

Modeling Factors That Affect Housing Prices in King County, USA

Methodology

Obtaining Data

All data was imported from kc_house_data csv file. No other query was needed.

	id	date	price	bedrooms	bathrooms	sqft_living	sqft_lot	floors	waterfront	view	...	grade	sqft_above	sqft_basement	yr_built
0	7129300520	10/13/2014	221900.0	3	1.00	1180	5650	1.0	NaN	0.0	...	7	1180	0.0	1955
1	6414100192	12/9/2014	538000.0	3	2.25	2570	7242	2.0	0.0	0.0	...	7	2170	400.0	1951
2	5631500400	2/25/2015	180000.0	2	1.00	770	10000	1.0	0.0	0.0	...	6	770	0.0	1933
3	2487200875	12/9/2014	604000.0	4	3.00	1960	5000	1.0	0.0	0.0	...	7	1050	910.0	1965
4	1954400510	2/18/2015	510000.0	3	2.00	1680	8080	1.0	0.0	0.0	...	8	1680	0.0	1987

5 rows × 21 columns

- Initial inspection showed 21597 data entries with 21 columns, which is a sizeable amount of data
- Some columns, such as sqft of the living room, are continuous data, while others, such as waterfront and grade, are categorical and will need to be tweaked for effective model application.

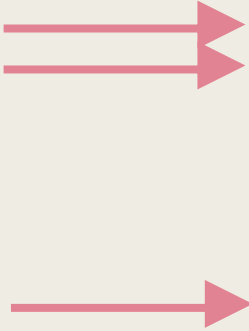
Methodology

Obtaining and Cleaning Data

Data was scanned for null values, which would interfere with statistical modeling. Three columns showed presence of null values and different approaches were taken to each:

- 63 entries with a null values in view were dropped since they were a relatively small percentage of the data
- Null values in waterfront were replaced with the median (0).
- Year renovated was dropped entirely as a column due to high amounts of missing data.

Null values




id	0
date	0
price	0
bedrooms	0
bathrooms	0
sqft_living	0
sqft_lot	0
floors	0
waterfront	2376
view	63
condition	0
grade	0
sqft_above	0
sqft_basement	0
yr_built	0
yr_renovated	3842
zipcode	0
lat	0
long	0
sqft_living15	0
sqft_lot15	0
dtype:	int64

Methodology

Data Type Conversion

Before

```
Data columns (total 20 columns):
id                21534 non-null int64
date              21534 non-null object
price             21534 non-null float64
bedrooms          21534 non-null int64
bathrooms         21534 non-null float64
sqft_living       21534 non-null int64
sqft_lot          21534 non-null int64
floors            21534 non-null float64
waterfront        21534 non-null float64
view              21534 non-null float64
condition         21534 non-null int64
grade             21534 non-null int64
sqft_above        21534 non-null int64
sqft_basement     21534 non-null object
yr_built          21534 non-null int64
zipcode           21534 non-null int64
lat               21534 non-null float64
long              21534 non-null float64
sqft_living15     21534 non-null int64
sqft_lot15        21534 non-null int64
dtypes: float64(7), int64(11), object(2)
memory usage: 3.5+ MB
```



**-ID & date were
dropped due to
high number of
unique entries**

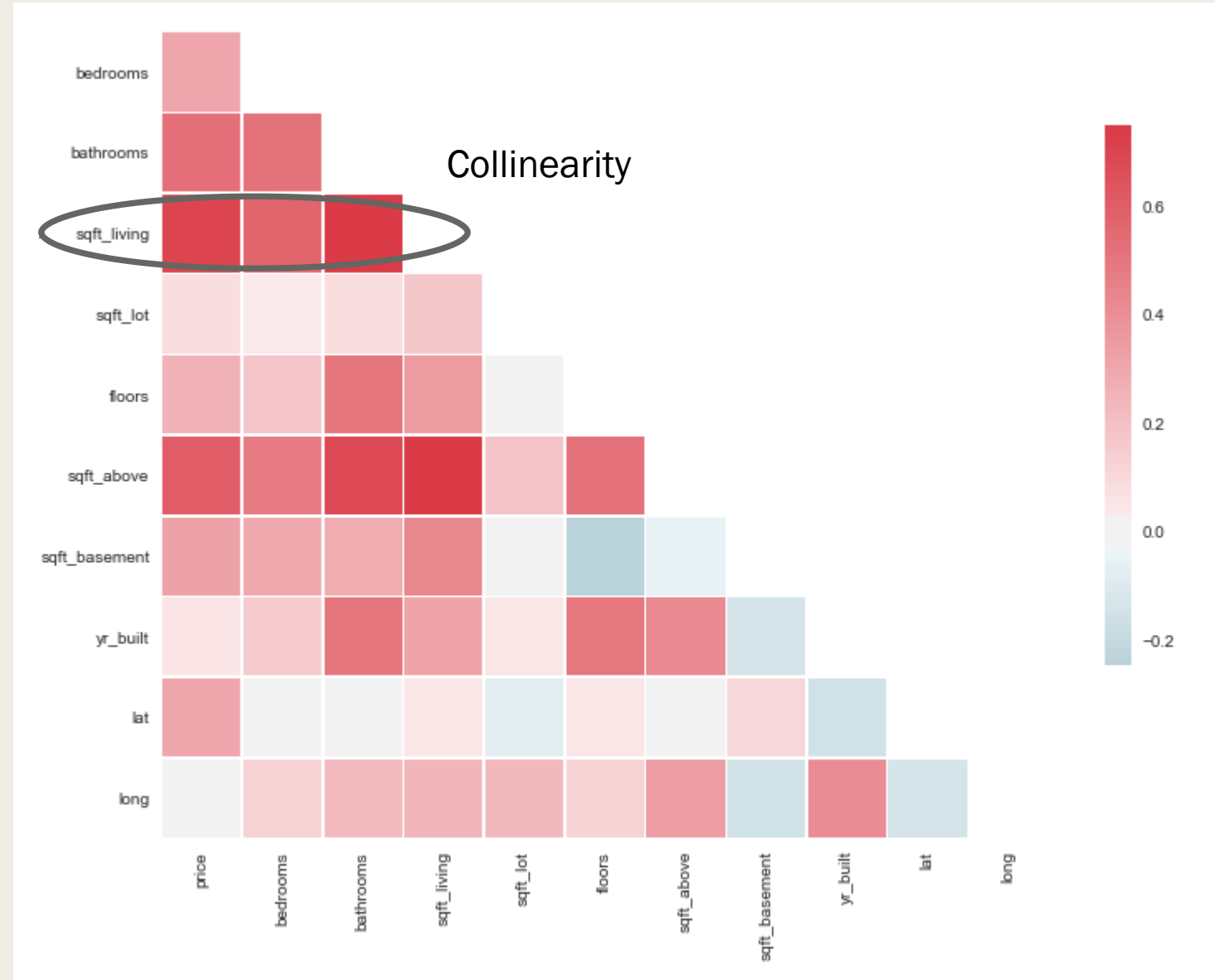
**-sqft_living15 and
sqft_lot15 also
dropped since year
renovation was
dropped**

After

```
Data columns (total 15 columns):
price             21082 non-null float64
bedrooms          21082 non-null int64
bathrooms         21082 non-null float64
sqft_lot          21082 non-null int64
floors            21082 non-null float64
waterfront        21082 non-null object
view              21082 non-null object
condition         21082 non-null object
grade             21082 non-null object
sqft_above        21082 non-null int64
sqft_basement     21082 non-null float64
yr_built          21082 non-null int64
zipcode           21082 non-null object
lat               21082 non-null float64
long              21082 non-null float64
dtypes: float64(6), int64(4), object(5)
```

Assessing Multicollinearity

Using a heatmap, sqft living was collinear with many things, which justified dropping column altogether. This may seem wasteful of data, but sqft living was simply a combination of both sqft above with sqft basement for most cases, so the final model would still have this information.



Assessing Multicollinearity

Absolute Correlation >.75

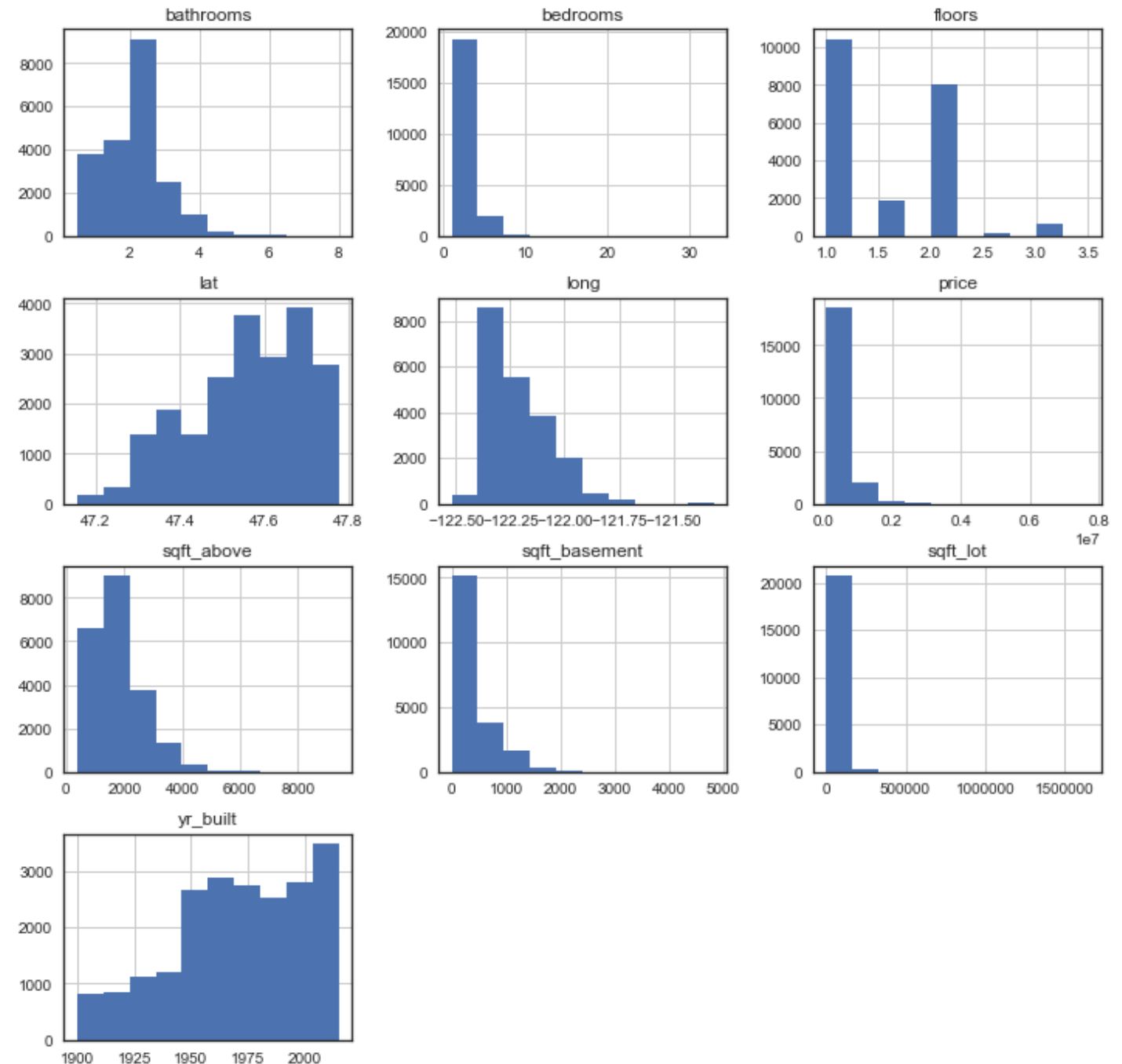
	price	bedrooms	bathrooms	sqft_living	sqft_lot	floors	sqft_above	sqft_basement	yr_built	lat	long
price	True	False	False	False	False	False	False	False	False	False	False
bedrooms	False	True	False	False	False	False	False	False	False	False	False
bathrooms	False	False	True	True	False	False	False	False	False	False	False
sqft_living	False	False	True	True	False	False	True	False	False	False	False
sqft_lot	False	False	False	False	True	False	False	False	False	False	False
floors	False	False	False	False	False	True	False	False	False	False	False
sqft_above	False	False	False	True	False	False	True	False	False	False	False
sqft_basement	False	False	False	False	False	False	False	True	False	False	False
yr_built	False	False	False	False	False	False	False	False	True	False	False
lat	False	False	False	False	False	False	False	False	False	True	False
long	False	False	False	False	False	False	False	False	False	False	True

Sqft living's high correlation with bathrooms and sqft above justified dropped the column

Normalization and Scaling

Most column contained highly skewed data, which warranted log transformation.

However, columns with negative values and zeroes, such as longitude and sqft basement, could not be log transformed.

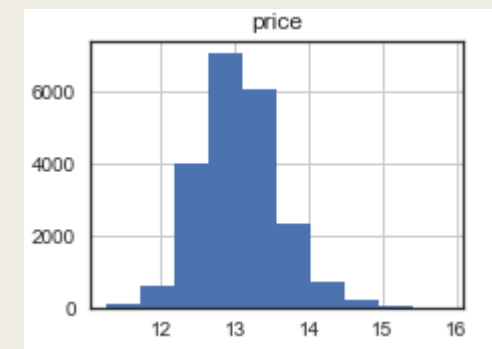
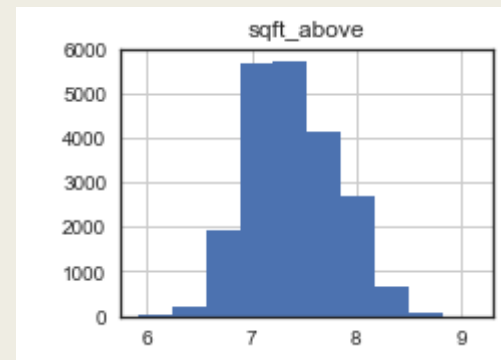
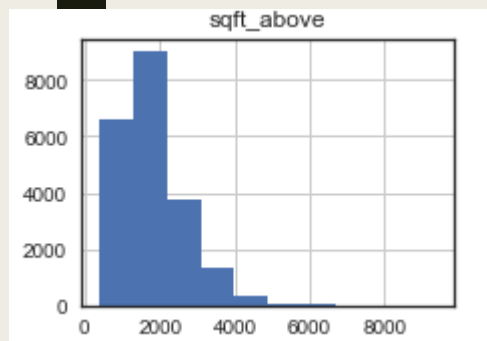
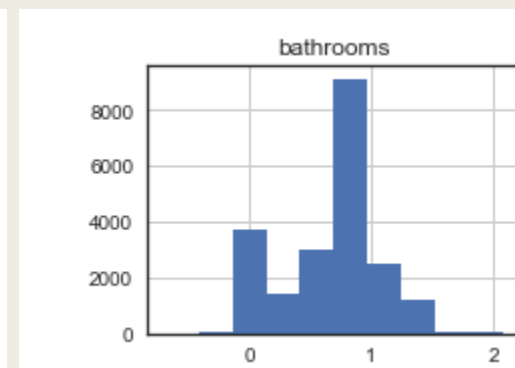
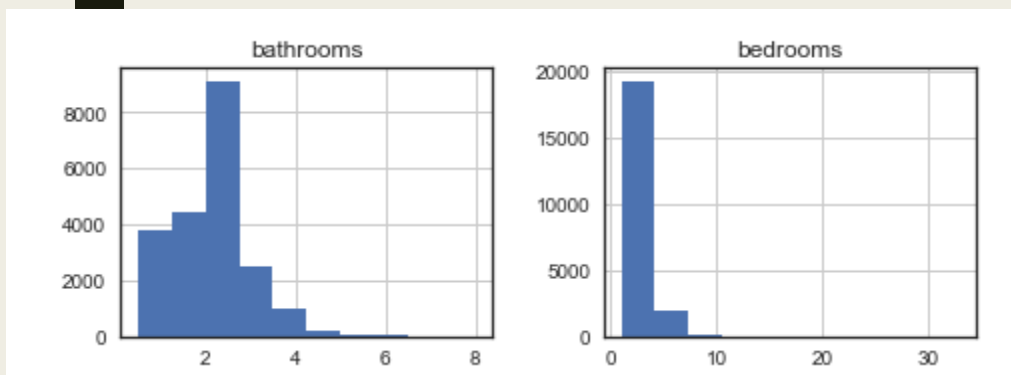


Before

Methodology

Post-Normalization

After



Methodology

Stepwise Selection to Ensure Significance

```
Add bedrooms          with p-value 0.0
Add grade_11           with p-value 0.0
Add sqft_above         with p-value 0.0
Add lat                with p-value 0.0
Add sqft_basement      with p-value 0.0
Add const              with p-value 0.0
Add view_4             with p-value 1.238e-159
Add grade_7            with p-value 1.46157e-96
Add grade_6            with p-value 1.7623e-143
Add grade_8            with p-value 1.04616e-171
Add grade_5            with p-value 1.01562e-160
Add condition_3        with p-value 3.52779e-141
Add grade_9            with p-value 1.26756e-73
Add view_3             with p-value 1.25905e-63
Add view_2             with p-value 6.27837e-73
Add grade_4            with p-value 3.95185e-50
Add waterfront_1       with p-value 6.16782e-48
Add view_1             with p-value 8.5074e-44
Add condition_5        with p-value 1.0856e-42
Add grade_12           with p-value 1.86227e-28
Add condition_4        with p-value 1.78479e-19
Add grade_13           with p-value 7.91774e-16
Add sqft_lot           with p-value 1.70146e-13
Add bathrooms          with p-value 0.00369537
Features:
['bedrooms', 'grade_11', 'sqft_above', 'lat', 'sqft_basement', 'const', 'view_4', 'grade_7', 'grade_6', 'grade_8', 'grade_5',
'condition_3', 'grade_9', 'view_3', 'view_2', 'grade_4', 'waterfront_1', 'view_1', 'condition_5', 'grade_12', 'condition_4', 'g
rade_13', 'sqft_lot', 'bathrooms']
```

Methodology

K-Fold Cross Validation to Ensure Fit

```
cv_20_results = cross_val_score(linreg, X, y, cv=20, scoring="neg_mean_squared_error")  
print(cv_20_results)  
print(np.mean(cv_20_results))
```

```
[-0.06812241 -0.074362    -0.07085126 -0.08489064 -0.07350715 -0.07311299  
 -0.07057717 -0.07529035 -0.07240392 -0.06898902 -0.07006055 -0.07990278  
 -0.0717607  -0.07717531 -0.07507136 -0.07498257 -0.07535882 -0.072871  
 -0.05442297 -0.04882939]  
-0.07162711853527273
```

MSE for all folds is extremely low, and so is the average. This model can successfully predict new data

Methodology

The Final Model

- This model is able to explain 74% of the variation in price.
- Most entries are still preserved
- Lack of categorical data columns reduces kurtosis

Dep. Variable:	price	R-squared:	0.742
Model:	OLS	Adj. R-squared:	0.742
Method:	Least Squares	F-statistic:	2639.
Date:	Mon, 17 Dec 2018	Prob (F-statistic):	0.00
Time:	21:19:05	Log-Likelihood:	-2086.1
No. Observations:	21081	AIC:	4220.
Df Residuals:	21057	BIC:	4411.
Df Model:	23		
Covariance Type:	nonrobust		

Interpretation

	coef	std err	t	P> t	[0.025	0.975]
Intercept	13.3171	0.022	615.630	0.000	13.275	13.359
grade_11[T.1]	0.1600	0.016	10.075	0.000	0.129	0.191
view_4[T.1]	0.2974	0.019	15.650	0.000	0.260	0.335
grade_7[T.1]	-0.5258	0.011	-49.850	0.000	-0.546	-0.505
grade_6[T.1]	-0.6473	0.013	-49.309	0.000	-0.673	-0.622
grade_8[T.1]	-0.3738	0.010	-38.777	0.000	-0.393	-0.355
grade_5[T.1]	-0.7486	0.022	-34.748	0.000	-0.791	-0.706
condition_3[T.1]	0.0780	0.020	3.967	0.000	0.039	0.116
grade_9[T.1]	-0.1726	0.010	-17.639	0.000	-0.192	-0.153
view_3[T.1]	0.2319	0.013	18.477	0.000	0.207	0.257
view_2[T.1]	0.1705	0.009	18.571	0.000	0.153	0.189
grade_4[T.1]	-0.7562	0.053	-14.138	0.000	-0.861	-0.651
waterfront_1[T.1]	0.4174	0.027	15.180	0.000	0.364	0.471
view_1[T.1]	0.2135	0.015	14.190	0.000	0.184	0.243
condition_5[T.1]	0.2692	0.021	13.113	0.000	0.229	0.309
grade_12[T.1]	0.3472	0.030	11.581	0.000	0.288	0.406

condition_4[T.1]	0.1746	0.020	8.840	0.000	0.136	0.213
grade_13[T.1]	0.6004	0.075	7.999	0.000	0.453	0.748
bedrooms	-0.0173	0.003	-6.909	0.000	-0.022	-0.012
sqft_above	0.1800	0.004	46.252	0.000	0.172	0.188
lat	0.2064	0.002	108.005	0.000	0.203	0.210
sqft_basement	0.0946	0.002	39.443	0.000	0.090	0.099
sqft_lot	-0.0140	0.002	-6.626	0.000	-0.018	-0.010
bathrooms	0.0088	0.003	2.903	0.004	0.003	0.015
Omnibus:	434.995	Durbin-Watson:	1.994			
Prob(Omnibus):	0.000	Jarque-Bera (JB):	660.724			
Skew:	0.220	Prob(JB):	3.35e-144			
Kurtosis:	3.747	Cond. No.	63.2			

Interpretation

A grade of 11 or higher greatly increases selling price of a house

condition_4[T.1]	0.1746	0.020	8.840	0.000	0.136	0.213
grade_13[T.1]	0.6004	0.075	7.999	0.000	0.453	0.748
bedrooms	-0.0173	0.003	-6.909	0.000	-0.022	-0.012
sqft_above	0.1800	0.004	46.252	0.000	0.172	0.188
lat	0.2064	0.002	108.005	0.000	0.203	0.210
sqft_basement	0.0946	0.002	39.443	0.000	0.090	0.099
sqft_lot	-0.0140	0.002	-6.626	0.000	-0.018	-0.010
bathrooms	0.0088	0.003	2.903	0.004	0.003	0.015
Omnibus:	434.995	Durbin-Watson:	1.994			
Prob(Omnibus):	0.000	Jarque-Bera (JB):	660.724			
Skew:	0.220	Prob(JB):	3.35e-144			
Kurtosis:	3.747	Cond. No.	63.2			

	coef	std err	t	P> t	[0.025	0.975]
Intercept	13.3171	0.022	615.630	0.000	13.275	13.359
grade_11[T.1]	0.1600	0.016	10.075	0.000	0.129	0.191
view_4[T.1]	0.2974	0.019	15.650	0.000	0.260	0.335
grade_7[T.1]	-0.5258	0.011	-49.850	0.000	-0.546	-0.505
grade_6[T.1]	-0.6473	0.013	-49.309	0.000	-0.673	-0.622
grade_8[T.1]	-0.3738	0.010	-38.777	0.000	-0.393	-0.355
grade_5[T.1]	-0.7486	0.022	-34.748	0.000	-0.791	-0.706
condition_3[T.1]	0.0780	0.020	3.967	0.000	0.039	0.116
grade_9[T.1]	-0.1726	0.010	-17.639	0.000	-0.192	-0.153
view_3[T.1]	0.2319	0.013	18.477	0.000	0.207	0.257
view_2[T.1]	0.1705	0.009	18.571	0.000	0.153	0.189
grade_4[T.1]	-0.7562	0.053	-14.138	0.000	-0.861	-0.651
waterfront_1[T.1]	0.4174	0.027	15.180	0.000	0.364	0.471
view_1[T.1]	0.2135	0.015	14.190	0.000	0.184	0.243
condition_5[T.1]	0.2692	0.021	13.113	0.000	0.229	0.309
grade_12[T.1]	0.3472	0.030	11.581	0.000	0.288	0.406

Interpretation

Waterfront view also has high impact on price

condition_4[T.1]	0.1746	0.020	8.840	0.000	0.136	0.213
grade_13[T.1]	0.6004	0.075	7.999	0.000	0.453	0.748
bedrooms	-0.0173	0.003	-6.909	0.000	-0.022	-0.012
sqft_above	0.1800	0.004	46.252	0.000	0.172	0.188
lat	0.2064	0.002	108.005	0.000	0.203	0.210
sqft_basement	0.0946	0.002	39.443	0.000	0.090	0.099
sqft_lot	-0.0140	0.002	-6.626	0.000	-0.018	-0.010
bathrooms	0.0088	0.003	2.903	0.004	0.003	0.015
Omnibus:	434.995	Durbin-Watson:		1.994		
Prob(Omnibus):	0.000	Jarque-Bera (JB):		660.724		
Skew:	0.220	Prob(JB):		3.35e-144		
Kurtosis:	3.747	Cond. No.		63.2		

	coef	std err	t	P> t	[0.025	0.975]
Intercept	13.3171	0.022	615.630	0.000	13.275	13.359
grade_11[T.1]	0.1600	0.016	10.075	0.000	0.129	0.191
view_4[T.1]	0.2974	0.019	15.650	0.000	0.260	0.335
grade_7[T.1]	-0.5258	0.011	-49.850	0.000	-0.546	-0.505
grade_6[T.1]	-0.6473	0.013	-49.309	0.000	-0.673	-0.622
grade_8[T.1]	-0.3738	0.010	-38.777	0.000	-0.393	-0.355
grade_5[T.1]	-0.7486	0.022	-34.748	0.000	-0.791	-0.706
condition_3[T.1]	0.0780	0.020	3.967	0.000	0.039	0.116
grade_9[T.1]	-0.1726	0.010	-17.639	0.000	-0.192	-0.153
view_3[T.1]	0.2319	0.013	18.477	0.000	0.207	0.257
view_2[T.1]	0.1705	0.009	18.571	0.000	0.153	0.189
grade_4[T.1]	-0.7562	0.053	-14.138	0.000	-0.861	-0.651
waterfront_1[T.1]	0.4174	0.027	15.180	0.000	0.364	0.471
view_1[T.1]	0.2135	0.015	14.190	0.000	0.184	0.243
condition_5[T.1]	0.2692	0.021	13.113	0.000	0.229	0.309
grade_12[T.1]	0.3472	0.030	11.581	0.000	0.288	0.406

Interpretation

General increase in views lead to higher sell prices

condition_4[T.1]	0.1746	0.020	8.840	0.000	0.136	0.213
grade_13[T.1]	0.6004	0.075	7.999	0.000	0.453	0.748
bedrooms	-0.0173	0.003	-6.909	0.000	-0.022	-0.012
sqft_above	0.1800	0.004	46.252	0.000	0.172	0.188
lat	0.2064	0.002	108.005	0.000	0.203	0.210
sqft_basement	0.0946	0.002	39.443	0.000	0.090	0.099
sqft_lot	-0.0140	0.002	-6.626	0.000	-0.018	-0.010
bathrooms	0.0088	0.003	2.903	0.004	0.003	0.015
Omnibus:	434.995	Durbin-Watson:	1.994			
Prob(Omnibus):	0.000	Jarque-Bera (JB):	660.724			
Skew:	0.220	Prob(JB):	3.35e-144			
Kurtosis:	3.747	Cond. No.	63.2			

	coef	std err	t	P> t	[0.025	0.975]
Intercept	13.3171	0.022	615.630	0.000	13.275	13.359
grade_11[T.1]	0.1600	0.016	10.075	0.000	0.129	0.191
view_4[T.1]	0.2974	0.019	15.650	0.000	0.260	0.335
grade_7[T.1]	-0.5258	0.011	-49.850	0.000	-0.546	-0.505
grade_6[T.1]	-0.6473	0.013	-49.309	0.000	-0.673	-0.622
grade_8[T.1]	-0.3738	0.010	-38.777	0.000	-0.393	-0.355
grade_5[T.1]	-0.7486	0.022	-34.748	0.000	-0.791	-0.706
condition_3[T.1]	0.0780	0.020	3.967	0.000	0.039	0.116
grade_9[T.1]	-0.1726	0.010	-17.639	0.000	-0.192	-0.153
view_3[T.1]	0.2319	0.013	18.477	0.000	0.207	0.257
view_2[T.1]	0.1705	0.009	18.571	0.000	0.153	0.189
grade_4[T.1]	-0.7562	0.053	-14.138	0.000	-0.861	-0.651
waterfront_1[T.1]	0.4174	0.027	15.180	0.000	0.364	0.471
view_1[T.1]	0.2135	0.015	14.190	0.000	0.184	0.243
condition_5[T.1]	0.2692	0.021	13.113	0.000	0.229	0.309
grade_12[T.1]	0.3472	0.030	11.581	0.000	0.288	0.406

Interpretation

Those further north in King Country should consider higher prices

condition_4[T.1]	0.1746	0.020	8.840	0.000	0.136	0.213
grade_13[T.1]	0.6004	0.075	7.999	0.000	0.453	0.748
bedrooms	-0.0173	0.003	-6.909	0.000	-0.022	-0.012
sqft_above	0.1800	0.004	46.252	0.000	0.172	0.188
lat	0.2064	0.002	108.005	0.000	0.203	0.210
sqft_basement	0.0946	0.002	39.443	0.000	0.090	0.099
sqft_lot	-0.0140	0.002	-6.626	0.000	-0.018	-0.010
bathrooms	0.0088	0.003	2.903	0.004	0.003	0.015
Omnibus:	434.995	Durbin-Watson:	1.994			
Prob(Omnibus):	0.000	Jarque-Bera (JB):	660.724			
Skew:	0.220	Prob(JB):	3.35e-144			
Kurtosis:	3.747	Cond. No.	63.2			

	coef	std err	t	P> t	[0.025	0.975]
Intercept	13.3171	0.022	615.630	0.000	13.275	13.359
grade_11[T.1]	0.1600	0.016	10.075	0.000	0.129	0.191
view_4[T.1]	0.2974	0.019	15.650	0.000	0.260	0.335
grade_7[T.1]	-0.5258	0.011	-49.850	0.000	-0.546	-0.505
grade_6[T.1]	-0.6473	0.013	-49.309	0.000	-0.673	-0.622
grade_8[T.1]	-0.3738	0.010	-38.777	0.000	-0.393	-0.355
grade_5[T.1]	-0.7486	0.022	-34.748	0.000	-0.791	-0.706
condition_3[T.1]	0.0780	0.020	3.967	0.000	0.039	0.116
grade_9[T.1]	-0.1726	0.010	-17.639	0.000	-0.192	-0.153
view_3[T.1]	0.2319	0.013	18.477	0.000	0.207	0.257
view_2[T.1]	0.1705	0.009	18.571	0.000	0.153	0.189
grade_4[T.1]	-0.7562	0.053	-14.138	0.000	-0.861	-0.651
waterfront_1[T.1]	0.4174	0.027	15.180	0.000	0.364	0.471
view_1[T.1]	0.2135	0.015	14.190	0.000	0.184	0.243
condition_5[T.1]	0.2692	0.021	13.113	0.000	0.229	0.309
grade_12[T.1]	0.3472	0.030	11.581	0.000	0.288	0.406

Interpretation

Do not advertise too many bedrooms or too big a lot as that can have a negative impact

condition_4[T.1]	0.1746	0.020	8.840	0.000	0.136	0.213
grade_13[T.1]	0.6004	0.075	7.999	0.000	0.453	0.748
bedrooms	-0.0173	0.003	-6.909	0.000	-0.022	-0.012
sqft_above	0.1800	0.004	46.252	0.000	0.172	0.188
lat	0.2064	0.002	108.005	0.000	0.203	0.210
sqft_basement	0.0946	0.002	39.443	0.000	0.090	0.099
sqft_lot	-0.0140	0.002	-6.626	0.000	-0.018	-0.010
bathrooms	0.0088	0.003	2.903	0.004	0.003	0.015
Omnibus:	434.995	Durbin-Watson:	1.994			
Prob(Omnibus):	0.000	Jarque-Bera (JB):	660.724			
Skew:	0.220	Prob(JB):	3.35e-144			
Kurtosis:	3.747	Cond. No.	63.2			

	coef	std err	t	P> t	[0.025	0.975]
Intercept	13.3171	0.022	615.630	0.000	13.275	13.359
grade_11[T.1]	0.1600	0.016	10.075	0.000	0.129	0.191
view_4[T.1]	0.2974	0.019	15.650	0.000	0.260	0.335
grade_7[T.1]	-0.5258	0.011	-49.850	0.000	-0.546	-0.505
grade_6[T.1]	-0.6473	0.013	-49.309	0.000	-0.673	-0.622
grade_8[T.1]	-0.3738	0.010	-38.777	0.000	-0.393	-0.355
grade_5[T.1]	-0.7486	0.022	-34.748	0.000	-0.791	-0.706
condition_3[T.1]	0.0780	0.020	3.967	0.000	0.039	0.116
grade_9[T.1]	-0.1726	0.010	-17.639	0.000	-0.192	-0.153
view_3[T.1]	0.2319	0.013	18.477	0.000	0.207	0.257
view_2[T.1]	0.1705	0.009	18.571	0.000	0.153	0.189
grade_4[T.1]	-0.7562	0.053	-14.138	0.000	-0.861	-0.651
waterfront_1[T.1]	0.4174	0.027	15.180	0.000	0.364	0.471
view_1[T.1]	0.2135	0.015	14.190	0.000	0.184	0.243
condition_5[T.1]	0.2692	0.021	13.113	0.000	0.229	0.309
grade_12[T.1]	0.3472	0.030	11.581	0.000	0.288	0.406

Interpretation

As expected, general living area, apart from the basement, increases the price.

condition_4[T.1]	0.1746	0.020	8.840	0.000	0.136	0.213
grade_13[T.1]	0.6004	0.075	7.999	0.000	0.453	0.748
bedrooms	-0.0173	0.003	-6.909	0.000	-0.022	-0.012
sqft_above	0.1800	0.004	46.252	0.000	0.172	0.188
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Prob(Omnibus):	0.000	Jarque-Bera (JB):	660.724			
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Kurtosis:	3.747	Cond. No.	63.2			

	coef	std err	t	P> t	[0.025	0.975]
Intercept	13.3171	0.022	615.630	0.000	13.275	13.359
grade_11[T.1]	0.1600	0.016	10.075	0.000	0.129	0.191
view_4[T.1]	0.2974	0.019	15.650	0.000	0.260	0.335
grade_7[T.1]	-0.5258	0.011	-49.850	0.000	-0.546	-0.505
grade_6[T.1]	-0.6473	0.013	-49.309	0.000	-0.673	-0.622
grade_8[T.1]	-0.3738	0.010	-38.777	0.000	-0.393	-0.355
grade_5[T.1]	-0.7486	0.022	-34.748	0.000	-0.791	-0.706
condition_3[T.1]	0.0780	0.020	3.967	0.000	0.039	0.116
grade_9[T.1]	-0.1726	0.010	-17.639	0.000	-0.192	-0.153
view_3[T.1]	0.2319	0.013	18.477	0.000	0.207	0.257
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grade_12[T.1]	0.3472	0.030	11.581	0.000	0.288	0.406

Overall Takeaways

- Renovate home, if necessary, to ensure a high grade from King County grading system
- Increase price of home if there is a view to waterfront, or if it resides further north in King County.
- Put some effort into advertising and getting people to view your home
- When renovating, do *not* expand lot size or number of bedrooms and bathrooms. Instead, expand the general living space, except for the basement.