Catepillar_Visualization_Preprocessing

May 28, 2017

1 Caterpillar Tube Pricing

1.1 Project 1 - Visualization and Data Preprocessing

1.1.1 Team Members:

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Model quoted prices for industrial tube assemblies
Source: Kaggle
https://www.kaggle.com/c/caterpillar-tube-pricing
21 files provided 3 files merged using SQL: train_set, specs, tube

Data Set Description Caterpillar builds large earth moving machines for constructions and mining. Each machine comprises of several smaller componenents including tubes to help keep the moving parts moving. There are two tube assemblies that come in a number of dimentions with several base materials, number of bends, bend radius, bolt patterns, and end types. Our team decided to use tubing data set for this project, predicting the price a supplier will quote for a given assembly.

The goal from the following section is to interrogate various contributing factors in the assembly, the structure/bend/dimension factor of each tube, sub components, vendor, and the pricing per quantity. The result of this section will produce a single data set with relevant attributes both continuous and categorical. In an effort to create a single data set from several different data files SQL was used to do a join before further formatting the data. The outcome is a single data set consisting of approximately 30K records with 32 columns. This columns with different variable names are described below.

tube_assembly_id: This variable is to identify the tube.

supplier: This variable holds the vendor's identification number.

quote_date: This variable has the date of the quote. The formatting was done to this variable.

annual_usage: This variable is tied to the date of the quote and stores the usage.

min_order_quantity: This variable is tied to the price as the quantity is used for pricing.

bracket_pricing: This variable holds the pricing with or without bracket.

quantity: The cost is given assuming purchase of quantity of tubes.

cost tube_assembly: This variable holds the price based on the quantity ordered.

spec1 - spec10: These variables hold the unique specifications with respective codes for the tube assembly.

material_id: This variable holds the code for the material.

diameter: This variable holds the diameter of the ordered tube.
wall: This variable holds the thickness of the tube wall.
length: This variable holds the length of the tube.
num_bends: The variable holds the number of bends in a given tube assembly.
bend_radius: This varibale holds the radius of the respected bend.
end_a_1x, end_a_2x, end_x_1x, end_x_2x, end_a, end_x: These variables hold the code for the shape of different ends of the tube.
num_boss: This variable holds the quantity of boss.
num_bracket: This variable holds the number of brackets in a given tube.

Tube Assemblies are made of multiple parts. The main piece is the tube which has a specific diameter, wall thickness, length, number of bends and bend radius. Either end of the tube (End A or End X) typically has some form of end connection allowing the tube assembly to attach to other features. Special tooling is typically required for short end straight lengths (end_a_1x, end_a_2x refer to if the end length is less than 1 times or 2 times the tube diameter, respectively). Other components can be permanently attached to a tube such as bosses, brackets or other custom features.

Prices can be quoted in 2 ways: bracket and non-bracket pricing. Bracket pricing has multiple levels of purchase based on quantity (in other words, the cost is given assuming a purchase of quantity tubes). Non-bracket pricing has a minimum order amount (min_order) for which the price would apply. Each quote is issued with an annual_usage, an estimate of how many tube assemblies will be purchased in a given year.

```
In [1]: %matplotlib inline
        import pandas as pd
        import numpy as np
        import matplotlib.pyplot as plt
        import seaborn as sns
        from scipy.optimize import curve_fit

        # import consolidated file

        df = pd.read_csv('/Users/GS7271/Documents/MSDS7331/Project/train_set.csv')

        # eliminate redundant primary keys leftover from SQL merge

        del df['tube_assembly']
        del df['tube_assembly.1']
        del df['spec10']

        # convert variables to the right type

        df['quote_date'] = pd.to_datetime(df['quote_date'],format="%Y-%m-%d")

        df = df.replace("Y", 1)
        df = df.replace("N", 0)
        df = df.replace("Yes", 1)
        df = df.replace("No", 0)
```

```
df['bracket_pricing']=df['bracket_pricing'].astype('bool')
df['end_a_1x']=df['end_a_1x'].astype('bool')
df['end_a_2x']=df['end_a_2x'].astype('bool')
df['end_x_1x']=df['end_x_1x'].astype('bool')
df['end_x_2x']=df['end_x_2x'].astype('bool')

# group variables per type

continuous_features = ['cost', 'diameter', 'wall', 'length', 'bend_radius']
categ_features = ['tube_assembly_id', 'supplier', 'spec1', 'spec2', 'spec3'
boolean_features = ['bracket_pricing','end_a_1x', 'end_a_2x', 'end_x_1x', '
integer_features = ['annual_usage', 'quantity', 'min_order_quantity', 'num_

df[integer_features] = df[integer_features].astype(np.int64)

print(df.info())
df.dtypes
df.tail()
```

```
<class 'pandas.core.frame.DataFrame'>
RangeIndex: 30213 entries, 0 to 30212
Data columns (total 32 columns):
tube_assembly_id      30213 non-null object
supplier              30213 non-null object
quote_date            30213 non-null datetime64[ns]
annual_usage          30213 non-null int64
min_order_quantity    30213 non-null int64
bracket_pricing       30213 non-null bool
quantity              30213 non-null int64
cost                  30213 non-null float64
spec1                 5797 non-null object
spec2                 5551 non-null object
spec3                 4650 non-null object
spec4                 3336 non-null object
spec5                 2312 non-null object
spec6                 1687 non-null object
spec7                 306 non-null object
spec8                 56 non-null object
spec9                 4 non-null object
material_id           29984 non-null object
diameter              30213 non-null float64
wall                  30213 non-null float64
length                30213 non-null float64
num_bends             30213 non-null int64
bend_radius           30213 non-null float64
end_a_1x              30213 non-null bool
end_a_2x              30213 non-null bool
end_x_1x              30213 non-null bool
```

```
end_x_2x              30213 non-null bool
end_a                 30213 non-null object
end_x                 30213 non-null object
num_boss              30213 non-null int64
num_bracket           30213 non-null int64
other                 30213 non-null int64
dtypes: bool(5), datetime64[ns](1), float64(5), int64(7), object(14)
memory usage: 6.4+ MB
None
```

```
Out[1]:       tube_assembly_id supplier quote_date  annual_usage  min_order_quantit
        30208          TA-21190   S-0041 2013-09-10           869                 7
        30209          TA-21191   S-0041 2013-09-10           752
        30210          TA-21195   S-0041 2013-08-05             1                 8
        30211          TA-21196   S-0062 2005-05-09           422
        30212          TA-21197   S-0026 2009-07-30             3

              bracket_pricing  quantity       cost    spec1    spec2  ...    \
        30208           False        75   5.945260      NaN      NaN  ...
        30209           False         1   6.131658  SP-0007  SP-0024  ...
        30210           False        80   5.066130      NaN      NaN  ...
        30211           False         1  18.214141  SP-0007  SP-0080  ...
        30212           False         1  53.618624  SP-0007  SP-0080  ...

              bend_radius end_a_1x end_a_2x end_x_1x end_x_2x   end_a   end_x  \
        30208       31.75    False    False    False    False  EF-003  EF-018
        30209       31.75    False    False    False    False  EF-003  EF-018
        30210       38.10    False    False    False    False  EF-003  EF-009
        30211       50.80     True     True    False    False  EF-003  EF-017
        30212       50.80     True     True    False    False  EF-003  EF-017

              num_boss  num_bracket  other
        30208        0            0      0
        30209        0            0      0
        30210        0            0      0
        30211        0            0      0
        30212        0            0      0

        [5 rows x 32 columns]
```

```
In [2]: df.describe()
```

```
Out[2]:        annual_usage  min_order_quantity      quantity          cost  \
        count   30213.000000        30213.000000  30213.000000  30213.000000
        mean      120.369377            2.084699     38.389369     13.433317
        std      1590.331872           12.742776     70.761392     28.663200
        min         0.000000            0.000000      1.000000      0.503553
```

25%	0.000000	0.000000	2.000000	3.878190
50%	0.000000	0.000000	10.000000	6.521146
75%	2.000000	0.000000	40.000000	13.431781
max	150000.000000	535.000000	2500.000000	1000.000000

	diameter	wall	length	num_bends	bend_radiu
count	30213.000000	30213.000000	30213.000000	30213.000000	30213.00000
mean	17.223018	1.384782	97.647605	3.813061	42.23122
std	18.125973	0.638610	63.230131	2.199564	200.31345
min	3.180000	0.710000	0.000000	0.000000	0.00000
25%	9.520000	0.890000	48.000000	2.000000	19.05000
50%	12.700000	1.240000	86.000000	3.000000	31.75000
75%	19.050000	1.650000	133.000000	5.000000	50.80000
max	203.200000	7.900000	1333.000000	17.000000	9999.00000

	num_boss	num_bracket	other
count	30213.000000	30213.000000	30213.000000
mean	0.025254	0.003542	0.013603
std	0.184975	0.069664	0.150840
min	0.000000	0.000000	0.000000
25%	0.000000	0.000000	0.000000
50%	0.000000	0.000000	0.000000
75%	0.000000	0.000000	0.000000
max	5.000000	3.000000	8.000000

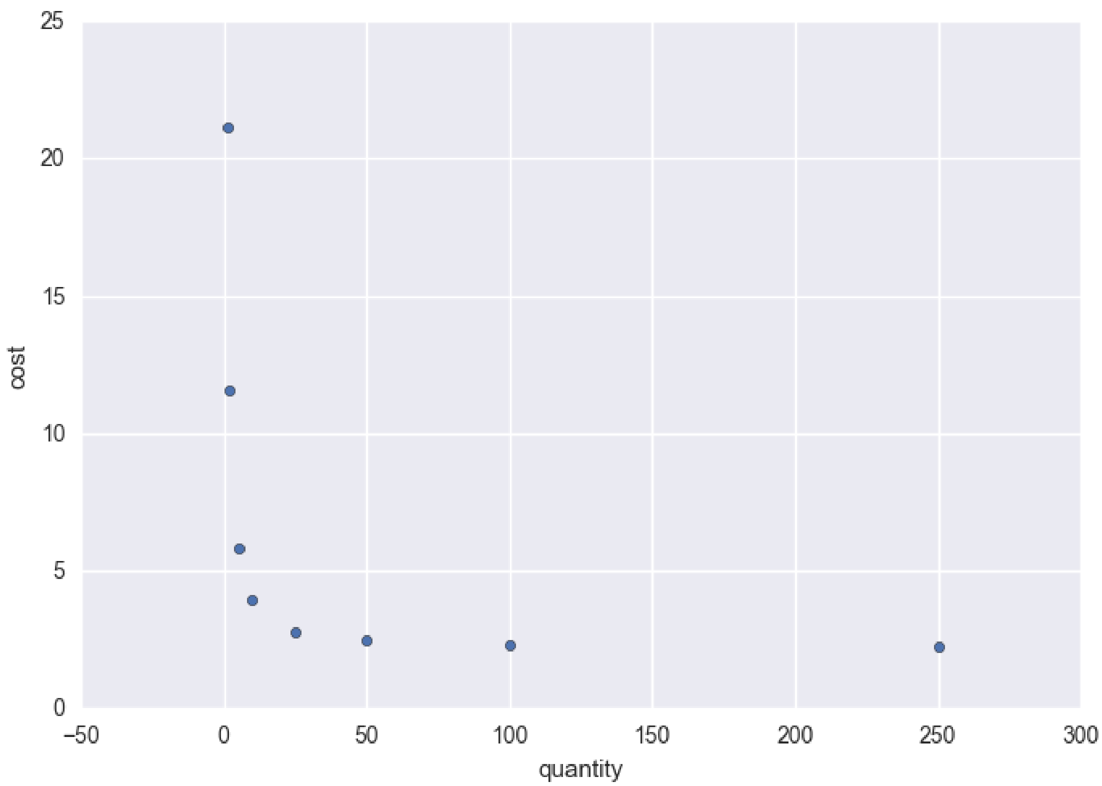
1.1.2 Interactive Chart

Interactive chart that shows cost behavior by quantity

```
In [5]: input_tube_assembly = raw_input('Enter Tube Assembly ID: ')

        df[df.tube_assembly_id == input_tube_assembly].plot.scatter(x = 'quantity',
```

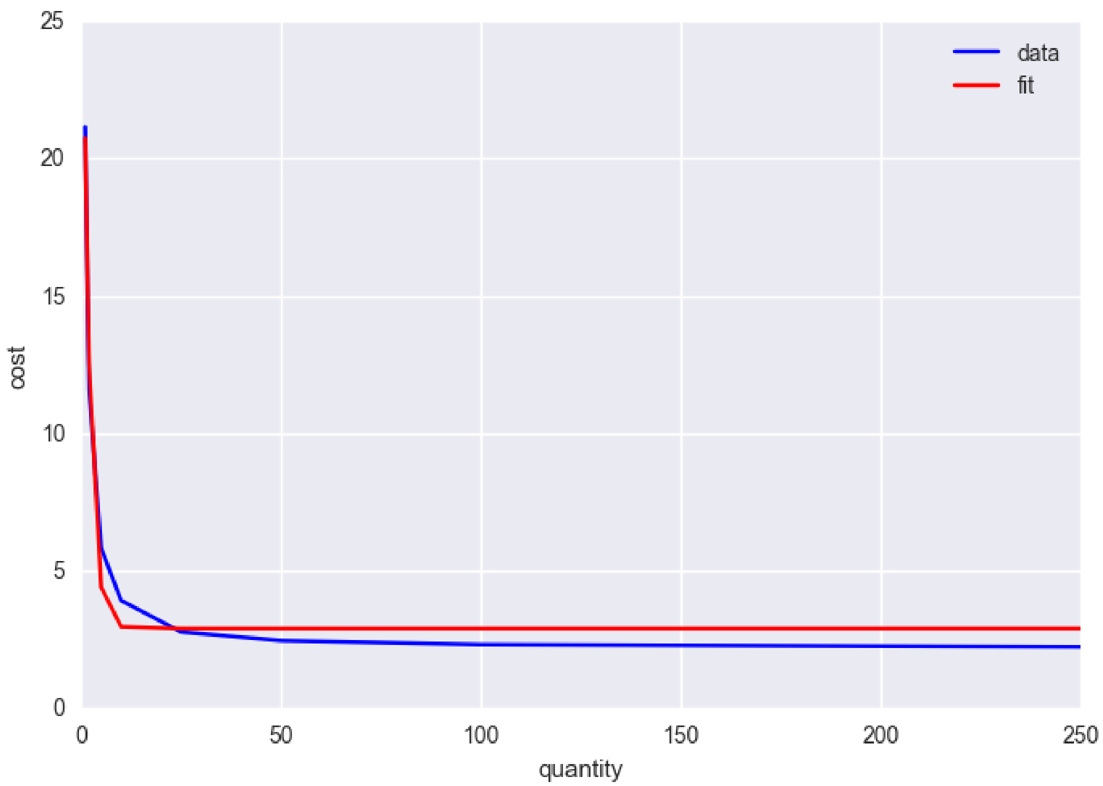
```
Enter Tube Assembly ID: TA-08034
```

```
Out[5]: <matplotlib.axes._subplots.AxesSubplot at 0x116a8f890>
```



