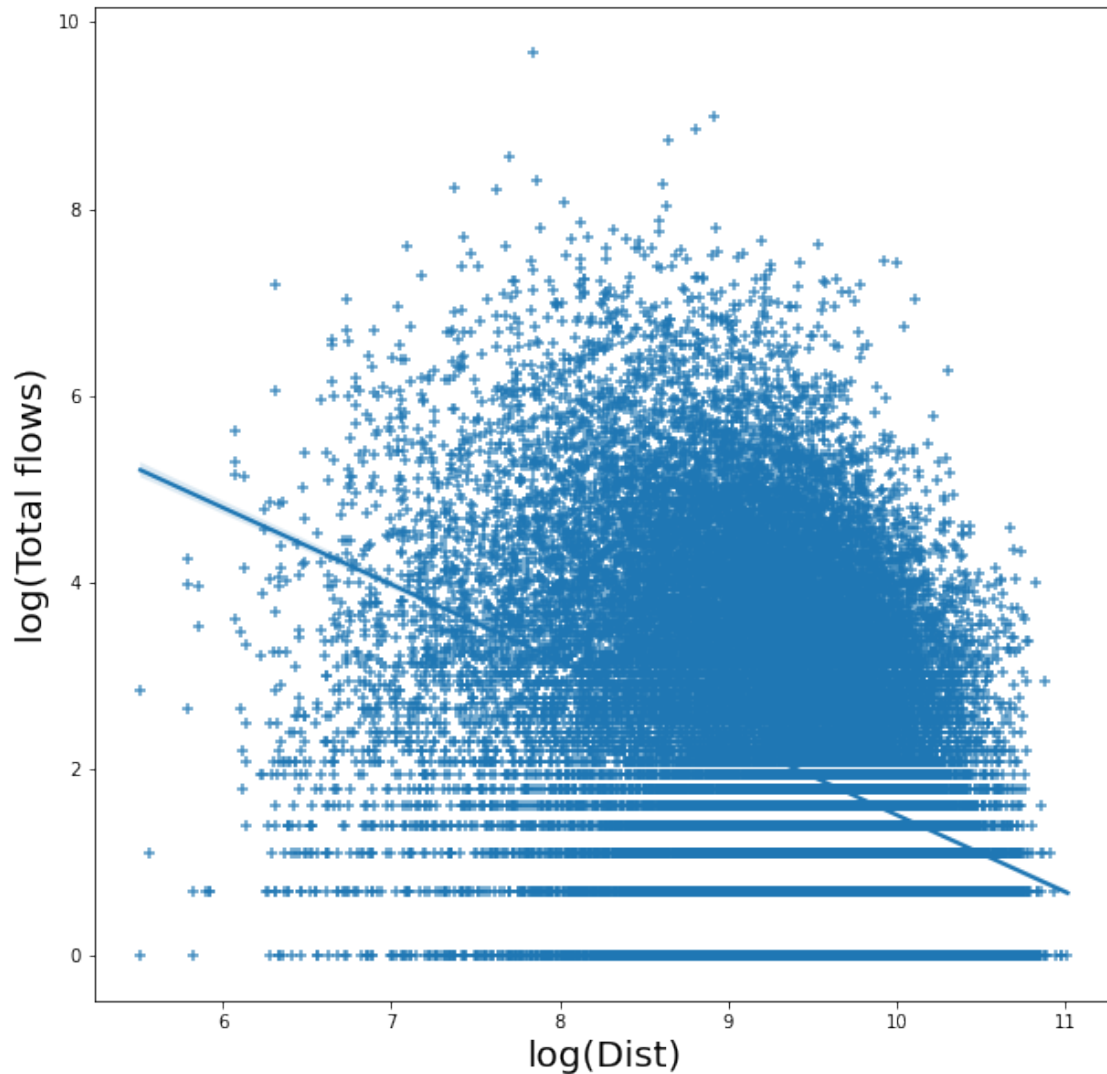
#subset the dataframe to the flows we want
cdata_flows = cdata[["flows", "Dist"]]
#remove all 0 values (logarithms can't deal with 0 values)
cdata_flows = cdata_flows[(cdata_flows!=0).all(1)]

#extract the x and y converting to log
x = np.log(cdata_flows["Dist"])
y = np.log(cdata_flows["flows"])

#create the subplot
fig, ax = plt.subplots(figsize = (10,10))
#plot the results along with the line of best fit
```

```
sns.regplot(x=x, y=y, marker="+", ax=ax)
ax.set_xlabel("log(Dist)", fontsize = 20)
ax.set_ylabel("log(Total flows)", fontsize = 20)
```

```
[89]: Text(0, 0.5, 'log(Total flows)')
```



```
[90]: import statsmodels.api as sm
import statsmodels.formula.api as smf

#delete NA value before taking logarithms
cdata = cdata[cdata['Oi_pop']!=0]
cdata = cdata[cdata['Dj_job']!=0]
cdata = cdata[cdata['Dist']!=0]
```

```

#take the variables and produce logarithms of them
x_variables = ["Oi_pop", "Dj_job", "Dist"]
log_x_vars = []
for x in x_variables:
    cdata[f"log_{x}"] = np.log(cdata[x])
    log_x_vars.append(f"log_{x}")

```

```
[91]: cdata.head(5)
```

```

[91]:  station_origin station_destination  flows  Oi_pop  Dj_job      Dist \
0      Abbey Road  Bank and Monument      0    599   78549  8131.525097
1      Abbey Road      Beckton          1    599    442  8510.121774
2      Abbey Road    Blackwall          3    599    665  3775.448872
3      Abbey Road    Canary Wharf         1    599   58772  5086.514220
4      Abbey Road    Canning Town        37    599   15428  2228.923167

      log_Oi_pop  log_Dj_job  log_Dist
0      6.395262    11.271478   9.003504
1      6.395262     6.091310   9.049012
2      6.395262     6.499787   8.236275
3      6.395262    10.981421   8.534348
4      6.395262     9.643939   7.709274

```

1.1.1 Origin constrained-Inverse law

```

[92]: #create the formula (the "-1" indicates no intercept in the regression model).
formula = 'flows ~ station_origin + log_Dj_job + log_Dist-1'
#run a production constrained sim
prodSim = smf.glm(formula = formula, data=cdata, family=sm.families.Poisson()).
    ↪fit()

```

```

[93]: #let's have a look at it's summary
#print(prodSim.summary())

```

```

[94]: #get the predictions
predictions = prodSim.get_prediction()
predictions_summary_frame = predictions.summary_frame()
cdata["prodSimFitted"] = round(predictions_summary_frame["mean"],0)

```

```

[95]: #now we can create pivot table to turn paired list into matrix (and compute the
    ↪margins as well)
cdamat1 = cdata.pivot_table(values = "prodSimFitted", index="station_origin",
    ↪columns = "station_destination",
                                aggfunc=np.sum, margins=True)
cdamat1

```



```

[95]: station_destination Abbey Road Acton Central Acton Town Aldgate \
station_origin
Abbey Road NaN NaN NaN NaN
Acton Central NaN NaN NaN NaN
Acton Town NaN NaN NaN 18.0
Aldgate NaN NaN 2.0 NaN
Aldgate East NaN NaN 2.0 52.0
...
Woodford NaN NaN 7.0 35.0
Woodgrange Park NaN 4.0 NaN NaN
Woodside Park NaN NaN 5.0 20.0
Woolwich Arsenal 29.0 NaN NaN NaN
All 445.0 391.0 2156.0 8753.0

station_destination Aldgate East All Saints Alperton Amersham Anerley \
station_origin
Abbey Road NaN NaN NaN NaN NaN
Acton Central NaN NaN NaN NaN NaN
Acton Town 18.0 NaN 9.0 1.0 NaN
Aldgate 47.0 NaN NaN 0.0 NaN
Aldgate East NaN NaN 1.0 0.0 NaN
...
Woodford 39.0 NaN NaN NaN NaN
Woodgrange Park NaN NaN NaN NaN NaN
Woodside Park 20.0 NaN 2.0 NaN NaN
Woolwich Arsenal NaN 33.0 NaN NaN NaN
All 9308.0 504.0 582.0 108.0 140.0

station_destination Angel ... Wimbledon Wimbledon Park Wood Green \
station_origin
Abbey Road NaN ... NaN NaN NaN
Acton Central NaN ... NaN NaN NaN
Acton Town 20.0 ... 16.0 3.0 5.0
Aldgate 21.0 ... 4.0 NaN 3.0
Aldgate East 23.0 ... 5.0 1.0 3.0
...
Woodford 32.0 ... 15.0 NaN 10.0
Woodgrange Park NaN ... NaN NaN NaN
Woodside Park 25.0 ... 11.0 NaN 6.0
Woolwich Arsenal NaN ... NaN NaN NaN
All 9203.0 ... 3426.0 523.0 2161.0

station_destination Wood Lane Wood Street Woodford Woodgrange Park \
station_origin
Abbey Road NaN NaN NaN NaN
Acton Central NaN NaN NaN 1.0
Acton Town 13.0 NaN 2.0 NaN

```

Aldgate	2.0	NaN	1.0	NaN
Aldgate East	2.0	NaN	1.0	NaN
...
Woodford	NaN	NaN	NaN	NaN
Woodgrange Park	NaN	NaN	NaN	NaN
Woodside Park	NaN	NaN	NaN	NaN
Woolwich Arsenal	NaN	NaN	NaN	NaN
All	1647.0	341.0	654.0	156.0

station_destination	Woodside Park	Woolwich Arsenal	All
station_origin			
Abbey Road	NaN	5.0	599.0
Acton Central	NaN	NaN	1223.0
Acton Town	2.0	NaN	3749.0
Aldgate	1.0	NaN	2882.0
Aldgate East	1.0	NaN	3167.0
...
Woodford	NaN	NaN	4866.0
Woodgrange Park	NaN	NaN	532.0
Woodside Park	NaN	NaN	3092.0
Woolwich Arsenal	NaN	NaN	7890.0
All	603.0	1009.0	1541806.0

[399 rows x 399 columns]

```
[96]: #now we can create pivot table to turn paired list into matrix (and compute the
      ↪ margins as well)
cdamat1 = cdata.pivot_table(values="prodSimFitted", index="station_origin",
      ↪ columns="station_destination",
                                aggfunc=np.sum, margins=True)
cdamat1
```

```
[96]: station_destination  Abbey Road  Acton Central  Acton Town  Aldgate  \
station_origin
Abbey Road              NaN              NaN              NaN      NaN
Acton Central           NaN              NaN              NaN      NaN
Acton Town              NaN              NaN              NaN     18.0
Aldgate                 NaN              NaN              2.0      NaN
Aldgate East            NaN              NaN              2.0     52.0
...
Woodford                NaN              NaN              7.0     35.0
Woodgrange Park         NaN              4.0              NaN      NaN
Woodside Park           NaN              NaN              5.0     20.0
Woolwich Arsenal        29.0              NaN              NaN      NaN
All                     445.0            391.0            2156.0   8753.0

station_destination  Aldgate East  All Saints  Alperton  Amersham  Anerley  \
```

station_origin					
Abbey Road	NaN	NaN	NaN	NaN	NaN
Acton Central	NaN	NaN	NaN	NaN	NaN
Acton Town	18.0	NaN	9.0	1.0	NaN
Aldgate	47.0	NaN	NaN	0.0	NaN
Aldgate East	NaN	NaN	1.0	0.0	NaN
...
Woodford	39.0	NaN	NaN	NaN	NaN
Woodgrange Park	NaN	NaN	NaN	NaN	NaN
Woodside Park	20.0	NaN	2.0	NaN	NaN
Woolwich Arsenal	NaN	33.0	NaN	NaN	NaN
All	9308.0	504.0	582.0	108.0	140.0

station_destination	Angel	...	Wimbledon	Wimbledon Park	Wood Green	\
station_origin	...					
Abbey Road	NaN	...	NaN	NaN	NaN	
Acton Central	NaN	...	NaN	NaN	NaN	
Acton Town	20.0	...	16.0	3.0	5.0	
Aldgate	21.0	...	4.0	NaN	3.0	
Aldgate East	23.0	...	5.0	1.0	3.0	
...	
Woodford	32.0	...	15.0	NaN	10.0	
Woodgrange Park	NaN	...	NaN	NaN	NaN	
Woodside Park	25.0	...	11.0	NaN	6.0	
Woolwich Arsenal	NaN	...	NaN	NaN	NaN	
All	9203.0	...	3426.0	523.0	2161.0	

station_destination	Wood Lane	Wood Street	Woodford	Woodgrange Park	\
station_origin					
Abbey Road	NaN	NaN	NaN	NaN	
Acton Central	NaN	NaN	NaN	1.0	
Acton Town	13.0	NaN	2.0	NaN	
Aldgate	2.0	NaN	1.0	NaN	
Aldgate East	2.0	NaN	1.0	NaN	
...	
Woodford	NaN	NaN	NaN	NaN	
Woodgrange Park	NaN	NaN	NaN	NaN	
Woodside Park	NaN	NaN	NaN	NaN	
Woolwich Arsenal	NaN	NaN	NaN	NaN	
All	1647.0	341.0	654.0	156.0	

station_destination	Woodside Park	Woolwich Arsenal	All
station_origin			
Abbey Road	NaN	5.0	599.0
Acton Central	NaN	NaN	1223.0
Acton Town	2.0	NaN	3749.0
Aldgate	1.0	NaN	2882.0

Aldgate East	1.0	NaN	3167.0
...
Woodford	NaN	NaN	4866.0
Woodgrange Park	NaN	NaN	532.0
Woodside Park	NaN	NaN	3092.0
Woolwich Arsenal	NaN	NaN	7890.0
All	603.0	1009.0	1541806.0

[399 rows x 399 columns]

