Intro to Data Science

Project 1: ANOVA analysis

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Outline

1. Abstract
2. Theory
3. Exploratory Data analysis
4. Analysis Results & Explanation
5. Conclusion

1 Abstract

After detecting that a factor has a significant effect on a dependent variable globally, we often want to go further into detail and ask which specific factor levels differ from one another. Running a one-way ANOVA on the data would answer the very general question: “is there at least one treatment which significantly differs from the others?” If the ANOVA test is significant, another question could be asked: “what treatments differ from one another?” This question requires testing the differences between all pairs of treatments. Pairwise multiple comparisons tools were developed to address this issue.

2 Theory

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3 Exploratory Data analysis

In this section, we use the method of One-way Anova to explorate the data

In [2]:

```
import pandas as pd
import numpy as np
import statsmodels.api as sm
from statsmodels.formula.api import ols
```

Firstly, we load the data as the dataframe type set.

In [3]:

```
data = pd.read_csv('DSCI6002_prj1_data.csv', header = None)
data_array = np.array(data)
df = pd.DataFrame(data_array ,columns = ['treatments','value'])
df.dtypes
```

Out[3]:

```
treatments    object
value         object
dtype: object
```

Since the data type of the column of 'value' is object, we need to convert the value from object to numeric.

In [4]:

```
# convert the value column to numeric type
df['value'] = pd.to_numeric(df['value'])
df.dtypes
```

Out[4]:

```
treatments     object
value         float64
dtype: object
```

In [5]:

```
model = ols('value~C(treatments)', data = df ).fit()
model.summary()
```

Out[5]:

OLS Regression Results

Dep. Variable:	value	**R-squared:**	0.016
Model:	OLS	**Adj. R-squared:**	0.012
Method:	Least Squares	**F-statistic:**	4.619
Date:	Thu, 18 Nov 2021	**Prob (F-statistic):**	0.00106
Time:	15:53:06	**Log-Likelihood:**	-4837.1
No. Observations:	1172	**AIC:**	9684.
Df Residuals:	1167	**BIC:**	9709.
Df Model:	4		
Covariance Type:	nonrobust		

	coef	std err	t	P>|t|	[0.025	0.975]
Intercept	42.2032	0.945	44.648	0.000	40.349	44.058
C(treatments)[T.Graduate]	1.4968	1.534	0.976	0.329	-1.512	4.506
C(treatments)[T.HS]	-2.0975	1.143	-1.834	0.067	-4.341	0.146
C(treatments)[T.Jr Coll]	-1.0063	1.796	-0.560	0.575	-4.529	2.517
C(treatments)[T.Less than HS]	-5.5668	1.662	-3.350	0.001	-8.827	-2.306

Omnibus:	0.432	**Durbin-Watson:**	1.984
Prob(Omnibus):	0.806	**Jarque-Bera (JB):**	0.513
Skew:	0.028	**Prob(JB):**	0.774
Kurtosis:	2.914	**Cond. No.**	6.26

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

by implementing the method of One-way Anova to the model, we can get the parameters.

In [6]:

```
### One-way ANOVA
anova_table = sm.stats.anova_lm(model,typ = 2)
anova_table
```

Out[6]:

	sum_sq	df	F	PR(>F)
C(treatments)	4176.452688	4.0	4.618904	0.001056
Residual	263802.838942	1167.0	NaN	NaN

In [7]:

```
esq_sm = anova_table['sum_sq'][0]/(anova_table['sum_sq'][0]+anova_table['sum_sq'][1])
anova_table['EtaSq'] = [esq_sm,'NaN']
anova_table
```

Out[7]:

	sum_sq	df	F	PR(>F)	EtaSq
C(treatments)	4176.452688	4.0	4.618904	0.001056	0.015585
Residual	263802.838942	1167.0	NaN	NaN	NaN

By applying the method of Multiple Pairwise Comparisons and Turkey HSD test, the results show us that the difference between each group.

In [8]:

```
pair_t = model.t_test_pairwise('C(treatments)')
pair_t.result_frame
```

Out[8]:

	coef	std err	t	P>|t|	Conf. Int. Low	Conf. Int. Upp.	pvalue-hs	reject-hs
Graduate-Bachelor's	1.496838	1.533586	0.976038	0.329248	-1.512057	4.505733	0.698223	False
HS-Bachelor's	-2.097484	1.143460	-1.834331	0.066859	-4.340952	0.145984	0.292485	False
Jr Coll-Bachelor's	-1.006255	1.795528	-0.560423	0.575299	-4.529079	2.516569	0.760113	False
Less than HS-Bachelor's	-5.566798	1.661832	-3.349796	0.000835	-8.827311	-2.306286	0.007486	True
HS-Graduate	-3.594322	1.368362	-2.626733	0.008734	-6.279048	-0.909597	0.067772	False
Jr Coll-Graduate	-2.503093	1.946493	-1.285950	0.198716	-6.322110	1.315924	0.587763	False
Less than HS-Graduate	-7.063636	1.823897	-3.872826	0.000114	-10.642120	-3.485153	0.001135	True
Jr Coll-HS	1.091230	1.656638	0.658701	0.510218	-2.159092	4.341551	0.760113	False
Less than HS-HS	-3.469314	1.510700	-2.296494	0.021824	-6.433306	-0.505322	0.143123	False
Less than HS-Jr Coll	-4.560544	2.049057	-2.225679	0.026226	-8.580791	-0.540296	0.147393	False