1.1.3 Curve fitting

```
In [6]: def func(x, a, b, c):
            return a * np.exp(-b * x) + c

        xdata = df[df.tube_assembly_id == input_tube_assembly].quantity
        ydata = df[df.tube_assembly_id == input_tube_assembly].cost
        popt, pcov = curve_fit(func, xdata, ydata)
        plt.plot(xdata, ydata, 'b-', label='data')
        plt.plot(xdata, func(xdata, *popt), 'r-', label='fit')
        plt.xlabel('quantity')
        plt.ylabel('cost')
        plt.legend()
        plt.show()
```



1.1.4 Elimination of outliers

```
In [53]: # Length cannot be zero
         df_new = df[df.length > 0]
         # Bend radius cannot be greater than 360 degrees
         df_new = df[df.bend_radius <= 360]
```

1.1.5 Log Transformation - Cost has a funnel shape

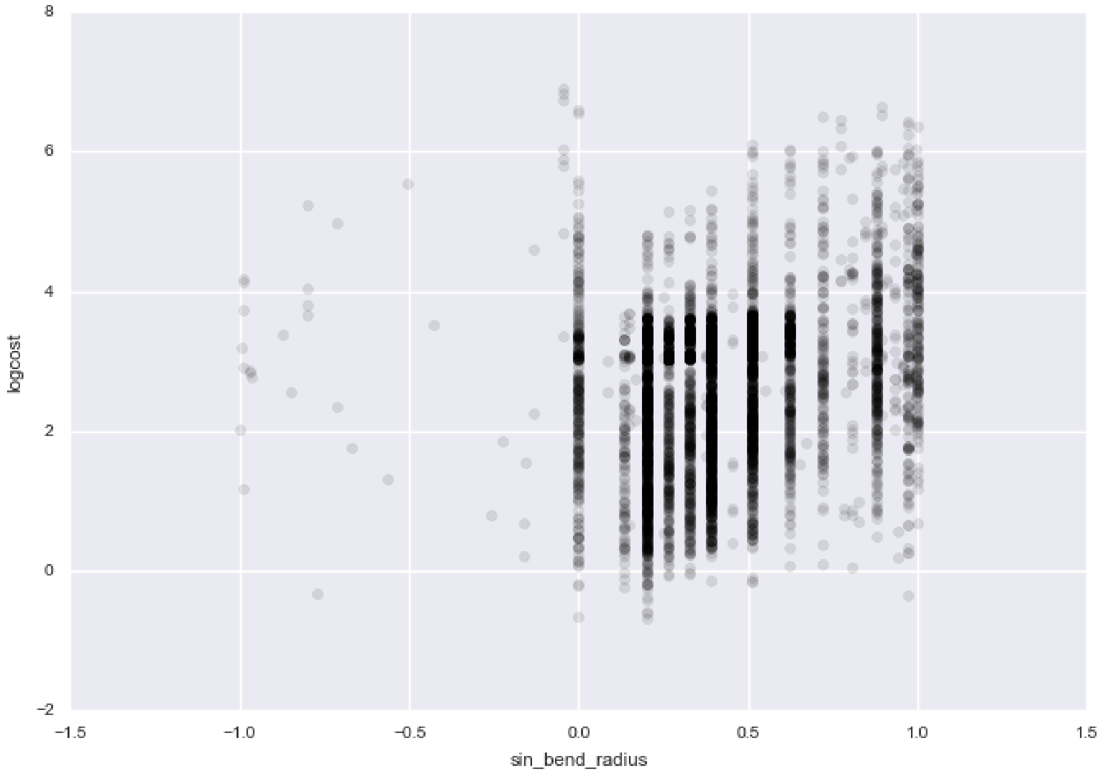
```
In [54]: df_new["logcost"] = np.log(df_new["cost"])
```

```
/Users/GS7271/anaconda/lib/python2.7/site-packages/ipykernel/__main__.py:1: Setting
A value is trying to be set on a copy of a slice from a DataFrame.
Try using .loc[row_indexer,col_indexer] = value instead

See the caveats in the documentation: http://pandas.pydata.org/pandas-docs/stable/i
  if __name__ == '__main__':
```

1.1.6 Sin Transformation - Bend Radius

```
In [55]: df_new["sin_bend_radius"] = np.sin(df_new["bend_radius"])
         ax = df_new[df_new.quantity == 1].plot.scatter(x = 'sin_bend_radius', y =
```

```
/Users/GS7271/anaconda/lib/python2.7/site-packages/ipykernel/__main__.py:1: Setting
A value is trying to be set on a copy of a slice from a DataFrame.
Try using .loc[row_indexer,col_indexer] = value instead

See the caveats in the documentation: http://pandas.pydata.org/pandas-docs/stable/i
  if __name__ == '__main__':
```

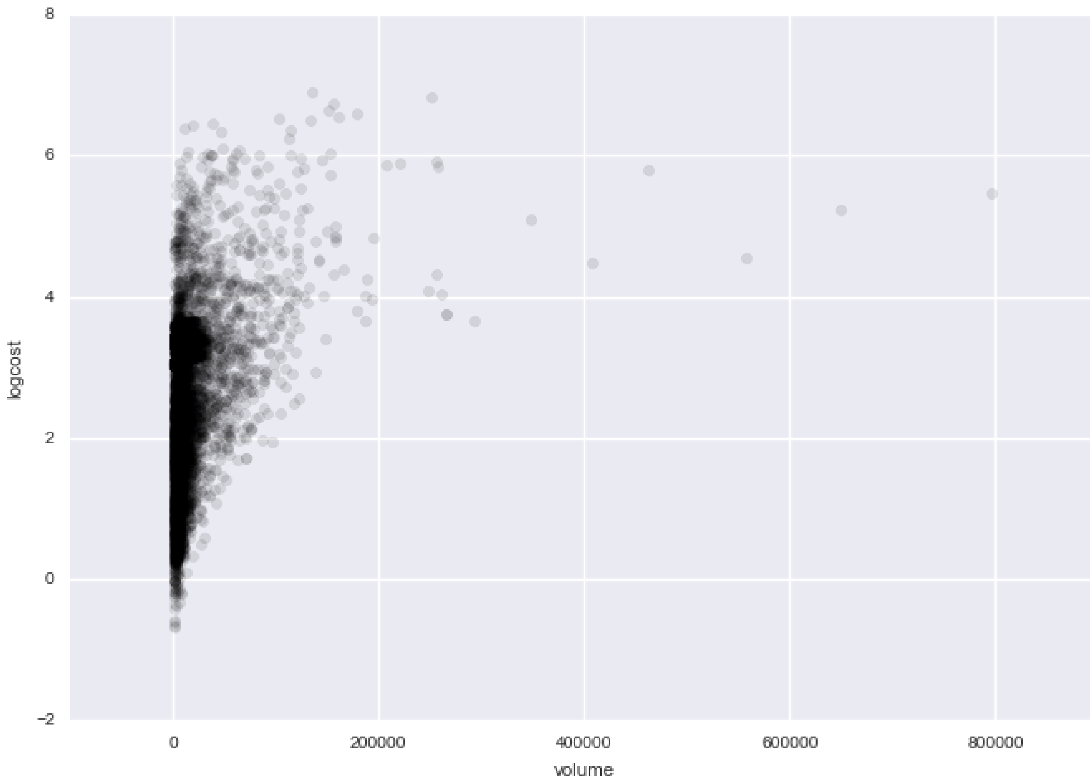


1.1.7 Creation of a New Variable: Volume = *f(wall thickness, diameter, length)*

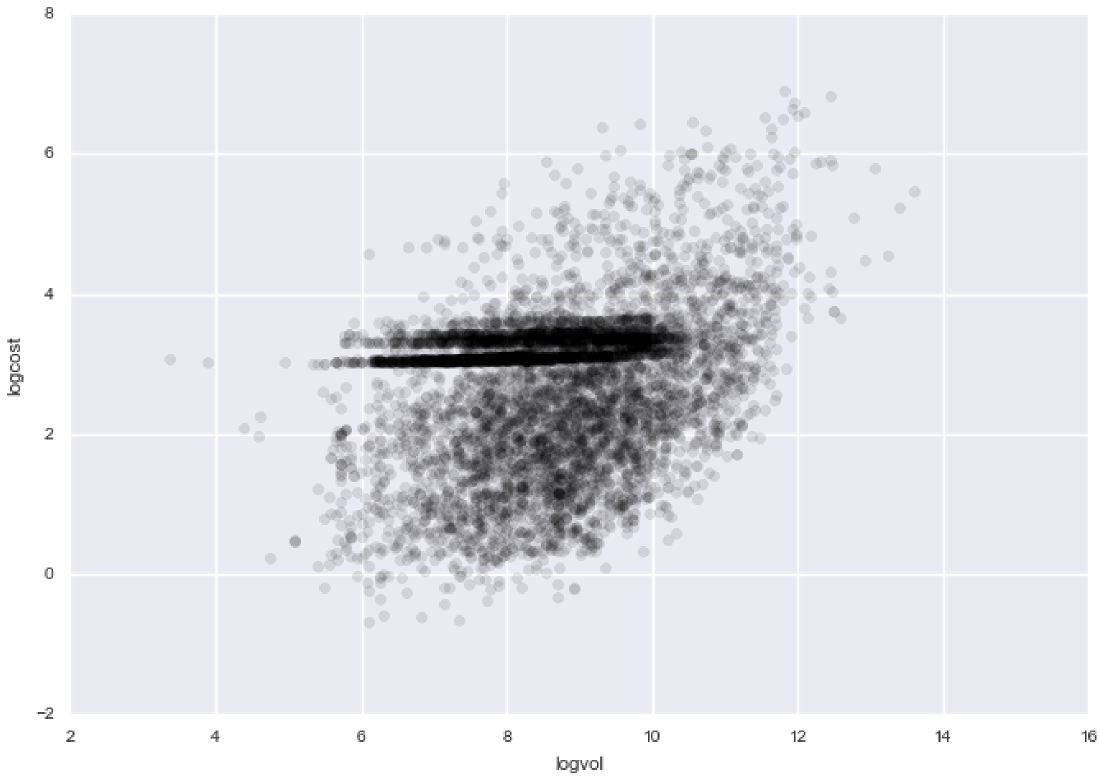
$$Volume = \pi(wall^2 + diameter \times wall)length$$

```
In [61]: df_new = df_new[df_new.length > 0]
```

```
In [63]: import math
         df_new["volume"] = math.pi*(pow((df_new["wall"]), 2) + (df_new["wall"]*df_
         ax = df_new[df_new.quantity == 1].plot.scatter(x = 'volume', y = 'logcost'
```



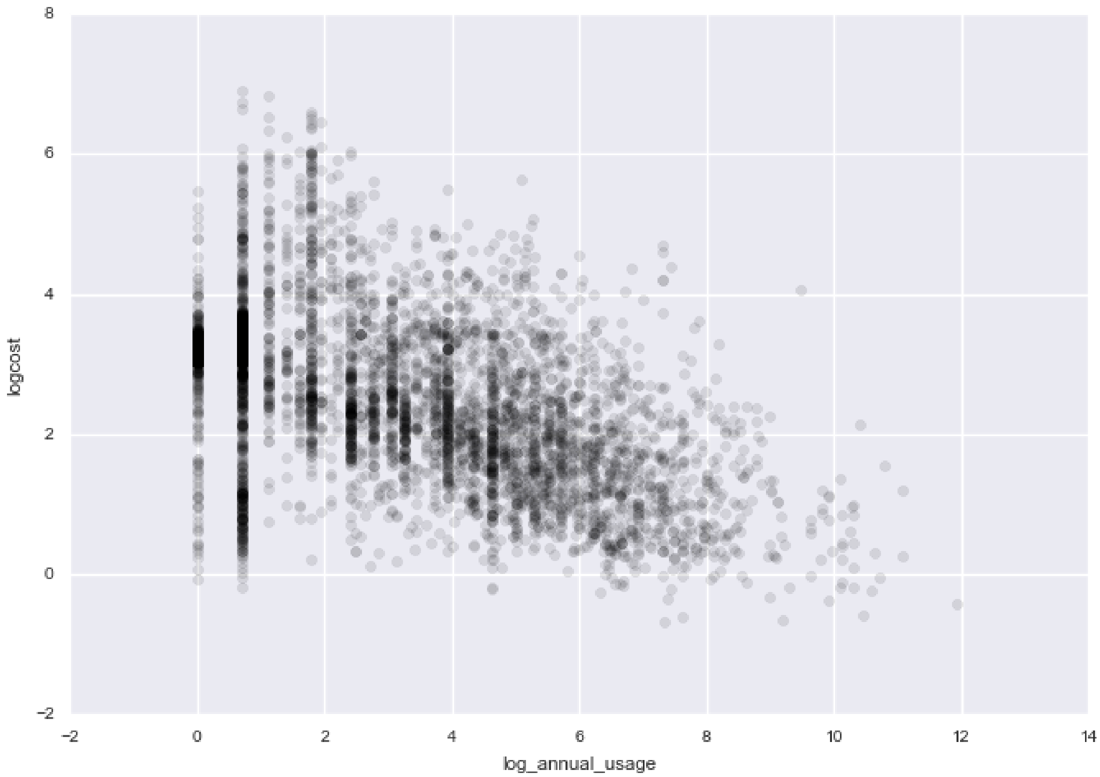

```
In [64]: df_new["logvol"] = np.log(df_new["volume"])
         ax = df_new[df_new.quantity == 1].plot.scatter(x = 'logvol', y = 'logcost'
```




```
In [85]: # Verify that no observations have volume = 0 thus creating an error on tl
         df_new.tube_assembly_id[df_new["volume"] == 0]

Out[85]: Series([], Name: tube_assembly_id, dtype: object)
```

