King County Housing with Multiple Linear Regression

Authors: Diane Tunnicliffe, Dana Rausch, Matthew Lipman

Notebook 3: Models and Evaluations

This notebook contains linear regression models for our raw, cleaned, and transformed attempted many variations of our model and improved upon them with each iteration t best fit for our data. This notebook includes the ten iterations of the model, along with taken to improve them, as well as exploration of necessary assumptions and outputs. are evluated sequentially and culminate in a final evaluation and conclusion.

In [468]:

```
# importing the packages we will be using for this project
import pandas as pd
# setting pandas display to avoid scientific notation in my data
pd.options.display.float_format = '{:.2f}'.format
import numpy as np
import matplotlib.pyplot as plt
import seaborn as sns
import sklearn

from bs4 import BeautifulSoup
import json
import requests

import folium

import haversine as hs

import statsmodels.api as sm
from statsmodels.formula.api import ols
from statsmodels.stats import diagnostic as diag
from statsmodels.stats.outliers_influence import variance_inflat

from sklearn.metrics import r2_score
from sklearn.linear_model import LinearRegression
from sklearn.neighbors import NearestNeighbors
from sklearn.model_selection import train_test_split
from sklearn.metrics import mean_squared_error, r2_score, mean_al

import scipy.stats as stats

import pylab

%matplotlib inline
```

Model #1

Our first model takes the original raw data and features, within one standard deviation
for price.

In [469]:
```
df = pd.read_csv('./data/all_features_with_logs.csv', index_col=
```

In [470]:
```
# define features and target
features = ['sqft_living', 'closest_distance_to_top_school', 'mi
target = ['price']

# separate dataframe into feature matrix x and target vector y
X = df[features]
y = df[target]

# now we can instantiate our linear regression estimator and fit
lm1 = LinearRegression()
lm1.fit(X, y)

print('R^2: ', r2_score(y, lm1_preds))
```

```
R^2:  0.5360882304825976
```

In [471]:

```
formula = "price ~ sqft_living+closest_distance_to_top_school+mi
model = ols(formula= formula, data=df).fit()
model.summary()
```

Out[471]:

OLS Regression Results

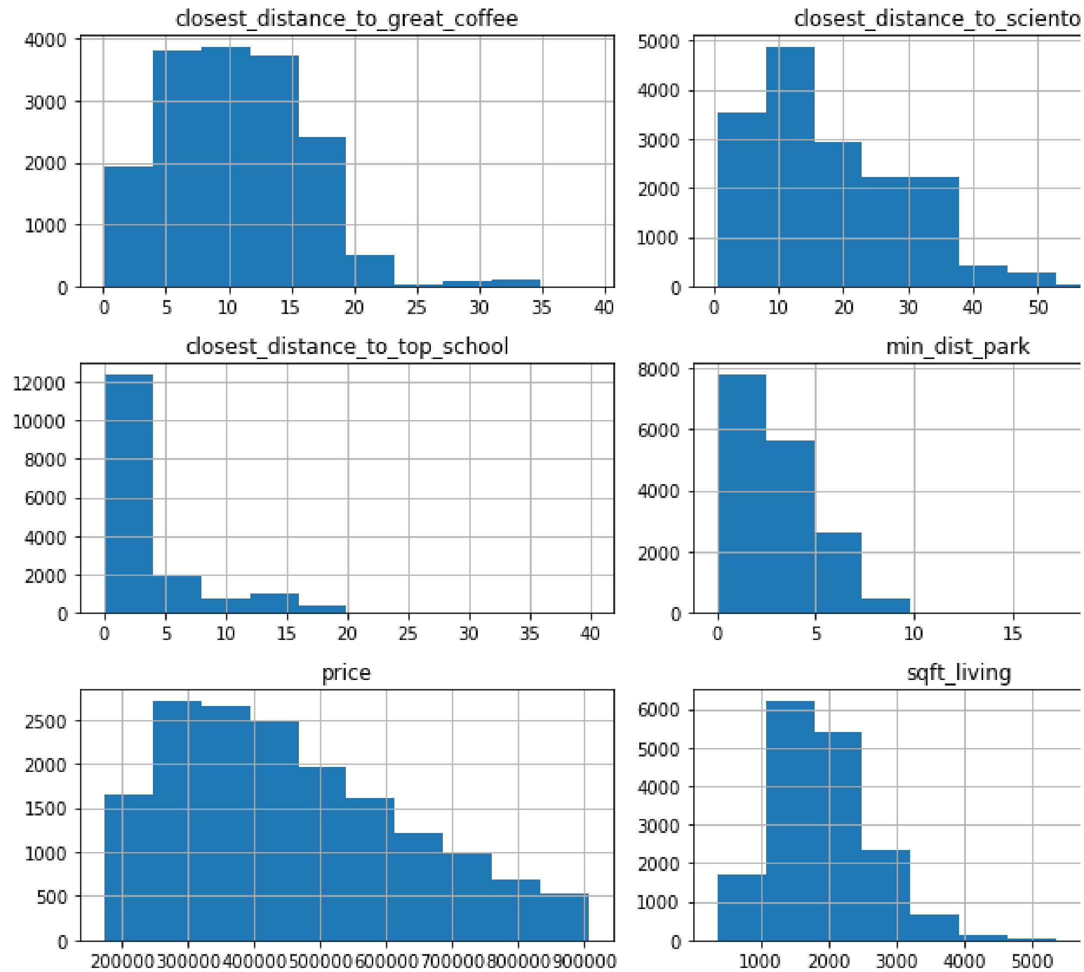
Dep. Variable:	price	**R-squared:**	0.536
Model:	OLS	**Adj. R-squared:**	0.536
Method:	Least Squares	**F-statistic:**	3810.
Date:	Tue, 01 Dec 2020	**Prob (F-statistic):**	0.00
Time:	12:37:42	**Log-Likelihood:**	-2.1650e+05
No. Observations:	16493	**AIC:**	4.330e+05
Df Residuals:	16487	**BIC:**	4.330e+05
Df Model:	5		
Covariance Type:	nonrobust		

	coef	std err	t	P>|t|	[0.025	0
Intercept	2.683e+05	3929.931	68.270	0.000	2.61e+05	2.76
sqft_living	153.6182	1.372	111.950	0.000	150.928	15
closest_distance_to_top_school	-1.022e+04	302.440	-33.785	0.000	-1.08e+04	-962
min_dist_park	-173.1658	468.670	-0.369	0.712	-1091.809	74
closest_distance_to_great_coffee	560.4484	186.671	3.002	0.003	194.554	92
closest_distance_to_scientology	-4317.5897	115.198	-37.480	0.000	-4543.391	-409

Omnibus:	367.787	**Durbin-Watson:**	1.993
Prob(Omnibus):	0.000	**Jarque-Bera (JB):**	408.256
Skew:	0.341	**Prob(JB):**	2.23e-89
Kurtosis:	3.358	**Cond. No.**	8.52e+03

Warnings:
[1] Standard Errors assume that the covariance matrix of the errors is correctly specifie
[2] The condition number is large, 8.52e+03. This might indicate that there are
strong multicollinearity or other numerical problems.

In [472]:
```
# checking the visual distribution of our data with histograms
df[['sqft_living', 'closest_distance_to_great_coffee', 'min_dist_
plt.tight_layout();
```

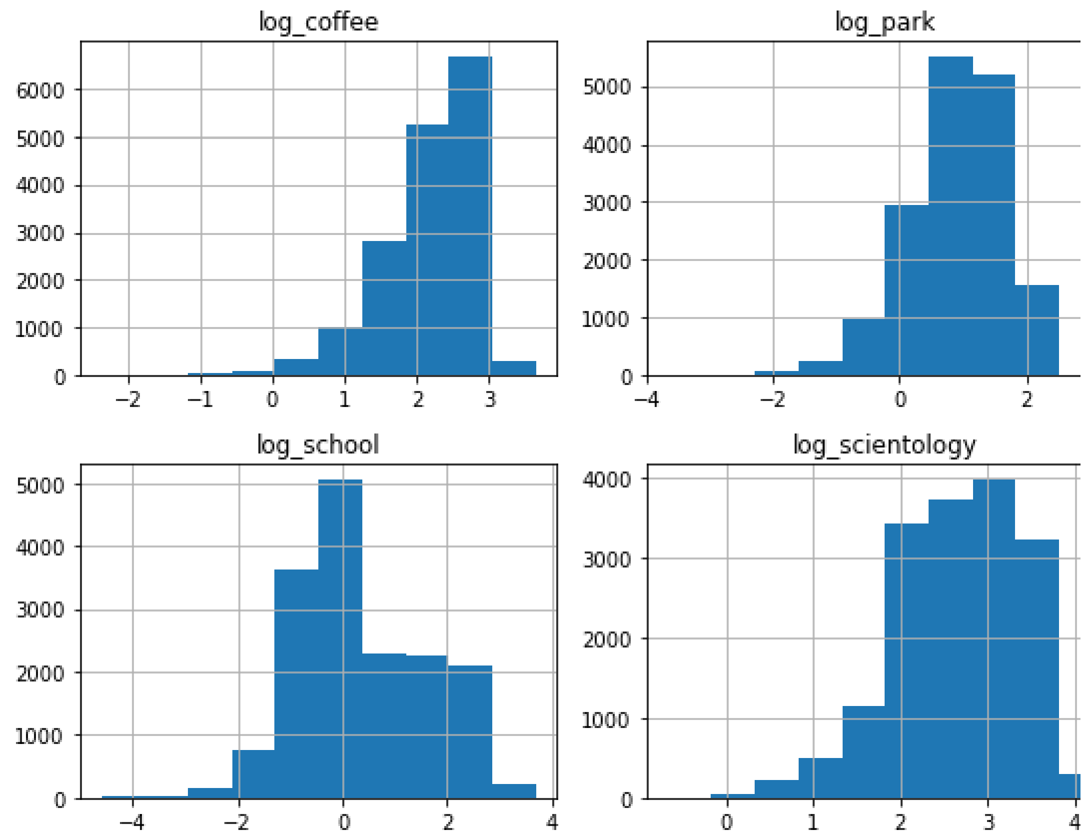


Our distributions for our features were not normal. Please see previous notebook for fu
investigation of this, analysis of skew and kurtosis, and decision-making regarding trar

Model #2

We performed a log-transformation for some of our features to see if this helped to ach
normal distribution and improve our model. (For actual process of log-transforming, an
visualizations of each feature before and after log-transformation, please see previous
titled 'data_wrangling'.)