In [9]:

```
mc = sm.stats.multicomp.MultiComparison(df['value'], df['treatments'])
mc_results = mc.tukeyhsd()
print(mc_results)
```

```
      Multiple Comparison of Means - Tukey HSD, FWER=0.05
=================================================================
  group1      group2    meandiff p-adj   lower    upper  reject
-----------------------------------------------------------------
Bachelor's     Graduate   1.4968 0.8514   -2.693  5.6867  False
Bachelor's           HS  -2.0975 0.3547  -5.2215  1.0265  False
Bachelor's      Jr Coll  -1.0063    0.9  -5.9117  3.8992  False
Bachelor's Less than HS  -5.5668 0.0074  -10.107 -1.0266   True
  Graduate           HS  -3.5943 0.0664  -7.3327  0.1441  False
  Graduate      Jr Coll  -2.5031 0.6756   -7.821  2.8148  False
  Graduate Less than HS  -7.0636 0.0011 -12.0466 -2.0807   True
        HS      Jr Coll   1.0912    0.9  -3.4348  5.6172  False
        HS Less than HS  -3.4693 0.1466  -7.5966   0.658  False
   Jr Coll Less than HS  -4.5605 0.1711 -10.1587  1.0376  False
-----------------------------------------------------------------
```

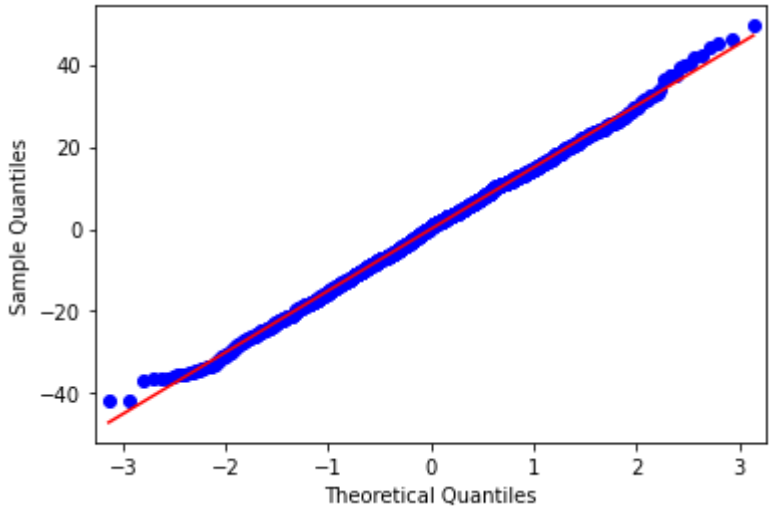
One-way ANOVA: Assumptions checks

In [10]:

```
res = model.resid
```

In [11]:

```
fig = sm.qqplot(res,line = 's')
```



In [12]:

```
import seaborn as sns
```

In [13]:

```
### Normality Assumption check
from scipy import stats

#using the Shapiro-wilk test
w_shapiro, pvalue_shapiro = stats.shapiro(res)
print(pvalue_shapiro)
```

```
0.33162370324134827
```

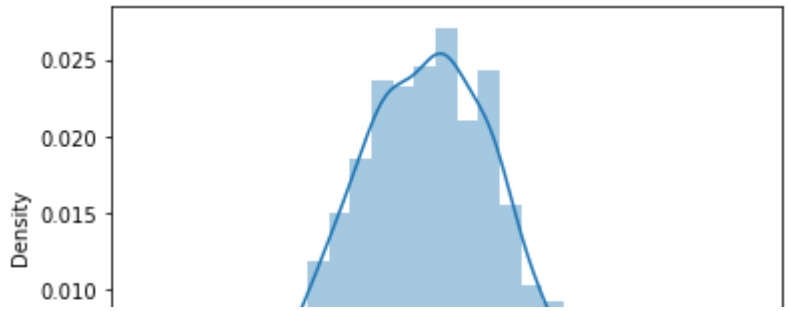
In [15]:

```
sns.distplot(res,bins = 'auto',hist = True)
```

```
D:\program\Anaconda\lib\site-packages\seaborn\distributions.py:2551: Futur
eWarning: `distplot` is a deprecated function and will be removed in a fut
ure version. Please adapt your code to use either `displot` (a figure-leve
l function with similar flexibility) or `histplot` (an axes-level function
for histograms).
  warnings.warn(msg, FutureWarning)
```