```
[97]: CalcRSqaured(cdata["flows"], cdata["prodSimFitted"])
```

```
[97]: 0.38827639501786243
```

```
[98]: CalcRMSE(cdata["flows"], cdata["prodSimFitted"])
```

```
[98]: 102.893
```

1.1.2 Origin constrained-negative exponential

```
[99]: # Run a doubly constrained SIM with a negative exponential cost function.
      prosim_exp_form = "flows ~ station_origin + log_Dj_job + Dist-1"
      prodsim_exp = smf.glm(formula=prosim_exp_form, data = cdata, family = sm.
        ↪families.Poisson()).fit()

      print(prodsim_exp.summary())
```

Generalized Linear Model Regression Results

```
=====
Dep. Variable:          flows    No. Observations:          61413
Model:                  GLM      Df Residuals:              61013
Model Family:           Poisson  Df Model:                  399
Link Function:          log      Scale:                  1.0000
Method:                  IRLS    Log-Likelihood:        -9.0994e+05
Date:                   Mon, 02 May 2022    Deviance:              1.6477e+06
Time:                   17:38:08    Pearson chi2:          2.40e+06
No. Iterations:         8
Covariance Type:        nonrobust
=====
```

```
=====
                                coef    std err          z
P>|z|    [0.025    0.975]
-----
station_origin[Abbey Road]      -2.9143     0.041   -70.509
0.000    -2.995    -2.833
station_origin[Acton Central]   -1.1621     0.029   -39.960
=====
```

0.000	-1.219	-1.105			
station_origin[Acton Town]			-1.6131	0.017	-92.801
0.000	-1.647	-1.579			
station_origin[Aldgate]			-2.9430	0.020	-150.138
0.000	-2.981	-2.905			
station_origin[Aldgate East]			-2.8548	0.019	-151.960
0.000	-2.892	-2.818			
station_origin[All Saints]			-2.8783	0.037	-77.219
0.000	-2.951	-2.805			
station_origin[Alperton]			-1.6542	0.026	-64.731
0.000	-1.704	-1.604			
station_origin[Amersham]			1.0008	0.030	33.747
0.000	0.943	1.059			
station_origin[Anerley]			-1.0369	0.040	-26.044
0.000	-1.115	-0.959			
station_origin[Angel]			-2.5875	0.017	-156.011
0.000	-2.620	-2.555			
station_origin[Archway]			-1.7164	0.015	-117.258
0.000	-1.745	-1.688			
station_origin[Arnos Grove]			-1.4184	0.019	-73.907
0.000	-1.456	-1.381			
station_origin[Arsenal]			-2.8836	0.022	-128.905
0.000	-2.927	-2.840			
station_origin[Baker Street]			-2.0100	0.013	-154.107
0.000	-2.036	-1.984			
station_origin[Balham]			-0.8774	0.012	-73.687
0.000	-0.901	-0.854			
station_origin[Bank and Monument]			-0.7522	0.008	-90.130
0.000	-0.769	-0.736			
station_origin[Barbican]			-3.8356	0.029	-131.979
0.000	-3.893	-3.779			
station_origin[Barking]			-0.5144	0.013	-40.520
0.000	-0.539	-0.490			
station_origin[Barkingside]			-1.4598	0.028	-51.227
0.000	-1.516	-1.404			
station_origin[Barons Court]			-2.1412	0.017	-127.494
0.000	-2.174	-2.108			
station_origin[Bayswater]			-3.2347	0.026	-124.738
0.000	-3.286	-3.184			
station_origin[Beckton]			-1.5104	0.030	-50.777
0.000	-1.569	-1.452			
station_origin[Beckton Park]			-3.1889	0.059	-54.287
0.000	-3.304	-3.074			
station_origin[Becontree]			-1.2801	0.022	-59.004
0.000	-1.323	-1.238			
station_origin[Belsize Park]			-2.5574	0.020	-127.623
0.000	-2.597	-2.518			
station_origin[Bermondsey]			-2.2016	0.015	-143.940

0.000	-2.232	-2.172			
station_origin[Bethnal Green]			-1.9074	0.014	-140.471
0.000	-1.934	-1.881			
station_origin[Blackfriars]			-2.1836	0.014	-160.677
0.000	-2.210	-2.157			
station_origin[Blackhorse Road]			-0.7628	0.012	-61.184
0.000	-0.787	-0.738			
station_origin[Blackwall]			-2.6252	0.033	-79.590
0.000	-2.690	-2.561			
station_origin[Bond Street]			-3.3899	0.023	-147.722
0.000	-3.435	-3.345			
station_origin[Borough]			-3.7200	0.028	-133.150
0.000	-3.775	-3.665			
station_origin[Boston Manor]			-2.2146	0.030	-74.504
0.000	-2.273	-2.156			
station_origin[Bounds Green]			-1.2461	0.016	-76.669
0.000	-1.278	-1.214			
station_origin[Bow Church]			-1.8999	0.025	-75.109
0.000	-1.950	-1.850			
station_origin[Bow Road]			-2.2046	0.017	-129.956
0.000	-2.238	-2.171			
station_origin[Brent Cross]			-2.4082	0.027	-90.490
0.000	-2.460	-2.356			
station_origin[Brentwood]			1.4828	0.022	66.904
0.000	1.439	1.526			
station_origin[Brixton]			-0.3423	0.009	-38.264
0.000	-0.360	-0.325			
station_origin[Brockley]			-0.6217	0.021	-28.949
0.000	-0.664	-0.580			
station_origin[Bromley-by-Bow]			-2.5528	0.021	-123.146
0.000	-2.593	-2.512			
station_origin[Brondesbury]			-1.0684	0.023	-46.193
0.000	-1.114	-1.023			
station_origin[Brondesbury Park]			-2.1561	0.038	-56.110
0.000	-2.231	-2.081			
station_origin[Bruce Grove]			-1.2927	0.033	-39.442
0.000	-1.357	-1.228			
station_origin[Buckhurst Hill]			-1.3528	0.026	-52.579
0.000	-1.403	-1.302			
station_origin[Burnt Oak]			-1.0474	0.019	-54.284
0.000	-1.085	-1.010			
station_origin[Bush Hill Park]			-0.3144	0.027	-11.466
0.000	-0.368	-0.261			
station_origin[Bushey]			-1.3622	0.065	-20.951
0.000	-1.490	-1.235			
station_origin[Caledonian Road]			-2.7788	0.020	-140.893
0.000	-2.817	-2.740			
station_origin[Caledonian Road & Barnsbury]			-2.7434	0.043	-63.361

0.000	-2.828	-2.659			
station_origin[Cambridge Heath]			-3.0280	0.056	-54.483
0.000	-3.137	-2.919			
station_origin[Camden Road]			-1.8319	0.029	-62.472
0.000	-1.889	-1.774			
station_origin[Camden Town]			-2.6922	0.018	-146.738
0.000	-2.728	-2.656			
station_origin[Canada Water]			-0.5030	0.009	-58.529
0.000	-0.520	-0.486			
station_origin[Canary Wharf]			-0.9442	0.010	-92.700
0.000	-0.964	-0.924			
station_origin[Canning Town]			-0.4441	0.009	-48.626
0.000	-0.462	-0.426			
station_origin[Cannon Street]			-2.7472	0.017	-159.727
0.000	-2.781	-2.714			
station_origin[Canonbury]			-1.3762	0.021	-64.979
0.000	-1.418	-1.335			
station_origin[Canons Park]			-0.8828	0.022	-40.580
0.000	-0.925	-0.840			
station_origin[Carpenders Park]			0.1979	0.028	7.092
0.000	0.143	0.253			
station_origin[Chadwell Heath]			0.7186	0.017	42.008
0.000	0.685	0.752			
station_origin[Chalfont & Latimer]			0.4170	0.033	12.566
0.000	0.352	0.482			
station_origin[Chalk Farm]			-2.8534	0.021	-133.761
0.000	-2.895	-2.812			
station_origin[Chancery Lane]			-3.9720	0.030	-131.809
0.000	-4.031	-3.913			
station_origin[Charing Cross]			-2.3038	0.014	-166.913
0.000	-2.331	-2.277			
station_origin[Chesham]			1.2150	0.033	36.390
0.000	1.150	1.280			
station_origin[Cheshunt]			-1.2998	0.077	-16.953
0.000	-1.450	-1.150			
station_origin[Chigwell]			-2.3385	0.047	-50.240
0.000	-2.430	-2.247			
station_origin[Chingford]			0.3059	0.023	13.317
0.000	0.261	0.351			
station_origin[Chiswick Park]			-2.7730	0.029	-97.136
0.000	-2.829	-2.717			
station_origin[Chorleywood]			0.0011	0.034	0.031
0.975	-0.065	0.067			
station_origin[Clapham Common]			-1.9095	0.016	-123.041
0.000	-1.940	-1.879			
station_origin[Clapham High Street]			-0.7051	0.026	-26.712
0.000	-0.757	-0.653			
station_origin[Clapham Junction]			0.6576	0.013	49.663

0.000	0.632	0.684			
station_origin[Clapham North]			-2.5475	0.020	-129.260
0.000	-2.586	-2.509			
station_origin[Clapham South]			-1.4345	0.014	-104.600
0.000	-1.461	-1.408			
station_origin[Clapton]			-1.2815	0.027	-48.255
0.000	-1.334	-1.229			
station_origin[Cockfosters]			-1.7197	0.032	-53.220
0.000	-1.783	-1.656			
station_origin[Colindale]			-0.6719	0.015	-44.691
0.000	-0.701	-0.642			
station_origin[Colliers Wood]			-0.9725	0.015	-65.714
0.000	-1.002	-0.943			
station_origin[Covent Garden]			-5.0230	0.049	-102.637
0.000	-5.119	-4.927			
station_origin[Crossharbour]			-1.9289	0.025	-77.665
0.000	-1.978	-1.880			
station_origin[Crouch Hill]			-2.2560	0.051	-44.294
0.000	-2.356	-2.156			
station_origin[Croxley]			-0.3692	0.032	-11.644
0.000	-0.431	-0.307			
station_origin[Crystal Palace]			0.1565	0.023	6.684
0.000	0.111	0.202			
station_origin[Custom House]			-2.5926	0.036	-71.624
0.000	-2.664	-2.522			
station_origin[Cutty Sark]			-1.4802	0.023	-65.702
0.000	-1.524	-1.436			
station_origin[Cyprus]			-2.6251	0.045	-58.173
0.000	-2.714	-2.537			
station_origin[Dagenham East]			-1.0684	0.024	-45.067
0.000	-1.115	-1.022			
station_origin[Dagenham Heathway]			-0.7136	0.018	-38.782
0.000	-0.750	-0.678			
station_origin[Dalston Junction]			-0.7147	0.017	-41.988
0.000	-0.748	-0.681			
station_origin[Dalston Kingsland]			-1.0659	0.020	-54.619
0.000	-1.104	-1.028			
station_origin[Debden]			-0.7706	0.026	-30.064
0.000	-0.821	-0.720			
station_origin[Denmark Hill]			-0.7401	0.024	-30.909
0.000	-0.787	-0.693			
station_origin[Deptford Bridge]			-1.1208	0.021	-53.515
0.000	-1.162	-1.080			
station_origin[Devons Road]			-2.1640	0.028	-78.557
0.000	-2.218	-2.110			
station_origin[Dollis Hill]			-2.0392	0.021	-98.262
0.000	-2.080	-1.999			
station_origin[Ealing Broadway]			-0.1107	0.011	-10.388

0.000	-0.132	-0.090			
station_origin[Ealing Common]			-2.1083	0.023	-91.189
0.000	-2.154	-2.063			
station_origin[Earl's Court]			-1.6292	0.012	-131.372
0.000	-1.653	-1.605			
station_origin[East Acton]			-2.2614	0.021	-105.343
0.000	-2.303	-2.219			
station_origin[East Finchley]			-1.1885	0.014	-82.111
0.000	-1.217	-1.160			
station_origin[East Ham]			-0.8444	0.013	-65.544
0.000	-0.870	-0.819			
station_origin[East India]			-2.0472	0.025	-83.239
0.000	-2.095	-1.999			
station_origin[East Putney]			-1.4433	0.015	-97.347
0.000	-1.472	-1.414			
station_origin[Eastcote]			-0.6394	0.021	-30.717
0.000	-0.680	-0.599			
station_origin[Edgware]			-0.7101	0.018	-38.723
0.000	-0.746	-0.674			
station_origin[Edgware Road]			-2.8753	0.020	-146.034
0.000	-2.914	-2.837			
station_origin[Edmonton Green]			-0.2908	0.023	-12.847
0.000	-0.335	-0.246			
station_origin[Elephant & Castle]			-1.7918	0.012	-149.169
0.000	-1.815	-1.768			
station_origin[Elm Park]			-0.4196	0.020	-20.773
0.000	-0.459	-0.380			
station_origin[Elverson Road]			-1.7220	0.030	-57.206
0.000	-1.781	-1.663			
station_origin[Embankment]			-2.7621	0.017	-164.610
0.000	-2.795	-2.729			
station_origin[Emerson Park]			-0.0402	0.055	-0.734
0.463	-0.148	0.067			
station_origin[Enfield Town]			0.1124	0.024	4.636
0.000	0.065	0.160			
station_origin[Epping]			0.6467	0.020	32.446
0.000	0.608	0.686			
station_origin[Euston]			-1.2108	0.010	-126.033
0.000	-1.230	-1.192			
station_origin[Euston Square]			-2.3759	0.015	-153.408
0.000	-2.406	-2.346			
station_origin[Fairlop]			-1.5577	0.032	-48.095
0.000	-1.621	-1.494			
station_origin[Farringdon]			-2.4174	0.015	-157.717
0.000	-2.447	-2.387			
station_origin[Finchley Central]			-0.7653	0.014	-54.248
0.000	-0.793	-0.738			
station_origin[Finchley Road]			-1.9823	0.016	-126.033

0.000	-2.013	-1.951			
station_origin[Finchley Road & Frognal]			-1.6518	0.030	-54.764
0.000	-1.711	-1.593			