In [473]:
```
# displaying the visual distribution of our log-transformed data
df[['log_coffee', 'log_park', 'log_school', 'log_scientology']].]
plt.tight_layout();
```



For the full visualizations (sns.distplot) of each feature before and after log-transformati see previous notebook ('data_wrangling.ipynb').

In [474]:
```
eatures = ['sqft_living', 'log_school', 'log_park', 'log_scientol
arget = ['price']

 = df[features]
 = df[target]

m2 = LinearRegression().fit(X, y)

m2_preds = lm2.predict(X)

rint('R^2: ', r2_score(y, lm2_preds))
```

```
R^2:  0.5682736472606391
```

In [475]:
```
formula = "price ~ sqft_living+log_school+log_park+log_scientolo
model = ols(formula= formula, data=df).fit()
```

In [476]:
```python
model.summary()
```

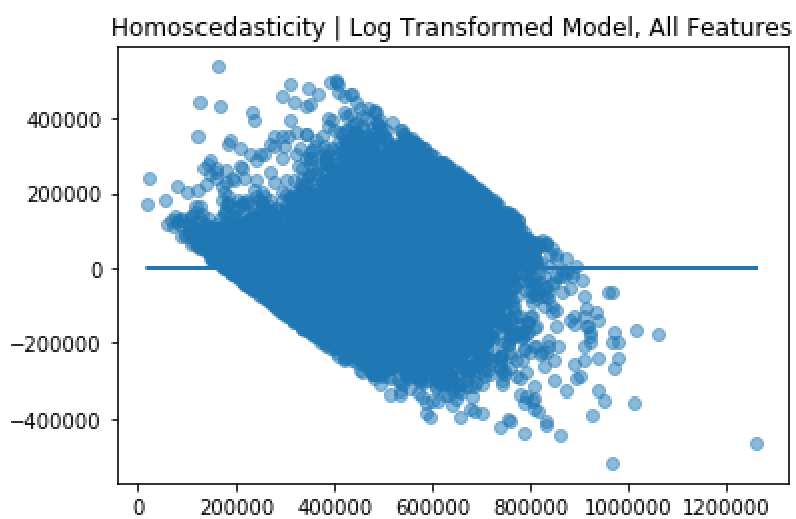
Out[476]:

OLS Regression Results

Dep. Variable:	price	**R-squared:**	0.568
Model:	OLS	**Adj. R-squared:**	0.568
Method:	Least Squares	**F-statistic:**	4340.
Date:	Tue, 01 Dec 2020	**Prob (F-statistic):**	0.00
Time:	12:37:44	**Log-Likelihood:**	-2.1590e+05
No. Observations:	16493	**AIC:**	4.318e+05
Df Residuals:	16487	**BIC:**	4.319e+05
Df Model:	5		
Covariance Type:	nonrobust		

	coef	**std err**	**t**	**P>|t|**	**[0.025**	**0.975]**

In [477]:
```python
predictors_log = ['sqft_living', 'log_school', 'log_scientology'
plt.scatter(model.predict(df[predictors_log]), model.resid, alpha
plt.plot(model.predict(df[predictors_log]), [0 for i in range(len
plt.title('Homoscedasticity | Log Transformed Model, All Features
```



The variability of price is not equal at all; this model is heteroscedastic. While this iterat
increased our R2 score some, we still hoped to achieve a higher one.

Model #3

To attempt to increase our R2 score, we then tried removing certain features to see if tl
increased.

In [478]:
```
df.corr()
```

Out[478]:

	price	sqft_living	grade	lat	long	min_dist_park
price	1.00	0.56	0.57	0.45	0.07	0.01
sqft_living	0.56	1.00	0.68	-0.02	0.27	0.01
grade	0.57	0.68	1.00	0.05	0.25	0.01
lat	0.45	-0.02	0.05	1.00	-0.13	0.01
long	0.07	0.27	0.25	-0.13	1.00	-0.01
min_dist_park	0.01	0.01	0.01	0.01	-0.01	1.00
closest_distance_to_top_school	-0.42	0.02	-0.03	-0.68	0.01	0.01
closest_distance_to_great_coffee	-0.18	-0.13	-0.13	-0.15	-0.37	0.02
closest_distance_to_scientology	-0.34	0.17	0.11	-0.73	0.63	-0.01
log_school	-0.41	0.08	0.01	-0.63	0.13	0.00
log_coffee	-0.14	-0.12	-0.11	-0.07	-0.43	0.02
log_scientology	-0.33	0.20	0.13	-0.63	0.62	-0.00
log_park	0.01	0.02	0.02	0.00	-0.01	0.90

Distance to parks seemed to have a relatively low correlation with price, so we experim
removing that first.

In [479]:
```
features = ['sqft_living', 'log_school', 'log_scientology', 'log_
target = ['price']
X = df[features]
y = df[target]

lm3 = LinearRegression().fit(X, y)

lm3_preds = lm3.predict(X)

print('R^2: ', r2_score(y, lm3_preds))
```

```
R^2:  0.5682691654558738
```

In [480]:
```
formula = "price ~ sqft_living+log_school+log_scientology+log_co
model = ols(formula= formula, data=df).fit()
```

In [481]:
```
model.summary()
```

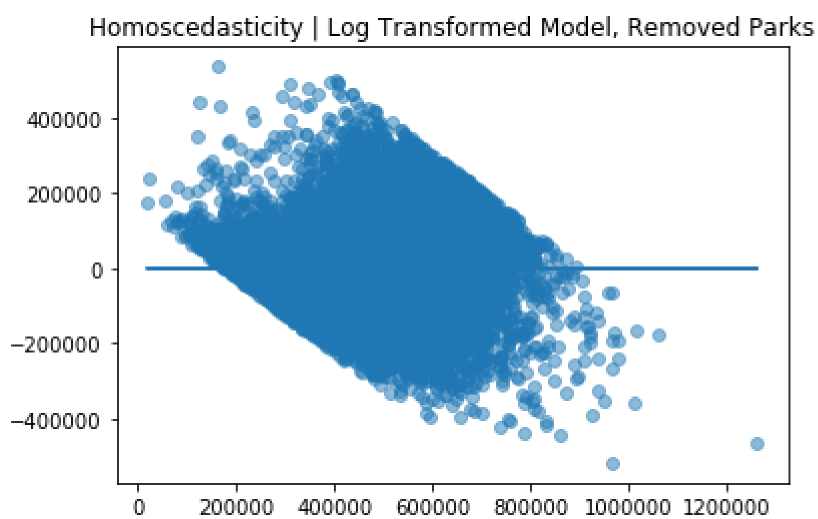
Out[481]:

OLS Regression Results

Dep. Variable:	price	**R-squared:**	0.568
Model:	OLS	**Adj. R-squared:**	0.568
Method:	Least Squares	**F-statistic:**	5426.
Date:	Tue, 01 Dec 2020	**Prob (F-statistic):**	0.00
Time:	12:37:45	**Log-Likelihood:**	-2.1590e+05
No. Observations:	16493	**AIC:**	4.318e+05
Df Residuals:	16488	**BIC:**	4.319e+05
Df Model:	4		
Covariance Type:	nonrobust		

	coef	std err	t	P>|t|	[0.025	0.975]

In [482]:
```
predictors_3 = ['sqft_living', 'log_school', 'log_coffee', 'log_s

plt.scatter(model.predict(df[predictors_3]), model.resid, alpha =
plt.plot(model.predict(df[predictors_3]), [0 for i in range(len(c
plt.title('Homoscedasticity | Log Transformed Model, Removed Parl
```



Once again, the variability of price is not equal at all; this model is heteroscedastic. An
we considered removing distance to parks, our R2 score actually dropped a bit as a re

Model #4

We attempted a new model with only sqare-foot living space and school as features.

In [483]:
```
# trying with only sqft_living and school

features = ['sqft_living', 'log_school']
target = ['price']
X = df[features]
y = df[target]

lm4 = LinearRegression().fit(X, y)

lm4_preds = lm4.predict(X)

print('R^2: ', r2_score(y, lm4_preds))
```

```
R^2:  0.5184159812175783
```

In [484]:
```
formula = "price ~ sqft_living+log_school"
model = ols(formula= formula, data=df).fit()
```

In [485]:
```
model.summary()
```

Out[485]:

OLS Regression Results

Dep. Variable:	price	**R-squared:**	0.518
Model:	OLS	**Adj. R-squared:**	0.518
Method:	Least Squares	**F-statistic:**	8876.
Date:	Tue, 01 Dec 2020	**Prob (F-statistic):**	0.00
Time:	12:37:45	**Log-Likelihood:**	-2.1680e+05
No. Observations:	16493	**AIC:**	4.336e+05
Df Residuals:	16490	**BIC:**	4.336e+05
Df Model:	2		
Covariance Type:	nonrobust		

	coef	std err	t	P>|t|	[0.025	0.975]
Intercept	1.956e+05	2782.391	70.284	0.000	1.9e+05	2.01e+05
sqft_living	149.2004	1.362	109.564	0.000	146.531	151.870
log_school	-6.475e+04	766.641	-84.462	0.000	-6.63e+04	-6.32e+04

Omnibus:	561.519	**Durbin-Watson:**	1.989
Prob(Omnibus):	0.000	**Jarque-Bera (JB):**	689.284
Skew:	0.402	**Prob(JB):**	2.11e-150
Kurtosis:	3.598	**Cond. No.**	5.92e+03

Warnings:
[1] Standard Errors assume that the covariance matrix of the errors is correctly specifie
[2] The condition number is large, 5.92e+03. This might indicate that there are
strong multicollinearity or other numerical problems.

Again, the model performs worse upon removal of features.

Model #5

We tried another model with all features, this time using the train_test_split method to t
our model.

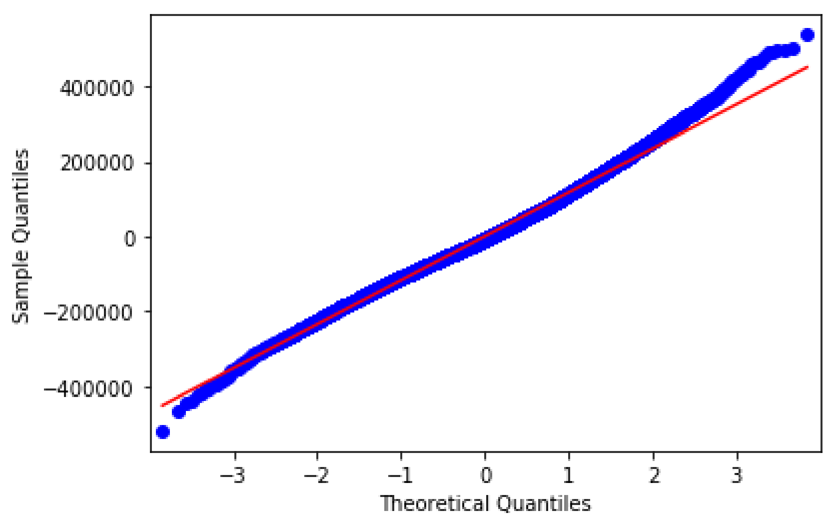
In [486]:
```
features = ['sqft_living', 'log_school', 'log_scientology', 'log_
target = ['price']
X = df[features]
y = df[target]

# fifth iteration of model: with all and train_test_split
X_train, X_test, y_train, y_test = train_test_split(X,y, random_s

lm5 = LinearRegression().fit(X_train, y_train)
lm5_preds = lm5.predict(X_test)

print('R^2: ', r2_score(y_test, lm5_preds))
```

```
R^2:  0.5793658205477772
```

In [487]:
```
y_predict = lm5.predict(X_test)

X2 = sm.add_constant(X)

# create an OLS model
model = sm.OLS(y, X2)

# fit the data
est = model.fit()
```

```
/Users/dtunnicliffe/anaconda3/envs/learn-env/lib/python3.6/site-p
numpy/core/fromnumeric.py:2580: FutureWarning: Method .ptp is dep
and will be removed in a future version. Use numpy.ptp instead.
  return ptp(axis=axis, out=out, **kwargs)
```

In [488]:
```
# check for the normality of the residuals
sm.qqplot(est.resid, line='s')
pylab.show()

# also check that the mean of the residuals is approx. 0.
mean_residuals = sum(est.resid)/ len(est.resid)
print("The mean of the residuals is {:.4}".format(mean_residuals
```



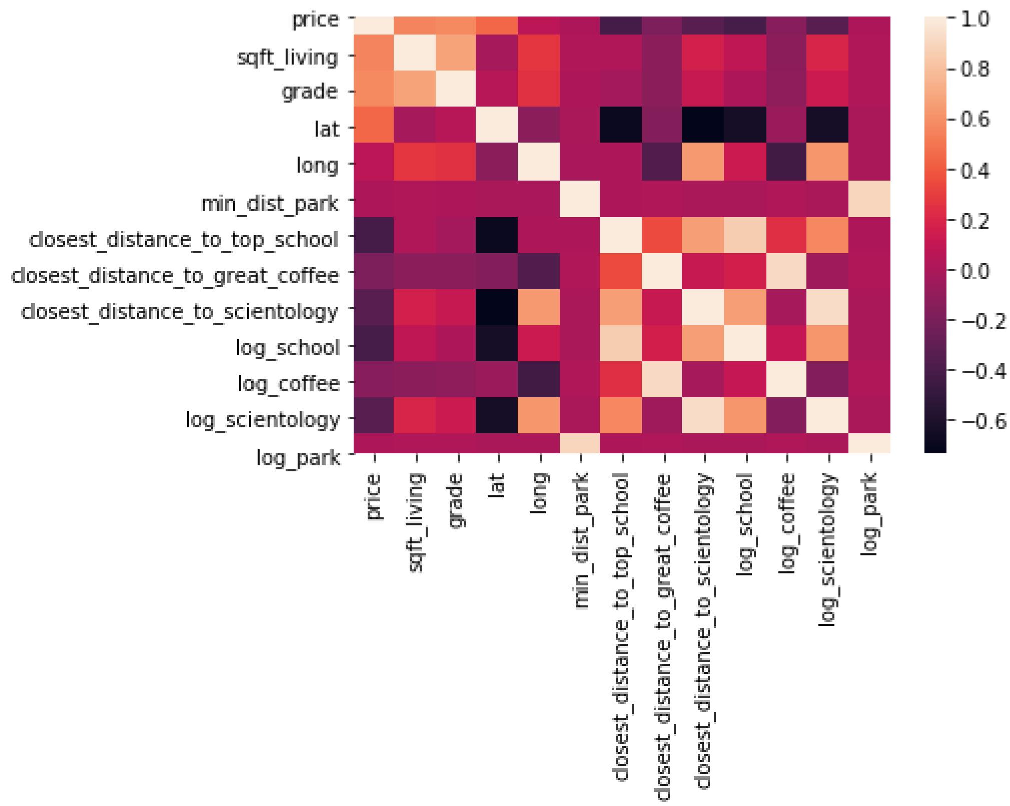

```
The mean of the residuals is 6.329e-10
```

This is the best one so far; the R2 improves when we use all our log-transformed featu
train_test_split.

Model #6

We checked for multicolinearity and found that there was multicolinearity between our
schools and distance to scientology churches. So we created an interaction column to
this.

In [489]:
```
sns.heatmap(df.corr());
```



In [490]:
```
df.corr()
```

Out[490]:

	price	sqft_living	grade	lat	long	min_dist_park
price	1.00	0.56	0.57	0.45	0.07	0.01
sqft_living	0.56	1.00	0.68	-0.02	0.27	0.01
grade	0.57	0.68	1.00	0.05	0.25	0.01
lat	0.45	-0.02	0.05	1.00	-0.13	0.01
long	0.07	0.27	0.25	-0.13	1.00	-0.01
min_dist_park	0.01	0.01	0.01	0.01	-0.01	1.00
closest_distance_to_top_school	-0.42	0.02	-0.03	-0.68	0.01	0.01
closest_distance_to_great_coffee	-0.18	-0.13	-0.13	-0.15	-0.37	0.02
closest_distance_to_scientology	-0.34	0.17	0.11	-0.73	0.63	-0.01
log_school	-0.41	0.08	0.01	-0.63	0.13	0.00
log_coffee	-0.14	-0.12	-0.11	-0.07	-0.43	0.02
log_scientology	-0.33	0.20	0.13	-0.63	0.62	-0.00
log_park	0.01	0.02	0.02	0.00	-0.01	0.90

In [491]:
```
# creating an interaction column for school and scientology
# because there is multicolinearity
df['interaction'] = df['log_school'] * df['log_scientology']

features = ['sqft_living', 'log_school', 'log_scientology', 'log_
target = ['price']

X = df[features]
y = df[target]

# running an iteration of the model with interaction column and i
X_train, X_test, y_train, y_test = train_test_split(X,y, random_s

lm6 = LinearRegression().fit(X_train, y_train)
lm6_preds = lm6.predict(X_test)

print('R^2: ', r2_score(y_test, lm6_preds))
```

```
R^2:  0.580345794192251
```

In [492]:
```
formula = "price ~ sqft_living+log_school+log_scientology+log_co:
model = ols(formula= formula, data=df).fit()
model.summary()
```

Out[492]:

OLS Regression Results

Dep. Variable:	price	**R-squared:**	0.569
Model:	OLS	**Adj. R-squared:**	0.569
Method:	Least Squares	**F-statistic:**	3625.
Date:	Tue, 01 Dec 2020	**Prob (F-statistic):**	0.00
Time:	12:37:46	**Log-Likelihood:**	-2.1589e+05
No. Observations:	16493	**AIC:**	4.318e+05
Df Residuals:	16486	**BIC:**	4.319e+05
Df Model:	6		
Covariance Type:	nonrobust		

	coef	**std err**	**t**	**P>|t|**	**[0.025**	**0.975]**
Intercept	4.125e+05	6444.968	64.005	0.000	4e+05	4.25e+05
sqft_living	157.4699	1.320	119.337	0.000	154.883	160.056
log_school	-1.943e+04	4014.391	-4.840	0.000	-2.73e+04	-1.16e+04
log_scientology	-7.411e+04	1706.168	-43.437	0.000	-7.75e+04	-7.08e+04
log_coffee	-1.947e+04	1552.695	-12.538	0.000	-2.25e+04	-1.64e+04
log_park	-524.3983	1214.941	-0.432	0.666	-2905.814	1857.017
interaction	-5999.1660	1304.786	-4.598	0.000	-8556.687	-3441.645

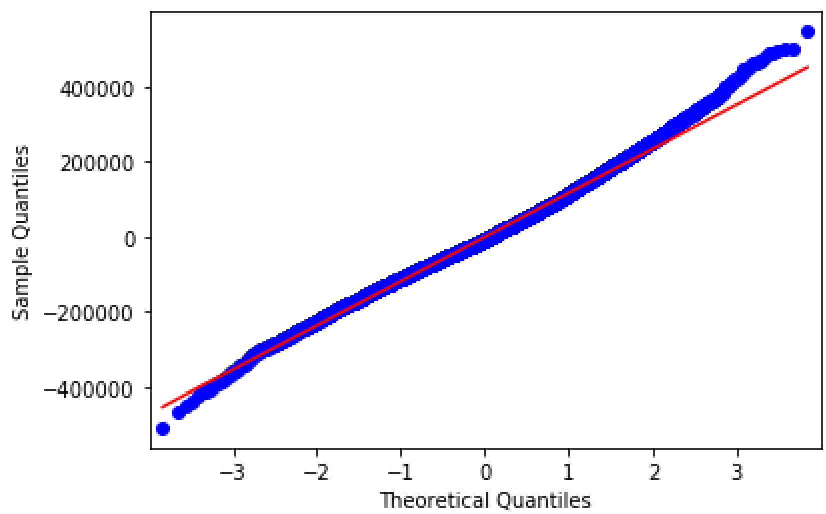
Omnibus:	341.490	**Durbin-Watson:**	1.987
Prob(Omnibus):	0.000	**Jarque-Bera (JB):**	419.795
Skew:	0.287	**Prob(JB):**	6.96e-92
Kurtosis:	3.530	**Cond. No.**	1.50e+04

Warnings:
[1] Standard Errors assume that the covariance matrix of the errors is correctly specifie
[2] The condition number is large, 1.5e+04. This might indicate that there are
strong multicollinearity or other numerical problems.

In [493]:
```
y_predict = lm6.predict(X_test)

X2 = sm.add_constant(X)

# create an OLS model
model = sm.OLS(y, X2)

# fit the data
est = model.fit()
```

```
/Users/dtunnicliffe/anaconda3/envs/learn-env/lib/python3.6/site-
numpy/core/fromnumeric.py:2580: FutureWarning: Method .ptp is de
and will be removed in a future version. Use numpy.ptp instead.
  return ptp(axis=axis, out=out, **kwargs)
```

In [494]:
```
# check for the normality of the residuals
sm.qqplot(est.resid, line='s')
pylab.show()

# also check that the mean of the residuals is approx. 0.
mean_residuals = sum(est.resid)/ len(est.resid)
print("The mean of the residuals is {:.4}".format(mean_residuals
```




```
The mean of the residuals is -4.463e-08
```

This is the best one so far. The model improves when we add an interaction feature.

Model #7

We wanted to include 'grade' as a feature. This is a categorical variable found in the kc dataset. The breakdown for the meaning of each grade designation can be found at [https://info.kingcounty.gov/assessor/esales/Glossary.aspx?type=r (https://info.kingcounty.gov/assessor/esales/Glossary.aspx?type=r)](https://info.kingcounty.gov/assessor/esales/Glossary.aspx?type=r) under 'Building Gra

In [495]:
```
# creating categorical dummy variables for grade
grade_dums = pd.get_dummies(df.grade, prefix='grade', drop_first=
```

In [496]:
```
# dropping original grade column
df = df.drop(['grade'], axis=1)
df_with_grade = pd.concat([df, grade_dums], axis=1)
```

In [497]:
```
features = ['sqft_living', 'log_coffee', 'log_park', 'interactio
target = ['price']
X = df_with_grade[features]
y = df_with_grade[target]

# running an iteration of the model with interaction column and
X_train, X_test, y_train, y_test = train_test_split(X,y, random_

lm7 = LinearRegression().fit(X_train, y_train)
lm7_preds = lm7.predict(X_test)

print('R^2: ', r2_score(y_test, lm7_preds))
```

```
R^2:  0.6434460298499262
```

In [498]:
```
formula = "price ~ sqft_living+log_coffee+log_park+interaction+l
model = ols(formula= formula, data=df_with_grade).fit()
model.summary()
```

Out[498]:

OLS Regression Results

Dep. Variable:	price	**R-squared:**	0.636
Model:	OLS	**Adj. R-squared:**	0.635
Method:	Least Squares	**F-statistic:**	2053.
Date:	Tue, 01 Dec 2020	**Prob (F-statistic):**	0.00
Time:	12:37:46	**Log-Likelihood:**	-2.1450e+05
No. Observations:	16493	**AIC:**	4.290e+05
Df Residuals:	16478	**BIC:**	4.292e+05
Df Model:	14		
Covariance Type:	nonrobust		

	coef	**std err**	**t**	**P>|t|**	**[0.025**	**0.975]**
Intercept	7.271e+05	7.66e+04	9.492	0.000	5.77e+05	8.77e+05
sqft_living	98.7885	1.631	60.558	0.000	95.591	101.986
log_coffee	-1.715e+04	1430.428	-11.989	0.000	-2e+04	-1.43e+04
log_park	-747.9155	1117.323	-0.669	0.503	-2937.988	1442.158
interaction	-5651.3951	1201.494	-4.704	0.000	-8006.453	-3296.337
log_school	-1.694e+04	3694.712	-4.585	0.000	-2.42e+04	-9699.935
log_scientology	-7.857e+04	1574.770	-49.893	0.000	-8.17e+04	-7.55e+04
grade_4	-2.21e+05	8.12e+04	-2.722	0.006	-3.8e+05	-6.18e+04
grade_5	-2.581e+05	7.67e+04	-3.365	0.001	-4.08e+05	-1.08e+05
grade_6	-2.793e+05	7.63e+04	-3.661	0.000	-4.29e+05	-1.3e+05
grade_7	-2.305e+05	7.62e+04	-3.024	0.002	-3.8e+05	-8.11e+04
grade_8	-1.628e+05	7.62e+04	-2.135	0.033	-3.12e+05	-1.34e+04
grade_9	-7.901e+04	7.63e+04	-1.036	0.300	-2.28e+05	7.05e+04
grade_10	-1.951e+04	7.64e+04	-0.255	0.798	-1.69e+05	1.3e+05
grade_11	1.338e+04	7.8e+04	0.171	0.864	-1.4e+05	1.66e+05

Omnibus:	727.783	**Durbin-Watson:**	1.997
Prob(Omnibus):	0.000	**Jarque-Bera (JB):**	989.161
Skew:	0.441	**Prob(JB):**	1.61e-215
Kurtosis:	3.814	**Cond. No.**	5.59e+05

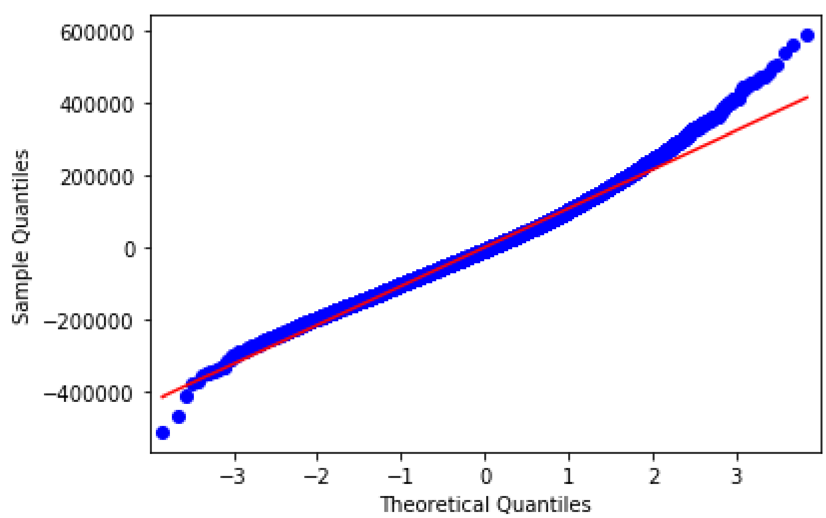
Warnings:

[1] Standard Errors assume that the covariance matrix of the errors is correctly specifie
[2] The condition number is large, 5.59e+05. This might indicate that there are strong multicollinearity or other numerical problems.

In [499]:
```
y_predict = lm7.predict(X_test)

X2 = sm.add_constant(X)

# create an OLS model
model = sm.OLS(y, X2)

# fit the data
est = model.fit()
```

```
/Users/dtunnicliffe/anaconda3/envs/learn-env/lib/python3.6/site-
numpy/core/fromnumeric.py:2580: FutureWarning: Method .ptp is de
and will be removed in a future version. Use numpy.ptp instead.
  return ptp(axis=axis, out=out, **kwargs)
```

In [500]:
```
# check for the normality of the residuals
sm.qqplot(est.resid, line='s')
pylab.show()

# also check that the mean of the residuals is approx. 0.
mean_residuals = sum(est.resid)/ len(est.resid)
print("The mean of the residuals is {:.4}".format(mean_residuals
```




```
The mean of the residuals is -4.478e-08
```

This has once again improved with the addition of the grade column.

Model #8

We then experimented with a quantile transformation of our data, as opposed to a log-transformation.

In [501]:
```
df = pd.read_csv('./data/all_features_quant_transformed.csv', in
df.head()
```

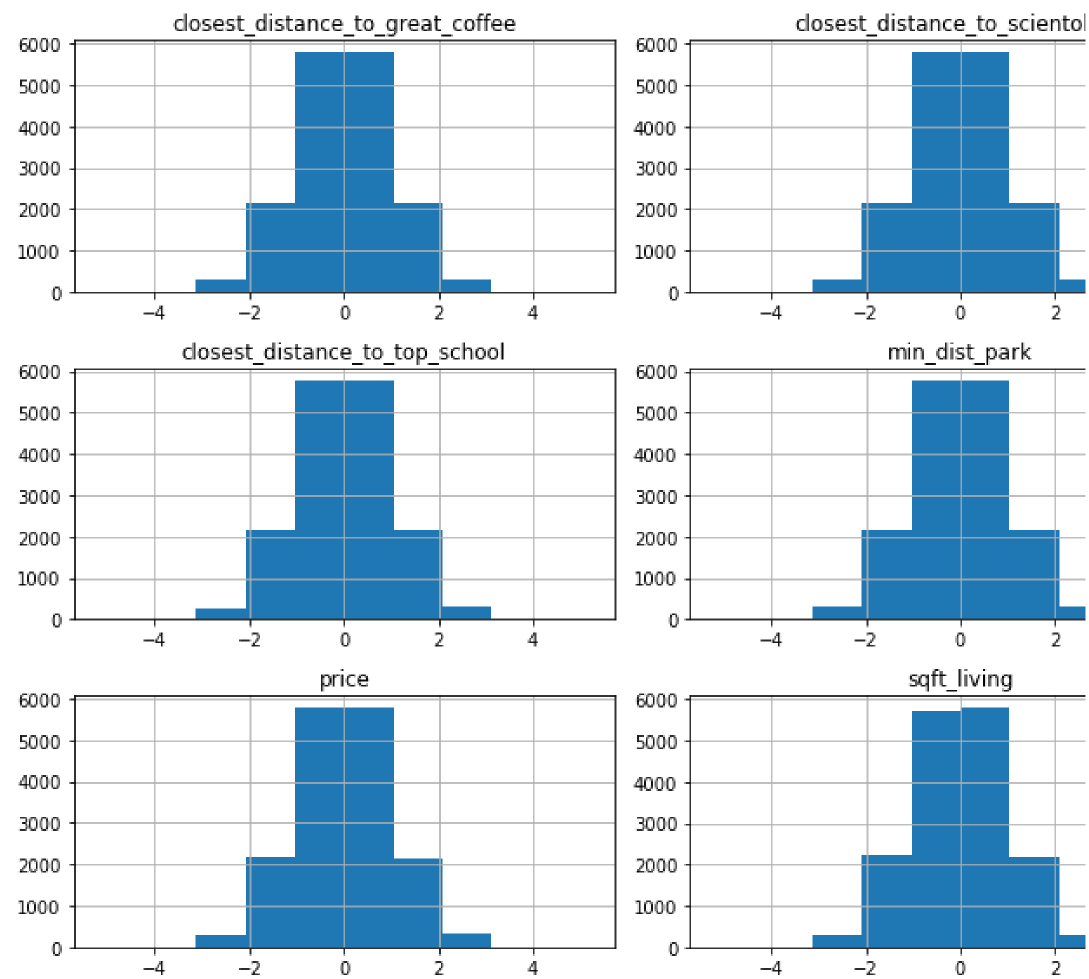
Out[501]:

	price	sqft_living	lat	long	min_dist_park	closest_distance_to_top_school	clo
0	-1.60	-1.08	47.51	-122.26	-0.31	-1.61	
1	0.49	0.94	47.72	-122.32	0.92	-0.50	
2	-2.54	-2.14	47.74	-122.23	-0.84	0.36	
3	0.78	0.17	47.52	-122.39	-0.08	0.30	
4	0.37	-0.22	47.62	-122.05	0.02	0.08	

5 rows × 22 columns

In [502]:
```
df.drop(columns=['log_school', 'log_coffee', 'log_scientology',
```

In [503]:
```
# checking the visual distribution of our data with histograms
df[['sqft_living', 'closest_distance_to_great_coffee', 'min_dist_
plt.tight_layout();
```



In [504]:

```
features = ['sqft_living', 'closest_distance_to_great_coffee', 'r
target = ['price']
X = df[features]
y = df[target]

# running an iteration of the model with quantile transformation
X_train, X_test, y_train, y_test = train_test_split(X,y, random_s

lm8 = LinearRegression().fit(X_train, y_train)
lm8_preds = lm8.predict(X_test)

print('R^2: ', r2_score(y_test, lm8_preds))
```

```
R^2:  0.6308144610145117
```

In [505]:

```
formula = "price ~ sqft_living+closest_distance_to_great_coffee+r
model = ols(formula= formula, data=df).fit()
```

In [506]:
```
model.summary()
```

Out[506]:

OLS Regression Results

Dep. Variable:	price	**R-squared:**	0.625
Model:	OLS	**Adj. R-squared:**	0.625
Method:	Least Squares	**F-statistic:**	1961.
Date:	Tue, 01 Dec 2020	**Prob (F-statistic):**	0.00
Time:	12:37:47	**Log-Likelihood:**	-15333.
No. Observations:	16493	**AIC:**	3.070e+04
Df Residuals:	16478	**BIC:**	3.081e+04
Df Model:	14		
Covariance Type:	nonrobust		

	coef	**std err**	**t**	**P>|t|**	**[0.025**	**0.975]**
Intercept	1.4887	0.434	3.430	0.001	0.638	2.339
sqft_living	0.4005	0.007	60.597	0.000	0.388	0.413
closest_distance_to_great_coffee	-0.0351	0.006	-6.328	0.000	-0.046	-0.024
min_dist_park	-0.0023	0.005	-0.474	0.636	-0.012	0.007
closest_distance_to_top_school	-0.2366	0.006	-37.579	0.000	-0.249	-0.224
closest_distance_to_scientology	-0.3240	0.006	-51.764	0.000	-0.336	-0.312
interaction	-0.0028	0.005	-0.559	0.576	-0.013	0.007
grade_4	-1.3811	0.462	-2.988	0.003	-2.287	-0.475
grade_5	-1.8401	0.437	-4.215	0.000	-2.696	-0.984
grade_6	-1.9693	0.434	-4.535	0.000	-2.821	-1.118
grade_7	-1.6686	0.434	-3.845	0.000	-2.519	-0.818
grade_8	-1.2934	0.434	-2.980	0.003	-2.144	-0.443
grade_9	-0.8742	0.434	-2.013	0.044	-1.726	-0.023
grade_10	-0.5436	0.435	-1.250	0.211	-1.396	0.309
grade_11	-0.2912	0.444	-0.655	0.512	-1.162	0.580

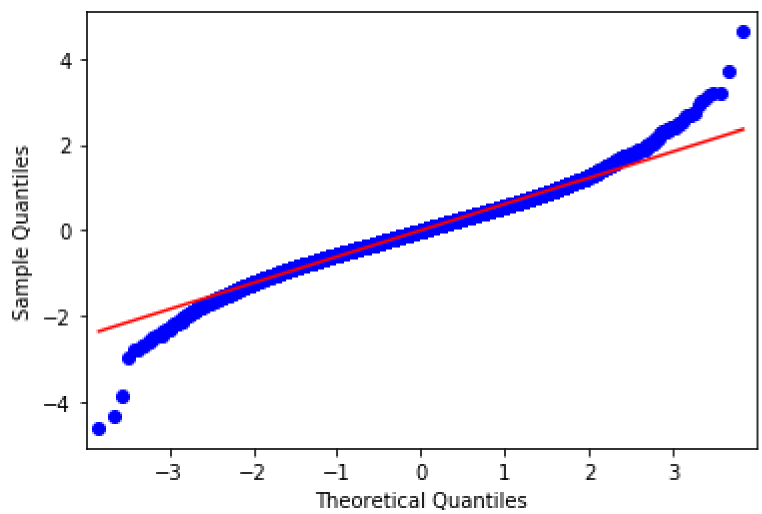
Omnibus:	696.435	**Durbin-Watson:**	2.004
Prob(Omnibus):	0.000	**Jarque-Bera (JB):**	2235.973
Skew:	0.085	**Prob(JB):**	0.00
Kurtosis:	4.796	**Cond. No.**	430.

Warnings:
[1] Standard Errors assume that the covariance matrix of the errors is correctly specifie

In [507]:
```
y_predict = lm8.predict(X_test)

X2 = sm.add_constant(X)

# create an OLS model
model = sm.OLS(y, X2)

# fit the data
est = model.fit()
```

```
/Users/dtunnicliffe/anaconda3/envs/learn-env/lib/python3.6/site-
numpy/core/fromnumeric.py:2580: FutureWarning: Method .ptp is de
and will be removed in a future version. Use numpy.ptp instead.
  return ptp(axis=axis, out=out, **kwargs)
```

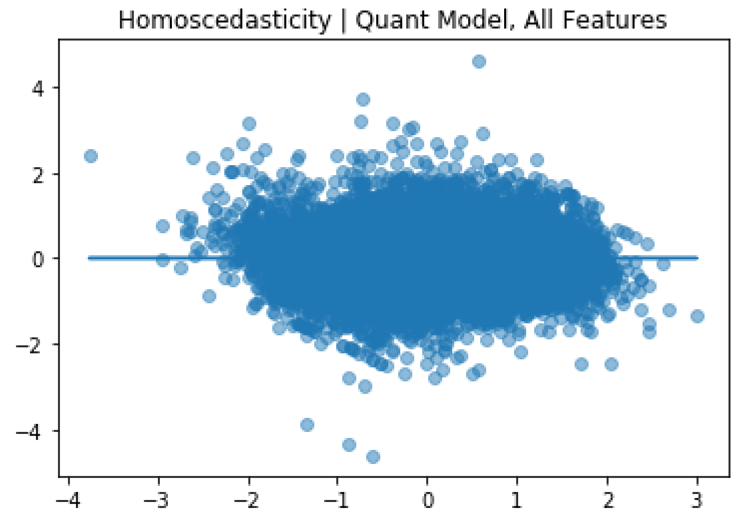
In [508]:
```
# check for the normality of the residuals
sm.qqplot(est.resid, line='s')
pylab.show()

# also check that the mean of the residuals is approx. 0.
mean_residuals = sum(est.resid)/ len(est.resid)
print("The mean of the residuals is {:.4}".format(mean_residuals
```




```
The mean of the residuals is -1.585e-15
```

Our residuals are relatively normal.

In [509]:
```
f = 'price ~ sqft_living+closest_distance_to_great_coffee+min_di

model = ols(formula = f, data = df).fit()
model.summary()
predictors_quant = ['sqft_living', 'closest_distance_to_great_co

plt.scatter(model.predict(df[predictors_quant]), model.resid, al
plt.plot(model.predict(df[predictors_quant]), [0 for i in range(
plt.title('Homoscedasticity | Quant Model, All Features');
```



Our qq-plots, homoscedasticity, and R-squared value continue to improve with each it

Model #9

We then experimented with a target we created, Price Per Square-Foot. While this targ unfortunately decreased our R2 significantly, we were able to use this new variable we' a new measurement by which to remove outliers and narrow our data further. Our last our original price target, but uses data narrowed to 1.5 standard deviations from the m per square foot. (For this entire process, please see previous notebook, 'data_wranglin point, we also updated our list of parks to eliminate forests and trail heads, and only in parks, to make for a more accurate "distance to closest park" measurement.

In [444]:
```python
df = pd.read_csv('./data/all_features_ppsqft_quant.csv', index_co
df.head()
```

Out[444]:

	price	sqft_living	lat	long	price_per_sqft	min_dist_park	closest_distance
0	221900.00	1180	47.51	-122.26	188.05	2.04	
1	538000.00	2570	47.72	-122.32	209.34	5.67	
2	180000.00	770	47.74	-122.23	233.77	1.34	
3	604000.00	1960	47.52	-122.39	308.16	2.45	
4	510000.00	1680	47.62	-122.05	303.57	3.72	

5 rows × 27 columns

In [445]:
```python
features = ['quant_sqft_living','quant_coffee', 'quant_parks', 'q
target = ['quant_price']
X = df[features]
y = df[target]

# running an iteration of the model using train_test_split
X_train, X_test, y_train, y_test = train_test_split(X,y, random_s

lm9 = LinearRegression().fit(X_train, y_train)
lm9_preds = lm9.predict(X_test)

print('R^2: ', r2_score(y_test, lm9_preds))
```

```
R^2:  0.7559870492262424
```

In [446]:

```
formula = "quant_price ~ quant_sqft_living+quant_coffee+quant_pa
model = ols(formula= formula, data=df).fit()
model.summary()
```

Out[446]:

OLS Regression Results

Dep. Variable:	quant_price	**R-squared:**	0.761
Model:	OLS	**Adj. R-squared:**	0.761
Method:	Least Squares	**F-statistic:**	3711.
Date:	Tue, 01 Dec 2020	**Prob (F-statistic):**	0.00
Time:	12:21:37	**Log-Likelihood:**	-12314.
No. Observations:	17495	**AIC:**	2.466e+04
Df Residuals:	17479	**BIC:**	2.479e+04
Df Model:	15		
Covariance Type:	nonrobust		

	coef	**std err**	**t**	**P>|t|**	**[0.025**	**0.975]**
Intercept	-0.7602	0.123	-6.167	0.000	-1.002	-0.519
quant_sqft_living	0.4987	0.006	89.561	0.000	0.488	0.510
quant_coffee	-0.0269	0.004	-6.792	0.000	-0.035	-0.019
quant_parks	-0.0059	0.004	-1.595	0.111	-0.013	0.001
quant_schools	-0.0690	0.021	-3.229	0.001	-0.111	-0.027
quant_scientology	-0.1565	0.014	-11.053	0.000	-0.184	-0.129
quant_interaction	-0.2132	0.031	-6.879	0.000	-0.274	-0.152
grade_5	0.1626	0.128	1.274	0.203	-0.088	0.413
grade_6	0.3070	0.123	2.492	0.013	0.066	0.549
grade_7	0.5833	0.123	4.736	0.000	0.342	0.825
grade_8	0.8820	0.124	7.131	0.000	0.640	1.124
grade_9	1.1951	0.125	9.596	0.000	0.951	1.439
grade_10	1.4316	0.126	11.387	0.000	1.185	1.678
grade_11	1.7193	0.129	13.377	0.000	1.467	1.971
grade_12	2.0848	0.144	14.463	0.000	1.802	2.367
grade_13	2.3285	0.236	9.847	0.000	1.865	2.792

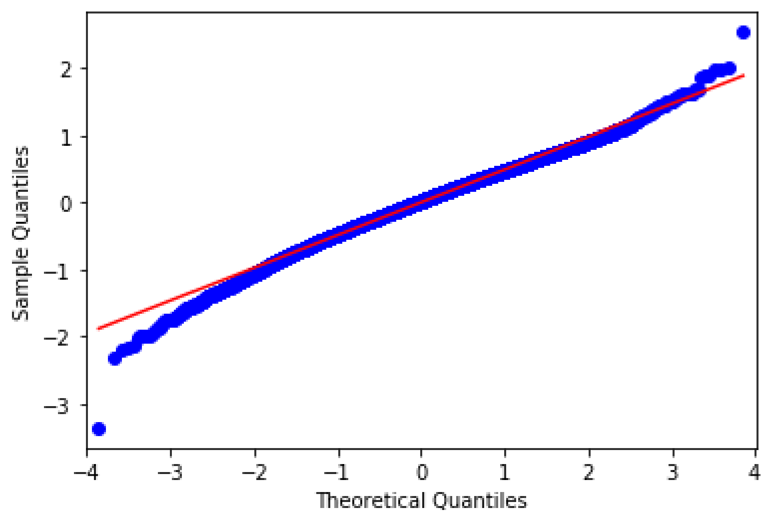
Omnibus:	391.796	**Durbin-Watson:**	1.997
Prob(Omnibus):	0.000	**Jarque-Bera (JB):**	511.788
Skew:	-0.283	**Prob(JB):**	7.35e-112
Kurtosis:	3.617	**Cond. No.**	175.

Warnings:
[1] Standard Errors assume that the covariance matrix of the errors is correctly specifie

In [447]:
```
y_predict = lm9.predict(X_test)

X2 = sm.add_constant(X)

# create an OLS model
model = sm.OLS(y, X2)

# fit the data
est = model.fit()
```

```
/Users/dtunnicliffe/anaconda3/envs/learn-env/lib/python3.6/site-
numpy/core/fromnumeric.py:2580: FutureWarning: Method .ptp is de
and will be removed in a future version. Use numpy.ptp instead.
  return ptp(axis=axis, out=out, **kwargs)
```

In [448]:
```
# check for the normality of the residuals
sm.qqplot(est.resid, line='s')
pylab.show()

# also check that the mean of the residuals is approx. 0.
mean_residuals = sum(est.resid)/ len(est.resid)
print("The mean of the residuals is {:.4}".format(mean_residuals
```




```
The mean of the residuals is -1.626e-15
```

Our residuals are relatively normal.

Recursive Feature Elimination (RFE)

In [449]:
```
# def lin_reg(X, y):
    """Recursive feature elimination (RFE) function"""
#     X_train, X_test, y_train, y_test = train_test_split(X, y, 
#     linreg = LinearRegression()
#     linreg.fit(X_train,y_train)
#     y_hat = linreg.predict(X_test)
#     y_hat_train = linreg.predict(X_train)
#     print('R_squared:', linreg.score(X, y))
#     #Display errors
#     print('Mean Absolute Error:', mean_absolute_error(y_test, 
#     print('Root Mean Squared Error test:', np.sqrt(mean_square
#     print('Root Mean Squared Error train:', np.sqrt(mean_squar
#     #Compare predicted and actual values
#     print('Mean Predicted Selling Price:', y_hat.mean())
#     print('Mean Selling Price:', y_test.mean())
#     return linreg
```

In [450]:
```
# lin_reg(X,y)
```

In [451]:
```
#RFE to check for insignificant features
# from sklearn.svm import SVR
# from sklearn.feature_selection import RFE

# estimator = SVR(kernel="linear")

# selector = RFE(estimator, step=1)
# selector = selector.fit(X, y)

# #Take a look at the R2 with only the most valuable features
# X_RFE = X[X.columns[selector.support_]]
# lin_reg(X_RFE, y)
```

Model #10

We then took our previous model and removed parks as a feature altogether, since furt
showed that this was not helping our R2 score. For the entire investigation into each fe
impact on the model, please see the notebook titled 'Iterating Through Final Model."

In [459]:
```
features = ['quant_sqft_living','quant_coffee', 'quant_schools', 
target = ['quant_price']
X = df[features]
y = df[target]

# running an iteration of the model using train_test_split
X_train, X_test, y_train, y_test = train_test_split(X,y, random_s

lm10 = LinearRegression().fit(X_train, y_train)
lm10_preds = lm10.predict(X_test)

print('R^2: ', r2_score(y_test, lm10_preds))
```

```
R^2:  0.7559686827061596
```

In [460]:
```
formula = "quant_price ~ quant_sqft_living+quant_coffee+quant_scl
model = ols(formula= formula, data=df).fit()
model.summary()
```

Out[460]:

OLS Regression Results

Dep. Variable:	quant_price	**R-squared:**	0.761
Model:	OLS	**Adj. R-squared:**	0.761
Method:	Least Squares	**F-statistic:**	3975.
Date:	Tue, 01 Dec 2020	**Prob (F-statistic):**	0.00
Time:	12:32:56	**Log-Likelihood:**	-12316.
No. Observations:	17495	**AIC:**	2.466e+04
Df Residuals:	17480	**BIC:**	2.478e+04
Df Model:	14		
Covariance Type:	nonrobust		

	coef	std err	t	P>|t|	[0.025	0.975]
Intercept	-0.7595	0.123	-6.162	0.000	-1.001	-0.518
quant_sqft_living	0.4986	0.006	89.550	0.000	0.488	0.510
quant_coffee	-0.0268	0.004	-6.779	0.000	-0.035	-0.019
quant_schools	-0.0690	0.021	-3.229	0.001	-0.111	-0.027
quant_scientology	-0.1564	0.014	-11.045	0.000	-0.184	-0.129
quant_interaction	-0.2133	0.031	-6.882	0.000	-0.274	-0.153
grade_5	0.1622	0.128	1.271	0.204	-0.088	0.412
grade_6	0.3062	0.123	2.486	0.013	0.065	0.548
grade_7	0.5827	0.123	4.730	0.000	0.341	0.824
grade_8	0.8813	0.124	7.125	0.000	0.639	1.124
grade_9	1.1946	0.125	9.592	0.000	0.951	1.439
grade_10	1.4313	0.126	11.385	0.000	1.185	1.678
grade_11	1.7186	0.129	13.371	0.000	1.467	1.971
grade_12	2.0842	0.144	14.458	0.000	1.802	2.367
grade_13	2.3268	0.236	9.839	0.000	1.863	2.790

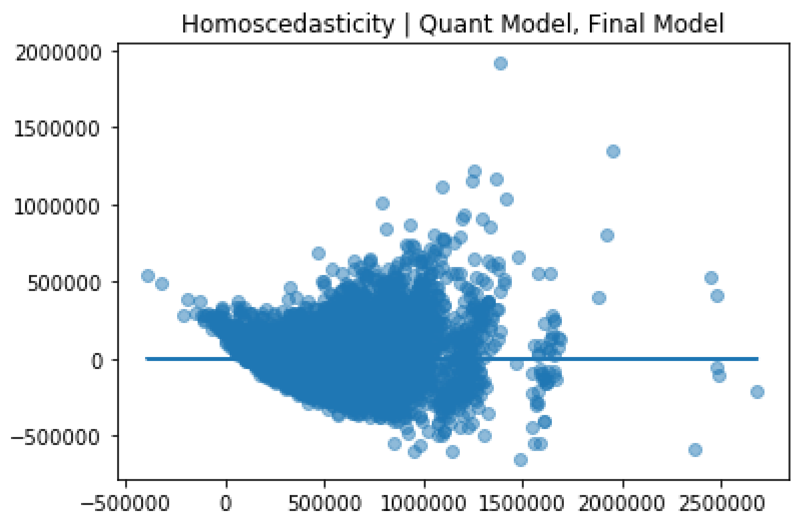
Omnibus:	391.327	**Durbin-Watson:**	1.997
Prob(Omnibus):	0.000	**Jarque-Bera (JB):**	510.627
Skew:	-0.283	**Prob(JB):**	1.31e-111
Kurtosis:	3.616	**Cond. No.**	175.

Warnings:
[1] Standard Errors assume that the covariance matrix of the errors is correctly specifie

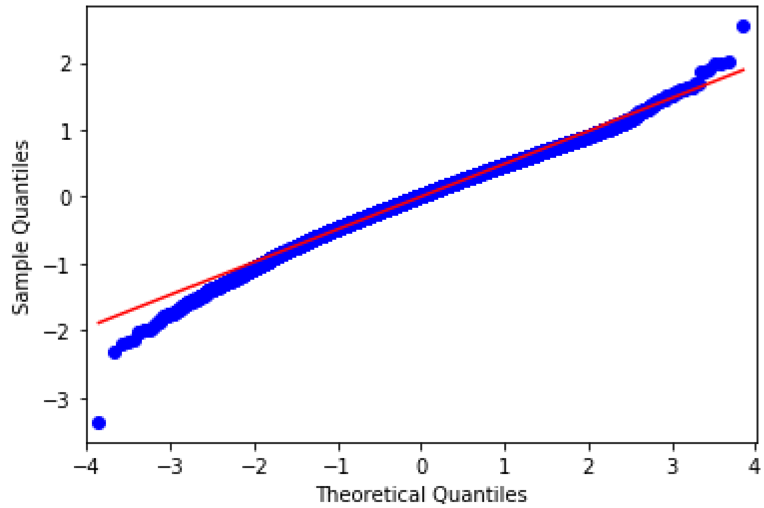
In [461]:
```
y_predict = lm10.predict(X_test)

X2 = sm.add_constant(X)

# create an OLS model
model = sm.OLS(y, X2)

# fit the data
est = model.fit()
```

```
/Users/dtunnicliffe/anaconda3/envs/learn-env/lib/python3.6/site-
numpy/core/fromnumeric.py:2580: FutureWarning: Method .ptp is de
and will be removed in a future version. Use numpy.ptp instead.
  return ptp(axis=axis, out=out, **kwargs)
```

In [466]:
```
f = 'price ~ quant_sqft_living+quant_coffee+quant_schools+quant_
model = ols(formula = f, data = df).fit()

predictors_quant = ['quant_sqft_living','quant_coffee', 'quant_s

plt.scatter(model.predict(df[predictors_quant]), model.resid, al
plt.plot(model.predict(df[predictors_quant]), [0 for i in range(
plt.title('Homoscedasticity | Quant Model, Final Model');
```



In [462]:
```
# check for the normality of the residuals
sm.qqplot(est.resid, line='s')
pylab.show()

# also check that the mean of the residuals is approx. 0.
mean_residuals = sum(est.resid)/ len(est.resid)
print("The mean of the residuals is {:.4}".format(mean_residuals
```




```
The mean of the residuals is -7.203e-16
```

Model #10

We then took our previous model and removed certain grades as features, as they wer our model and possibly creating heteroscedasticity.

In [510]:
```
features = ['quant_sqft_living','quant_coffee', 'quant_schools',
target = ['quant_price']
X = df[features]
y = df[target]

# running an iteration of the model using train_test_split
X_train, X_test, y_train, y_test = train_test_split(X,y, random_s

lm11 = LinearRegression().fit(X_train, y_train)
lm11_preds = lm11.predict(X_test)

print('R^2: ', r2_score(y_test, lm11_preds))
```

```
---------------------------------------------------------------------------
--
KeyError                                  Traceback (most recent
t)
<ipython-input-510-faae011a4c5d> in <module>()
      1 features = ['quant_sqft_living','quant_coffee', 'quant_sc
'quant_scientology', 'grade_6', 'grade_7', 'grade_8', 'grade_9',
0', 'grade_11', 'grade_12', 'grade_13', 'quant_interaction']
      2 target = ['quant_price']
----> 3 X = df[features]
      4 y = df[target]
      5

/Users/dtunnicliffe/anaconda3/envs/learn-env/lib/python3.6/site-p
pandas/core/frame.py in __getitem__(self, key)
   2999             if is_iterator(key):
   3000                 key = list(key)
-> 3001             indexer = self.loc._convert_to_indexer(key, a
aise_missing=True)
   3002 
   3003         # take() does not accept boolean indexers

/Users/dtunnicliffe/anaconda3/envs/learn-env/lib/python3.6/site-p
pandas/core/indexing.py in _convert_to_indexer(self, obj, axis, i
r, raise_missing)
   1283                 # When setting, missing keys are not allo
n with .loc:
   1284                 kwargs = {"raise_missing": True if is_se
raise_missing}
-> 1285                 return self._get_listlike_indexer(obj, ax
args)[1]
   1286         else:
   1287             try:

/Users/dtunnicliffe/anaconda3/envs/learn-env/lib/python3.6/site-p
pandas/core/indexing.py in _get_listlike_indexer(self, key, axis
issing)
   1090 
   1091         self._validate_read_indexer(
-> 1092             keyarr, indexer, o._get_axis_number(axis), ra
ing=raise_missing
   1093         )
   1094         return keyarr, indexer
```

```
/Users/dtunnicliffe/anaconda3/envs/learn-env/lib/python3.6/site-p
pandas/core/indexing.py in _validate_read_indexer(self, key, ind
s, raise_missing)
   1183             if not (self.name == "loc" and not raise_mis
   1184                 not_found = list(set(key) - set(ax))
-> 1185                 raise KeyError("{} not in index".format(n
))
   1186 
   1187             # we skip the warning on Categorical/Interval

KeyError: "['quant_interaction', 'grade_13', 'quant_schools', 'qu
_living', 'quant_scientology', 'quant_coffee'] not in index"
```

In [460]:
```
formula = "quant_price ~ quant_sqft_living+quant_coffee+quant_scl
model = ols(formula= formula, data=df).fit()
model.summary()
```

Out[460]:

OLS Regression Results

Dep. Variable:	quant_price	**R-squared:**	0.761
Model:	OLS	**Adj. R-squared:**	0.761
Method:	Least Squares	**F-statistic:**	3975.
Date:	Tue, 01 Dec 2020	**Prob (F-statistic):**	0.00
Time:	12:32:56	**Log-Likelihood:**	-12316.
No. Observations:	17495	**AIC:**	2.466e+04
Df Residuals:	17480	**BIC:**	2.478e+04
Df Model:	14		
Covariance Type:	nonrobust		

	coef	std err	t	P>|t|	[0.025	0.975]
Intercept	-0.7595	0.123	-6.162	0.000	-1.001	-0.518
quant_sqft_living	0.4986	0.006	89.550	0.000	0.488	0.510
quant_coffee	-0.0268	0.004	-6.779	0.000	-0.035	-0.019
quant_schools	-0.0690	0.021	-3.229	0.001	-0.111	-0.027
quant_scientology	-0.1564	0.014	-11.045	0.000	-0.184	-0.129
quant_interaction	-0.2133	0.031	-6.882	0.000	-0.274	-0.153
grade_5	0.1622	0.128	1.271	0.204	-0.088	0.412
grade_6	0.3062	0.123	2.486	0.013	0.065	0.548
grade_7	0.5827	0.123	4.730	0.000	0.341	0.824
grade_8	0.8813	0.124	7.125	0.000	0.639	1.124
grade_9	1.1946	0.125	9.592	0.000	0.951	1.439
grade_10	1.4313	0.126	11.385	0.000	1.185	1.678
grade_11	1.7186	0.129	13.371	0.000	1.467	1.971
grade_12	2.0842	0.144	14.458	0.000	1.802	2.367
grade_13	2.3268	0.236	9.839	0.000	1.863	2.790

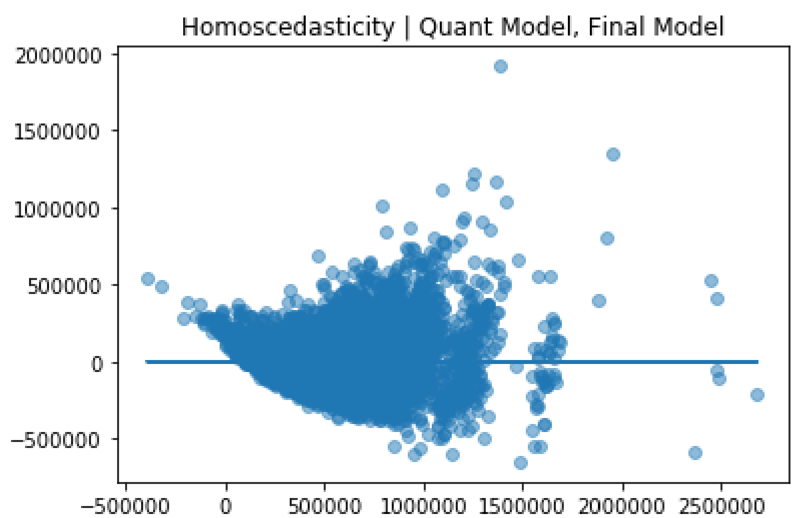
Omnibus:	391.327	**Durbin-Watson:**	1.997
Prob(Omnibus):	0.000	**Jarque-Bera (JB):**	510.627
Skew:	-0.283	**Prob(JB):**	1.31e-111
Kurtosis:	3.616	**Cond. No.**	175.

Warnings:
[1] Standard Errors assume that the covariance matrix of the errors is correctly specifie

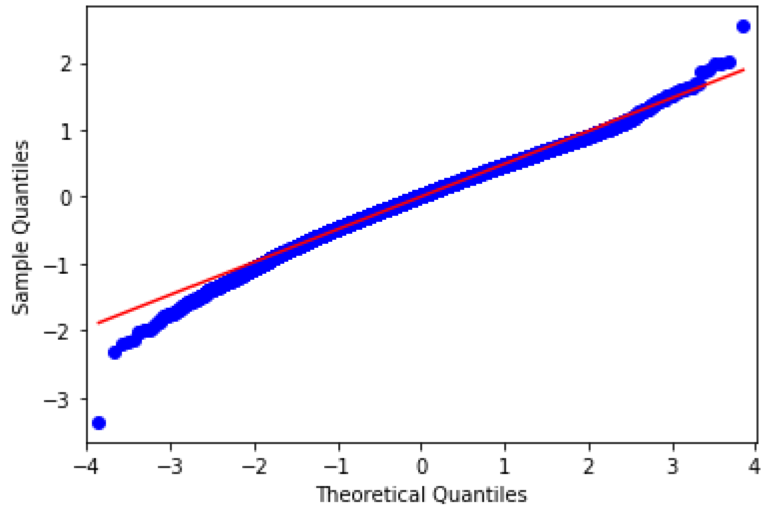
In [461]:
```
y_predict = lm10.predict(X_test)

X2 = sm.add_constant(X)

# create an OLS model
model = sm.OLS(y, X2)

# fit the data
est = model.fit()
```

```
/Users/dtunnicliffe/anaconda3/envs/learn-env/lib/python3.6/site-
numpy/core/fromnumeric.py:2580: FutureWarning: Method .ptp is de
and will be removed in a future version. Use numpy.ptp instead.
  return ptp(axis=axis, out=out, **kwargs)
```

In [466]:
```
f = 'price ~ quant_sqft_living+quant_coffee+quant_schools+quant_
model = ols(formula = f, data = df).fit()

predictors_quant = ['quant_sqft_living','quant_coffee', 'quant_sc

plt.scatter(model.predict(df[predictors_quant]), model.resid, al
plt.plot(model.predict(df[predictors_quant]), [0 for i in range(
plt.title('Homoscedasticity | Quant Model, Final Model');
```



In [462]:
```python
# check for the normality of the residuals
sm.qqplot(est.resid, line='s')
pylab.show()

# also check that the mean of the residuals is approx. 0.
mean_residuals = sum(est.resid)/ len(est.resid)
print("The mean of the residuals is {:.4}".format(mean_residuals
```




```
The mean of the residuals is -7.203e-16
```

Our residuals are relatively normal.

Our homoscedasticity declines with this final iteration; however, our R-squared, p-valu
Watson, and prob(F-statistic) are better than they were previously.

Results

The results of our complete analysis were as follows:

- The feature with the highest impact on our R-squared value was square-footage o space, which was positively correlated with house prices.
- The feature with the next-highest impact was distance to a top school, which was correlated with house prices.

- The feature with the next-highest impact was building grade, which was positively with house prices.
- The feature with the next-highest impact was distance to a scientology church, wh negatively correlated with house prices.
- The feature with the next-highest impact was distance to a great coffee shop, whic negatively correlated with house prices.
- The interaction between distance to a top school and distance to a scientology ch significant, as there was multicolinearity between the two. Accounting for this inter showed improvement to our model.
- And finally, the feature with the least impact was distance to a park, which had no impact on our model.

We are confident that the results we extrapolated from this analysis would generalize b data that we have. By looking at the available data, the trends and correlations we four for houses built from 1900 to 2015, so we are confident that they would hold true for h today. Despite the global pandemic, people are still buying and selling their homes. We that children are still largely attending schools, and we speculate that people continue well-built homes with a large amount of living space, now more than ever. And the data that people tend to pay more for a home that's near a good coffee shop and a scientol

If the recommendations that we made are put to use, we are confident that King Count Developers will have a successful career in the housing market. From the data, it is cle attributes we have discussed are correlated with high home sale prices, which is exact County Developers will want for their projects.

Final Evaluation and Conclusion

Our best model had an R-squared value of 0.761, telling us that the model fit the data accuracy of 76%. After reviewing this final iteration, we felt confident in our recommen all of our available features except parks be considered by home developers in order to selling price. Sqare-feet of living space, building grade, distance to great schools, coffe and churches of scientology, as well as the interaction between schools and scientolog all play a valuable role in predicting the price of a house in King County.

The prob(F-statistic) of 0.00 tells us that there is an extremely low probability of achievi results with the null hypothesis being true, and tells us that our regression is meaningfu values for our features are well below our alpha or significance level, showing that they contributing to the model significantly. With an alpha of 0.05, at a confidence level of 9 reject the null hypothesis that there is no relationship between our features and our tar price.

Our recommendations are as follows:

- increase square-footage of living space
- attain the highest possible building grade
- build and develop homes in close proximity to a top school district
- build and develop homes in close proximity to a highly-rated coffee shop
- build and develop homes in close proximity to a scientology church

By following the above recommendations, a housing development company in King Co
increase their chances of selling higher-priced homes.

In the future, our next steps would be reducing noise in the data to improve the accura
model. Additionally, we would like to investigate certain features, such as
constructional/architectural values of the house, to see what trends we could discern f
Some ideas would be whether basements are correlated with higher house prices, or w
amount of bathrooms has an impact.