Out[15]:

```
<AxesSubplot:ylabel='Density'>
```



In [26]:

```
# Using Bartlett's test
w_bartlett, pvalue_bartlett = stats.bartlett(df['value'][df['treatments'] == 'Less than HS'
                           ,df['value'][df['treatments'] == 'HS']
                           ,df['value'][df['treatments'] == 'Jr Coll']
                           ,df['value'][df['treatments'] == "Bachelor's"]
                           ,df['value'][df['treatments'] == "Graduate"])
print("Bartlett's test:\tw:{:7.4f}, pvalue:{:7.4f}".format(w_bartlett, pvalue_bartlett))
```

```
Bartlett's test:        w:17.7424, pvalue: 0.0014
```

In [25]:

```
#Using Levene Variance test
w_levene, pvalue_levene = stats.levene(df['value'][df['treatments'] == 'Less than HS']
                           ,df['value'][df['treatments'] == 'HS']
                           ,df['value'][df['treatments'] == 'Jr Coll']
                           ,df['value'][df['treatments'] == "Bachelor's"]
                           ,df['value'][df['treatments'] == "Graduate"])
print("Levene's test:\tw:{:7.4f}, pvalue:{:7.4f}".format(w_levene, pvalue_levene))
```

```
Levene's test:  w: 5.7617, pvalue: 0.0001
```

4 Analysis Results & Explanation

In [27]:

```
anova_table
```

Out[27]:

	sum_sq	df	F	PR(>F)	EtaSq
C(treatments)	4176.452688	4.0	4.618904	0.001056	0.015585
Residual	263802.838942	1167.0	NaN	NaN	NaN

As the result of One-way Anova shows, there is at least one treatment which significantly differs from the others. So we are eager to know which one group is different from other group. By implying the method of Multiple Pairwise Comparisons and Turkey HSD test, we can clearly to check the specifical group that differs from the others.

In [13]:

```
print(mc_results)
pair_t.result_frame
```

```
      Multiple Comparison of Means - Tukey HSD, FWER=0.05
=================================================================
  group1      group2    meandiff p-adj   lower    upper  reject
-----------------------------------------------------------------
Bachelor's     Graduate   1.4968 0.8514   -2.693  5.6867  False
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  Graduate           HS  -3.5943 0.0664  -7.3327  0.1441  False
  Graduate      Jr Coll  -2.5031 0.6756   -7.821  2.8148  False
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        HS      Jr Coll   1.0912    0.9  -3.4348  5.6172  False
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-----------------------------------------------------------------
```

Out[13]:

	coef	std err	t	P>|t|	Conf. Int. Low	Conf. Int. Upp.	pvalue-hs	reject-hs
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Less than HS-Jr Coll	-4.560544	2.049057	-2.225679	0.026226	-8.580791	-0.540296	0.147393	False

According to the results of Multiple Pairwise Comparisons and Turkey HSD test above, the reject status between group 'Less than HS' and "Bachelor's" is True as the same as between group 'Less than HS' and 'Graduate', and rest of groups are False. That illustrates the group of 'Less than HS' is significently different from groups of 'Bachelor's' and 'Graduate'.

In [30]:

```
print("Shapiro-wilk's test:\tw:{:7.4f}, pvalue:{:7.4f}".format(w_shapiro, pvalue_shapiro))
print("Bartlett's test:\tw:{:7.4f}, pvalue:{:7.4f}".format(w_bartlett, pvalue_bartlett))
print("Levene's test:\tw:{:7.4f}, pvalue:{:7.4f}".format(w_levene, pvalue_levene))
```

```
Shapiro-wilk's test:    w: 0.9984, pvalue: 0.3316
Bartlett's test:        w:17.7424, pvalue: 0.0014
Levene's test:  w: 5.7617, pvalue: 0.0001
```

For checking the normality, we use the method of Shapiro-wilk test.

Under the method of Shapiro-wilk test, the null-hypothesis of this test is that the population is normally distributed. The p value is greater than the chosen alpha level, then the null hypothesis (that the data came from a normally distributed population) can not be rejected (e.g., for an alpha level of alpha = 0.05.

For identifying whether there are equal variances between groups, we imply the methods of Bartlett's test and Levene Variance test.

We are testing the null hypothesis that the batch variances are all equal. Because the pvalue is less than the alpha value, we reject the null hypotheses at the 0.05 significance level and conclude that at least one batch variance is different from the others.

5 Conclusion

According to the results of one-way ANOVA and Multiple Pairwise Comparisons and Turkey HSD test, we can see the group of 'Less than HS' has a significent difference with the two groups of "Bachelor's" and 'Graduate'.

Also, the data is a normal distribution.

In [ ]:

In [ ]: