ECON6034 Econometrics and Business Statistics
Group Assignment (Semester 1 - 2023)

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Assignment Questions

Question 1

(a) Estimate the simple regression model,
price = $\beta_0 + \beta_1 milage + u$ (1)
and report your results in equation form along with the number of observations and R^2.

```
price = 24567.5  - 0.158352*mileage

(s.e.)  (964.722)   (0.0451005)

(t)     (25.47)     (-3.511)

N = 700, R^2 = 0.017355
```

A t-ratio of −3.511 indicates that the coefficient on mileage is statistically significant at a 1% level, just as $\beta 0$. However, R^2 of 0.017355 suggests that our model fits data quite poorly, and other factors should explain the price better.

(b) Interpret the estimated coefficient on mileage.

We can tell that per each one-unit increase in mileage, the price will decrease on average by 0.158352 units. In other words, each mile a car has been driven decreases its price on average by 0.158352 dollars.

(c) How does price change if two cars are identical except one has 25000 more miles?

We can tell that difference in price if only the mileage differs can be calculated: Difference in price = β_1 * Difference in mileage. Thus, we have − 0.158352*25000 = −3958.8. We can interpret it as follows: if we have two cars that are identical in all other factors but different in mileage, the one that has driven 25,000 more miles would cost, on average, 3958.8 fewer dollars than the other car.

(d) Divide the sample by the variable cylinder which is the number of cylinders in the engine – 4, 6 or 8. Re-estimate the simple regression model in i above for each of the subsamples. Report your results for each subsample in equation form along with the number of observations and R^2.

Results for a model where the number of cylinders is equal to 4:

```
price = 19757.3  - 0.0865002*mileage

(s.e.)  (1153.34)   (0.0533382)

(t)     (17.13)     (-1.622)

N = 336, R^2 = 0.007813
```

Results for a model where the number of cylinders is equal to 6:

```
price = 22895.4  - 0.142020*mileage

(s.e.)  (714.935)  (0.0341676)

(t)     (32.02)    (-4.157)

N = 278, R^2 = 0.058911
```

Results for a model where the number of cylinders is equal to 8:

```
price = 47309.0  - 0.419161*mileage

(s.e.)  (2511.97)   (0.114391)

(t)     (18.83)     (-3.664)

N = 86, R^2 = 0.137816
```

From the above data, we can see the following patterns: we have more cars with less number of cylinders. For instance, we have 336 cars with a number of cylinders equal to 4 and only 86 cars with eight cylinders. Even though vehicles with more cylinders tend to cost more than cars with fewer cylinders, cars with more cylinders tend to lose more of their value per mile they have driven. For instance, the base cost of a car with eight cylinders is 47309.0 dollars, and with four cylinders is only 19757.3. However, while a vehicle with eight cylinders will lose 0.41 dollars per mile, a car with four cylinders will lose only 0.08 dollars. Vehicles with eight cylinders, on average, are worth twice as much as cars with four cylinders. At the same time, they lose five times more value per mile driven than their 4-cylinder counterparts.

(e) For each subsample, interpret the estimated coefficient on mileage.

For subsample, where the number of cylinders equals 4, we estimate that each mile a car has driven on average will decrease its cost by 0.0865002 dollars.

For subsample, where the number of cylinders equals 6, we estimate that each mile a car has driven on average will decrease its cost by 0.142020 dollars.

For subsample, where the number of cylinders equals 8, we estimate that each mile a car has driven on average will decrease its cost by 0.419161 dollars.

Interestingly, even for subsamples, where the number of cylinders equals 6 or 8, the t-value indicates that mileage is statistically significant at a 1% level. However, this doesn't hold for the subsample where we deal with cars with four cylinders (critical value -2.58, t-ration is only −1.622). The above fact indicates that mileage is not a good predictor of the price for vehicles with four cylinders, and other factors should contribute. The lower score of R^2 for cars with four cylinders compared to R^2 for vehicles with 6 and 8 cylinders confirms that.

(f) For each subsample, how does the price change if two cars are identical except one has 25000 more miles?

For a subsample, where the number of cylinders is equal to 4, we can tell that difference in price, if only the mileage differs, can be calculated the following way: Difference in price = β_1 * Difference in mileage. Thus, we have − 0.0865002*25000 = −2,162.505. We can interpret it as follows: if we have two cars (both with four cylinders) that are identical in all other factors but different in mileage, the one that has driven 25,000 more miles would cost, on average, 2,162.5 fewer dollars than the other car.

For a subsample, where the number of cylinders is equal to 6, we can tell that difference in price, if only the mileage differs, can be calculated the following way: Difference in price = β_1 * Difference in mileage. Thus, we have − 0.142020*25000 = −3,550.5. We can interpret it as follows: if we have two cars (both with six cylinders) that are identical in all other factors but different in mileage, the one that has driven 25,000 more miles would cost, on average, 3,550.5 fewer dollars than the other car.

For a subsample, where the number of cylinders is equal to 8, we can tell that difference in price, if only the mileage differs, can be calculated the following way: Difference in price = β_1 * Difference in mileage. Thus, we have − 0.419161*25000 = −10479.025. We can interpret it as follows: if we have two cars (both with eight cylinders) that are identical in all other factors but different in mileage, the one that has driven 25,000 more miles would cost, on average, 10479.025 fewer dollars than the other car.

(g) Now estimate the following regression model and report the summary results in an equation form. (A summary results should include fitted equations with coefficients, standard error, t-statistic, p-value, sample size, F-statistic and R-squared).

$$price = \beta_0 + \beta_1 mileage + \beta_2 liter + \beta_3 doors + u \qquad (2)$$

(Gretl: Model->Ordinary Least Squares->and then select the "*price*" as the dependent variable and "*mileage*", "*liter*" and "*doors*" as Regressors->OK).

```
price =  12650.8 - 0.156405*mileage + 4874.15*liter -
845.438*doors

(s.e.) (1784.81)  (0.0374937)      (279.743)      (363.092)

(t)    (7.088)     (-4.172)         (17.42)        (-2.328)

(p-val)(3.35e-12)  (3.41e-05)       (1.07e-56)     (0.0202)

N = 700, R^2 = 0.323066, F(3, 696) = 110.7219
```

We can note a few interesting things from the model above:
i) R^2 is significantly higher than for any model that we trained previously. The above fact means that adding additional parameters helped to reduce the underfitting problem.
ii) F-Score of 110 indicates at a 1% significance level that our model is statistically significant.
iii) T-ratio for $\beta 0$,$\beta 1$, and $\beta 2$ indicates that these variables are statistically significant at a 1% level. However, the coefficient for doors is significant at the 5% level but not at the 1% level.

(h) **Comment on the individual significance of the coefficient *mileage* and *liter*. Use a 5% significance level and the critical value method (No need to carry out the steps in hypothesis tests)**

At the 5 percent significance level with 696 degrees of freedom, the critical value is +-1.96338.
The t ratio for $mileage$ (−4.172) and liters (17.42) is higher than provided critical values. Thus, we can state that they are statistically significant.

(i) Construct an estimate of the price elasticity with respect to *mileage* calculated at the mean of mileage and the mean of price. Interpret this estimate.

To find elasticity, we can use the formula: Elasticity=β(X/Y), where X is the mean of mileage, Y is the mean of the price, β is the coefficient of mileage. Our calculations are: -0.156405*(19782/21435), So the answer is -0.1443435. The calculations show that other things being constant, a 1% increase in mileage will decrease the price by 0.144%. If elasticity is less than one, demand is considered inelastic. Hence, our estimates indicate that the price is inelastic relative to mileage. In other words, we can tell that mileage doesn't significantly affect the price.

(j) Now, estimate the following regression model, present the summary results in an equation form and answer the following questions. (A summary results should include fitted equation with coefficients, standard error, t-statistic, p-value, sample size, F-statistic and R-squared).

$$log(price) = \beta_0 + \beta_1 log(mileage) + \beta_2 liter + \beta_3 doors + u \qquad (3)$$

$log(price)$ = 10.0409 −0.0789188$log(mileage)$ + 0.215044$liter$ −0.0120030$doors$

(s.e.)	(0.200995)	(0.0193680)	(0.0113774)	(0.0147581)
(t)	(49.96)	(−4.075)	(18.90)	(−0.8133)
(p-val)	(2.32e-232)	(5.14e-05)	(1.26e-64)	(0.4163)

N = 700, R^2 = 0.354563, F(3, 696) = 127.4461

(k) Interpret the estimated coefficient on log(mileage) in model (3).

The log (mileage) coefficient is -0.0789188. When other factors are constant, when the mileage increases by 1 percent, the price decreases by -0.0789188%. The p-value and t-ratio indicate that the coefficient on the log(mileage) is statistically significant.

(l) Interpret the estimated coefficients on *liter* and *doors* in model (3) and discuss how they compare with those obtained in the linear model (2) in (g).

Model (3) indicates that the liter coefficient is 0.215044. This means that a 1-unit increase in engine size tends to increase the price of the car by approximately 21.5044% while other things are constant. Otherwise, in the model (2), the liter coefficient is 4874.15. This demonstrates that if we maintain all other factors constant while increasing engine capacity by one unit, we may anticipate an increase in the price of the automobile of $4,874.15. Coefficients for a liter at both models are significant at a 5% level, significantly affecting the price.

For the doors in model (3), the coefficient is -0.0120030. This suggests that if all other factors remain equal, we should anticipate a price drop of around 1.2003% for each additional door on a car. However, at the 5% level, this coefficient is not statistically significant in the model (3). In model (3), the number of doors doesn't considerably affect the cost of the automobile, but in model (2), it is statistically significant. It can be concluded from this that the ‘doors’ do not affect the price of the car in the model (3), but it does affect the model (2).

(m) Use the F test to test the overall significance of the model (3) at the 5% significance level. Clearly state the hypotheses, test statistics and its distribution when the null hypothesis is true, critical value, and your conclusion.

We are assessing the overall significance of the model. Our hypotheses are:
Null Hypothesis (H0): $\beta 0$ =0 and $\beta 1$=0 and $\beta 2$=0 and $\beta 3$=0

Alternative Hypothesis (H1): $\beta 0$!=0 or $\beta 1$=!0 or $\beta 2$=!0 or $\beta 3$!=0

To find the F-critical value, we need to know the significance level (5%) and degrees of freedom. The degrees of freedom in the numerator are equal to a number of predictors in our model (3). Degrees of freedom in the denominator is equal to a number of observations minus a number of coefficients and minus one (so, 700-3-1=696). Thus, our F-critical value is 2.6177.

We reject the null hypothesis since our F-statistic is higher than the F-critical value. Hence, we conclude that at least one of the predictors is statistically significant in the model. What's more, the model as a whole is statistically significant.

(n) Compare models (2) and (3). Which model would you choose? And why?

In this task, we compare the log-log model(3) to the level-level one (2). The following criteria were used to decide which model is preferable:

i) R^2 shows how well the model fits the data. In this case, the higher R^2, the better. We can see that the log-log model has a higher R^2 (0.354563) than the level-level model (0.323066). It means that the log-log model fits the data better.

ii) Adjusted R^2 works in the same fashion as R^2, but unlike the latter one, it considers the number of features used to create the model. Again, as with R^2, a higher value of adjusted R^2 indicates a better fit to the data. As with R^2, we can see that the log-log model has a higher adjusted R^2 (0.351780) than the level-level model (0.320148).

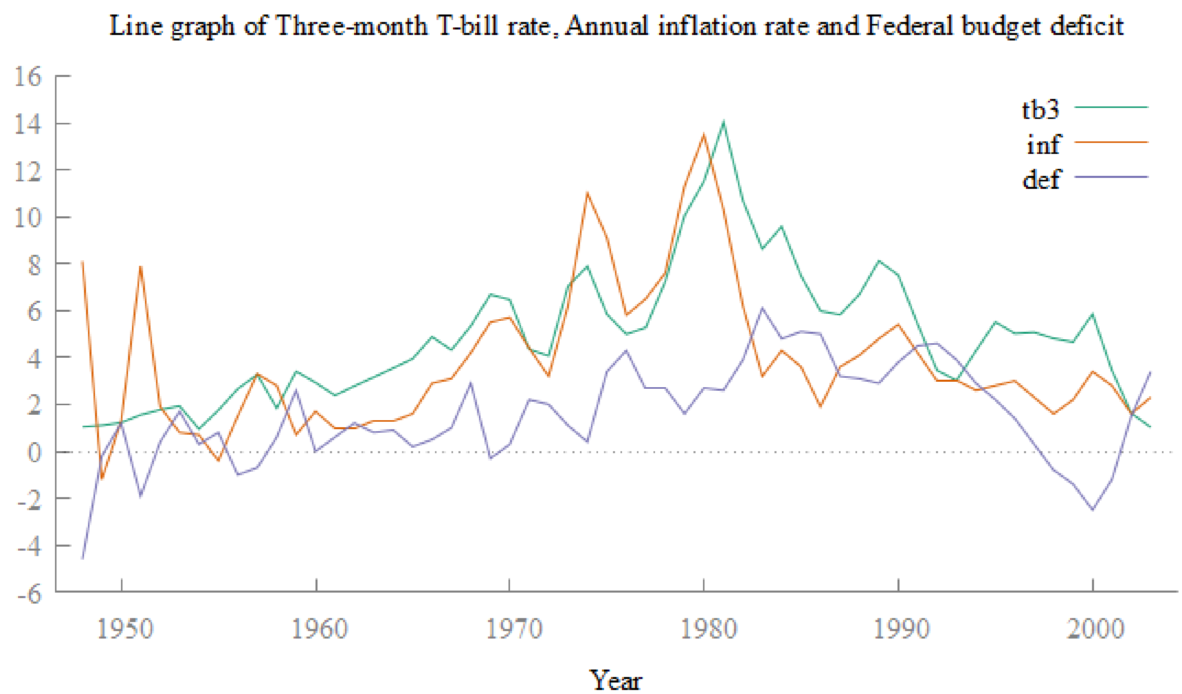
iii) F-statistic shows if the model as a "whole" is significant. The f-statistic of both values is relatively high to prove that they are statistically significant. However, we should note that the f-statistic for the log-log model (127.4461) is slightly higher than for the level-level model (110.7219). This suggests that the log-log model might be more statistically significant than the level-level one.

iv) Information criteria (namely Akaike (AIC) and Schwarz(SIC)) are both lower for the log-log model (AIC: 430.5404; SIC: 448.7447) than for the level-level model (AIC: 14585.17; SIC: 14603.38). In this case, a lower value indicates a better model. The reason behind this is that both AIC and SIC indicates a balance the goodness of fit and complexity of the model.

Based on the above criteria, we decided to pick the log-log model (3).

Question 2

a) **Use Gretl to obtain a line plot among these three variables (one graph) and comment on the plot.** ***(Hint: to make the graph in Gretl: highlight all three variables → right click → time series plot → on a single graph → OK)***



The line graph shows the time-series plot of three variables of the data, which includes: Three-month T-bill rate (*tb3*); the annual inflation rate (*inf*), which is based on the consumer price index, and Federal budget deficit (*def)* as a percentage of GDP and develops the following model.

The chart indicates that between 1948 and 1960, three parameters varied independently without any apparent relationship. Beginning in 1960, the three-month T-bill and yearly inflation rates began to align and follow the same trend. Notably, these two elements rose in tandem, peaking between 1980 and 1981, before embarking on a downward trajectory until 2000. While the federal budget deficit pattern seemed somewhat analogous to the other two factors, the correlation wasn't as robust.

b) **Obtain sample correlation coefficient between these variables and comment on the strength of the relationships? *(Hint: to obtain correlation in Gretl: highlight all three variables → right click → correlation matrix → OK).***

```
Correlation coefficients, using the observations 1948 - 2003
5% critical value (two-tailed) = 0,2632 for n = 56

            tb3         inf         def
         1.0000      0.6790      0.4399   tb3
                     1.0000      0.0975   inf
                                 1.0000   def
```

The correlation coefficient signifies the intensity and the course of the association between the chosen variables - tb3, inf, and def. A correlation coefficient of -1, representing a perfect negative correlation, implies that the variables move in divergent paths. Conversely, a correlation coefficient 1, which indicates a perfect positive correlation, suggests that the variables move robustly in the same direction. A correlation coefficient 0 denotes the absence of a relationship between the variables.

As per the Correlation matrix, the correlation coefficient between tb3 and inf is 0.679, indicating a fairly substantial positive link between the T-bill rate and inflation. The correlation coefficient between tb3 and def stands at 0.439, suggesting a positive relationship, albeit not as potent as the one between tb3 and inf. Additionally, the correlation coefficient 0.09 between inf and def suggests their relationship is positive but considerably weak.

c) **Estimate the above regression model and provide the Gretl output. (Hint: Model → ordinary least squares → select the appropriate variables to the boxes → Ok).**

Gretl Output:

```
Model 1: OLS, using observations 1948-2003 (T = 56)
Dependent variable: tb3

                  Coefficient Std. Error  t-ratio    p-value
    const           1.73327    0.431967    4.012      0.0002   ***
    inf             0.605866   0.0821348   7.376     1.12e-09  ***
    def             0.513058   0.118384    4.334     6.57e-05  ***

     Mean dependent var   4.908214   S.D. dependent var   2.868242
     Sum squared resid    180.0543   S.E. of regression   1.843163
     R-squared            0.602068   Adjusted R-squared   0.587051
     F(2, 53)             40.09424   P-value(F)           2.48e-11
     Log-likelihood      -112.1619   Akaike criterion     230.3239
     Schwarz criterion    236.3999   Hannan-Quinn         232.6796
     rho                  0.622882   Durbin-Watson        0.716153
```

Estimate the Regression model:

$tb3_t =$	1.733	+ 0.606inf_t	+ 0.513def_t
(s.e)	(0.431)	(0.082)	(0.118)
(t)	(4.012)	(7.376)	(04.334)
(p-value)	(0.0002)	(1.12e-09)	(6.57e-05)

N = 56, R^2 = 0.602, F(2, 53) = 40.094

d) **Interpret the coefficients α_1 and α_2. Does the sign of the coefficients agree with your expectations? Explain.**

With the coefficient $\hat{\alpha_1}$ **= 0.606,** it indicates that for every one-unit in the annual inflation rate (**inf_t**) increases, the three-month T-bill rate (tb3_t) would increase by approximately 0.606 units (assuming that all other variables are held constant).

With the coefficient $\hat{\alpha_2}$ **= 0.513,** it indicates that for every one-unit in the federal budget deficit (**def_t**) increases, the three-month T-bill rate (tb3_t) would increase by approximately 0.513 units (assuming that all other variables remain the same).

The sign of the coefficients indicates the direction of the relationship between the dependent variable and the independent variables. Both coefficients are positive numbers in this situation, showing a direct relationship: as the inflation rate or the federal budget deficit increases, the three-month T-bill rate also increases.

In economic theory, the increase in the inflation rate or federal budget deficit might lead to an increase in interest rates including the T-bill rate. The reasoning is based on the belief that lenders would seek more returns as compensation as the danger of retaining debt increases. These coefficients would fully suit the theory if such were the anticipatory assumption. However, it is difficult to draw an accurate conclusion without a clear prognosis before the coefficients were disclosed.

e) **Provide and interpret the coefficient of determination, R^2.**
The coefficient of determination, represented as R-squared (R^2), measures the proportion of the variance in the dependent variable that is predictable from the independent variables in a regression model. In simpler terms, it indicates how well the model fits the data.
The value of R^2 ranges from 0 to 1:

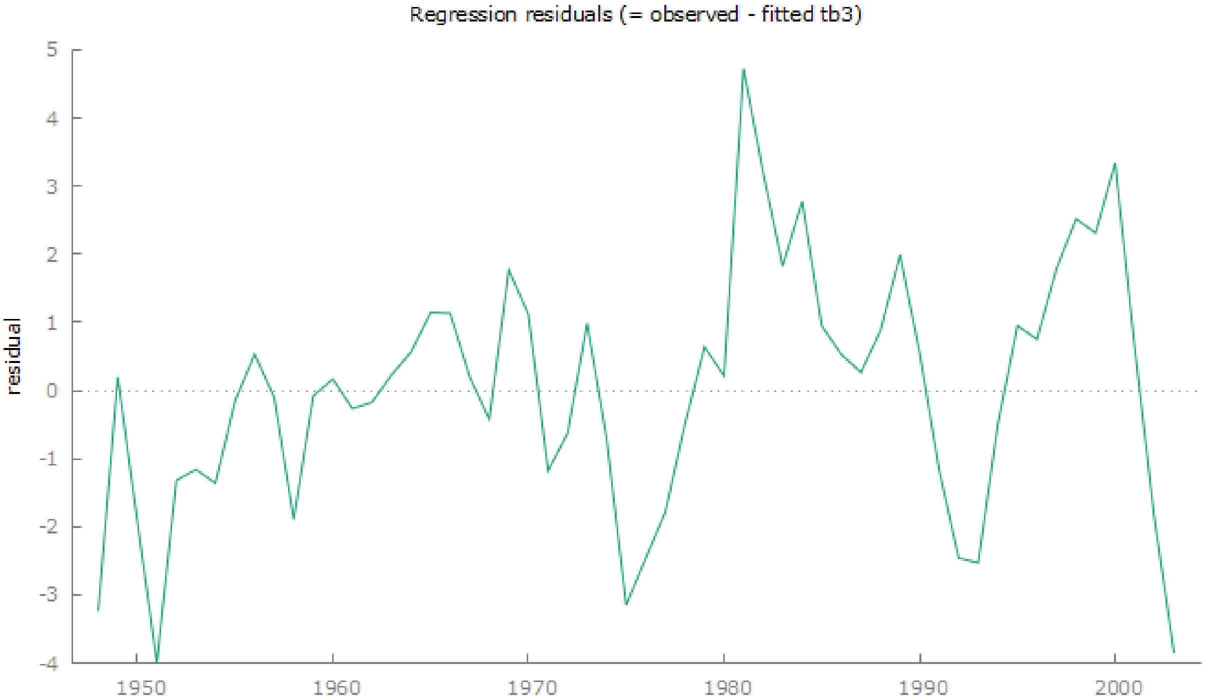
- A value of 0 means that the dependent variable cannot be predicted from the independent variables at all.
- A value of 1 means the model perfectly predicts the dependent variable.

In the model of our dataset, $R^2 = 0.602068$ - this number means that there is 60.206% of the variance in the dependent variable (the three-month T-bill rate) can be explained by the independent variables (the annual inflation rate and the federal budget deficit) in the Regression model. The remaining 39.794% could be attributed to other elements not included in this model or mistakes in measurement.

With $R^2 = 60.206\%$, the model suggests a fairly good fit to the data, but it also does not guarantee the model’s accuracy.

f) **Plot the residuals of the model and comment on any pattern.** ***(Gretl: in your regression output window, select the menu Graph->Residual plot->Against Time->ok.)***

Here is the regression plot against time:



The line graph shows a positive autocorrelation in the errors. It can be seen in this kind of pattern that the positive autocorrelation occurs when a certain signal fails and tends to be followed by a similar error.

g) **Add a one lag of *inf* and *def* to the equation in part (a) and re-estimate your model and report the result. Are the coefficients for the two lag variables individually significant at the 5% level?** ***In Gretl: Model->ordinary least squares->A dialog box will appear. Choose the "tb3" to the dependent variables box and "inf" and "def" as regressors. From the left bottom corner select->lags->add 1 lag for "inf" and "def" and then click->ok.)***

```
Model 4: OLS, using observations 1949-2003 (T = 55)
Dependent variable: tb3

             coefficient   std. error   t-ratio   p-value
  -------------------------------------------------------
  const        1.61148      0.400761     4.021    0.0002   ***
  inf          0.342616     0.125397     2.732    0.0087   ***
  inf_1        0.381980     0.133585     2.859    0.0062   ***
  def         -0.189666     0.221284    -0.8571   0.3955
  def_1        0.569273     0.196771     2.893    0.0056   ***

Mean dependent var   4.978545   S.D. dependent var   2.845528
Sum squared resid    137.7225   S.E. of regression   1.659654
R-squared            0.685018   Adjusted R-squared   0.659819
```

```
F(4, 50)             27.18481   P-value(F)           5.19e-12
Log-likelihood      -103.2841   Akaike criterion     216.5682
Schwarz criterion    226.6048   Hannan-Quinn         220.4494
rho                  0.621158   Durbin-Watson        0.763463

Excluding the constant, p-value was highest for variable 3 (def)
```

Based on the requirement, we have a significant level of 5%. Therefore, to identify whether the coefficient for the lag variables is statistically significant at the 5% significance level, we will check the p_value.

- As for the lag value of the annual inflation rate (inf_{t-1}), the hypotheses can be set:

$\boldsymbol{H_0}$**:** the coefficient of inf_{t-1} is not significant
$\boldsymbol{H_1}$: the coefficient of inf_{t-1} is significant
From Gretl output, we have p_value of the coefficient of inf_{t-1} is 0.0062. As $0.0062 < 0.05$, we reject the null hypothesis at the 5% significance level and conclude that the coefficient of inf_{t-1} is significant to the model.

- Regarding the lag value of the federal budget deficit (def_{t-1}), the hypothesizes can be described:

$\boldsymbol{H_0}$: the coefficient of def_{t-1} is not significant
$\boldsymbol{H_1}$: the coefficient of def_{t-1} is significant
According to the above table, we can see that the p_value of the coefficient of def_{t-1} is 0.0056 which is less than 0.05. Therefore, the null hypothesis can be rejected. This means that we can conclude that the coefficient of def_{t-1} is significant.

In conclusion, the lag of the annual inflation rate and the federal budget deficit affect the three-month T-bill rate, which means both these variables are important to our model.

h) **Conduct the second order autocorrelation test for the model in part (c) at the 5% significance level. Attach your *Gretl* results. Clearly states all steps in your test; Null and alternative hypotheses, the auxiliary regression and the test statistic, critical value, your decision and the conclusion. (*Gretl: Tests->Autocorrelation->Make lags order for test =2->Ok.)***

The Gretl output for the second autocorrelation test:

```
Breusch-Godfrey test for autocorrelation up to order 2
OLS, using observations 1948-2003 (T = 56)
Dependent variable: uhat

             coefficient   std. error   t-ratio   p-value
  --------------------------------------------------------
  const       0.104582     0.349972      0.2988   0.7663
  inf        -0.0428514    0.0674142    -0.6356   0.5279
  def         0.0169230    0.0983634     0.1720   0.8641
```

```
  uhat_1       0.711107     0.145926      4.873    1.11e-05 ***
  uhat_2      -0.139036     0.149749     -0.9285   0.3575

  Unadjusted R-squared = 0.370529

Test statistic: LMF = 15.010221,
with p-value = P(F(2,51) > 15.0102) = 7.48e-006

Alternative statistic: TR^2 = 20.749637,
with p-value = P(Chi-square(2) > 20.7496) = 3.12e-005

Ljung-Box Q' = 23.3077,
with p-value = P(Chi-square(2) > 23.3077) = 8.69e-006
```

To test 2nd order autocorrelation model, we will add two lag errors.

- We have the **auxiliary equation** formula:

$\varepsilon_t = \rho_1\varepsilon_{t-1} + \rho_2\varepsilon_{t-2} + v_t$ and at least one $\rho_i \neq 0$

The Breusch-Godfrey test for serial correlation:

In this case, we will apply the Breusch-Godfrey test. We consider the hypothesis test as:

$\boldsymbol{H_0}$: $\rho_1 = \rho_2 = 0$

H_A: at least one $\rho_i \neq 0$

- To find out the **test statistic**, we will apply the following formula:

χ^2 **= T x** $(\boldsymbol{R_{AUX}})^2$

= 56 x 0.370529

= 20.749624

- **Decision Rule:** To determine the critical value, we compare to a Chi-square distribution with 2 degrees of freedom. If the test statistic is greater than the critical value, we have enough evidence to reject the null hypothesis.

The Gretl output for critical value (Chi-square distribution) is:

```
Chi-square(2)
 right-tail probability = 0.05
 complementary probability = 0.95

 Critical value = 5.99146
```

According to the Gretl output for Chi-square distribution, we have critical value is 5.99146. As 20.749624 > 5.99146 which means the test statistic is greater than the critical value. Therefore, the null hypothesis will be rejected.

In conclusion, there is enough evidence at a 5% level of significance, we can determine that the errors have second-order autocorrelation.

i) **Re-estimate your model with Robust standard errors and provide your output. Compare your results with the output in part (c). Comment.** ***(Model->OLS-> Choose the "tb3" to the dependent variables box and "inf" and "def" as regressors. From the left bottom corner check the box "Robust standard errors".)***

The Gretl output for Robust standard errors model:

```
Model 3: OLS, using observations 1948-2003 (T = 56)
Dependent variable: tb3
HAC standard errors, bandwidth 2, Bartlett kernel

             coefficient   std. error   t-ratio   p-value
  --------------------------------------------------------
  const       1.73327       0.503048     3.446    0.0011   ***
  inf         0.605866      0.101227     5.985    1.91e-07 ***
  def         0.513058      0.195578     2.623    0.0113   **

Mean dependent var   4.908214   S.D. dependent var   2.868242
Sum squared resid    180.0543   S.E. of regression   1.843163
R-squared            0.602068   Adjusted R-squared   0.587051
F(2, 53)             21.15091   P-value(F)           1.77e-07
Log-likelihood      −112.1619   Akaike criterion     230.3239
Schwarz criterion    236.3999   Hannan-Quinn         232.6796
rho                  0.622882   Durbin-Watson        0.716153
```

After applying Robust standard errors, the coefficient estimates still remained constant. However, there is a change in standard errors for the independent variables. From the Gretl output for Robust standard errors above, it is indicated that the standard errors of the coefficient estimates have all risen. In particular, we can observe that the standard error of constant grows from 0.431967 to 0.503048. The annual inflation rate and the federal budget deficit's standard error are from 0.0821348 to 0.101227 and from 0.118384 to 0.195578, respectively. This means that in the previous model, we underestimated standard errors. As a result of heteroscedasticity, our estimations are less exact than the output in section (c).