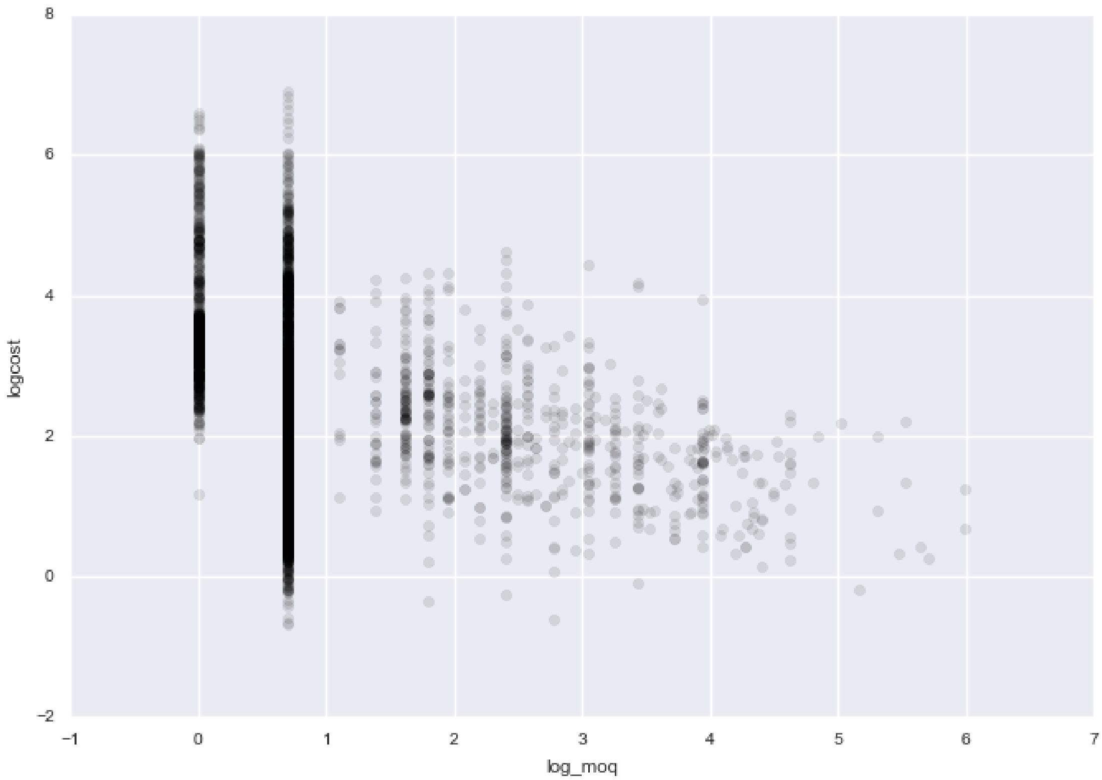
1.1.8 Log Transformation - Annual Usage

```
In [75]: df_new["log_annual_usage"] = np.log(df_new["annual_usage"] + 1)
         ax = df_new[df_new.quantity == 1].plot.scatter(x = 'log_annual_usage', y =
```



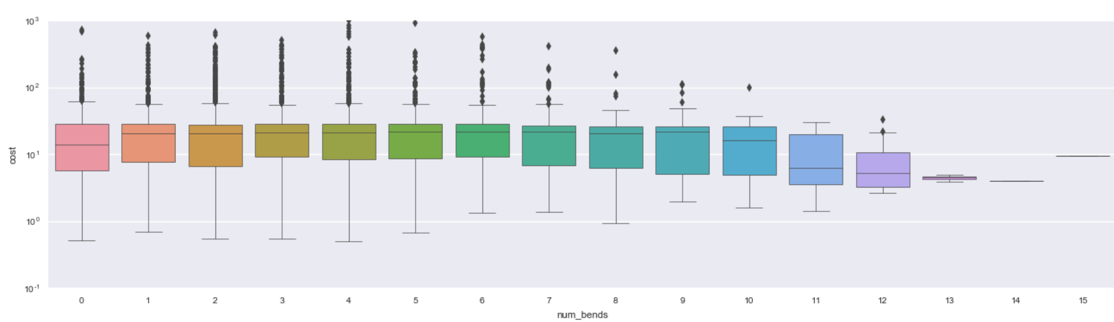
1.1.9 Log Transformation - Min Order Quantity

In [76]:
```
df_new["log_moq"] = np.log(df_new["min_order_quantity"] + 1)
ax = df_new[df_new.quantity == 1].plot.scatter(x = 'log_moq', y = 'logcost
```

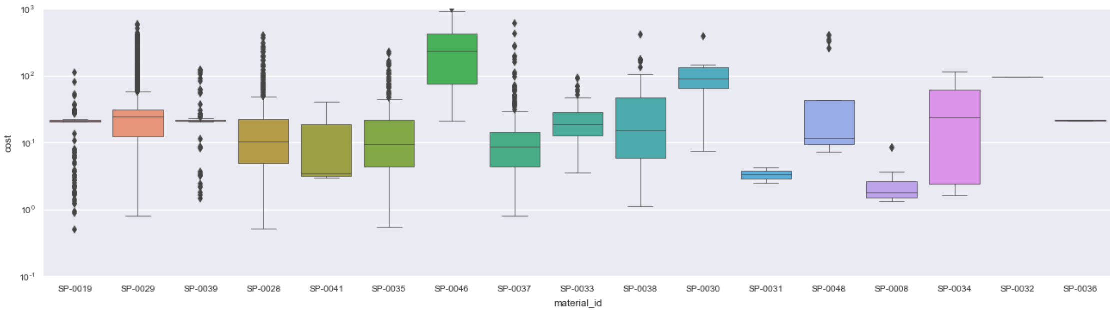


1.1.10 Boxplots of Categorical and Integer Variables

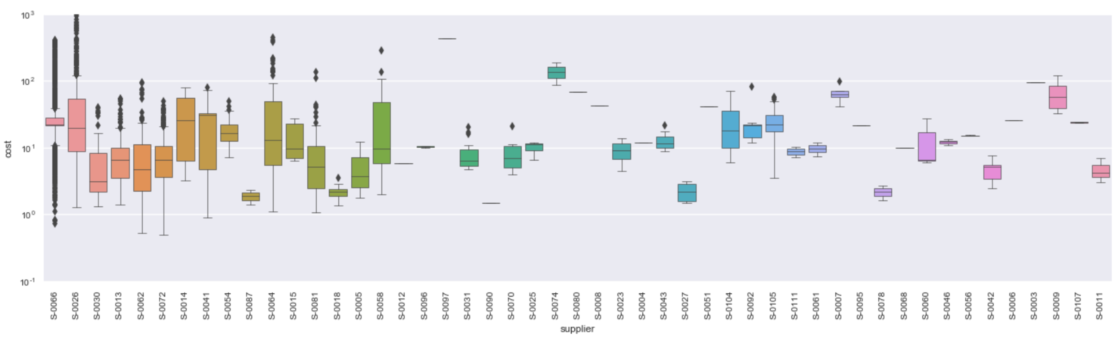
```
In [67]: plt.figure(figsize = (16, 4))
         sns.set_style("darkgrid")
         sns.set_context("notebook", font_scale=0.75, rc={"lines.linewidth": 0.5})
         ax = sns.boxplot(x = "num_bends", y = "cost", data = df_new[df_new.quantit
         sns.despine(left = True)
         ax.set_yscale('log')
```



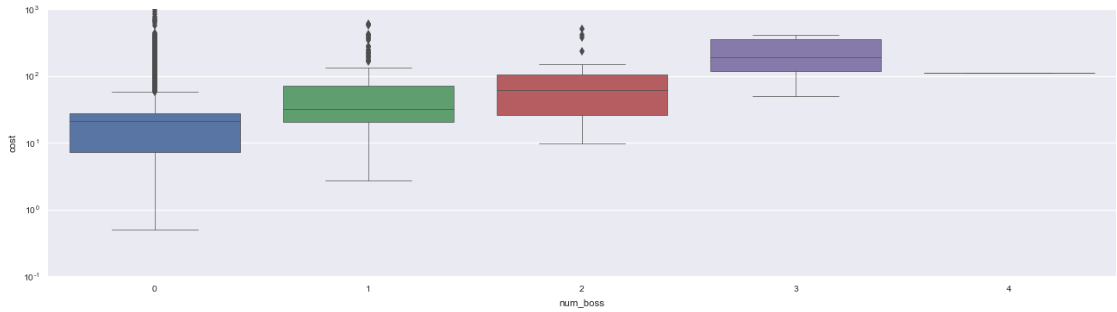
In [68]:
```
plt.figure(figsize = (16, 4))
sns.set_style("darkgrid")
sns.set_context("notebook", font_scale=0.75, rc={"lines.linewidth": 0.5})
ax = sns.boxplot(x = "material_id", y = "cost", data = df_new[df_new.quant
sns.despine(left = True)
ax.set_yscale('log')
```



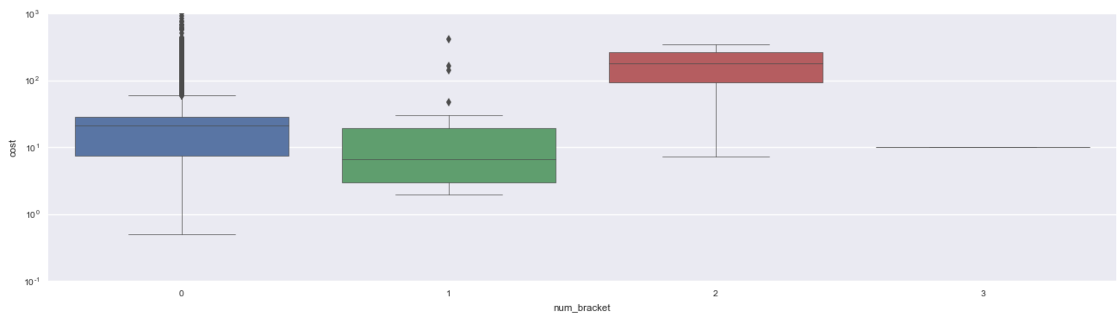
In [69]:
```
plt.figure(figsize = (16, 4))
sns.set_style("darkgrid")
sns.set_context("notebook", font_scale=0.75, rc={"lines.linewidth": 0.5})
ax = sns.boxplot(x = "supplier", y = "cost", data = df_new[df_new.quantity
ax.set_xticklabels(ax.xaxis.get_majorticklabels(), rotation=90)
sns.despine(left = True)
ax.set_yscale('log')
```



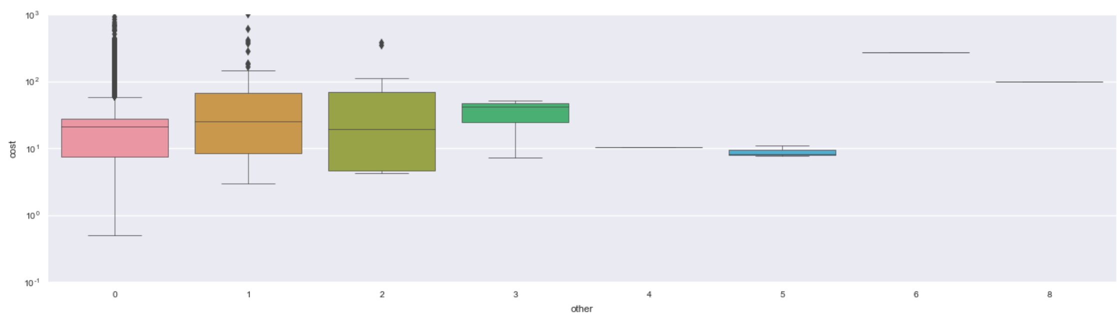
In [70]:
```
plt.figure(figsize = (16, 4))
sns.set_style("darkgrid")
sns.set_context("notebook", font_scale=0.75, rc={"lines.linewidth": 0.5})
ax = sns.boxplot(x = "num_boss", y = "cost", data = df_new[df_new.quantity
sns.despine(left = True)
ax.set_yscale('log')
```



In [71]:
```
plt.figure(figsize = (16, 4))
sns.set_style("darkgrid")
sns.set_context("notebook", font_scale=0.75, rc={"lines.linewidth": 0.5})
ax = sns.boxplot(x = "num_bracket", y = "cost", data = df_new[df_new.quant
sns.despine(left = True)
ax.set_yscale('log')
```

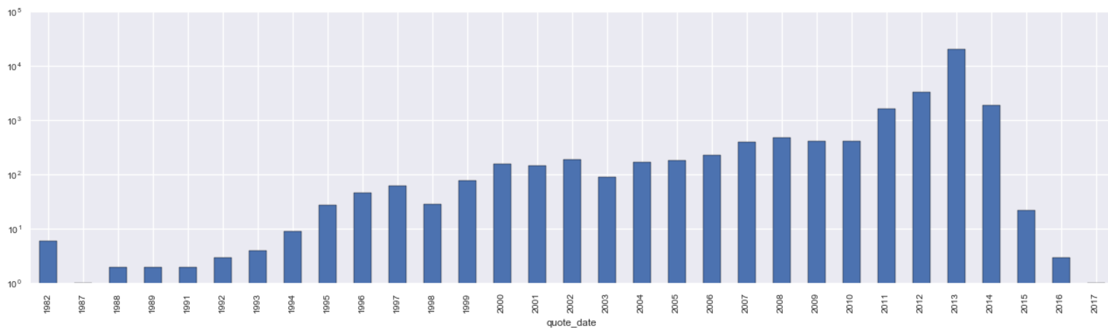


In [72]:
```
plt.figure(figsize = (16, 4))
sns.set_style("darkgrid")
sns.set_context("notebook", font_scale=0.75, rc={"lines.linewidth": 0.5})
ax = sns.boxplot(x = "other", y = "cost", data = df_new[df_new.quantity ==
sns.despine(left = True)
ax.set_yscale('log')
```



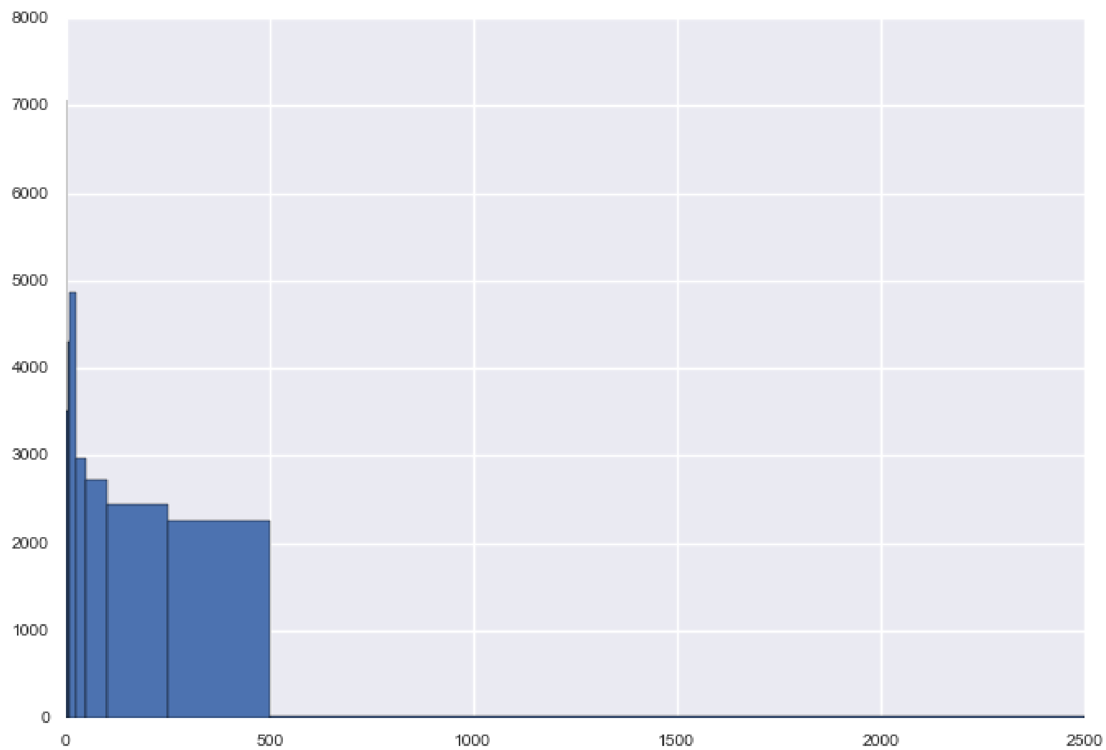
1.1.11 Distribution of Quotes by Year

```
In [73]: plt.figure(figsize = (16, 4))
         ax = df.groupby(df["quote_date"].dt.year)["quote_date"].count().plot(kind=
         ax.set_yscale('log')
```



1.1.12 Histogram of Quoted Quantities

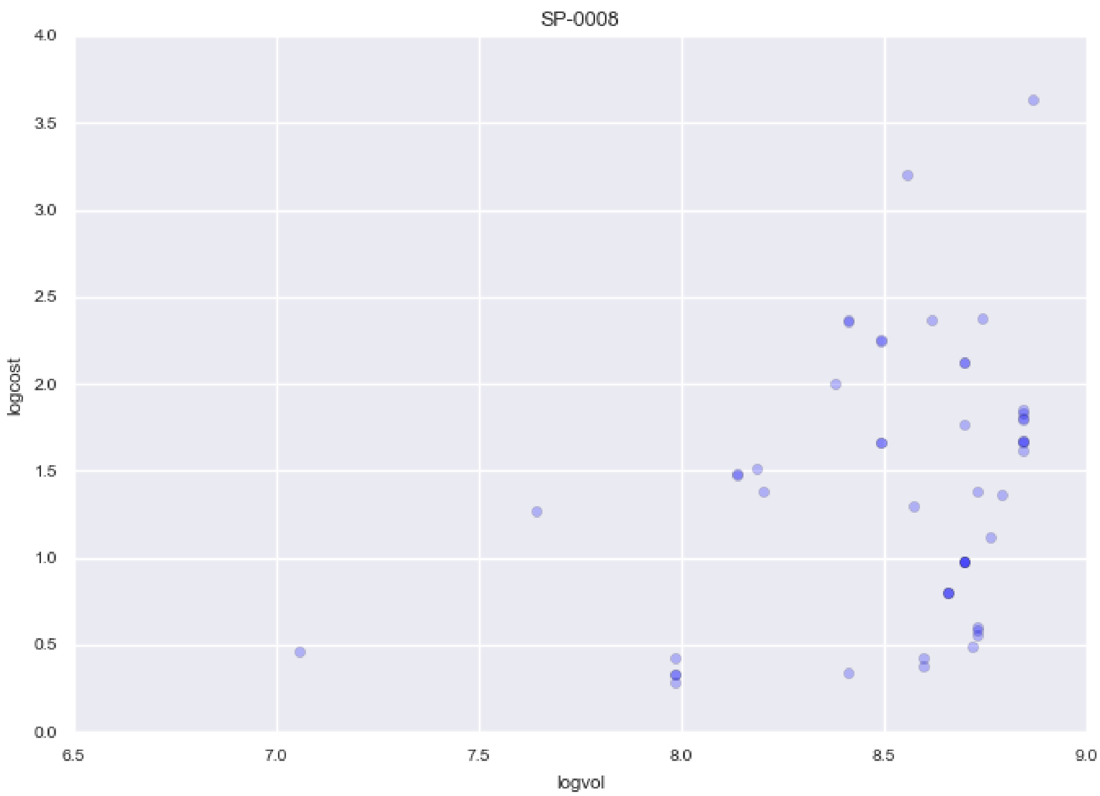
```
In [146]: plt.hist(df_new.quantity, bins = [0, 1, 2, 5, 10, 25, 50, 100, 250, 500,

Out[146]: (array([    0.,   7054.,   3513.,   4300.,   4870.,   2972.,   2725.,   2454.,
                  2256.,     23.]),
           array([   0,     1,     2,     5,    10,    25,    50,   100,   250,   500,  2500]
           <a list of 10 Patch objects>)
```

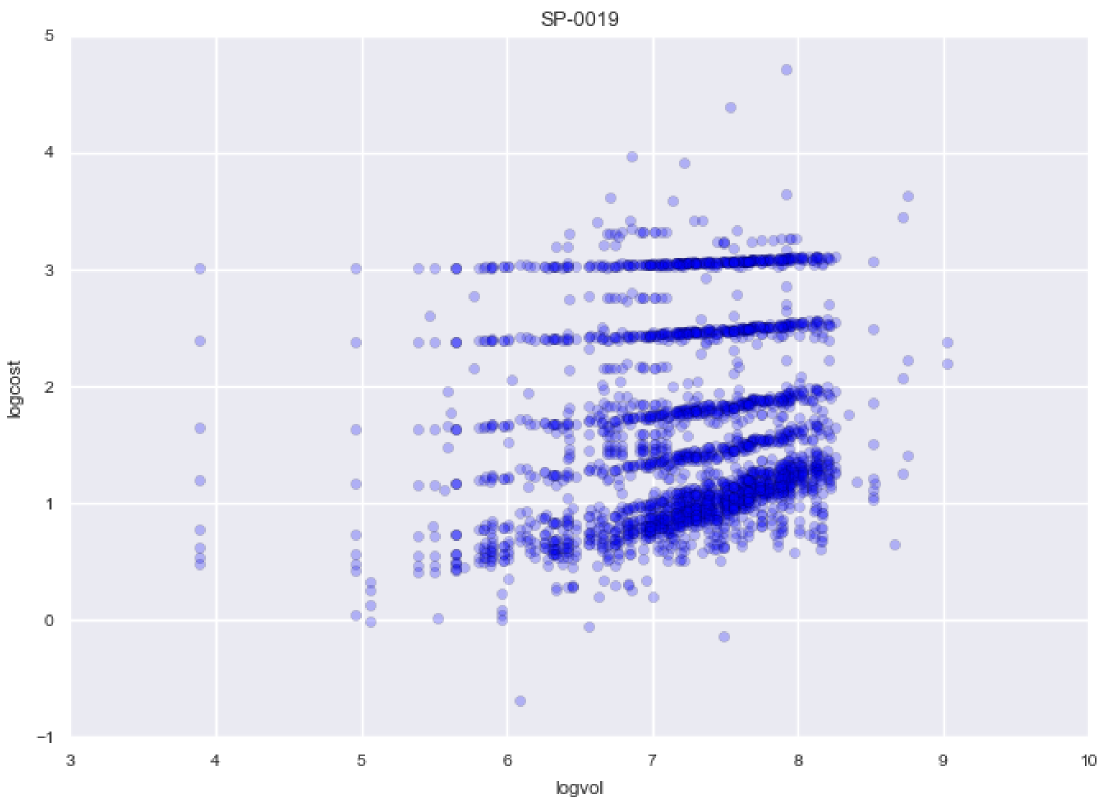


1.1.13 Log Cost as a function of Log Vol by Material

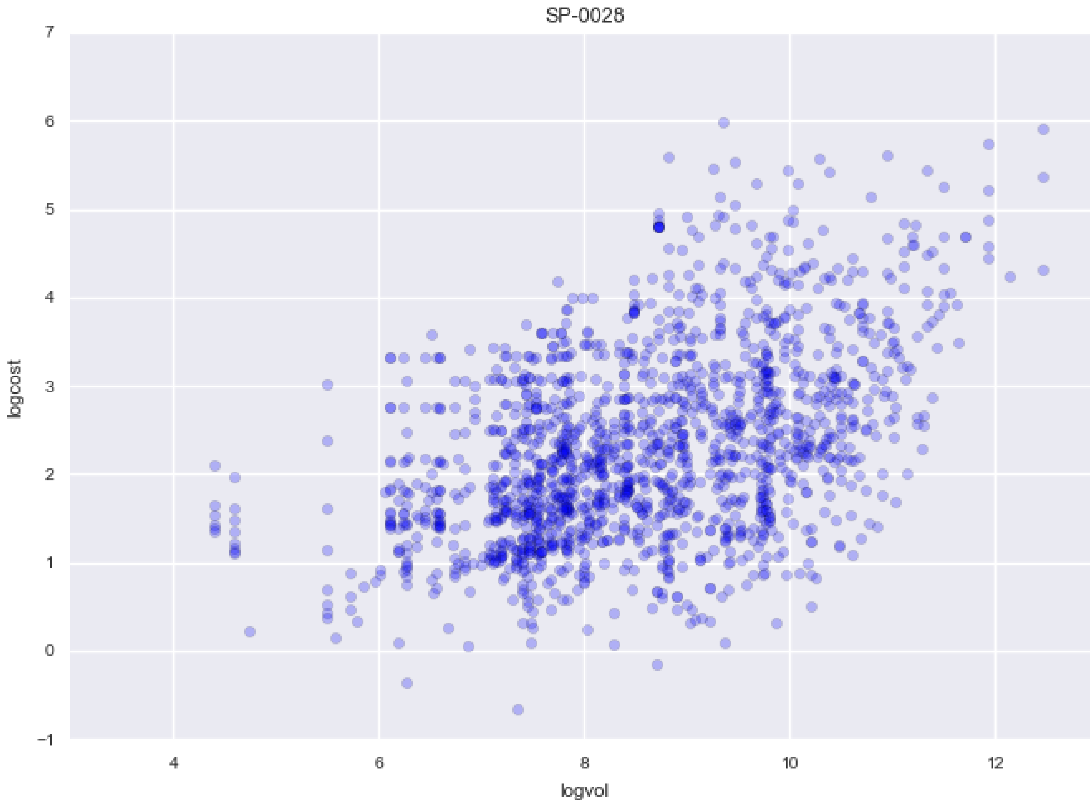
matplotlib.pyplot

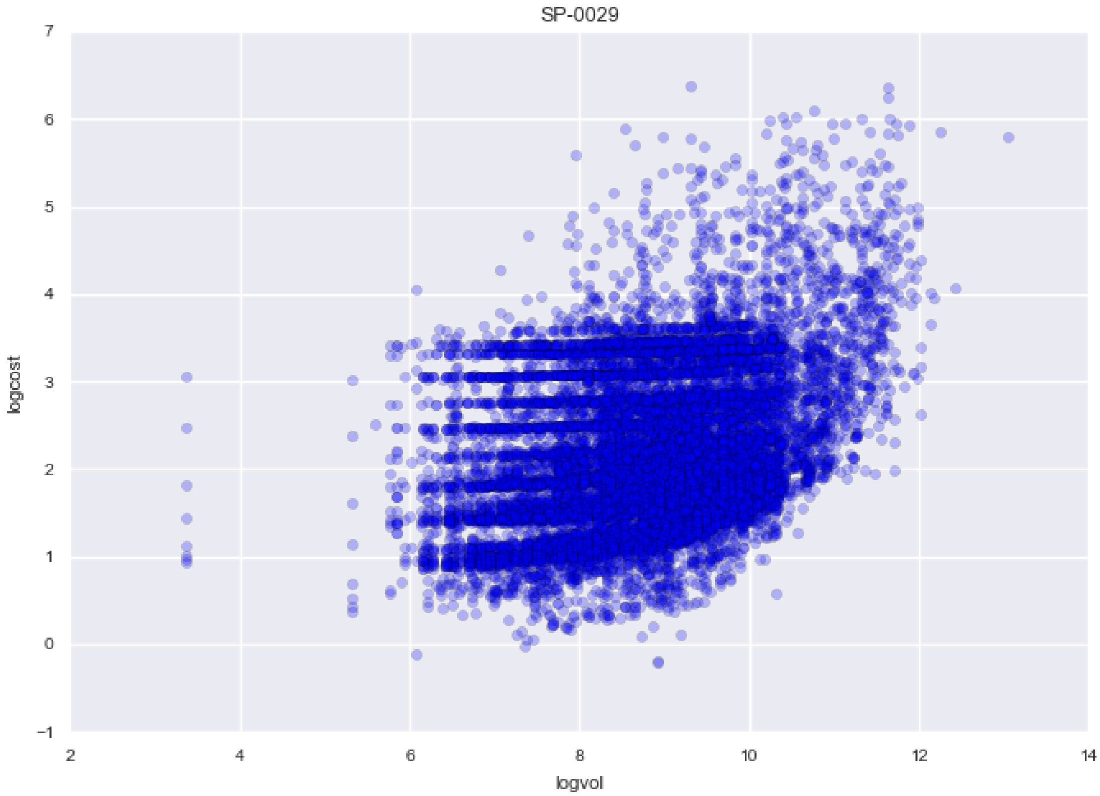
```
In [135]: material_list = list(df_new.material_id.unique())
          material_list = [x for x in material_list if str(x) != 'nan']
          material_list = sorted(material_list)

          for index, material in enumerate(material_list):
              axs[index] = df_new[df_new.material_id == material].plot.scatter(x =
              axs[index].set_title(material)
              index + 1
```

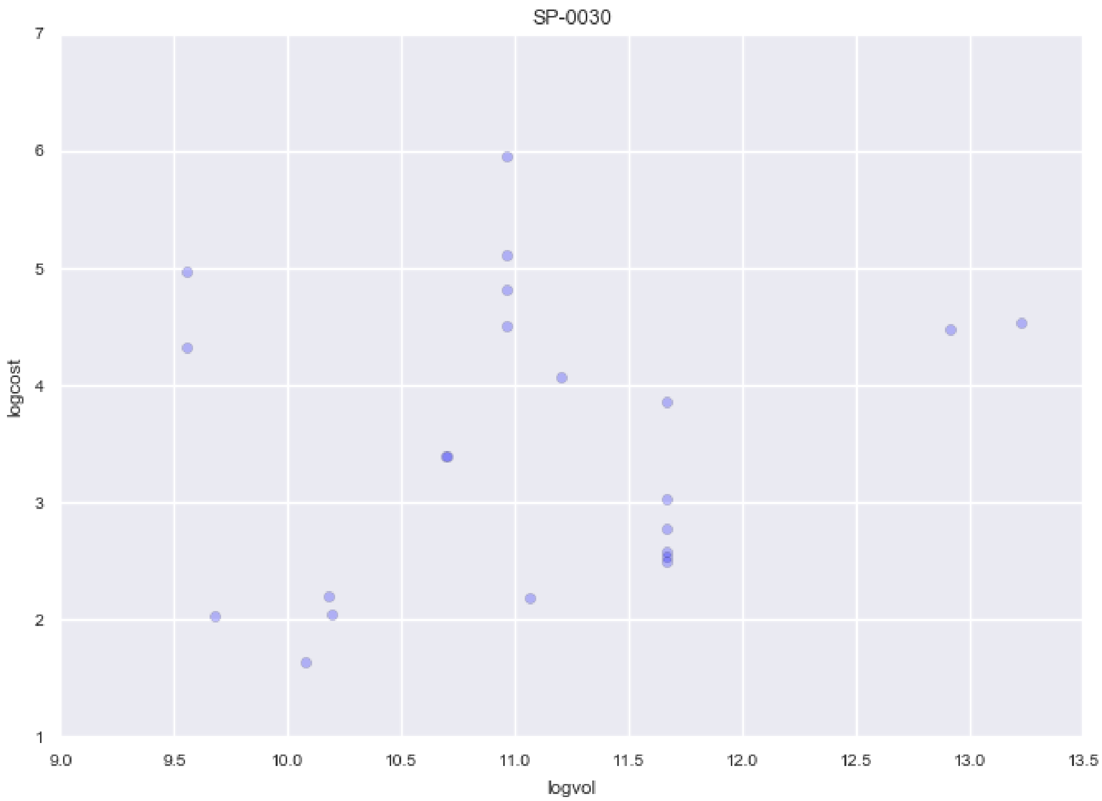

SP-0008
logcost
logvol
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
6.5
7.0
7.5
8.0
8.5
9.0



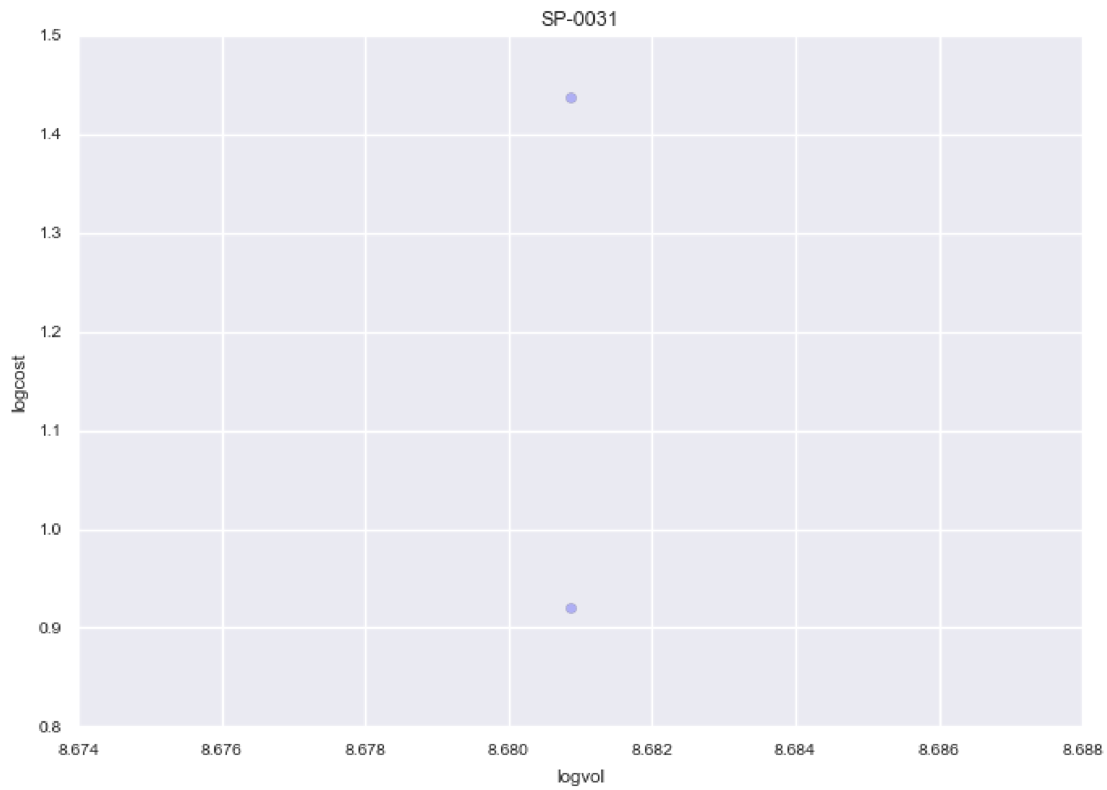
SP-0019
logcost
logvol
5
4
3
2
1
0
−1
3
4
5
6
7
8
9
10

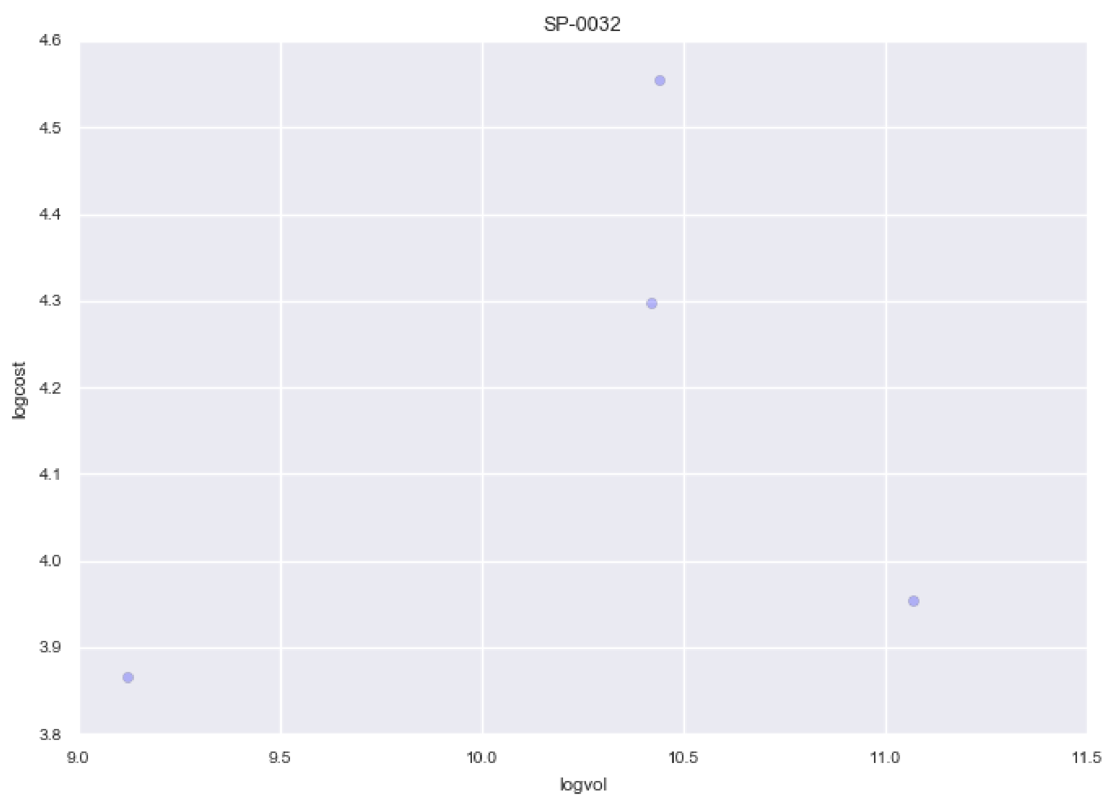

SP-0028
logcost
logvol
7
6
5
4
3
2
1
0
−1
4
6
8
10
12

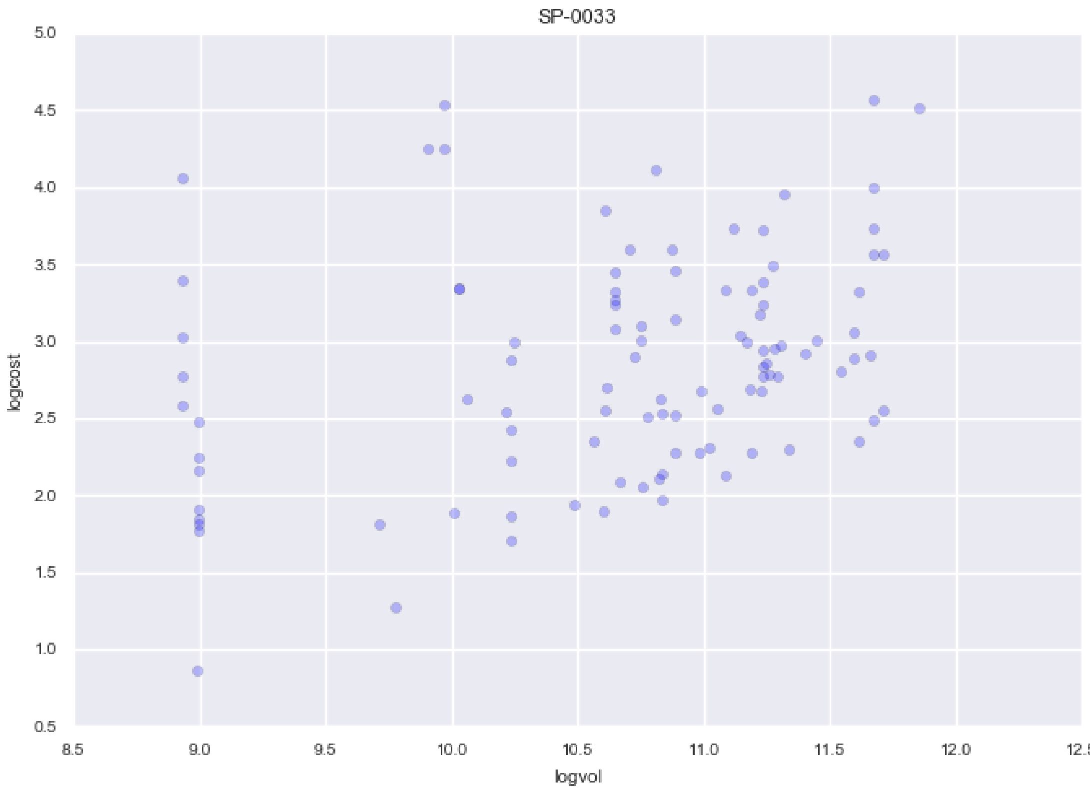

SP-0029
logcost
logvol
7
6
5
4
3
2
1
0
−1
2
4
6
8
10
12
14

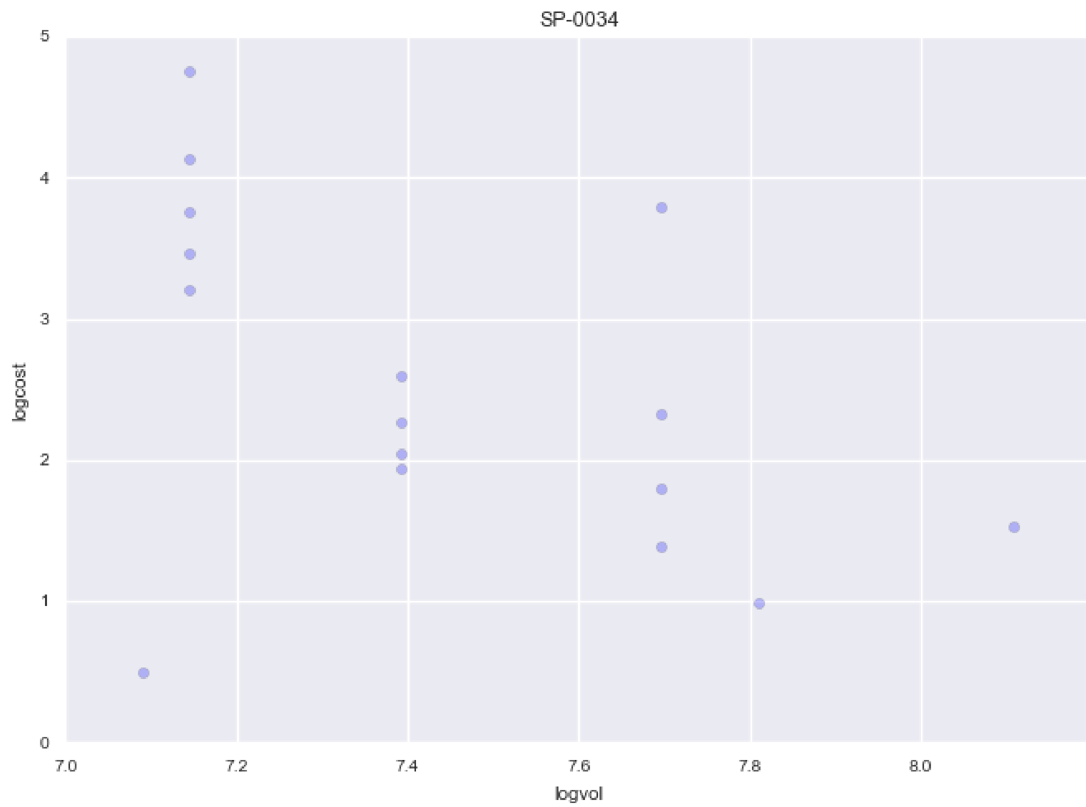


SP-0030
logcost
logvol
7
6
5
4
3
2
1
9.0
9.5
10.0
10.5
11.0
11.5
12.0
12.5
13.0
13.5


SP-0031
1.5
1.4
1.3
1.2
1.1
1.0
0.9
0.8
logcost
8.674
8.676
8.678
8.680
8.682
8.684
8.686
8.688
logvol

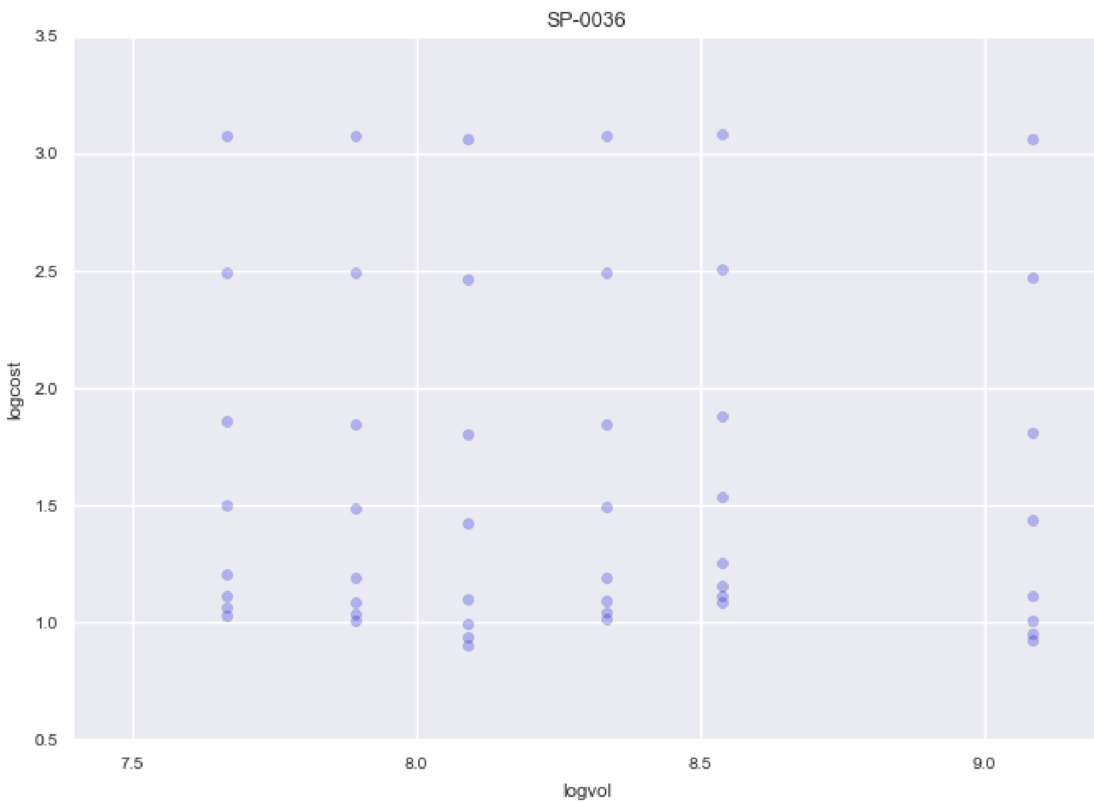

SP-0032
4.6
4.5
4.4
4.3
4.2
4.1
4.0
3.9
3.8
logcost
9.0
9.5
10.0
10.5
11.0
11.5
logvol

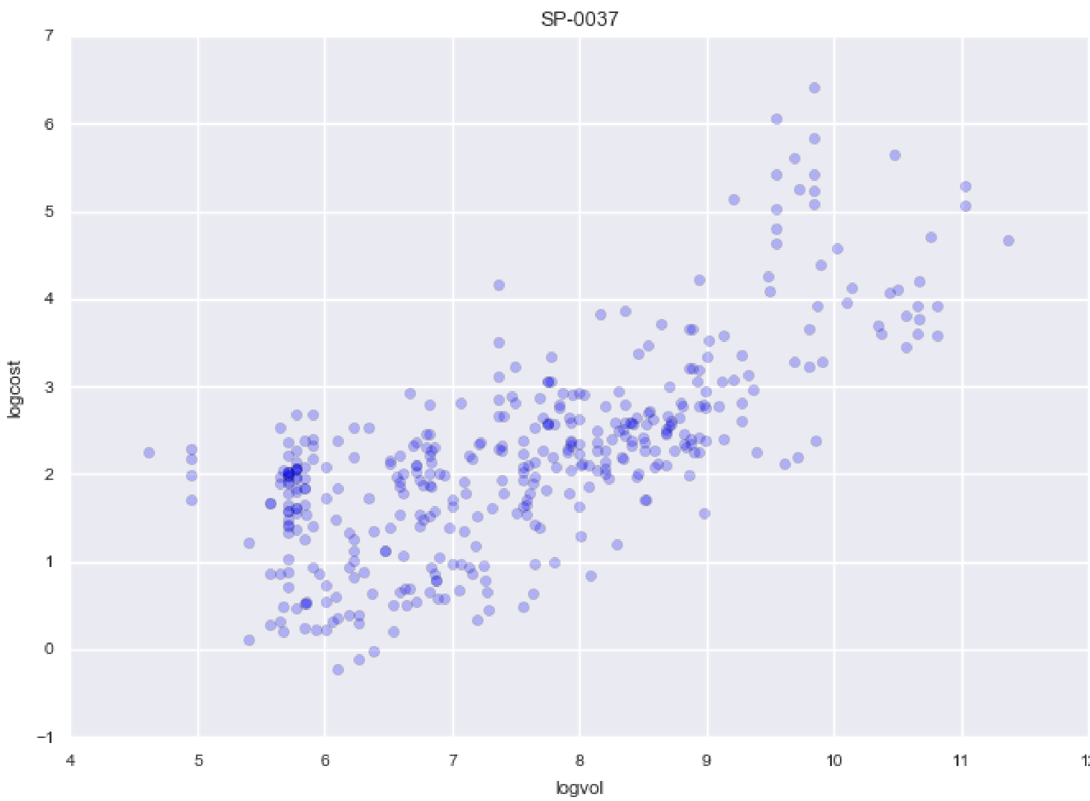

SP-0033
logcost
logvol
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
8.5
9.0
9.5
10.0
10.5
11.0
11.5
12.0
12.5

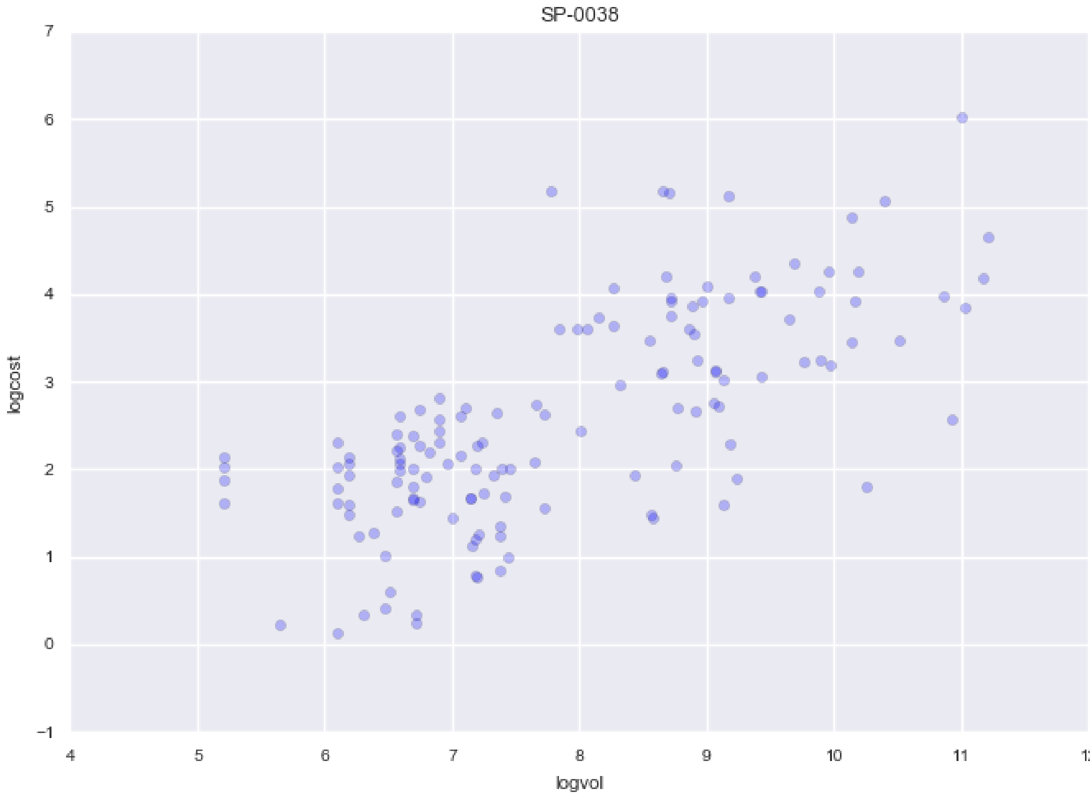


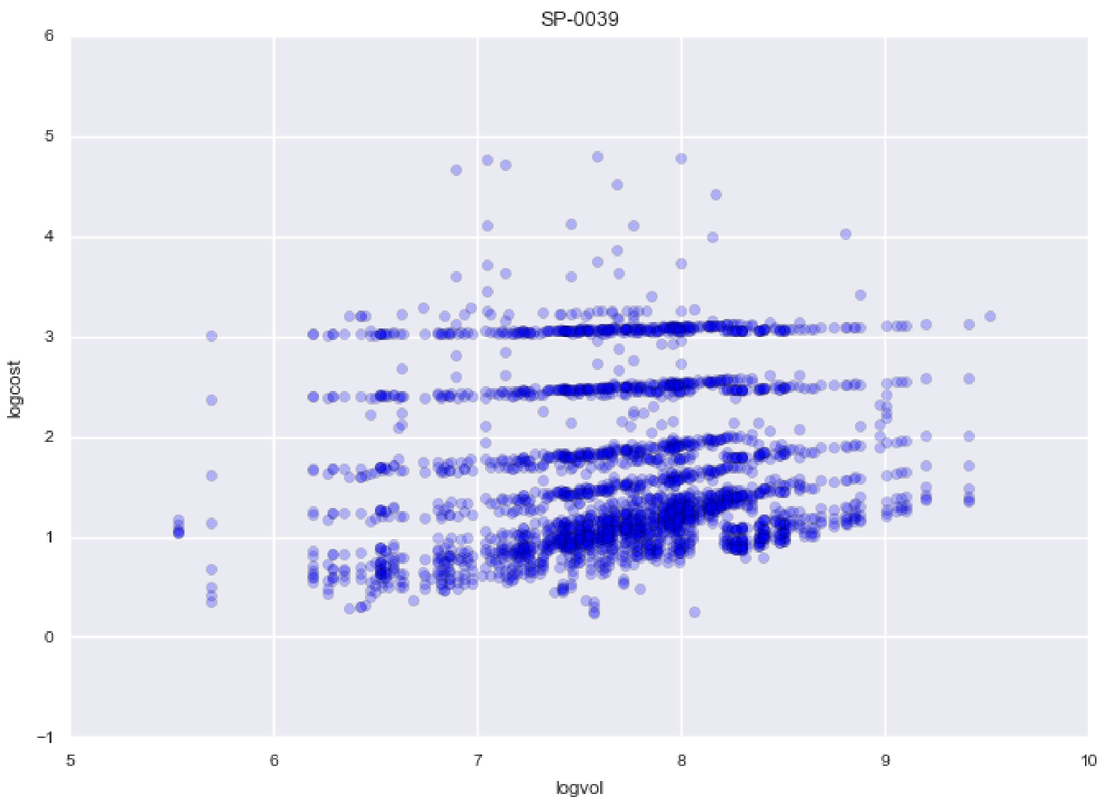
SP-0034
logcost
logvol
0
1
2
3
4
5
7.0
7.2
7.4
7.6
7.8
8.0


SP-0035
6
5
4
3
2
1
0
−1
logcost
4
5
6
7
8
9
10
11
12
logvol

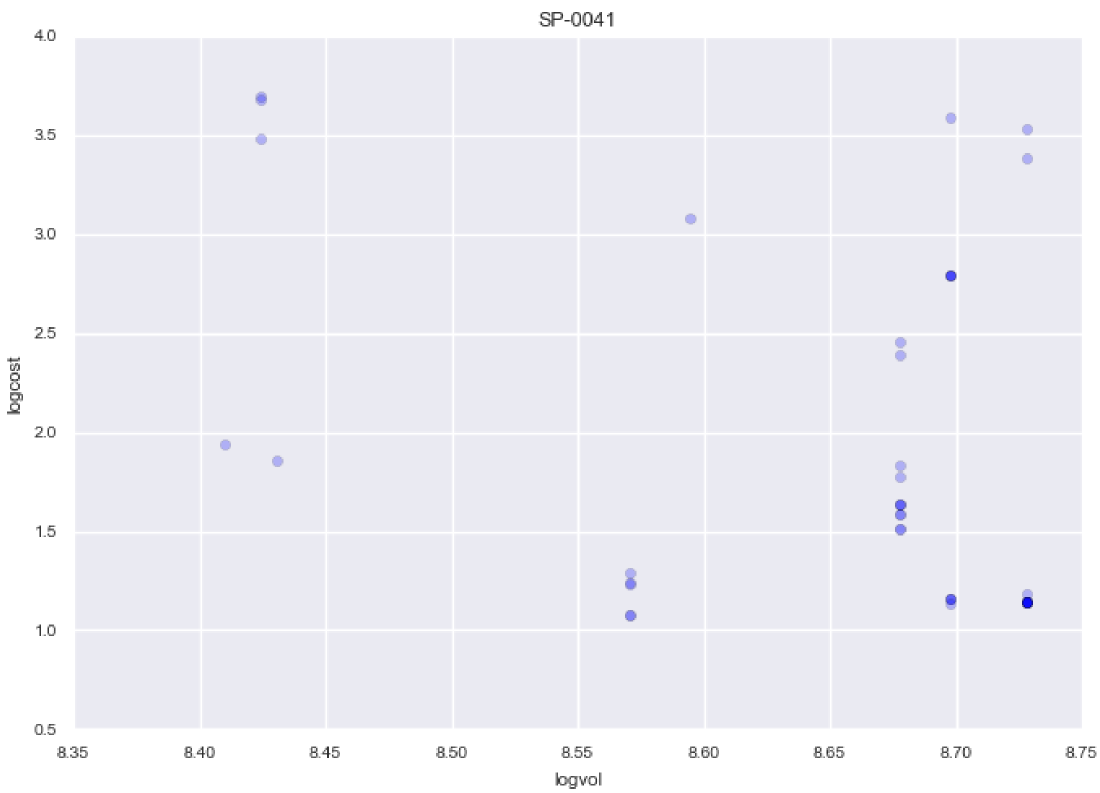

SP-0036
logcost
logvol
3.5
3.0
2.5
2.0
1.5
1.0
0.5
7.5
8.0
8.5
9.0

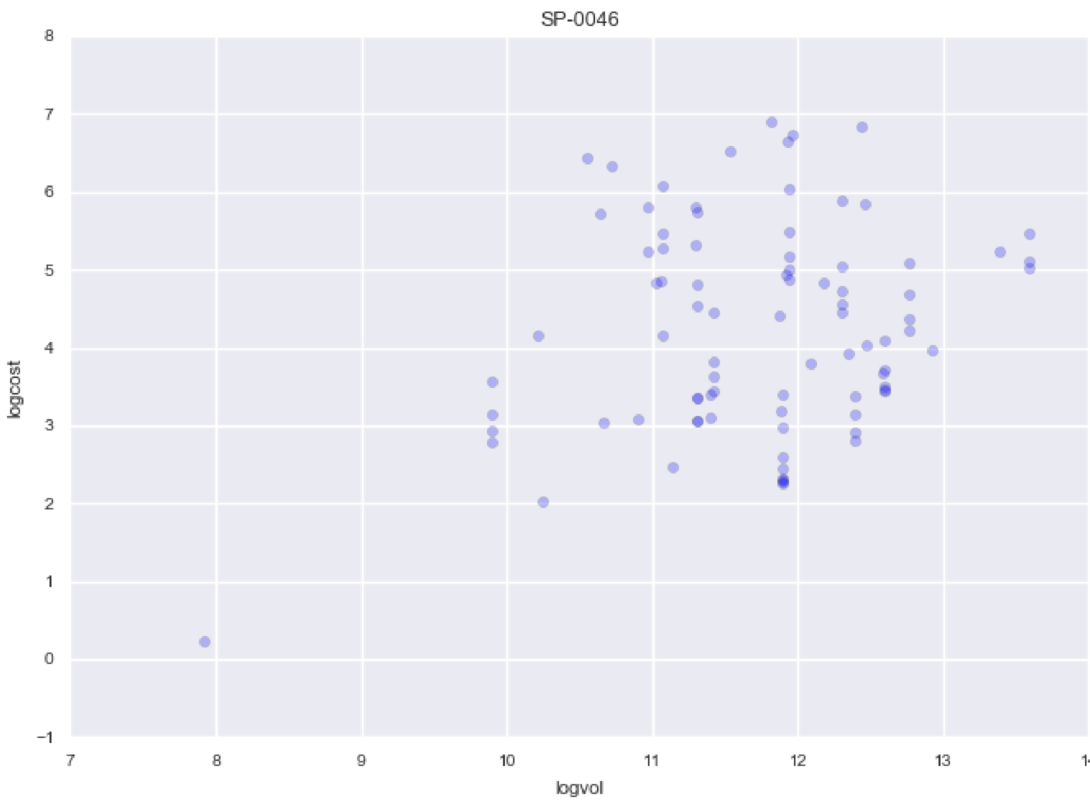

SP-0037
logcost
logvol
7
6
5
4
3
2
1
0
−1
4
5
6
7
8
9
10
11
12

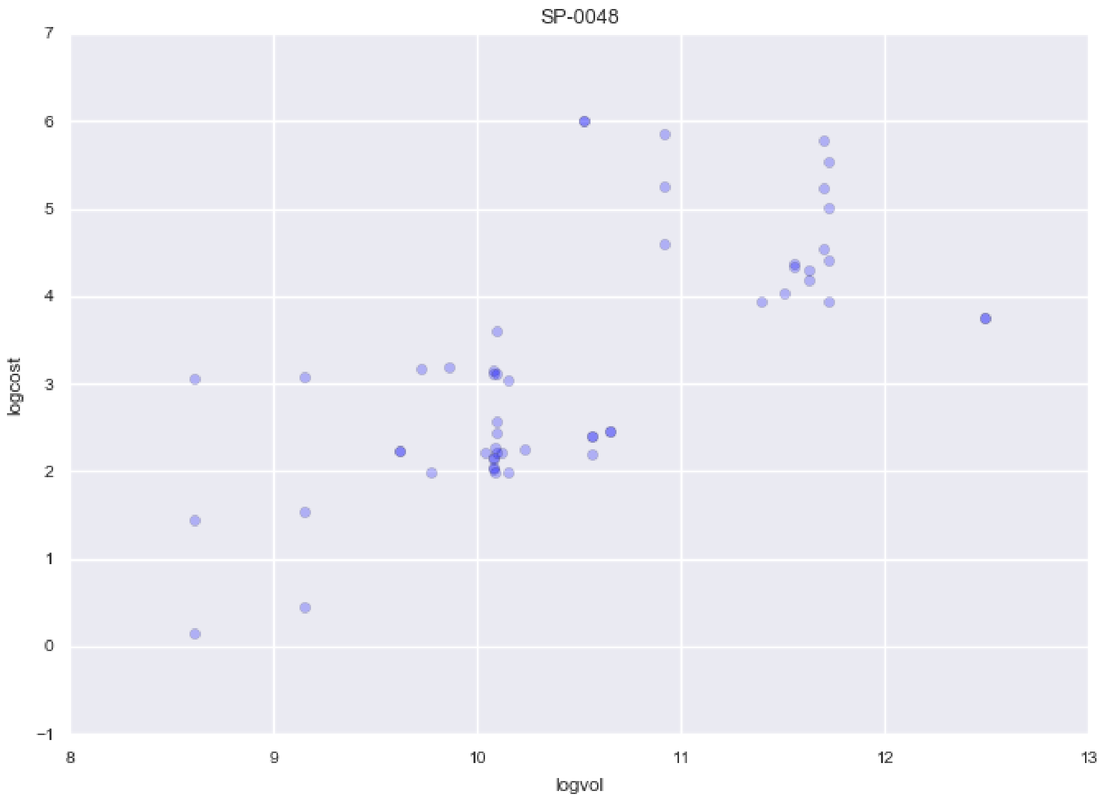

SP-0038
logcost
logvol
7
6
5
4
3
2
1
0
−1
4
5
6
7
8
9
10
11
12



SP-0039
logcost
logvol
6
5
4
3
2
1
0
−1
5
6
7
8
9
10

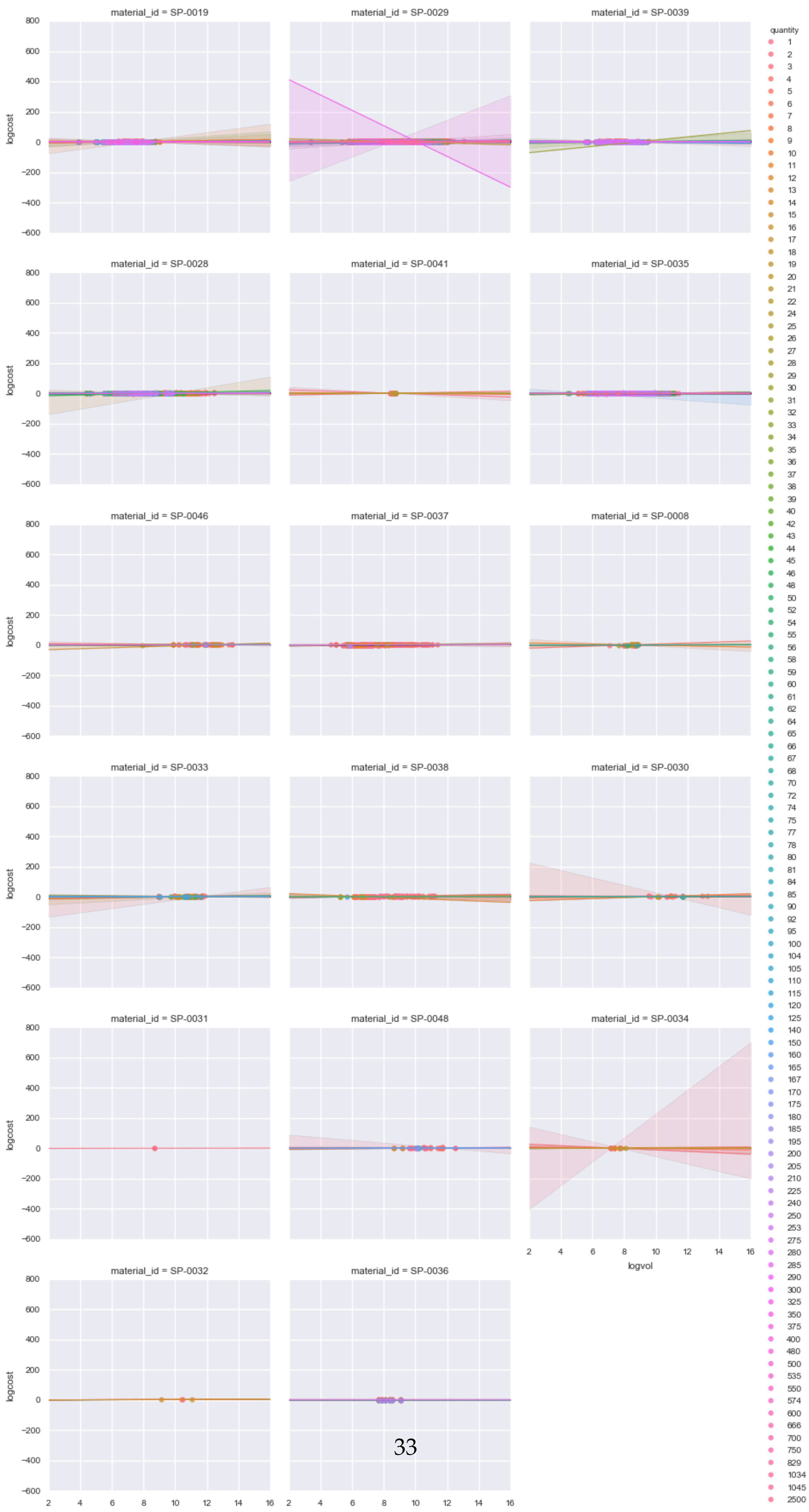

SP-0041
logcost
logvol
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
8.35
8.40
8.45
8.50
8.55
8.60
8.65
8.70
8.75


SP-0046
logcost
logvol
8
7
6
5
4
3
2
1
0
−1
7
8
9
10
11
12
13
14



Seaborn

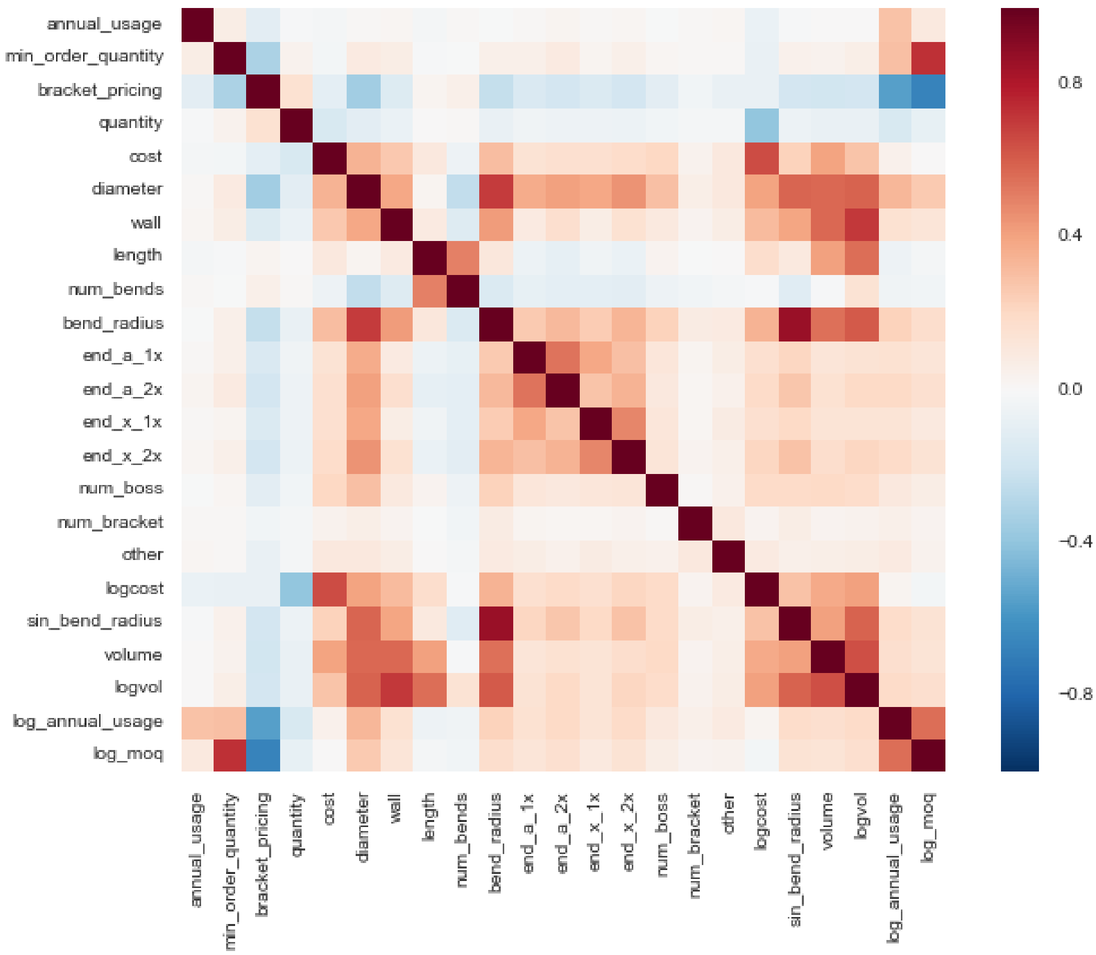
```
In [148]: g = sns.lmplot(x = "logvol", y = "logcost", hue = "quantity", col = "mate
```


material_id = SP-0019
material_id = SP-0029
material_id = SP-0039
material_id = SP-0028
material_id = SP-0041
material_id = SP-0035
material_id = SP-0046
material_id = SP-0037
material_id = SP-0008
material_id = SP-0033
material_id = SP-0038
material_id = SP-0030
material_id = SP-0031
material_id = SP-0048
material_id = SP-0034
material_id = SP-0032
material_id = SP-0036
logcost
logvol
quantity
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 42 43 44 45 46 48 50 52 54 55 56 58 59 60 61 62 64 65 66 67 68 70 72 74 75 77 78 80 81 84 85 90 92 95 100 104 105 110 115 120 125 140 150 160 165 167 170 175 180 185 195 200 205 210 225 240 250 253 275 280 285 290 300 325 350 375 400 480 500 535 550 574 600 666 700 750 829 1034 1045 2500

1.1.14 Heatmap - Correlation Matrix

```
In [77]: # data set and correlation between the variables after cleaning and format

         cm = df_new.corr()
         sns.heatmap(cm, square=True)
         plt.yticks(rotation=0)
         plt.xticks(rotation=90)
```

```
Out[77]: (array([  0.5,    1.5,    2.5,    3.5,    4.5,    5.5,    6.5,    7.5,    8.5,
                   9.5,   10.5,   11.5,   12.5,   13.5,   14.5,   15.5,   16.5,   17.5,
                  18.5,   19.5,   20.5,   21.5,   22.5]),
          <a list of 23 Text xticklabel objects>)
```




```
In [78]: transformed_features = ['logcost', 'logvol', 'log_annual_usage', 'log_moq'
         g = sns.pairplot(df_new[df_new.quantity == 1][transformed_features], hue =
```

1.1.15 Variable Selection

```
In [80]: selected_features = ['logcost', 'quantity','logvol','log_annual_usage', 'l
         df_selected = df_new[selected_features]
         df_selected.describe()
```

```
Out[80]:          logcost       quantity         logvol  log_annual_usage  \
         count  30167.000000  30167.000000  30167.000000     30167.000000
         mean       2.037891     38.411808      8.424958         1.121780
         std        0.923779     70.783022      1.216863         1.918749
         min       -0.686067      1.000000      3.370963         0.000000
         25%        1.354651      2.000000      7.555244         0.000000
         50%        1.874623     10.000000      8.323847         0.000000
         75%        2.596691     40.000000      9.304021         1.098612
```

```
max         6.907755   2500.000000     13.587518         11.918397

              log_moq     num_bends  sin_bend_radius       num_boss  \
count  30167.000000  30167.000000     30167.000000  30167.000000
mean       0.273000      3.814234         0.366004      0.025259
std        0.786436      2.199544         0.204199      0.185029
min        0.000000      0.000000        -0.999755      0.000000
25%        0.000000      2.000000         0.199105      0.000000
50%        0.000000      3.000000         0.327894      0.000000
75%        0.000000      5.000000         0.509426      0.000000
max        6.284134     17.000000         0.999464      5.000000

          num_bracket         other
count  30167.000000  30167.000000
mean       0.003547      0.013492
std        0.069717      0.150527
min        0.000000      0.000000
25%        0.000000      0.000000
50%        0.000000      0.000000
75%        0.000000      0.000000
max        3.000000      8.000000
```

1.2 PCA

In [81]:
```python
from sklearn.decomposition import PCA

pca = PCA(n_components = 2)
pca.fit(df_selected)
```

Out[81]:
```
PCA(copy=True, n_components=2, whiten=False)
```

In [82]:
```python
pca.components_
```

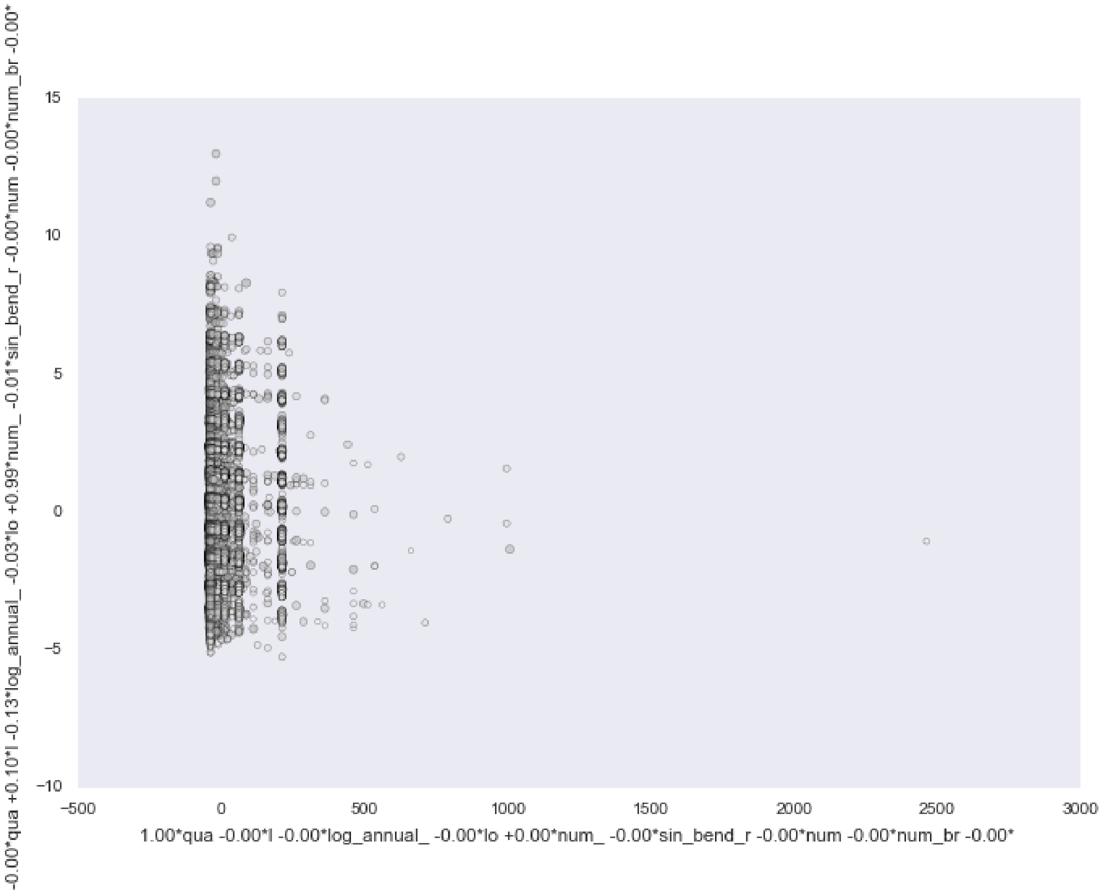
Out[82]:
```
array([[ -5.19053693e-03,   9.99975362e-01,  -1.29511373e-03,
         -4.42584877e-03,  -9.06787152e-04,   4.57173578e-04,
         -1.63318768e-04,  -8.81461683e-05,  -1.89796759e-05,
         -4.72643679e-05],
       [ -7.88660611e-03,   8.98457604e-04,  -9.62730156e-02,
          1.30993423e-01,   3.46719322e-02,  -9.85995963e-01,
          9.73422287e-03,   4.44975943e-03,   1.20182199e-03,
          1.74395278e-03]])
```

In [83]:
```python
X = df_selected.ix[:, df_selected.columns != 'logcost']
Y = df_selected.logcost
#target_names = iris.target_names

pca = PCA(n_components = 2)
X_pca = pca.fit(X).transform(X) # fit data and then transform it

print ('pca:', pca.components_)
```

```
('pca:', array([[  9.99988833e-01,  -1.29468841e-03,  -4.42597154e-03,
         -9.06844370e-04,   4.57161931e-04,  -1.63267524e-04,
         -8.81154622e-05,  -1.89778540e-05,  -4.72530495e-05],
       [ -9.40510603e-04,   9.53147201e-02,  -1.30948714e-01,
         -3.46218946e-02,   9.86126820e-01,  -9.84772718e-03,
         -4.50834326e-03,  -1.20592977e-03,  -1.76532025e-03]]))
```

```
In [84]: def get_feature_names_from_weights(weights, names):
             tmp_array = []
             for comp in weights:
                 tmp_string = ''
                 for fidx,f in enumerate(names):
                     if fidx>0 and comp[fidx]>=0:
                         tmp_string+='+'
                     tmp_string += '%.2f*%s ' % (comp[fidx],f[:-5])
                 tmp_array.append(tmp_string)
             return tmp_array

         pca_weight_strings = get_feature_names_from_weights(pca.components_, X)

         df_selected_pca = pd.DataFrame(X_pca,columns=[pca_weight_strings])

         from pandas.tools.plotting import scatter_plot

         plt.figure(figsize = (16, 16))

         ax = scatter_plot(df_selected_pca, pca_weight_strings[0], pca_weight_strin
         newfig = plt.figure()
```

```
<matplotlib.figure.Figure at 0x12e0eb390>
```




```
<matplotlib.figure.Figure at 0x12e0ebad0>
```

1.3 Conclusion

As shown in the *interactive* chart (cost vs. quantity) and the PCA first component (value = 9.99988833e-01), the cost of a tube assembly is heavily influenced by the quantity quoted.

The cost curve can be modeled by quantity on an individual basis:

$$cost = a \times e^{-b \times quantity} + c$$

Tube assemblies with unrealistic values (e.g. length = 0 or bend radius > 360 degrees) were dropped. Also, regarding data quality, it seems that some of the quote dates are not reliable (the data ranges from 1982 to 2017).

Logartithmic transformations proved to be very helpful to approximate linear relationships. Similarly the sinus functions was applied to bend radius. Another geometric function applied was the volume of the tube.

Although the number of bends doesn't seem to have a major impact on cost per the boxplot, the second component on the PCA analysis assigns it a high coefficient.

The scatter plots of Log Cost as a function of Log Vol by Material were attempted using matplotlib and Seaborn. Seaborn was significantly easier to use, but the result is highly dubious.

Finally, as shown in the pairplot the following relationships were discovered, cost is - directly proportional to volume, bend radius, num_boss - indirectly proportional to annual usage, minimum order quantity

The influence of categorical variables (e.g. Material and Supplier) still need to be considered to develop an accurate model.

```
In [ ]:
```