station_origin[Finsbury Park]			-0.3892	0.009	-44.260
0.000	-0.406	-0.372			
station_origin[Forest Gate]			-0.5833	0.021	-27.204
0.000	-0.625	-0.541			
station_origin[Forest Hill]			-0.1850	0.021	-8.802
0.000	-0.226	-0.144			
station_origin[Fulham Broadway]			-2.3591	0.018	-128.072
0.000	-2.395	-2.323			
station_origin[Gallions Reach]			-2.2560	0.040	-56.239
0.000	-2.335	-2.177			
station_origin[Gants Hill]			-0.6025	0.015	-39.528
0.000	-0.632	-0.573			
station_origin[Gidea Park]			1.0780	0.018	59.689
0.000	1.043	1.113			
station_origin[Gloucester Road]			-2.2768	0.016	-145.601
0.000	-2.307	-2.246			
station_origin[Golders Green]			-1.4829	0.016	-94.388
0.000	-1.514	-1.452			
station_origin[Goldhawk Road]			-2.9549	0.028	-105.912
0.000	-3.010	-2.900			
station_origin[Goodge Street]			-5.0892	0.053	-96.715
0.000	-5.192	-4.986			
station_origin[Goodmayes]			0.3635	0.019	19.197
0.000	0.326	0.401			
station_origin[Gospel Oak]			-1.9762	0.031	-63.982
0.000	-2.037	-1.916			
station_origin[Grange Hill]			-1.8501	0.040	-46.653
0.000	-1.928	-1.772			
station_origin[Great Portland Street]			-3.7992	0.030	-125.473
0.000	-3.859	-3.740			
station_origin[Green Park]			-3.3950	0.023	-148.890
0.000	-3.440	-3.350			
station_origin[Greenford]			-1.0576	0.020	-52.310
0.000	-1.097	-1.018			
station_origin[Greenwich]			-1.8148	0.028	-65.647
0.000	-1.869	-1.761			
station_origin[Gunnersbury]			-2.1986	0.022	-100.896
0.000	-2.241	-2.156			
station_origin[Hackney Central]			-0.8168	0.018	-44.820
0.000	-0.852	-0.781			
station_origin[Hackney Downs]			-1.5651	0.035	-44.758
0.000	-1.634	-1.497			
station_origin[Hackney Wick]			-1.8563	0.027	-69.412
0.000	-1.909	-1.804			
station_origin[Haggerston]			-1.3921	0.023	-60.948

0.000	-1.437	-1.347			
station_origin[Hainault]			-0.3369	0.019	-17.639
0.000	-0.374	-0.299			
station_origin[Hammersmith]			-0.9841	0.011	-90.128
0.000	-1.005	-0.963			
station_origin[Hampstead]			-2.7373	0.024	-115.679
0.000	-2.784	-2.691			
station_origin[Hampstead Heath]			-2.0776	0.034	-61.948
0.000	-2.143	-2.012			
station_origin[Hanger Lane]			-1.8545	0.023	-79.859
0.000	-1.900	-1.809			
station_origin[Harlesden]			-2.6205	0.027	-98.868
0.000	-2.672	-2.569			
station_origin[Harold Wood]			1.2340	0.019	64.371
0.000	1.196	1.272			
station_origin[Harringay Green Lanes]			-1.6656	0.045	-37.245
0.000	-1.753	-1.578			
station_origin[Harrow & Wealdstone]			-1.2729	0.025	-51.360
0.000	-1.321	-1.224			
station_origin[Harrow-on-the-Hill]			-0.2232	0.014	-15.957
0.000	-0.251	-0.196			
station_origin[Hatch End]			-0.3714	0.035	-10.693
0.000	-0.439	-0.303			
station_origin[Hatton Cross]			-0.9812	0.028	-35.215
0.000	-1.036	-0.927			
station_origin[Headstone Lane]			-1.1261	0.046	-24.236
0.000	-1.217	-1.035			
station_origin[Heathrow Terminal 4]			-1.3373	0.036	-37.491
0.000	-1.407	-1.267			
station_origin[Heathrow Terminal 5]			-0.7346	0.033	-22.071
0.000	-0.800	-0.669			
station_origin[Heathrow Terminals 2 & 3]			-0.2498	0.022	-11.228
0.000	-0.293	-0.206			
station_origin[Hendon Central]			-1.2716	0.017	-75.245
0.000	-1.305	-1.238			
station_origin[Heron Quays]			-1.9748	0.024	-80.809
0.000	-2.023	-1.927			
station_origin[High Barnet]			-0.4872	0.019	-26.032
0.000	-0.524	-0.451			
station_origin[High Street Kensington]			-2.9988	0.022	-134.348
0.000	-3.043	-2.955			
station_origin[Highams Park]			0.1096	0.019	5.656
0.000	0.072	0.148			
station_origin[Highbury & Islington]			-0.6981	0.009	-79.233
0.000	-0.715	-0.681			
station_origin[Highgate]			-1.6817	0.016	-105.199
0.000	-1.713	-1.650			
station_origin[Hillingdon]			-0.6882	0.028	-24.550

0.000	-0.743	-0.633			
station_origin[Holborn]			-3.6432	0.025	-144.212
0.000	-3.693	-3.594			
station_origin[Holland Park]			-3.2070	0.026	-122.567
0.000	-3.258	-3.156			
station_origin[Holloway Road]			-2.6365	0.019	-138.008
0.000	-2.674	-2.599			
station_origin[Homerton]			-0.9519	0.018	-52.988
0.000	-0.987	-0.917			
station_origin[Honor Oak Park]			-0.6820	0.025	-27.794
0.000	-0.730	-0.634			
station_origin[Hornchurch]			-0.6442	0.025	-25.689
0.000	-0.693	-0.595			
station_origin[Hounslow Central]			-1.0657	0.022	-48.150
0.000	-1.109	-1.022			
station_origin[Hounslow East]			-1.1343	0.022	-50.815
0.000	-1.178	-1.091			
station_origin[Hounslow West]			-0.9132	0.023	-40.007
0.000	-0.958	-0.869			
station_origin[Hoxton]			-2.0803	0.032	-65.961
0.000	-2.142	-2.019			
station_origin[Hyde Park Corner]			-5.3891	0.062	-86.325
0.000	-5.511	-5.267			
station_origin[Ickenham]			-1.3423	0.037	-35.948
0.000	-1.415	-1.269			
station_origin[Ilford]			0.6224	0.015	41.043
0.000	0.593	0.652			
station_origin[Imperial Wharf]			-1.7220	0.034	-50.046
0.000	-1.789	-1.655			
station_origin[Island Gardens]			-1.9761	0.027	-72.416
0.000	-2.030	-1.923			
station_origin[Kennington]			-2.6792	0.018	-150.679
0.000	-2.714	-2.644			
station_origin[Kensal Green]			-2.5840	0.024	-107.519
0.000	-2.631	-2.537			
station_origin[Kensal Rise]			-1.1777	0.023	-50.459
0.000	-1.223	-1.132			
station_origin[Kensington]			-4.3481	0.048	-89.687
0.000	-4.443	-4.253			
station_origin[Kentish Town]			-2.8299	0.021	-133.274
0.000	-2.872	-2.788			
station_origin[Kentish Town West]			-2.4148	0.038	-63.724
0.000	-2.489	-2.341			
station_origin[Kenton]			-1.7268	0.031	-54.841
0.000	-1.788	-1.665			
station_origin[Kew Gardens]			-2.0003	0.022	-91.124
0.000	-2.043	-1.957			
station_origin[Kilburn]			-1.7649	0.016	-111.013

0.000	-1.796	-1.734			
station_origin[Kilburn High Road]			-2.2666	0.054	-41.878
0.000	-2.373	-2.161			
station_origin[Kilburn Park]			-2.7857	0.024	-116.992
0.000	-2.832	-2.739			
station_origin[King George V]			-1.9795	0.033	-60.556
0.000	-2.044	-1.915			
station_origin[King's Cross St. Pancras]			-0.7464	0.008	-88.309
0.000	-0.763	-0.730			
station_origin[Kingsbury]			-1.1567	0.020	-57.399
0.000	-1.196	-1.117			
station_origin[Knightsbridge]			-3.8724	0.030	-127.337
0.000	-3.932	-3.813			
station_origin[Ladbroke Grove]			-2.6209	0.021	-122.545
0.000	-2.663	-2.579			
station_origin[Lambeth North]			-3.9316	0.031	-128.615
0.000	-3.991	-3.872			
station_origin[Lancaster Gate]			-2.5901	0.018	-144.556
0.000	-2.625	-2.555			
station_origin[Langdon Park]			-2.1579	0.027	-80.478
0.000	-2.210	-2.105			
station_origin[Latimer Road]			-3.5243	0.035	-101.847
0.000	-3.592	-3.456			
station_origin[Leicester Square]			-4.1908	0.032	-129.234
0.000	-4.254	-4.127			
station_origin[Lewisham]			0.2362	0.013	18.464
0.000	0.211	0.261			
station_origin[Leyton]			-1.0901	0.013	-83.639
0.000	-1.116	-1.065			
station_origin[Leyton Midland Road]			-0.6373	0.035	-18.389
0.000	-0.705	-0.569			
station_origin[Leytonstone]			-0.9842	0.014	-71.578
0.000	-1.011	-0.957			
station_origin[Leytonstone High Road]			-0.9041	0.040	-22.418
0.000	-0.983	-0.825			
station_origin[Limehouse]			-0.9020	0.015	-59.944
0.000	-0.931	-0.872			
station_origin[Liverpool Street]			-0.6146	0.008	-74.432
0.000	-0.631	-0.598			
station_origin[London Bridge]			-0.5957	0.008	-72.351
0.000	-0.612	-0.580			
station_origin[London City Airport]			-1.3820	0.023	-60.040
0.000	-1.427	-1.337			
station_origin[London Fields]			-1.6173	0.031	-52.280
0.000	-1.678	-1.557			
station_origin[Loughton]			-0.5849	0.020	-28.873
0.000	-0.625	-0.545			
station_origin[Maida Vale]			-2.8149	0.022	-125.510

0.000	-2.859	-2.771			
station_origin[Manor House]			-1.7399	0.015	-117.191
0.000	-1.769	-1.711			
station_origin[Manor Park]			-0.7278	0.025	-29.484
0.000	-0.776	-0.679			
station_origin[Mansion House]			-4.7117	0.044	-106.000
0.000	-4.799	-4.625			
station_origin[Marble Arch]			-3.4206	0.024	-140.911
0.000	-3.468	-3.373			
station_origin[Maryland]			-1.7631	0.034	-51.245
0.000	-1.831	-1.696			
station_origin[Marylebone]			-2.1576	0.014	-152.903
0.000	-2.185	-2.130			
station_origin[Mile End]			-1.7154	0.013	-128.603
0.000	-1.742	-1.689			
station_origin[Mill Hill East]			-2.0634	0.029	-72.307
0.000	-2.119	-2.007			
station_origin[Moor Park]			-1.1700	0.040	-29.419
0.000	-1.248	-1.092			
station_origin[Moorgate]			-2.5931	0.016	-159.685
0.000	-2.625	-2.561			
station_origin[Morden]			-0.2128	0.013	-16.558
0.000	-0.238	-0.188			
station_origin[Mornington Crescent]			-4.3183	0.039	-112.102
0.000	-4.394	-4.243			
station_origin[Mudchute]			-2.0867	0.028	-74.944
0.000	-2.141	-2.032			
station_origin[Neasden]			-2.0231	0.022	-93.711
0.000	-2.065	-1.981			
station_origin[New Cross]			-1.0810	0.027	-40.090
0.000	-1.134	-1.028			
station_origin[New Cross Gate]			-1.0570	0.025	-42.496
0.000	-1.106	-1.008			
station_origin[Newbury Park]			-0.4821	0.017	-28.789
0.000	-0.515	-0.449			
station_origin[North Acton]			-1.8388	0.019	-96.721
0.000	-1.876	-1.802			
station_origin[North Ealing]			-3.1130	0.045	-69.315
0.000	-3.201	-3.025			
station_origin[North Greenwich]			-0.9743	0.011	-85.235
0.000	-0.997	-0.952			
station_origin[North Harrow]			-1.0574	0.024	-44.606
0.000	-1.104	-1.011			
station_origin[North Wembley]			-2.2429	0.031	-72.473
0.000	-2.304	-2.182			
station_origin[Northfields]			-1.4318	0.019	-73.918
0.000	-1.470	-1.394			
station_origin[Northolt]			-0.5010	0.018	-27.998

0.000	-0.536	-0.466			
station_origin[Northwick Park]			-1.4267	0.023	-63.122
0.000	-1.471	-1.382			
station_origin[Northwood]			-0.3553	0.023	-15.388
0.000	-0.401	-0.310			
station_origin[Northwood Hills]			-0.8862	0.027	-32.863
0.000	-0.939	-0.833			
station_origin[Norwood Junction]			-0.8159	0.039	-21.015
0.000	-0.892	-0.740			
station_origin[Notting Hill Gate]			-2.1986	0.015	-142.651
0.000	-2.229	-2.168			
station_origin[Oakwood]			-1.3635	0.025	-55.333
0.000	-1.412	-1.315			
station_origin[Old Street]			-2.3239	0.015	-155.387
0.000	-2.353	-2.295			
station_origin[Osterley]			-1.6840	0.027	-61.844
0.000	-1.737	-1.631			
station_origin[Oval]			-2.5446	0.018	-143.743
0.000	-2.579	-2.510			
station_origin[Oxford Circus]			-3.1082	0.020	-156.424
0.000	-3.147	-3.069			
station_origin[Paddington]			-0.6767	0.009	-76.623
0.000	-0.694	-0.659			
station_origin[Park Royal]			-2.9426	0.043	-68.869
0.000	-3.026	-2.859			
station_origin[Parsons Green]			-1.9718	0.016	-121.164
0.000	-2.004	-1.940			
station_origin[Peckham Rye]			-0.6303	0.021	-29.828
0.000	-0.672	-0.589			
station_origin[Penge West]			-1.6258	0.053	-30.763
0.000	-1.729	-1.522			
station_origin[Perivale]			-1.7613	0.026	-68.831
0.000	-1.811	-1.711			
station_origin[Piccadilly Circus]			-4.1304	0.032	-130.578
0.000	-4.192	-4.068			
station_origin[Pimlico]			-2.5052	0.017	-146.696
0.000	-2.539	-2.472			
station_origin[Pinner]			-0.4826	0.020	-24.534
0.000	-0.521	-0.444			
station_origin[Plaistow]			-1.9880	0.018	-112.203
0.000	-2.023	-1.953			
station_origin[Pontoon Dock]			-1.5548	0.023	-67.334
0.000	-1.600	-1.510			
station_origin[Poplar]			-1.8535	0.022	-84.808
0.000	-1.896	-1.811			
station_origin[Preston Road]			-1.5267	0.021	-71.039
0.000	-1.569	-1.485			
station_origin[Prince Regent]			-2.3555	0.033	-70.881

0.000	-2.421	-2.290			
station_origin[	Pudding Mill Lane]		-3.2553	0.049	-67.101
0.000	-3.350	-3.160			
station_origin[	Putney Bridge]		-2.2257	0.019	-114.980
0.000	-2.264	-2.188			
station_origin[	Queen's Park]		-1.7977	0.015	-119.515
0.000	-1.827	-1.768			
station_origin[	Queens Road Peckham]		-0.9124	0.023	-38.935
0.000	-0.958	-0.866			
station_origin[	Queensbury]		-0.9161	0.020	-46.734
0.000	-0.954	-0.878			
station_origin[	Queensway]		-2.7719	0.020	-137.787
0.000	-2.811	-2.732			
station_origin[	Ravenscourt Park]		-2.8876	0.026	-110.833
0.000	-2.939	-2.836			
station_origin[	Rayners Lane]		-0.6165	0.018	-34.128
0.000	-0.652	-0.581			
station_origin[	Rectory Road]		-1.8014	0.033	-54.628
0.000	-1.866	-1.737			
station_origin[	Redbridge]		-1.7317	0.023	-75.522
0.000	-1.777	-1.687			
station_origin[	Regent's Park]		-4.9888	0.052	-95.444
0.000	-5.091	-4.886			
station_origin[	Richmond]		-0.8403	0.015	-55.293
0.000	-0.870	-0.811			
station_origin[	Rickmansworth]		-0.1565	0.029	-5.417
0.000	-0.213	-0.100			
station_origin[	Roding Valley]		-2.6406	0.050	-52.817
0.000	-2.739	-2.543			
station_origin[	Romford]		1.2713	0.016	78.806
0.000	1.240	1.303			
station_origin[	Rotherhithe]		-1.4631	0.026	-56.901
0.000	-1.513	-1.413			
station_origin[	Royal Albert]		-2.5733	0.040	-64.843
0.000	-2.651	-2.496			
station_origin[	Royal Oak]		-3.2706	0.027	-119.757
0.000	-3.324	-3.217			
station_origin[	Royal Victoria]		-1.7116	0.023	-74.865
0.000	-1.756	-1.667			
station_origin[	Ruislip]		-1.0369	0.028	-36.579
0.000	-1.092	-0.981			
station_origin[	Ruislip Gardens]		-1.2158	0.033	-37.004
0.000	-1.280	-1.151			
station_origin[	Ruislip Manor]		-1.0629	0.027	-38.755
0.000	-1.117	-1.009			
station_origin[	Russell Square]		-3.7050	0.026	-140.105
0.000	-3.757	-3.653			
station_origin[	Seven Kings]		0.3098	0.018	16.759

0.000	0.274	0.346			
station_origin[Seven Sisters]			-0.2734	0.009	-28.806
0.000	-0.292	-0.255			
station_origin[Shadwell]			-1.0420	0.014	-76.695
0.000	-1.069	-1.015			
station_origin[Shenfield]			-0.2576	0.064	-4.041
0.000	-0.383	-0.133			
station_origin[Shepherd's Bush]			-1.2841	0.011	-112.706
0.000	-1.306	-1.262			
station_origin[Shepherd's Bush Market]			-2.6983	0.024	-110.910
0.000	-2.746	-2.651			
station_origin[Shoreditch High Street]			-2.1907	0.033	-65.773
0.000	-2.256	-2.125			
station_origin[Silver Street]			-0.5862	0.025	-23.033
0.000	-0.636	-0.536			
station_origin[Sloane Square]			-2.3474	0.015	-152.256
0.000	-2.378	-2.317			
station_origin[Snaresbrook]			-2.0260	0.025	-82.568
0.000	-2.074	-1.978			
station_origin[South Acton]			-1.6752	0.040	-42.129
0.000	-1.753	-1.597			
station_origin[South Ealing]			-1.8052	0.022	-81.069
0.000	-1.849	-1.762			
station_origin[South Hampstead]			-2.3698	0.064	-37.184
0.000	-2.495	-2.245			
station_origin[South Harrow]			-1.3035	0.026	-49.369
0.000	-1.355	-1.252			
station_origin[South Kensington]			-2.2724	0.015	-148.476
0.000	-2.302	-2.242			
station_origin[South Kenton]			-2.0868	0.031	-66.992
0.000	-2.148	-2.026			
station_origin[South Quay]			-2.0059	0.025	-79.700
0.000	-2.055	-1.957			
station_origin[South Ruislip]			-1.0585	0.028	-38.438
0.000	-1.113	-1.005			
station_origin[South Tottenham]			-1.6922	0.049	-34.475
0.000	-1.788	-1.596			
station_origin[South Wimbledon]			-1.1688	0.017	-67.020
0.000	-1.203	-1.135			
station_origin[South Woodford]			-1.0370	0.017	-61.710
0.000	-1.070	-1.004			
station_origin[Southbury]			-1.0609	0.043	-24.611
0.000	-1.145	-0.976			
station_origin[Southfields]			-1.2581	0.015	-83.219
0.000	-1.288	-1.228			
station_origin[Southgate]			-0.9474	0.018	-53.418
0.000	-0.982	-0.913			
station_origin[Southwark]			-2.5157	0.016	-161.770

0.000	-2.546	-2.485			
station_origin[St James Street]			-1.3439	0.031	-42.687
0.000	-1.406	-1.282			
station_origin[St. James's Park]			-3.4710	0.024	-142.995
0.000	-3.519	-3.423			
station_origin[St. John's Wood]			-2.5453	0.019	-137.068
0.000	-2.582	-2.509			
station_origin[St. Paul's]			-4.2238	0.034	-123.148
0.000	-4.291	-4.157			
station_origin[Stamford Brook]			-2.6277	0.024	-109.128
0.000	-2.675	-2.580			
station_origin[Stamford Hill]			-2.0462	0.046	-44.937
0.000	-2.135	-1.957			
station_origin[Stanmore]			-0.5335	0.021	-25.982
0.000	-0.574	-0.493			
station_origin[Star Lane]			-3.2840	0.048	-68.169
0.000	-3.378	-3.190			
station_origin[Stepney Green]			-2.7812	0.020	-138.347
0.000	-2.821	-2.742			
station_origin[Stockwell]			-1.3683	0.011	-119.748
0.000	-1.391	-1.346			
station_origin[Stoke Newington]			-1.5757	0.031	-51.137
0.000	-1.636	-1.515			
station_origin[Stonebridge Park]			-2.4308	0.027	-91.154
0.000	-2.483	-2.379			
station_origin[Stratford]			0.5533	0.007	77.232
0.000	0.539	0.567			
station_origin[Stratford High Street]			-2.9759	0.052	-57.539
0.000	-3.077	-2.875			
station_origin[Stratford International]			-1.3242	0.022	-60.817
0.000	-1.367	-1.282			
station_origin[Sudbury Hill]			-1.5349	0.028	-54.774
0.000	-1.590	-1.480			
station_origin[Sudbury Town]			-1.5302	0.027	-57.521
0.000	-1.582	-1.478			
station_origin[Surrey Quays]			-0.6937	0.018	-38.695
0.000	-0.729	-0.659			
station_origin[Swiss Cottage]			-2.3318	0.018	-130.461
0.000	-2.367	-2.297			
station_origin[Sydenham]			-0.2891	0.024	-12.030
0.000	-0.336	-0.242			
station_origin[Temple]			-5.1469	0.054	-95.538
0.000	-5.252	-5.041			
station_origin[Theobalds Grove]			-0.4497	0.044	-10.197
0.000	-0.536	-0.363			
station_origin[Theydon Bois]			-1.1472	0.039	-29.375
0.000	-1.224	-1.071			
station_origin[Tooting Bec]			-1.1182	0.014	-81.886

0.000	-1.145	-1.091			
station_origin[Tooting Broadway]			-0.6050	0.012	-50.556
0.000	-0.628	-0.582			
station_origin[Tottenham Court Road]			-3.5812	0.025	-146.164
0.000	-3.629	-3.533			
station_origin[Tottenham Hale]			-0.8445	0.012	-68.716
0.000	-0.869	-0.820			
station_origin[Totteridge & Whetstone]			-1.2211	0.022	-55.947
0.000	-1.264	-1.178			
station_origin[Tower Gateway]			-2.5077	0.035	-72.047
0.000	-2.576	-2.440			
station_origin[Tower Hill]			-1.9102	0.012	-153.337
0.000	-1.935	-1.886			
station_origin[Tufnell Park]			-2.5764	0.020	-128.570
0.000	-2.616	-2.537			
station_origin[Turkey Street]			-0.3511	0.036	-9.808
0.000	-0.421	-0.281			
station_origin[Turnham Green]			-1.8930	0.018	-107.669
0.000	-1.927	-1.859			
station_origin[Turnpike Lane]			-1.2059	0.014	-88.080
0.000	-1.233	-1.179			
station_origin[Upminster]			-1.2003	0.038	-31.860
0.000	-1.274	-1.127			
station_origin[Upminster Bridge]			-1.2155	0.036	-33.381
0.000	-1.287	-1.144			
station_origin[Upney]			-1.8231	0.025	-73.519
0.000	-1.872	-1.775			
station_origin[Upper Holloway]			-2.4799	0.052	-47.567
0.000	-2.582	-2.378			
station_origin[Upton Park]			-1.3077	0.014	-90.952
0.000	-1.336	-1.280			
station_origin[Uxbridge]			0.3933	0.020	19.534
0.000	0.354	0.433			
station_origin[Vauxhall]			-0.9762	0.010	-98.648
0.000	-0.996	-0.957			
station_origin[Victoria]			-0.4166	0.008	-52.697
0.000	-0.432	-0.401			
station_origin[Walthamstow Central]			0.0430	0.010	4.396
0.000	0.024	0.062			
station_origin[Walthamstow Queens Road]			-0.3734	0.032	-11.672
0.000	-0.436	-0.311			
station_origin[Wandsworth Road]			-1.6512	0.041	-40.633
0.000	-1.731	-1.572			
station_origin[Wanstead]			-1.9454	0.023	-83.392
0.000	-1.991	-1.900			
station_origin[Wanstead Park]			-0.5726	0.037	-15.671
0.000	-0.644	-0.501			
station_origin[Wapping]			-1.7156	0.029	-59.507

0.000	-1.772	-1.659			
station_origin[Warren Street]			-3.4586	0.024	-146.299
0.000	-3.505	-3.412			
station_origin[Warwick Avenue]			-2.8124	0.021	-131.860
0.000	-2.854	-2.771			
station_origin[Waterloo]			0.0893	0.007	12.458
0.000	0.075	0.103			
station_origin[Watford]			0.2292	0.028	8.332
0.000	0.175	0.283			
station_origin[Watford High Street]			-0.5367	0.047	-11.532
0.000	-0.628	-0.445			
station_origin[Watford Junction]			-0.1962	0.045	-4.322
0.000	-0.285	-0.107			
station_origin[Wembley Central]			-1.8085	0.022	-82.370
0.000	-1.852	-1.765			
station_origin[Wembley Park]			-0.6207	0.013	-46.370
0.000	-0.647	-0.594			
station_origin[West Acton]			-2.5429	0.030	-85.223
0.000	-2.601	-2.484			
station_origin[West Brompton]			-2.3805	0.017	-138.448
0.000	-2.414	-2.347			
station_origin[West Croydon]			0.4132	0.028	14.762
0.000	0.358	0.468			
station_origin[West Finchley]			-1.9500	0.026	-74.486
0.000	-2.001	-1.899			
station_origin[West Ham]			-1.3350	0.012	-109.315
0.000	-1.359	-1.311			
station_origin[West Hampstead]			-1.1983	0.011	-104.484
0.000	-1.221	-1.176			
station_origin[West Harrow]			-1.8791	0.032	-58.942
0.000	-1.942	-1.817			
station_origin[West India Quay]			-4.4897	0.079	-56.971
0.000	-4.644	-4.335			
station_origin[West Kensington]			-2.6317	0.020	-131.001
0.000	-2.671	-2.592			
station_origin[West Ruislip]			-0.8051	0.031	-25.852
0.000	-0.866	-0.744			
station_origin[West Silvertown]			-2.4557	0.034	-72.454
0.000	-2.522	-2.389			
station_origin[Westbourne Park]			-2.6540	0.021	-125.111
0.000	-2.696	-2.612			
station_origin[Westferry]			-1.8492	0.022	-83.433
0.000	-1.893	-1.806			
station_origin[Westminster]			-3.6972	0.026	-140.268
0.000	-3.749	-3.646			
station_origin[White City]			-2.4743	0.021	-117.290
0.000	-2.516	-2.433			
station_origin[White Hart Lane]			-1.2322	0.032	-38.943

0.000	-1.294	-1.170			
station_origin[Whitechapel]			-1.4704	0.011	-135.297
0.000	-1.492	-1.449			
station_origin[Willesden Green]			-1.4256	0.015	-97.693
0.000	-1.454	-1.397			
station_origin[Willesden Junction]			-1.5945	0.015	-106.354
0.000	-1.624	-1.565			
station_origin[Wimbledon]			-0.4842	0.013	-36.066
0.000	-0.510	-0.458			
station_origin[Wimbledon Park]			-2.1316	0.025	-84.337
0.000	-2.181	-2.082			
station_origin[Wood Green]			-1.0608	0.014	-77.275
0.000	-1.088	-1.034			
station_origin[Wood Lane]			-3.2053	0.031	-103.720
0.000	-3.266	-3.145			
station_origin[Wood Street]			-0.9426	0.028	-34.034
0.000	-0.997	-0.888			
station_origin[Woodford]			-0.6336	0.016	-40.333
0.000	-0.664	-0.603			
station_origin[Woodgrange Park]			-0.8964	0.044	-20.499
0.000	-0.982	-0.811			
station_origin[Woodside Park]			-1.1491	0.019	-60.222
0.000	-1.187	-1.112			
station_origin[Woolwich Arsenal]			0.5180	0.013	40.453
0.000	0.493	0.543			
log_Dj_job			0.7552	0.001	1185.004
0.000	0.754	0.756			
Dist			-0.0002	1.88e-07	-814.175
0.000	-0.000	-0.000			
=====					
=====					

```
[100]: #get the predictions
predictions_exp = prodsim_exp.get_prediction()
predictions_exp_summary_frame = predictions_exp.summary_frame()
cdata["prosimest_exp"] = round(predictions_exp_summary_frame["mean"],0)

#here's the matrix
cdamat2 = cdata.pivot_table(values="prosimest_exp", index="station_origin",
                             columns="station_destination",
                             aggfunc=np.sum, margins=True)
cdamat2
```

```
[100]: station_destination  Abbey Road  Acton Central  Acton Town  Aldgate  \
station_origin
Abbey Road                NaN                NaN                NaN                NaN
```

Acton Central	NaN	NaN	NaN	NaN
Acton Town	NaN	NaN	NaN	13.0
Aldgate	NaN	NaN	1.0	NaN
Aldgate East	NaN	NaN	1.0	40.0
...
Woodford	NaN	NaN	1.0	41.0
Woodgrange Park	NaN	1.0	NaN	NaN
Woodside Park	NaN	NaN	2.0	19.0
Woolwich Arsenal	34.0	NaN	NaN	NaN
All	392.0	359.0	2161.0	8549.0

station_destination	Aldgate East	All Saints	Alperton	Amersham	Anerley \
station_origin					
Abbey Road	NaN	NaN	NaN	NaN	NaN
Acton Central	NaN	NaN	NaN	NaN	NaN
Acton Town	13.0	NaN	14.0	0.0	NaN
Aldgate	37.0	NaN	NaN	0.0	NaN
Aldgate East	NaN	NaN	0.0	0.0	NaN
...
Woodford	52.0	NaN	NaN	NaN	NaN
Woodgrange Park	NaN	NaN	NaN	NaN	NaN
Woodside Park	19.0	NaN	0.0	NaN	NaN
Woolwich Arsenal	NaN	36.0	NaN	NaN	NaN
All	9502.0	538.0	617.0	166.0	170.0

station_destination	Angel ...	Wimbledon	Wimbledon Park	Wood Green \
station_origin	...			
Abbey Road	NaN ...	NaN	NaN	NaN
Acton Central	NaN ...	NaN	NaN	NaN
Acton Town	16.0 ...	13.0	3.0	2.0
Aldgate	27.0 ...	2.0	NaN	2.0
Aldgate East	29.0 ...	2.0	0.0	3.0
...
Woodford	30.0 ...	2.0	NaN	6.0
Woodgrange Park	NaN ...	NaN	NaN	NaN
Woodside Park	32.0 ...	3.0	NaN	4.0
Woolwich Arsenal	NaN ...	NaN	NaN	NaN
All	9870.0 ...	1983.0	410.0	1778.0

station_destination	Wood Lane	Wood Street	Woodford	Woodgrange Park \
station_origin				
Abbey Road	NaN	NaN	NaN	NaN
Acton Central	NaN	NaN	NaN	0.0
Acton Town	20.0	NaN	0.0	NaN
Aldgate	2.0	NaN	1.0	NaN
Aldgate East	2.0	NaN	1.0	NaN
...

Woodford	NaN	NaN	NaN	NaN
Woodgrange Park	NaN	NaN	NaN	NaN
Woodside Park	NaN	NaN	NaN	NaN
Woolwich Arsenal	NaN	NaN	NaN	NaN
All	1602.0	397.0	660.0	160.0

station_destination	Woodside Park	Woolwich Arsenal	All
station_origin			
Abbey Road	NaN	7.0	595.0
Acton Central	NaN	NaN	1226.0
Acton Town	1.0	NaN	3744.0
Aldgate	1.0	NaN	2885.0
Aldgate East	1.0	NaN	3160.0
...
Woodford	NaN	NaN	4867.0
Woodgrange Park	NaN	NaN	532.0
Woodside Park	NaN	NaN	3100.0
Woolwich Arsenal	NaN	NaN	7893.0
All	422.0	1089.0	1541347.0

[399 rows x 399 columns]

```
[101]: CalcRSquared(cdata["flows"],cdata["prosimest_exp"])
```

```
[101]: 0.4680648443542878
```

```
[102]: CalcRMSE(cdata["flows"],cdata["prosimest_exp"])
```

```
[102]: 96.263
```

```
[103]: #create some Di and Dj columns in the dataframe and store row and column totals
        ↳in them:
        #to create O_i, take cdatasub ...then... group by origcodenew ...then...
        ↳summarise by calculating the sum of Total
O_i = pd.DataFrame(cdata.groupby(["station_origin"])["flows"].agg(np.sum))
O_i.rename(columns={"flows":"O_i"}, inplace = True)
cdata = cdata.merge(O_i, on = "station_origin", how = "left" )

D_j = pd.DataFrame(cdata.groupby(["station_destination"])["flows"].agg(np.sum))
D_j.rename(columns={"flows":"D_j"}, inplace = True)
cdata = cdata.merge(D_j, on = "station_destination", how = "left" )
```

```
[104]: #We can do this by pulling out the parameter values
coefs = pd.DataFrame(prodSim.params)
coefs.reset_index(inplace=True)
coefs.rename(columns = {0:"alpha_i", "index":"coef"}, inplace = True)
to_repl = ["(station_origin)", "\[,", "\]"]
```

```

for x in to_repl:
    coefs["coef"] = coefs["coef"].str.replace(x, "")
#then once you have done this you can join them back into the dataframes
cdata = cdata.merge(coefs, left_on="station_origin", right_on="coef", how = "
↳"left")
cdata.drop(columns = ["coef"], inplace = True)
#check this has worked
cdata.head()

```

/usr/local/lib/python3.7/dist-packages/ipykernel_launcher.py:7: FutureWarning:
The default value of regex will change from True to False in a future version.

```
import sys
```

```

[104]: station_origin station_destination flows Oi_pop Dj_job Dist \
0      Abbey Road   Bank and Monument      0    599   78549 8131.525097
1      Abbey Road           Beckton        1    599    442 8510.121774
2      Abbey Road       Blackwall         3    599    665 3775.448872
3      Abbey Road     Canary Wharf         1    599   58772 5086.514220
4      Abbey Road     Canning Town        37    599   15428 2228.923167

      log_Oi_pop log_Dj_job log_Dist prodSimFitted prosimest_exp O_i D_j \
0      6.395262   11.271478  9.003504           55.0           78.0 599 78549
1      6.395262    6.091310  9.049012            1.0            1.0 599   442
2      6.395262    6.499787  8.236275            3.0            4.0 599   665
3      6.395262   10.981421  8.534348           66.0           99.0 599 58772
4      6.395262    9.643939  7.709274           49.0           56.0 599 15428

      alpha_i
0  3.250242
1  3.250242
2  3.250242
3  3.250242
4  3.250242

```

```

[105]: alpha_i = prodsim_exp.params[0:-2]
gamma = prodsim_exp.params[-2]
beta = -prodsim_exp.params[-1]

```

```
[106]: print(alpha_i)
```

```

station_origin[Abbey Road]      -2.914322
station_origin[Acton Central]   -1.162092
station_origin[Acton Town]      -1.613081
station_origin[Aldgate]         -2.943047
station_origin[Aldgate East]    -2.854752
...
station_origin[Wood Street]     -0.942621

```



```
station_origin[Woodford]          -0.633605
station_origin[Woodgrange Park]   -0.896422
station_origin[Woodside Park]     -1.149110
station_origin[Woolwich Arsenal]   0.518041
Length: 398, dtype: float64
```

```
[107]: print(beta)
```

```
0.0001531661934636844
```

1.2 IV.1. Scenario A

```
[108]: def new_sal(row):
        if row["station_destination"] == "Canary Wharf":
            val = row["Dj_job"]/2
        else:
            val = row["Dj_job"]
        return val

cdata["Dj_jobScenario"] = cdata.apply(new_sal, axis =1)
cdata.head(5)
```

```
[108]: station_origin station_destination flows Oi_pop Dj_job Dist \
0 Abbey Road Bank and Monument 0 599 78549 8131.525097
1 Abbey Road Beckton 1 599 442 8510.121774
2 Abbey Road Blackwall 3 599 665 3775.448872
3 Abbey Road Canary Wharf 1 599 58772 5086.514220
4 Abbey Road Canning Town 37 599 15428 2228.923167

log_Oi_pop log_Dj_job log_Dist prodSimFitted prosimest_exp O_i D_j \
0 6.395262 11.271478 9.003504 55.0 78.0 599 78549
1 6.395262 6.091310 9.049012 1.0 1.0 599 442
2 6.395262 6.499787 8.236275 3.0 4.0 599 665
3 6.395262 10.981421 8.534348 66.0 99.0 599 58772
4 6.395262 9.643939 7.709274 49.0 56.0 599 15428

alpha_i Dj_jobScenario
0 3.250242 78549.0
1 3.250242 442.0
2 3.250242 665.0
3 3.250242 29386.0
4 3.250242 15428.0
```

```
[109]: cdata["prodsimest1"] = np.exp(cdata["alpha_i"]+gamma*np.
        ↳log(cdata["Dj_jobScenario"])) - beta*cdata["Dist"])

cdata["prodsimest1"] = round(cdata["prodsimest1"],0)
#now we can convert the pivot table into a matrix
```

```

cdamat2 = cdata.pivot_table(values = "prodsimest1", index="station_origin",
    ↪columns = "station_destination",
                                aggfunc=np.sum, margins=True)
cdamat2

```

```

[109]: station_destination  Abbey Road  Acton Central  Acton Town  Aldgate  \
station_origin
Abbey Road                NaN                NaN                NaN                NaN
Acton Central              NaN                NaN                NaN                NaN
Acton Town                 NaN                NaN                NaN                6211.0
Aldgate                    NaN                NaN                693.0                NaN
Aldgate East               NaN                NaN                764.0                22117.0
...
Woodford                   NaN                NaN                466.0                13464.0
Woodgrange Park            NaN                475.0                NaN                NaN
Woodside Park              NaN                NaN                673.0                6687.0
Woolwich Arsenal           20015.0                NaN                NaN                NaN
All                        223747.0                175216.0                949432.0                4500044.0

station_destination  Aldgate East  All Saints  Alperton  Amersham  Anerley  \
station_origin
Abbey Road                NaN                NaN                NaN                NaN                NaN
Acton Central              NaN                NaN                NaN                NaN                NaN
Acton Town                 6072.0                NaN                6579.0                20.0                NaN
Aldgate                    19626.0                NaN                NaN                2.0                NaN
Aldgate East               NaN                NaN                157.0                2.0                NaN
...
Woodford                   17021.0                NaN                NaN                NaN                NaN
Woodgrange Park            NaN                NaN                NaN                NaN                NaN
Woodside Park              6535.0                NaN                138.0                NaN                NaN
Woolwich Arsenal           NaN                21447.0                NaN                NaN                NaN
All                        4963839.0                305391.0                228590.0                13112.0                80764.0

station_destination  Angel  ...  Wimbledon  Wimbledon Park  Wood Green  \
station_origin
Abbey Road                NaN  ...                NaN                NaN                NaN
Acton Central              NaN  ...                NaN                NaN                NaN
Acton Town                 7672.0  ...                6415.0                1394.0                923.0
Aldgate                    14473.0  ...                1105.0                NaN                1315.0
Aldgate East               15940.0  ...                1217.0                264.0                1448.0
...
Woodford                   9922.0  ...                743.0                NaN                1876.0
Woodgrange Park            NaN  ...                NaN                NaN                NaN
Woodside Park              10919.0  ...                1073.0                NaN                1313.0
Woolwich Arsenal           NaN  ...                NaN                NaN                NaN
All                        5189481.0  ...                1031203.0                207794.0                908306.0

```

station_destination	Wood Lane	Wood Street	Woodford	Woodgrange Park	\
station_origin					
Abbey Road	NaN	NaN	NaN	NaN	
Acton Central	NaN	NaN	NaN	159.0	
Acton Town	9433.0	NaN	109.0	NaN	
Aldgate	1078.0	NaN	350.0	NaN	
Aldgate East	1188.0	NaN	499.0	NaN	
...	
Woodford	NaN	NaN	NaN	NaN	
Woodgrange Park	NaN	NaN	NaN	NaN	
Woodside Park	NaN	NaN	NaN	NaN	
Woolwich Arsenal	NaN	NaN	NaN	NaN	
All	823241.0	182788.0	262847.0	75852.0	

station_destination	Woodside Park	Woolwich Arsenal	All
station_origin			
Abbey Road	NaN	3556.0	265599.0
Acton Central	NaN	NaN	590588.0
Acton Town	259.0	NaN	1794670.0
Aldgate	287.0	NaN	1503789.0
Aldgate East	317.0	NaN	1725377.0
...
Woodford	NaN	NaN	1565235.0
Woodgrange Park	NaN	NaN	248690.0
Woodside Park	NaN	NaN	1065752.0
Woolwich Arsenal	NaN	NaN	4332175.0
All	198590.0	629453.0	789370351.0

[399 rows x 399 columns]

```
[110]: #calculate some new  $w_j^{\alpha}$  and  $d_{ij}^{\beta}$  values
Dj_gamma = cdata["Dj_jobScenario"]**gamma
dist_beta = cdata["Dist"]**(-beta)
#calcualte the first stage of the  $A_i$  values
cdata["Ai1"] = Dj_gamma * dist_beta
#now do the sum over all  $j$ s bit
A_i = pd.DataFrame(cdata.groupby(["station_origin"])["Ai1"].agg(np.sum))
#now divide into 1
A_i["Ai1"] = 1/A_i["Ai1"]
A_i.rename(columns={"Ai1":"A_i"}, inplace=True)
#and write the  $A_i$  values back into the dataframe
cdata = cdata.merge(A_i, left_on="station_origin", right_index=True, how="left")

[111]: #to check everything works, recreate the original estimates
cdata["prodsimest2"] = cdata["A_i"]*cdata["O_i"]*Dj_gamma*dist_beta
#round
cdata["prodsimest2"] = round(cdata["prodsimest2"])
```

```
[112]: cdatamat4 = cdata.pivot_table(values = "prodsimest2", index="station_origin",
    ↪columns = "station_destination",
    aggfunc=np.sum, margins=True)
cdatamat4
```

```
[112]: station_destination  Abbey Road  Acton Central  Acton Town  Aldgate  \
station_origin
Abbey Road                NaN                NaN                NaN                NaN
Acton Central              NaN                NaN                NaN                NaN
Acton Town                 NaN                NaN                NaN                24.0
Aldgate                    NaN                NaN                7.0                NaN
Aldgate East               NaN                NaN                8.0                20.0
...
Woodford                   NaN                NaN                12.0               32.0
Woodgrange Park            NaN                9.0                NaN                NaN
Woodside Park              NaN                NaN                8.0                21.0
Woolwich Arsenal           31.0                NaN                NaN                NaN
All                        281.0              557.0              3072.0             7734.0

station_destination  Aldgate East  All Saints  Alperton  Amersham  Anerley  \
station_origin
Abbey Road                NaN                NaN                NaN                NaN                NaN
Acton Central              NaN                NaN                NaN                NaN                NaN
Acton Town                 24.0                NaN                4.0                2.0                NaN
Aldgate                    19.0                NaN                NaN                1.0                NaN
Aldgate East               NaN                NaN                3.0                2.0                NaN
...
Woodford                   32.0                NaN                NaN                NaN                NaN
Woodgrange Park            NaN                NaN                NaN                NaN                NaN
Woodside Park              21.0                NaN                4.0                NaN                NaN
Woolwich Arsenal           NaN                37.0                NaN                NaN                NaN
All                        8272.0              390.0              1099.0             469.0             140.0

station_destination  Angel  ...  Wimbledon  Wimbledon Park  Wood Green  \
station_origin
Abbey Road          NaN  ...                NaN                NaN                NaN
Acton Central        NaN  ...                NaN                NaN                NaN
Acton Town           25.0  ...              21.0                3.0                9.0
Aldgate              19.0  ...              16.0                NaN                7.0
Aldgate East         20.0  ...              17.0                3.0                7.0
...
Woodford             33.0  ...              27.0                NaN                12.0
Woodgrange Park      NaN  ...                NaN                NaN                NaN
Woodside Park        22.0  ...              18.0                NaN                8.0
Woolwich Arsenal      NaN  ...                NaN                NaN                NaN
All                  8644.0  ...             6638.0                876.0             3117.0
```

station_destination	Wood Lane	Wood Street	Woodford	Woodgrange Park	\
station_origin					
Abbey Road	NaN	NaN	NaN	NaN	
Acton Central	NaN	NaN	NaN	3.0	
Acton Town	7.0	NaN	4.0	NaN	
Aldgate	5.0	NaN	3.0	NaN	
Aldgate East	6.0	NaN	3.0	NaN	
...	
Woodford	NaN	NaN	NaN	NaN	
Woodgrange Park	NaN	NaN	NaN	NaN	
Woodside Park	NaN	NaN	NaN	NaN	
Woolwich Arsenal	NaN	NaN	NaN	NaN	
All	2040.0	268.0	1190.0	139.0	

station_destination	Woodside Park	Woolwich Arsenal	All
station_origin			
Abbey Road	NaN	17.0	599.0
Acton Central	NaN	NaN	1222.0
Acton Town	4.0	NaN	3745.0
Aldgate	3.0	NaN	2891.0
Aldgate East	3.0	NaN	3179.0
...
Woodford	NaN	NaN	4870.0
Woodgrange Park	NaN	NaN	531.0
Woodside Park	NaN	NaN	3090.0
Woolwich Arsenal	NaN	NaN	7890.0
All	1177.0	1811.0	1542413.0

[399 rows x 399 columns]

```
[113]: # visualize the changes
changes_job=cdata.groupby('station_destination',as_index = False).agg({'flows':
    ↳ 'sum', 'prodsimest2': 'sum'})
changes_job['changes_flows1']= changes_job['prodsimest2']- changes_job['flows']
changes_job.sort_values(by=['changes_flows1'],ascending = False, inplace = True)
changes_job.head(10)
```

	station_destination	flows	prodsimest2	changes_flows1
326	Stratford	55954	74119.0	18165.0
386	Whitechapel	17633	21640.0	4007.0
167	Highbury & Islington	25385	28929.0	3544.0
53	Canada Water	20443	23714.0	3271.0
55	Canning Town	15428	18687.0	3259.0
371	West Brompton	5859	9113.0	3254.0
388	Willesden Junction	4165	7181.0	3016.0
293	Shepherd's Bush	9890	12830.0	2940.0
141	Gunnersbury	4775	7644.0	2869.0

374	West Ham	5487	8288.0	2801.0
-----	----------	------	--------	--------

```
[114]: #with absolute number
changes_job['changes_flows1_abs']=abs(changes_job['changes_flows1'])
changes_job.sort_values(by=["changes_flows1_abs"],ascending = False, inplace =_
↪True)
changes_job.head(10)
```

```
[114]:
```

	station_destination	flows	prodsimest2	changes_flows1 \
54	Canary Wharf	58772	30481.0	-28291.0
326	Stratford	55954	74119.0	18165.0
15	Bank and Monument	78549	62870.0	-15679.0
251	Oxford Circus	44368	31325.0	-13043.0
355	Victoria	33251	24541.0	-8710.0
197	King's Cross St. Pancras	33330	24717.0	-8613.0
213	London Bridge	29926	22750.0	-7176.0
138	Green Park	26754	21351.0	-5403.0
364	Waterloo	23408	18403.0	-5005.0
119	Farringdon	25592	20614.0	-4978.0

	changes_flows1_abs
54	28291.0
326	18165.0
15	15679.0
251	13043.0
355	8710.0
197	8613.0
213	7176.0
138	5403.0
364	5005.0
119	4978.0

1.3 IV.2. Scenario B–Part1

```
[115]: # set the new beta
beta_1 = 1
```

```
[116]: #calculate some new wj~alpha and d_ij~beta values
Dj_gamma1 = cdata["Dj_job"]**gamma
dist_beta1 = cdata["Dist"]**beta_1
#calcualte the first stage of the Ai values
cdata["Ai1_new1"] = Dj_gamma1 * dist_beta1
#now do the sum over all js bit
A_i_new1 = pd.DataFrame(cdata.groupby(["station_origin"])["Ai1_new1"].agg(np.
↪sum))
#now divide into 1
A_i_new1["Ai1_new1"] = 1/A_i_new1["Ai1_new1"]
```

```
A_i_new1.rename(columns={"Ai1_new1":"A_i_new1"}, inplace=True)
#and write the A_i values back into the dataframe
cdata = cdata.merge(A_i_new1, left_on="station_origin", right_index=True,
↳how="left")
```

```
[117]: #to check everything works, recreate the original estimates
cdata["prodsimest3"] = cdata["A_i_new1"]*cdata["O_i"]*Dj_gamma1*dist_beta1
#round
cdata["prodsimest3"] = round(cdata["prodsimest3"])
```

```
[118]: cdatamat5 = cdata.pivot_table(values = "prodsimest3", index="station_origin",
↳columns = "station_destination",
aggfunc=np.sum, margins=True)
cdatamat5
```

```
[118]: station_destination  Abbey Road  Acton Central  Acton Town  Aldgate  \
station_origin
Abbey Road                NaN                NaN                NaN                NaN
Acton Central              NaN                NaN                NaN                NaN
Acton Town                 NaN                NaN                NaN                17.0
Aldgate                    NaN                NaN                2.0                NaN
Aldgate East               NaN                NaN                2.0                58.0
...                        ...                ...                ...                ...
Woodford                   NaN                NaN                7.0                35.0
Woodgrange Park            NaN                3.0                NaN                NaN
Woodside Park              NaN                NaN                5.0                20.0
Woolwich Arsenal           31.0                NaN                NaN                NaN
All                        532.0               390.0               2168.0            8876.0

station_destination  Aldgate East  All Saints  Alperton  Amersham  Anerley  \
station_origin
Abbey Road                NaN                NaN                NaN                NaN                NaN
Acton Central              NaN                NaN                NaN                NaN                NaN
Acton Town                 17.0                NaN               10.0                1.0                NaN
Aldgate                    51.0                NaN                NaN                0.0                NaN
Aldgate East               NaN                NaN                1.0                0.0                NaN
...                        ...                ...                ...                ...                ...
Woodford                   40.0                NaN                NaN                NaN                NaN
Woodgrange Park            NaN                NaN                NaN                NaN                NaN
Woodside Park              20.0                NaN                2.0                NaN                NaN
Woolwich Arsenal           NaN                34.0                NaN                NaN                NaN
All                        9413.0               548.0               576.0               97.0             156.0

station_destination  Angel  ...  Wimbledon  Wimbledon Park  Wood Green  \
station_origin
Abbey Road                NaN  ...                NaN                NaN                NaN
Acton Central              NaN  ...                NaN                NaN                NaN
```

Acton Town	19.0	...	16.0	3.0	5.0
Aldgate	21.0	...	3.0	NaN	2.0
Aldgate East	23.0	...	4.0	1.0	2.0
...
Woodford	32.0	...	14.0	NaN	9.0
Woodgrange Park	NaN	...	NaN	NaN	NaN
Woodside Park	25.0	...	11.0	NaN	6.0
Woolwich Arsenal	NaN	...	NaN	NaN	NaN
All	9162.0	...	3152.0	533.0	2158.0

station_destination	Wood Lane	Wood Street	Woodford	Woodgrange Park	\
station_origin					
Abbey Road	NaN	NaN	NaN		NaN
Acton Central	NaN	NaN	NaN		1.0
Acton Town	14.0	NaN	2.0		NaN
Aldgate	2.0	NaN	1.0		NaN
Aldgate East	2.0	NaN	1.0		NaN
...
Woodford	NaN	NaN	NaN		NaN
Woodgrange Park	NaN	NaN	NaN		NaN
Woodside Park	NaN	NaN	NaN		NaN
Woolwich Arsenal	NaN	NaN	NaN		NaN
All	1665.0	387.0	658.0		170.0

station_destination	Woodside Park	Woolwich Arsenal	All
station_origin			
Abbey Road	NaN	5.0	599.0
Acton Central	NaN	NaN	1225.0
Acton Town	2.0	NaN	3744.0
Aldgate	1.0	NaN	2885.0
Aldgate East	1.0	NaN	3172.0
...
Woodford	NaN	NaN	4871.0
Woodgrange Park	NaN	NaN	527.0
Woodside Park	NaN	NaN	3095.0
Woolwich Arsenal	NaN	NaN	7893.0
All	595.0	954.0	1541819.0

[399 rows x 399 columns]

```
[119]: # visualize the changes
changes_cost1=cdata.groupby('station_destination',as_index = False).
    ↳agg({'flows':'sum','prodsimest3':'sum'})
changes_cost1['changes_flows2']=
    ↳changes_cost1['prodsimest3']-changes_cost1['flows']
changes_cost1.sort_values(by=["changes_flows2"],ascending=False, inplace=True)
changes_cost1.head(10)
```



```
[119]: station_destination flows prodsimest3 changes_flows2
326          Stratford 55954      63319.0      7365.0
53          Canada Water 20443      25342.0      4899.0
386          Whitechapel 17633      22531.0      4898.0
112          Embankment 10220      14162.0      3942.0
313          Southwark 10326      14093.0      3767.0
383          Westminster 15466      18544.0      3078.0
56          Cannon Street 4698       7597.0      2899.0
64          Charing Cross 7016       9825.0      2809.0
167 Highbury & Islington 25385      28131.0      2746.0
374          West Ham 5487       8131.0      2644.0
```

```
[120]: #with absolute number
changes_cost1['changes_flows2_abs']=abs(changes_cost1['changes_flows2'])
changes_cost1.sort_values(by=["changes_flows2_abs"],ascending=False,
    ↪inplace=True)
changes_cost1.head(10)
```

```
[120]: station_destination flows prodsimest3 changes_flows2 \
54          Canary Wharf 58772      49095.0      -9677.0
15          Bank and Monument 78549      70850.0      -7699.0
326          Stratford 55954      63319.0      7365.0
251          Oxford Circus 44368      37082.0      -7286.0
355          Victoria 33251      26853.0      -6398.0
147          Hammersmith 18250      13123.0      -5127.0
53          Canada Water 20443      25342.0      4899.0
386          Whitechapel 17633      22531.0      4898.0
197 King's Cross St. Pancras 33330      28619.0      -4711.0
252          Paddington 20193      16129.0      -4064.0

changes_flows2_abs
54          9677.0
15          7699.0
326          7365.0
251          7286.0
355          6398.0
147          5127.0
53          4899.0
386          4898.0
197          4711.0
252          4064.0
```

1.4 IV.2. Scenario B–Part2

```
[121]: # set the new beta
beta_2 = 1.5
```

```
[122]: #calculate some new  $w_j^{\sim\alpha}$  and  $d_{ij}^{\sim\beta}$  values
Dj_gamma2 = cdata["Dj_job"]**gamma
dist_beta2 = cdata["Dist"]**beta_2
#calculate the first stage of the  $A_i$  values
cdata["Ai1_new2"] = Dj_gamma2 * dist_beta2
#now do the sum over all  $j$ s bit
A_i_new2 = pd.DataFrame(cdata.groupby(["station_origin"])["Ai1_new2"].agg(np.
    ↪sum))
#now divide into 1
A_i_new2["Ai1_new2"] = 1/A_i_new2["Ai1_new2"]
A_i_new2.rename(columns={"Ai1_new2":"A_i_new2"}, inplace=True)
#and write the  $A_i$  values back into the dataframe
cdata = cdata.merge(A_i_new2, left_on="station_origin", right_index=True,
    ↪how="left")
```

```
[123]: #to check everything works, recreate the original estimates
cdata["prodsimest4"] = cdata["A_i_new2"]*cdata["O_i"]*Dj_gamma2*dist_beta2
#round
cdata["prodsimest4"] = round(cdata["prodsimest4"])
```

```
[124]: cdatamat6 = cdata.pivot_table(values="prodsimest4", index="station_origin",
    ↪columns="station_destination",
    aggfunc=np.sum, margins=True)
cdatamat6
```

```
[124]: station_destination  Abbey Road  Acton Central  Acton Town  Aldgate  \
station_origin
Abbey Road                NaN                NaN                NaN        NaN
Acton Central              NaN                NaN                NaN        NaN
Acton Town                 NaN                NaN                NaN        12.0
Aldgate                    NaN                NaN                1.0        NaN
Aldgate East               NaN                NaN                1.0        77.0
...                        ...                ...                ...        ...
Woodford                   NaN                NaN                5.0        35.0
Woodgrange Park            NaN                2.0                NaN        NaN
Woodside Park              NaN                NaN                4.0        18.0
Woolwich Arsenal           30.0                NaN                NaN        NaN
All                        977.0            370.0            2293.0      8734.0

station_destination  Aldgate East  All Saints  Alperton  Amersham  Anerley  \
station_origin
Abbey Road                NaN                NaN                NaN        NaN        NaN
```

Acton Central	NaN	NaN	NaN	NaN	NaN
Acton Town	12.0	NaN	13.0	0.0	NaN
Aldgate	61.0	NaN	NaN	0.0	NaN
Aldgate East	NaN	NaN	0.0	0.0	NaN
...
Woodford	41.0	NaN	NaN	NaN	NaN
Woodgrange Park	NaN	NaN	NaN	NaN	NaN
Woodside Park	18.0	NaN	1.0	NaN	NaN
Woolwich Arsenal	NaN	32.0	NaN	NaN	NaN
All	9180.0	625.0	531.0	68.0	213.0

station_destination	Angel	...	Wimbledon	Wimbledon Park	Wood Green	\
station_origin		...				
Abbey Road	NaN	...	NaN	NaN	NaN	
Acton Central	NaN	...	NaN	NaN	NaN	
Acton Town	14.0	...	12.0	2.0	3.0	
Aldgate	16.0	...	1.0	NaN	1.0	
Aldgate East	19.0	...	1.0	0.0	1.0	
...	
Woodford	29.0	...	9.0	NaN	8.0	
Woodgrange Park	NaN	...	NaN	NaN	NaN	
Woodside Park	25.0	...	8.0	NaN	5.0	
Woolwich Arsenal	NaN	...	NaN	NaN	NaN	
All	8426.0	...	2284.0	607.0	2363.0	

station_destination	Wood Lane	Wood Street	Woodford	Woodgrange Park	\
station_origin					
Abbey Road	NaN	NaN	NaN	NaN	
Acton Central	NaN	NaN	NaN	1.0	
Acton Town	16.0	NaN	1.0	NaN	
Aldgate	1.0	NaN	0.0	NaN	
Aldgate East	1.0	NaN	0.0	NaN	
...	
Woodford	NaN	NaN	NaN	NaN	
Woodgrange Park	NaN	NaN	NaN	NaN	
Woodside Park	NaN	NaN	NaN	NaN	
Woolwich Arsenal	NaN	NaN	NaN	NaN	
All	1717.0	643.0	667.0	229.0	

station_destination	Woodside Park	Woolwich Arsenal	All
station_origin			
Abbey Road	NaN	2.0	598.0
Acton Central	NaN	NaN	1226.0
Acton Town	1.0	NaN	3752.0
Aldgate	0.0	NaN	2872.0
Aldgate East	0.0	NaN	3160.0
...

Woodford	NaN	NaN	4869.0
Woodgrange Park	NaN	NaN	532.0
Woodside Park	NaN	NaN	3091.0
Woolwich Arsenal	NaN	NaN	7891.0
All	671.0	715.0	1541411.0

[399 rows x 399 columns]

```
[125]: # visualize the changes
changes_cost2=cdata.groupby('station_destination',as_index = False).
    ↳agg({'flows':'sum','prodsimest4':'sum'})
changes_cost2['changes_flows3']=
    ↳changes_cost2['prodsimest4']-changes_cost2['flows']
changes_cost2.sort_values(by=["changes_flows3"],ascending = False, inplace =
    ↳True)
changes_cost2.head(10)
```

```
[125]:      station_destination  flows  prodsimest4  changes_flows3
227           Moorgate    24574      30337.0      5763.0
313           Southwark    10326      16070.0      5744.0
112           Embankment   10220      15855.0      5635.0
383           Westminster  15466      20085.0      4619.0
56           Cannon Street   4698       8915.0      4217.0
374           West Ham     5487       9468.0      3981.0
53           Canada Water  20443      24072.0      3629.0
315           St. James's Park 13339      16764.0      3425.0
327  Stratford High Street    788       3903.0      3115.0
64           Charing Cross   7016      10111.0      3095.0
```

```
[126]: #with absolute number
changes_cost2['changes_flows3_abs']=abs(changes_cost2['changes_flows3'])
changes_cost2.sort_values(by=["changes_flows3_abs"],ascending = False, inplace=
    ↳ True)
changes_cost2.head(10)
```

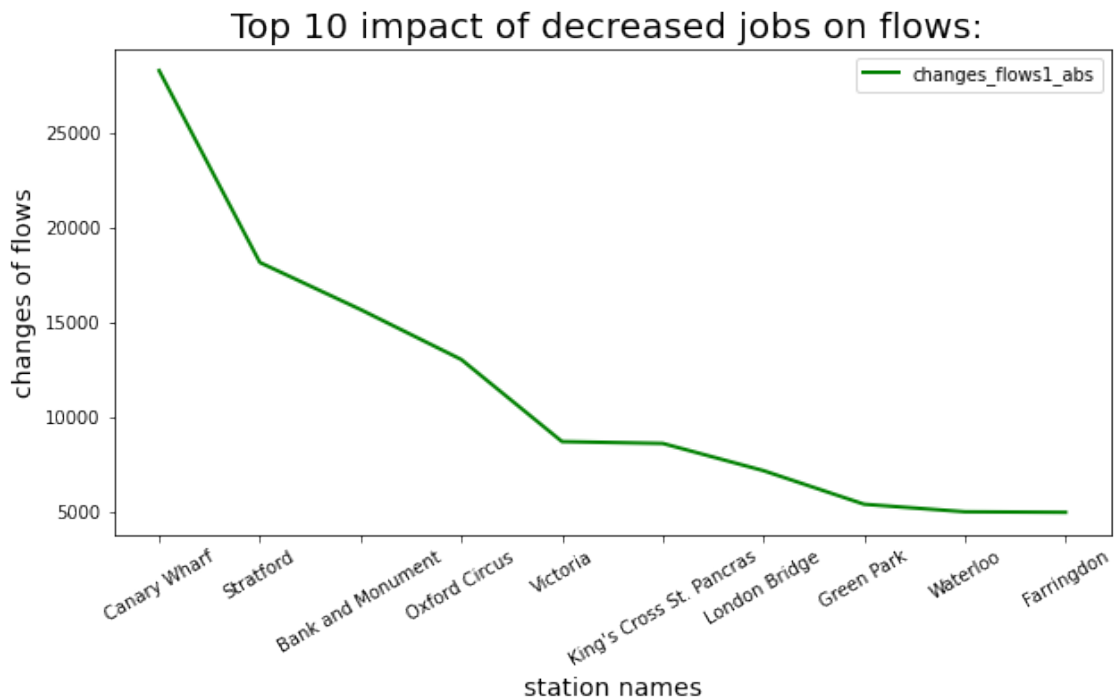
```
[126]:      station_destination  flows  prodsimest4  changes_flows3 \
54           Canary Wharf   58772      46297.0      -12475.0
251           Oxford Circus  44368      35605.0      -8763.0
355           Victoria     33251      25273.0      -7978.0
15           Bank and Monument 78549      71230.0      -7319.0
227           Moorgate    24574      30337.0      5763.0
313           Southwark    10326      16070.0      5744.0
112           Embankment   10220      15855.0      5635.0
147           Hammersmith   18250      12734.0      -5516.0
119           Farringdon   25592      20451.0      -5141.0
252           Paddington   20193      15063.0      -5130.0
```

	changes_flows3_abs
54	12475.0
251	8763.0
355	7978.0
15	7319.0
227	5763.0
313	5744.0
112	5635.0
147	5516.0
119	5141.0
252	5130.0

1.5 IV.3. Compare three scenarios

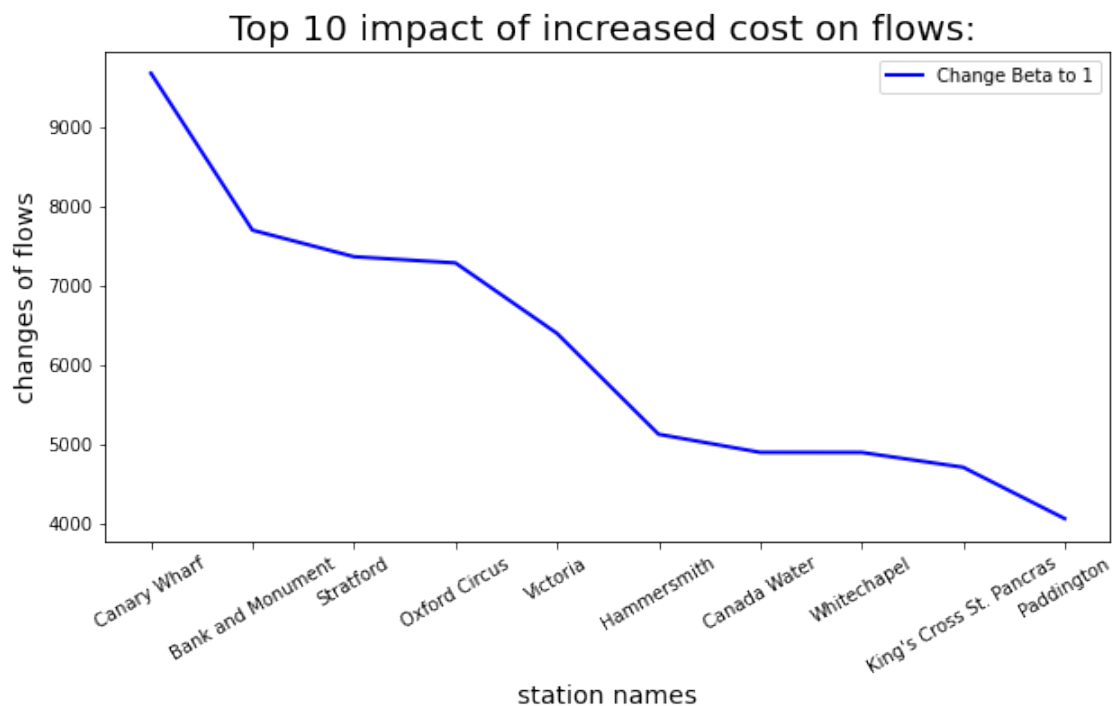
```
[127]: # plot the line chart
plt.figure(figsize=(10,5))
plt.title('Top 10 impact of decreased jobs on flows: ',fontsize=20)
plt.xlabel('station names',fontsize=14)
plt.ylabel('changes of flows',fontsize=14)

in1, = plt.plot(changes_job['station_destination'][0:
    ↪10],changes_job['changes_flows1_abs'][0:10],color="green",linewidth=2)
plt.xticks(rotation=30)
plt.legend(handles = [in1,],labels=['changes_flows1_abs'],loc=1)
plt.show()
```



```
[128]: # plot the line chart
plt.figure(figsize=(10,5))
plt.title('Top 10 impact of increased cost on flows: ',fontsize=20)
plt.xlabel('station names',fontsize=14)
plt.ylabel('changes of flows',fontsize=14)

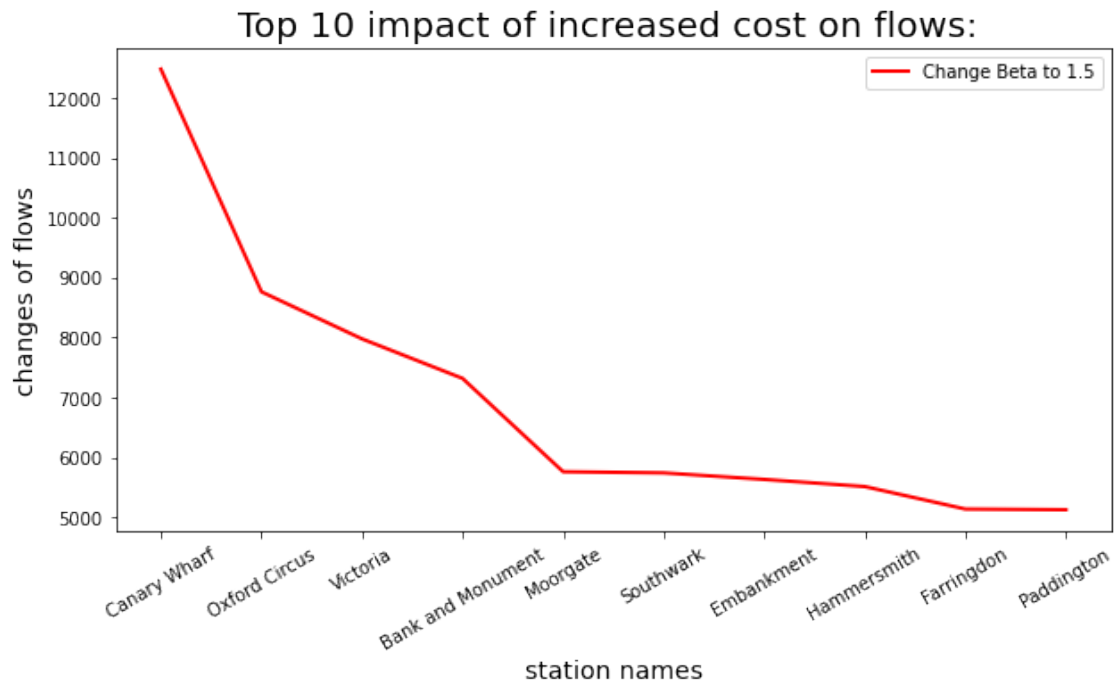
in1, = plt.plot(changes_cost1['station_destination'][0:
↪10],changes_cost1['changes_flows2_abs'][0:10],color="blue",linewidth=2)
plt.xticks(rotation=30)
plt.legend(handles = [in1,],labels=['Change Beta to 1'],loc=1)
plt.show()
```



```
[129]: # plot the line chart
plt.figure(figsize=(10,5))
plt.title('Top 10 impact of increased cost on flows: ',fontsize=20)
plt.xlabel('station names',fontsize=14)
plt.ylabel('changes of flows',fontsize=14)

in1, = plt.plot(changes_cost2['station_destination'][0:
↪10],changes_cost2['changes_flows3_abs'][0:10],color="red",linewidth=2)
plt.xticks(rotation=30)
plt.legend(handles = [in1,],labels=['Change Beta to 1.5'],loc=1)
```

```
plt.show()
```



```
[130]: changes_job_plot=changes_job
changes_job_plot=changes_job_plot.drop(['station_destination','flows',
↳ 'prodsimest2','changes_flows1'], axis=1)
changes_job_plot["rank"]= range(len(changes_job_plot))
changes_job_plot
```

```
[130]:
```

	changes_flows1_abs	rank
54	28291.0	0
326	18165.0	1
15	15679.0	2
251	13043.0	3
355	8710.0	4
..
187	15.0	393
222	15.0	394
57	13.0	395
190	7.0	396
22	3.0	397

```
[398 rows x 2 columns]
```

```
[131]: changes_cost1_plot=changes_cost1
changes_cost1_plot=changes_cost1_plot.drop(['station_destination','flows',
↳ 'prodsimest3','changes_flows2'], axis=1)
changes_cost1_plot["rank"]= range(len(changes_cost1_plot))
changes_cost1_plot
```

```
[131]:      changes_flows2_abs  rank
54                9677.0     0
15                7699.0     1
326               7365.0     2
251               7286.0     3
355               6398.0     4
..                ...     ...
36                 3.0    393
22                 3.0    394
102                3.0    395
136                1.0    396
118                1.0    397
```

[398 rows x 2 columns]

```
[132]: changes_cost2_plot=changes_cost2
changes_cost2_plot=changes_cost2_plot.drop(['station_destination','flows',
↳ 'prodsimest4','changes_flows3'], axis=1)
changes_cost2_plot["rank"]= range(len(changes_cost2_plot))
changes_cost2_plot
```

```
[132]:      changes_flows3_abs  rank
54                12475.0     0
251               8763.0     1
355               7978.0     2
15                7319.0     3
227               5763.0     4
..                ...     ...
156                3.0    393
260                2.0    394
189                2.0    395
181                1.0    396
329                1.0    397
```

[398 rows x 2 columns]

```
[133]: # plot the line chart
plt.figure(figsize=(10,5))
plt.title('Impact in flows under three scenarios: ',fontsize=20)
plt.xlabel('Rank',fontsize=14)
plt.ylabel('changes of flows',fontsize=14)
```



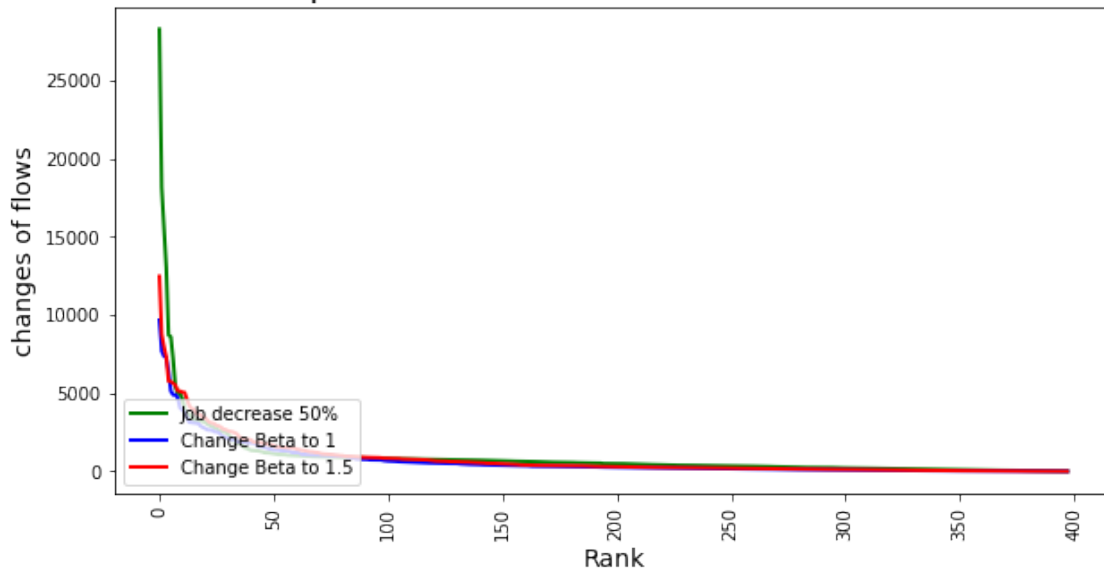
```

in1, = plt.
    ↳plot(changes_job_plot['rank'],changes_job_plot['changes_flows1_abs'],color="green",linewidth=2)
in2, = plt.
    ↳plot(changes_cost1_plot['rank'],changes_cost1_plot['changes_flows2_abs'],color="blue",linewidth=2)
in3, = plt.
    ↳plot(changes_cost2_plot['rank'],changes_cost2_plot['changes_flows3_abs'],color="red",linewidth=2)

plt.xticks(rotation=90)
plt.legend(handles = [in1,in2,in3,],labels=['Job decrease 50%', 'Change Beta to 1', 'Change Beta to 1.5'],loc=3)
plt.show()

```

Impact in flows under three scenarios:



```

[134]: changes_job_plot1=changes_job_plot[0:10]
        changes_cost1_plot1=changes_cost1_plot[0:10]
        changes_cost2_plot1=changes_cost2_plot[0:10]

```

```

[135]: # plot the line chart
        plt.figure(figsize=(10,5))
        plt.title('Top 10 impact in flows under three scenarios: ',fontsize=20)
        plt.xlabel('Rank',fontsize=14)
        plt.ylabel('changes of flows',fontsize=14)

        in1, = plt.
            ↳plot(changes_job_plot1['rank'],changes_job_plot1['changes_flows1_abs'],color="green",linewidth=2)

```

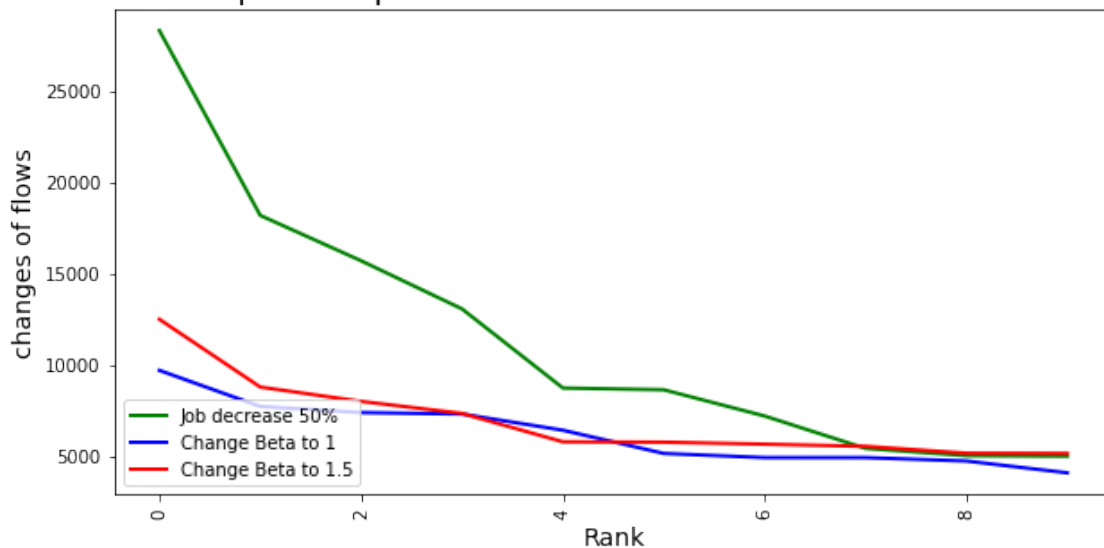
```

in2, = plt.
    plot(changes_cost1_plot1['rank'],changes_cost1_plot1['changes_flows2_abs'],color="blue",lin
in3, = plt.
    plot(changes_cost2_plot1['rank'],changes_cost2_plot1['changes_flows3_abs'],color="red",line

plt.xticks(rotation=90)
plt.legend(handles = [in1,in2,in3,],labels=['Job decrease 50%','Change Beta to 1',
    'Change Beta to 1.5'],loc=3)
plt.show()

```

Top 10 impact in flows under three scenarios:



```

[136]: changes_job_plot2=np.mean(changes_job['changes_flows1_abs'])
        changes_cost1_plot2=np.mean(changes_cost1['changes_flows2_abs'])
        changes_cost2_plot2=np.mean(changes_cost2['changes_flows3_abs'])

```

```

[137]: plt.figure(figsize=(10,5))
        plt.title('Mean absolute changes of flows for three scenarios: ',fontsize=20)
        plt.ylabel('Mean absolute changes of flows',fontsize=14)
        num_list = [changes_job_plot2, changes_cost1_plot2, changes_cost2_plot2]
        name_list = ['Job decrease 50%','Change Beta to 1','Change Beta to 1.5']
        plt.bar(range(len(num_list)),num_list,color = "rgb",tick_label=name_list)
        plt.show()

```

/usr/local/lib/python3.7/dist-packages/ipykernel_launcher.py:6:
MatplotlibDeprecationWarning: Using a string of single character colors as a
color sequence is deprecated. Use an explicit list instead.

Mean absolute changes of flows for three scenarios:

