

# Laboratory 05

## Table of contents

<b>1</b>	<b>Reply on the feedback of Lab 4</b>	<b>1</b>
<b>2</b>	<b>Context</b>	<b>1</b>
<b>3</b>	<b>Objectives</b>	<b>1</b>
<b>4</b>	<b>Solutions</b>	<b>2</b>
4.1	A peek on the dataset as always . . . . .	2
4.2	Q1: The bivariate regression equation . . . . .	2
4.3	Q2: Whether bi-variate regression is a good choice for the data . . . . .	2
4.4	Q3: Bivariate regression analysis . . . . .	4
4.5	Q4: The slope from the standardized regression . . . . .	5
4.6	Q5: Cognitive function score if drink 3 cups of tea per day . . . . .	6
4.7	Q6: Tea predicts cognitive function? . . . . .	7

## 1 Reply on the feedback of Lab 4

For all typos on Lab 4 (e.g. 4.4 Q3): All fixed on the online version.

## 2 Context

A researcher enjoys drinking tea when trying to do brain-melting things like studying statistics. He feels that tea helps him think, and he wants to verify whether tea really improves cognitive function. The researcher recruits a large group of respondents and randomly assigns each one with a different number of cups of tea to drink every day <sup>1</sup>. After one month, he measures the cognitive function score of each participant and saves the data in `tea.sav`.

## 3 Objectives

1. Write down the bivariate regression equation to be estimated. The goal is to study whether tea affects cognitive function.
2. Do you think the bivariate regression is a good choice for the data? Why or why not?
3. Conduct the bivariate regression analysis using the data. Interpret the intercept and the slope from the raw regression.
4. Interpret the slope from the standardized regression. From which regression (raw or standardized) is the slope easier to interpret and understand?
5. Predict the cognitive function score of a respondent who drinks 3 cups of tea per day. Do you think your prediction is accurate (close to the truth)?
6. Test the hypothesis that tea predicts cognitive function using the regression. Does your result imply any findings about the causal effect of tea on cognitive function?

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<sup>1</sup>Oh wait, could this kind of torture be approved by the IRB?

## 4 Solutions

### 4.1 A peek on the dataset as always

```
1 import pandas as pd
2
3 tea = pd.read_spss('./datasets/tea.sav')
4 print(tea.describe())
```

	tea	cog_fun
count	716.000000	716.000000
mean	3.032123	50.611732
std	1.669245	9.882814
min	0.000000	24.000000
25%	2.000000	44.000000
50%	3.000000	51.000000
75%	4.000000	57.000000
max	8.000000	80.000000

### 4.2 Q1: The bivariate regression equation

**Answer**

Given the independent variable  $X$ , the predicted  $\hat{Y}_{cog\_fun}$ <sup>2</sup> is:

$$\hat{Y}_{cog\_fun} = \beta_0 + \beta_1 X$$

### 4.3 Q2: Whether bi-variate regression is a good choice for the data

**Answer**

The bi-variate regression may not be a strong model for this data for:

1. The Pearson's Correlation: The Pearson's correlation coefficient ( $r \approx 0.0777$ ) indicates a relatively weak positive relationship between tea consumption and cognitive function. The  $p$ -value ( $p \approx 0.0378$ ) is below 0.05, suggesting that the weak correlation is statistically significant.
2. Linearity and Distribution: The scatter plot in Figure 1 shows that a weak and flat linear relationship between tea consumption and cognitive function, which aligns with the low Pearson's  $r$ . While the histograms in Figure 2 show that the cognitive function scores are approximately normally distributed.
3. However, the sample size ( $N = 716$ ) is relatively large, which may be beneficial for conducting a regression.

Based on this weak linear trend, although bi-variate regression could be employed as they meet the assumption of a linear regression, the model may not explain much variability in cognitive function. Other factors like age, education background even SES may (and must) influence cognitive function. For sake of this assignment, I will assume that other variables either do not vary significantly across participants or are not measured.

**Solution**

```
1 import scipy.stats as stats
2 tea_pearsonr, tea_pvalue = stats.pearsonr(tea.tea, tea.cog_fun)
3 print(f'Pearson\'s r: {tea_pearsonr}\n'
4       f'p-value: {tea_pvalue}')

```

```
Pearson's r: 0.07765252417388956
p-value: 0.03776954868447832
```

---

<sup>2</sup>Add  $\epsilon$  if consider the error term.

```

1 import matplotlib.pyplot as plt
2 import seaborn as sns
3
4 tea_scatter = sns.lmplot(tea, x='tea', y='cog_fun')
5 tea_scatter.fig.suptitle('Scatter plot on tea v. cog_fun')
6 plt.show()

```

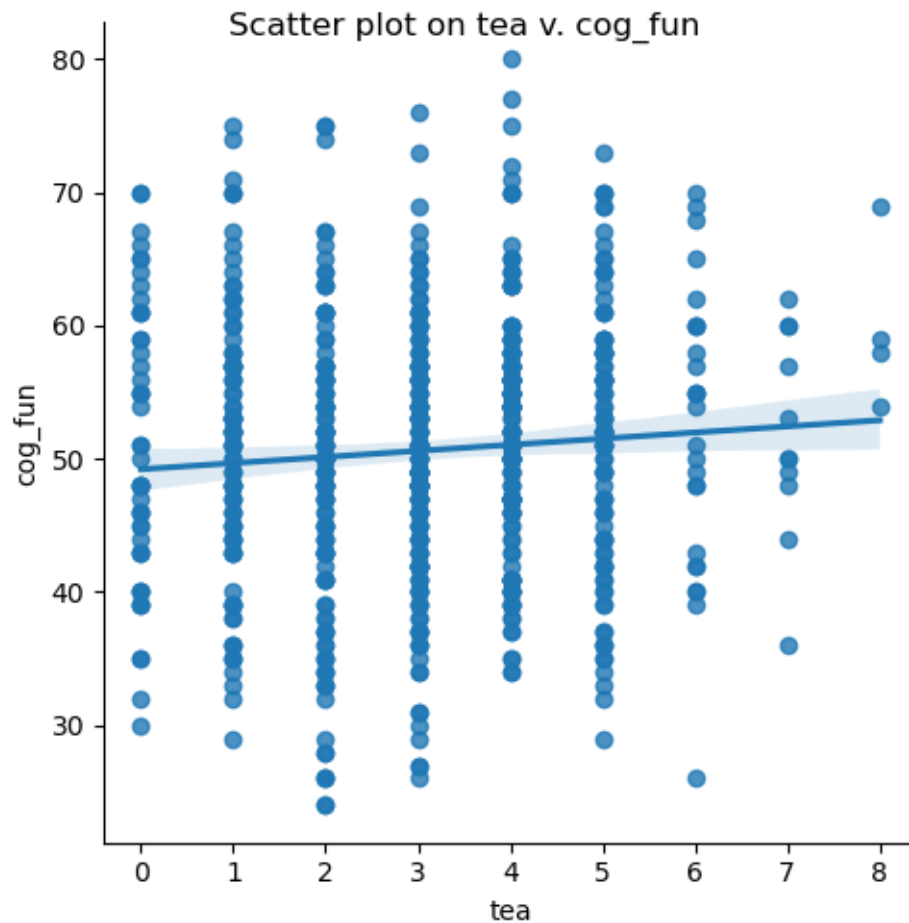


Figure 1: Scatter Plot on tea v. cog\_fun

```

1 fig, ax =plt.subplots(1,2)
2 sns.histplot(tea, x='tea', kde=True, bins=8, ax=ax[0])
3 sns.histplot(tea, x='cog_fun', kde=True, ax=ax[1])
4 ax[0].set_title('Tea')
5 ax[1].set_title('Cognitive Function')
6 fig.suptitle('Histograms on variables: Tea and Cognitive Function')
7
8 plt.show()

```

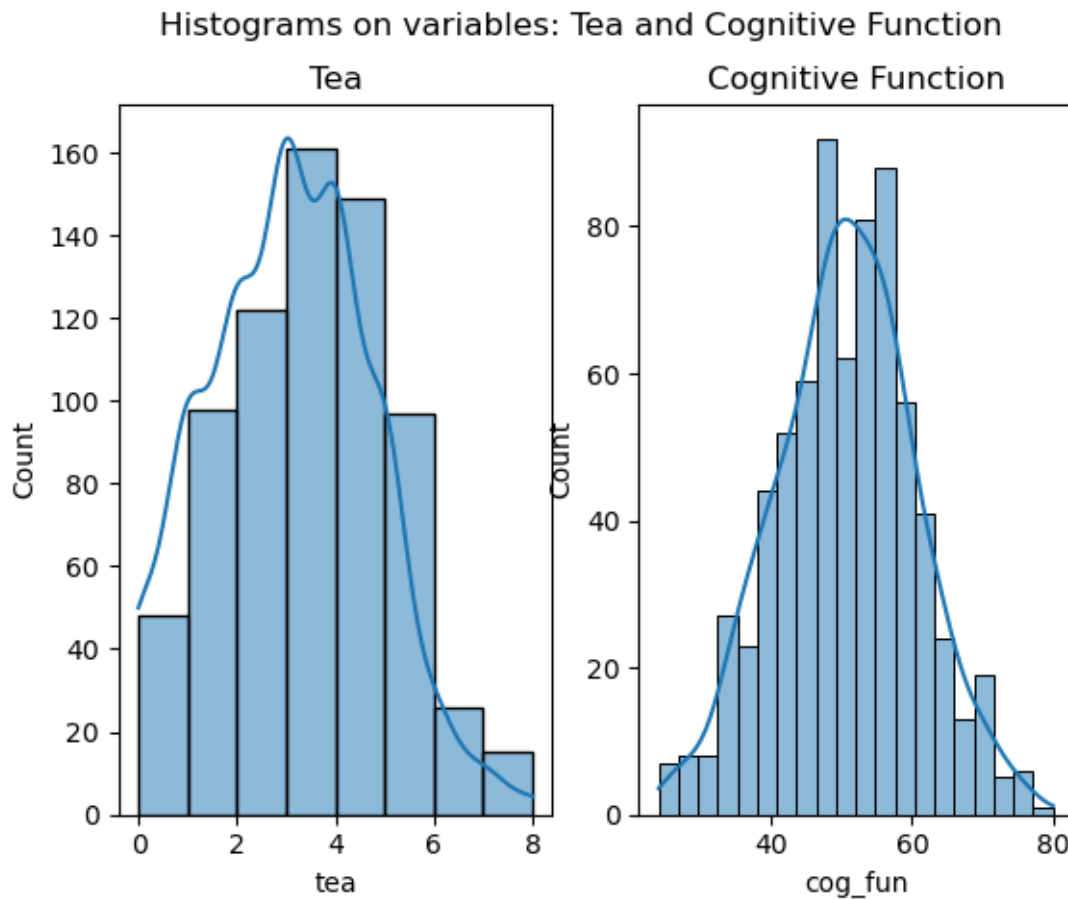


Figure 2: Distribution of cups of tea and cognitive function scores

#### 4.4 Q3: Bivariate regression analysis

##### Answer

Intercept:  $\beta_0 \approx 49.2177$ , suggests that when a respondent drinks 0 cups of tea per day, the expected cognitive function score is 49.2177.

Slope:  $\beta_1 \approx 0.4597$ , indicates a positive relationship between tea consumption and cognitive function. For each additional cup of tea consumed per day, the cognitive function score increases by approximately 0.4597 points.

##### Solution

```

1 def print_linregress(x, y):
2     b1, b0, r, p, stderr = stats.linregress(x=x, y=y)
3     print(f'Intercept: {b0}')
4     print(f'Slope: {b1}')
5     print(f'R-squared: {r**2}')
6     print(f'P-value: {p}')
7     print(f'Standard error: {stderr}')
8
9 print_linregress(tea['tea'], tea['cog_fun'])

```

```

Intercept: 49.217731459509174
Slope: 0.45974402348753085
R-squared: 0.006029914510576479
P-value: 0.03776954868447834
Standard error: 0.22090119534570854

```

In the world of python, `scipy.stats` works fine for applying basic linear models, **however**, `statsmodels` gives you this pretty damn cool all-in-one summary output as shown below:

```

1 import statsmodels.api as sm
2
3 def bivariate_regression(x, y):
4     X = sm.add_constant(x)
5     model = sm.OLS(y, X).fit()
6     summary = model.summary()
7     print(summary)
8     return model
9
10 tea_model = bivariate_regression(tea['tea'], tea['cog_fun'])

```

```

                                OLS Regression Results
=====
Dep. Variable:                  cog_fun    R-squared:                0.006
Model:                            OLS      Adj. R-squared:            0.005
Method:                 Least Squares    F-statistic:                4.331
Date:                  Mon, 28 Oct 2024    Prob (F-statistic):        0.0378
Time:                  19:52:27           Log-Likelihood:            -2653.5
No. Observations:                  716     AIC:                       5311.
Df Residuals:                      714     BIC:                       5320.
Df Model:                            1
Covariance Type:                  nonrobust
=====

```

	coef	std err	t	P> t	[0.025	0.975]
const	49.2177	0.764	64.382	0.000	47.717	50.719
tea	0.4597	0.221	2.081	0.038	0.026	0.893

```

=====
Omnibus:                        0.140    Durbin-Watson:              1.912
Prob(Omnibus):                  0.932    Jarque-Bera (JB):           0.229
Skew:                          -0.009    Prob(JB):                   0.892
Kurtosis:                      2.914     Cond. No.                   7.65
=====

```

Notes:

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

## 4.5 Q4: The slope from the standardized regression

**Answer**

**Q4a: Interpret the slope from the standardized regression.**

$$\beta^* \approx 0.07765$$

The standardized slope is approximately 0.07765, means that for every one standard deviation increase in tea consumption, the cognitive function score increases by 0.07765 standard deviations.

**Q4b: From which regression (raw or standardized) is the slope easier to interpret and understand?**

It depends.

The raw slope is easy to interpret in the context of the actual units of measurement as it represents the change in the dependent variable (`cog_fun`) for a one-unit change in the independent variable (`tea`).

The standardized slope makes comparing effects across different variables or studies much easier as it tells us how many standard deviations the dependent variable changes for a one standard deviation change

in the independent variable.

### Solution

Both the independent (tea) and dependent variables (cog\_fun) are transformed into z-scores, then:

```
1 # Preparing standardized
2 tea['tea_std'] = tea['tea'].apply(lambda x: (x - tea['tea'].mean()) /
   ↪ tea['tea'].std())
3 tea['cog_fun_std'] = tea['cog_fun'].apply(lambda x: (x - tea['cog_fun'].mean()) /
   ↪ tea['cog_fun'].std())
4
5 # Intercept and slope of standardized regression
6 print_linregress(tea['tea_std'], tea['cog_fun_std'])
```

```
Intercept: -1.2880252063838454e-16
Slope: 0.07765252417388924
R-squared: 0.006029914510576491
P-value: 0.0377695486844781
Standard error: 0.03731105688226283
```

```
1 # And the pretty damn detailed OLS summary
2 bivariate_regression(tea['tea_std'], tea['cog_fun_std'])
```

```

                                OLS Regression Results
=====
Dep. Variable:                  cog_fun_std    R-squared:                0.006
Model:                            OLS         Adj. R-squared:            0.005
Method:                 Least Squares         F-statistic:                4.331
Date:                  Mon, 28 Oct 2024        Prob (F-statistic):          0.0378
Time:                      19:52:27           Log-Likelihood:            -1013.3
No. Observations:                716          AIC:                   2031.
Df Residuals:                    714          BIC:                   2040.
Df Model:                          1
Covariance Type:                  nonrobust
=====
               coef      std err          t      P>|t|      [0.025      0.975]
-----
const        -6.765e-17    0.037  -1.81e-15    1.000    -0.073    0.073
tea_std         0.0777     0.037    2.081     0.038     0.004    0.151
=====
Omnibus:                 0.140    Durbin-Watson:                1.912
Prob(Omnibus):            0.932    Jarque-Bera (JB):              0.229
Skew:                    -0.009    Prob(JB):                      0.892
Kurtosis:                 2.914    Cond. No.                      1.00
=====
```

Notes:

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

<statsmodels.regression.linear\_model.RegressionResultsWrapper at 0x7ff15145ae90>

## 4.6 Q5: Cognitive function score if drink 3 cups of tea per day

### Answer

Given  $X = 3$ , the cognitive function score for a respondent who drinks 3 cups of tea per day is:

$$\hat{Y} = \beta_0 + \beta_1 \times 3 \approx 50.5970$$

However, the prediction might not be very close to the true score. Although the slope is statistically

significant (with a  $p$ -value of  $p = 0.038$ ), the low  $R$ -squared ( $R^2 \approx 0.006$ ) indicates that statistically, there's only 0.6% of the variance in cognitive function scores is explained by tea consumption.

### Solution

```
1 cog_fun_after_3_cups = tea_model.predict([1.0, 3]) # The 1.0 here is the constant
  ↳ required by statsmodels
2 print(f'Cognitive function score if drink 3 cups of tea per day: \n'
3       f'{cog_fun_after_3_cups[0]}')
```

Cognitive function score if drink 3 cups of tea per day:  
50.59696352997175

## 4.7 Q6: Tea predicts cognitive function?

### Answers

The  $p$ -value for the slope is:

$$p \approx 0.0378$$

Since the  $p$ -value is less than 0.05 ( $p < 0.05$ ), we can reject the null hypothesis ( $H_0$ ). This suggests that there is evidence of an association between tea consumption and cognitive function scores.

However, the low  $R$ -squared value ( $R^2 \approx 0.006$ ) indicates that tea consumption explains only a tiny fraction of the variability in cognitive function.

While the results suggest a statistically significant but weak association between tea consumption and cognitive function, they do not provide evidence of a causal effect. Besides, if simply drinking more tea could raise cognitive scores, we might think about advising children to drink tea to guarantee a bright future! That said, those less inclined to drink tea might still end up in schools of education.

### Solution

Hypothesis:

$H_0$ : The slope ( $\beta_1$ ) is zero, meaning tea consumption does not predict cognitive function.

$H_1$ : The slope ( $\beta_1$ ) is not zero, meaning tea consumption does predict cognitive function.

```
1 tea_p_value = tea_model.pvalues['tea']
2
3 def test_hypothesis(p_value, alpha=0.05):
4     print(f'Given the p-value={p_value} and alpha={alpha}:')
5     if p_value < alpha:
6         print("Reject the null hypothesis.")
7     else:
8         print("Fail to reject the null hypothesis.")
9
10 test_hypothesis(tea_p_value, alpha=0.05)
```

Given the p-value=0.03776954868447742 and alpha=0.05:  
Reject the null hypothesis.