Application of Econometric Techniques to the Determination of Property Prices – Part 2

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MULTIPLE REGRESSION ANALYSIS

- **Multiple regression analysis can be used to study the relationship between a dependent variable and two or more independent variables.**

- **Purposes:**
  - **Prediction**
  - **Explanation**
  - **Theory building**

Simple vs. Multiple Regression

- **One dependent variable Y predicted from one independent variable X**
- **One regression coefficient**
- **r^2: Proportion of variation in dependent variable Y predicted from X**

- **One dependent variable Y predicted from a set of independent variables (X_1, X_2,..... X_k)**
- **One regression coefficient for each independent variable**
- **R^2: Proportion of variation in dependent variable Y predictable by set of independent variables (X's)**

Multiple Regression Model

$$Y = \alpha + \beta_1 X_1 + \beta_2 X_2 + \cdots + \beta_k X_k$$

- **The βs of the multiple regression model are called partial regression coefficients.**

- **The partial regression coefficients (βs) measure the distinct contribution of a variable, excluding any overlap with other predictor variables.**

Assumptions

- **Linearity**
- **Normality**
- **Independence**
- **Homoscedasticity**

Building Multiple Regression Models

- **Simultaneous**
  - **All independent variables entered together**

- **Stepwise**
  - **Independent variables entered according to some order**
    - **By size or correlation with dependent variable**
    - **In order of significance**

- **Hierarchical**
  - **Independent variables entered in stages**

Significance of Multiple Regression Coefficients

- **The regression coefficients describe the relationship between each independent variable and the dependent variable.**
  - **A positive regression coefficient indicates that as the value of the independent variable increases, the dependent variable also tends to increase, and vice versa.**

- **The p-value for each regression coefficient tests the null hypothesis that the coefficient is equal to zero (i.e. no effect on the dependent variable).**
  - **If the p-value for a variable is less than your significance level, your sample provides enough evidence to reject the null hypothesis for the entire population.**

Coefficient of Multiple Determination (R^2) and Adjusted R^2

- **The coefficient of multiple determination (R^2) is defined as the proportion of the total variation in Y "explained" by the multiple regression of Y on the x-variables.**

- **To factor in the reduction in the degrees of freedom as additional independent additional variables are added, an adjusted R^2 is also computed.**

- **Thus, the adjusted R-squared is more useful in comparing the goodness-of-fit for regression models that contain differing numbers of independent variables.**

Multicollinearity

- **Multicollinearity exists whenever an independent variable is highly correlated with one or more of the other independent variables in multiple regression equation.**

- **Multicollinearity is a problem because it makes regression models less reliable. This is due to wider confidence intervals that can lower the statistical significance of regression coefficients.**

- **Multicollinearity can be detected by examining the correlation between the independent variables. The rule of thumb is that correlation of more than ∓ 0.8 implies multicollinearity may be present.**

- **The Variance Inflation Factor (VIF) may be calculated and used to detect multicollinearity. A Variance Inflation factor greater than 5 suggests the presence of multicollinearity.**

Multiple Regression Using Excel

- Go to Data > Data Analysis
- Select: Regression
- Input Y Range
- Input X Range (Select all X variables)
- Select Labels if selection includes the label
- Select output range
- Click OK

MULTIPLE REGRESSION USING EVIEWS

- **STEP 1**
  - **Load data into EViews**

- **STEP 2**
  - **Select Y variable first, then select X variables and open as equation.**
  - **Go to Quick> Estimate Equation > Type the variables into the command window, starting with the dependent variable, constant then the independent variables.**

- **STEP 3**
  - **In METHOD dropdown, select LEAST SQUARES.**

- **STEP 4**
  - **Click OK**

Example 1

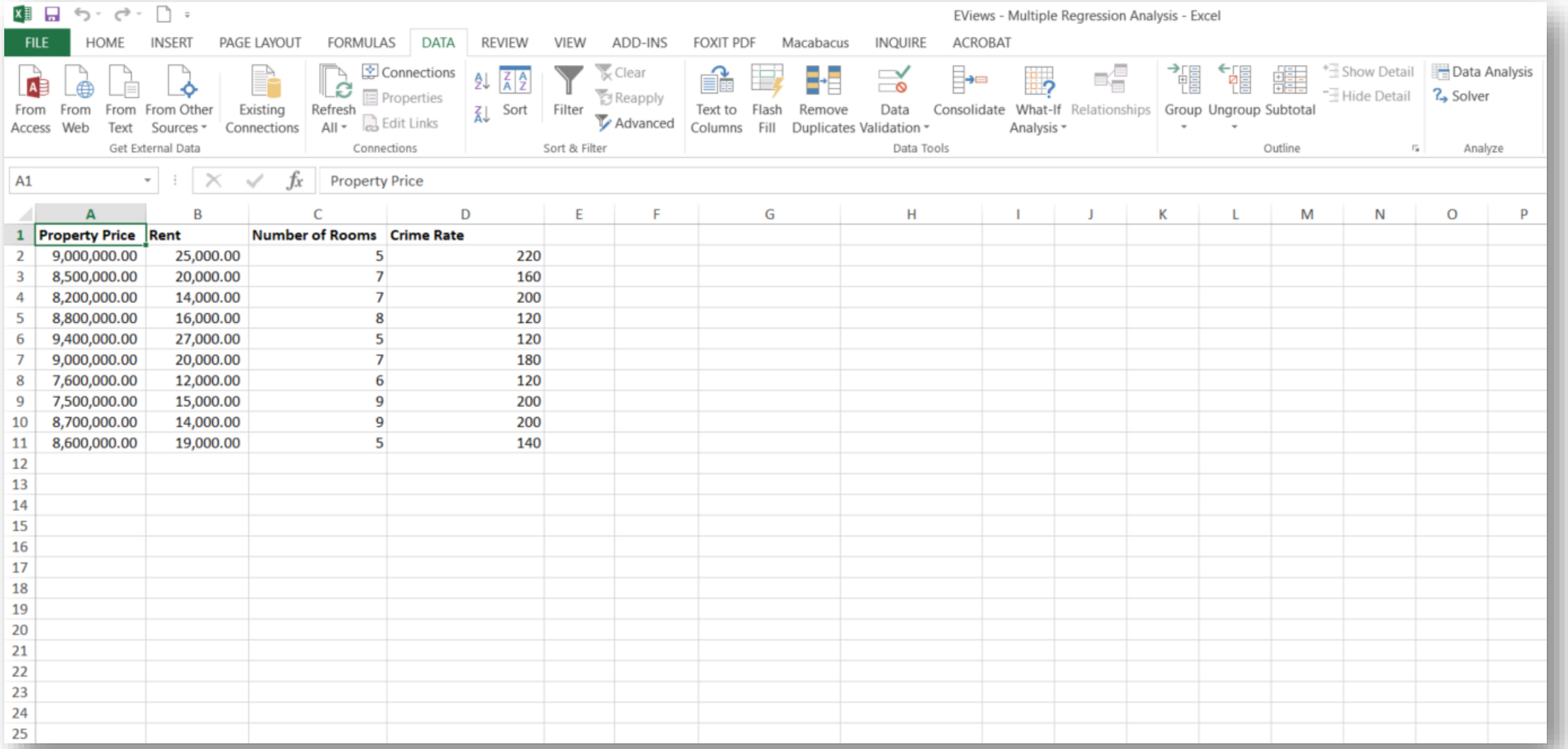
a) **Using the data available here (Example 1), estimate a multiple regression equation to determine how the price of a property is influenced by the following factors: Rent, number of rooms and crime rate.**

b) **Comment on the following:**

- ❑ **Regression coefficients and p-values**
- ❑ **Adjusted coefficient of determination (R^2)**

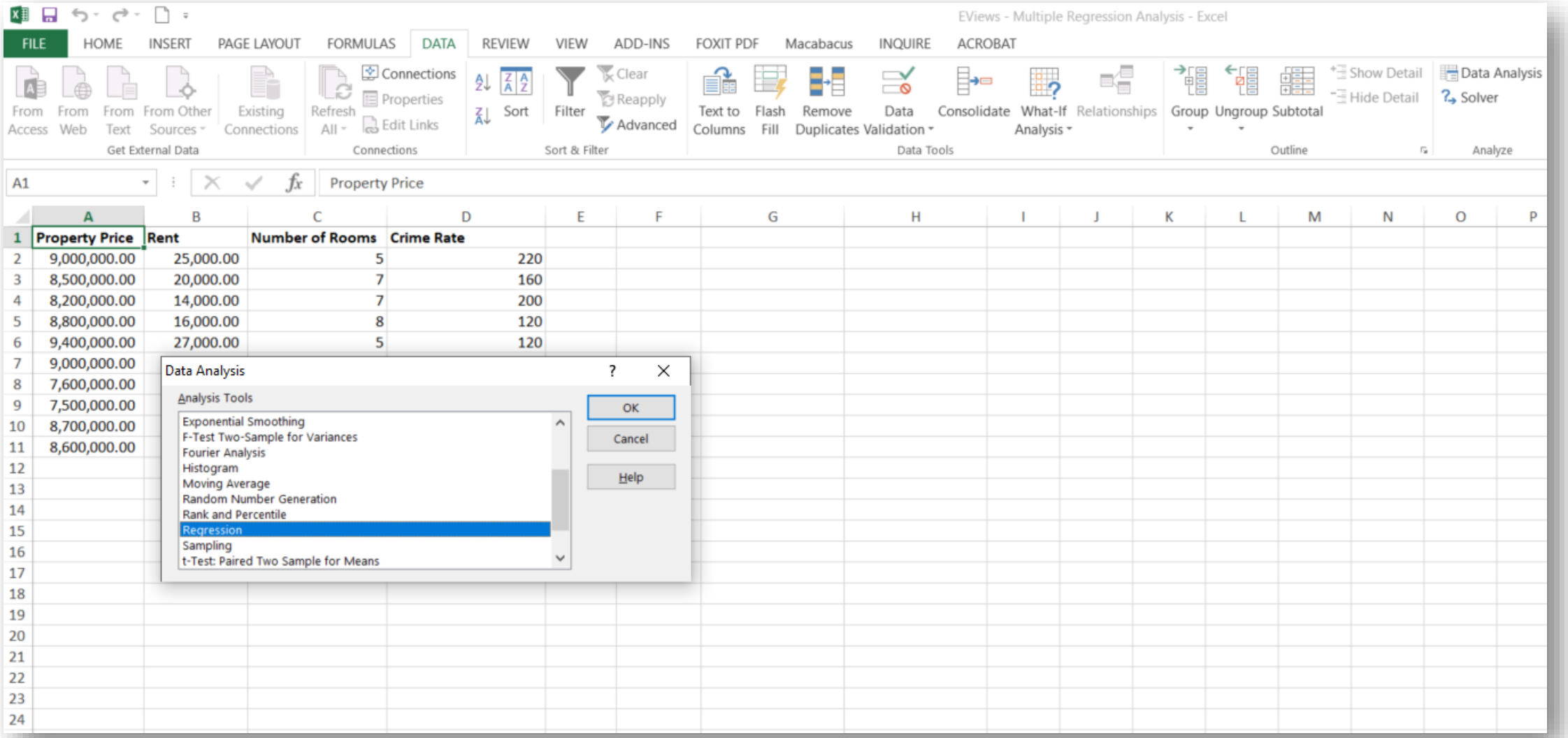
c) **Test for multicollinearity among the independent variables.**

Example 1a (Answer – MS Excel)



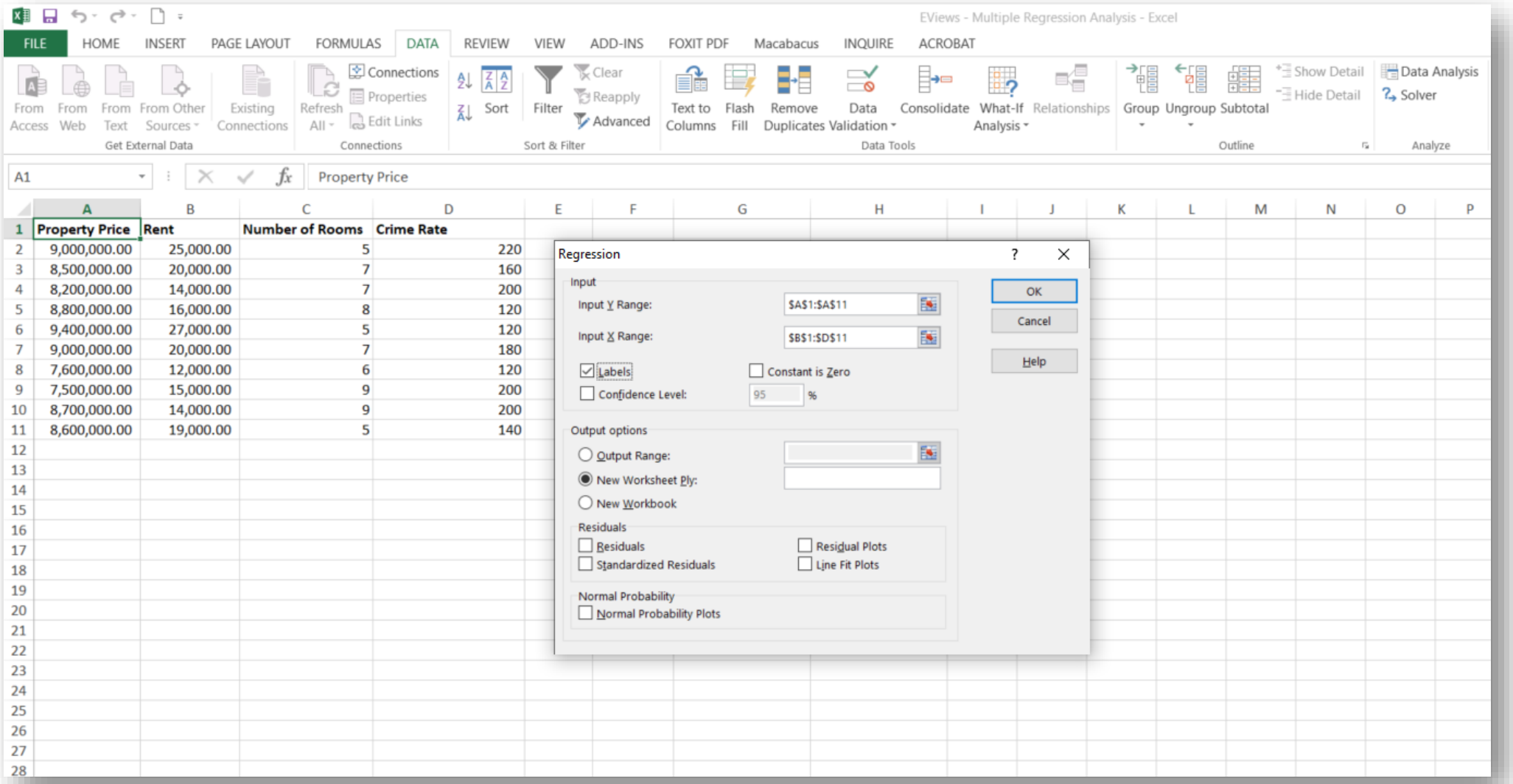
	A	B	C	D
1	Property Price	Rent	Number of Rooms	Crime Rate
2	9,000,000.00	25,000.00	5	220
3	8,500,000.00	20,000.00	7	160
4	8,200,000.00	14,000.00	7	200
5	8,800,000.00	16,000.00	8	120
6	9,400,000.00	27,000.00	5	120
7	9,000,000.00	20,000.00	7	180
8	7,600,000.00	12,000.00	6	120
9	7,500,000.00	15,000.00	9	200
10	8,700,000.00	14,000.00	9	200
11	8,600,000.00	19,000.00	5	140

Example 1a (Answer – MS Excel)



Property Price	Rent	Number of Rooms	Crime Rate
9,000,000.00	25,000.00	5	220
8,500,000.00	20,000.00	7	160
8,200,000.00	14,000.00	7	200
8,800,000.00	16,000.00	8	120
9,400,000.00	27,000.00	5	120
9,000,000.00			
7,600,000.00			
7,500,000.00			
8,700,000.00			
8,600,000.00			

Example 1a (Answer – MS Excel)



Property Price	Rent	Number of Rooms	Crime Rate
9,000,000.00	25,000.00	5	220
8,500,000.00	20,000.00	7	160
8,200,000.00	14,000.00	7	200
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9,400,000.00	27,000.00	5	120
9,000,000.00	20,000.00	7	180
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7,500,000.00	15,000.00	9	200
8,700,000.00	14,000.00	9	200
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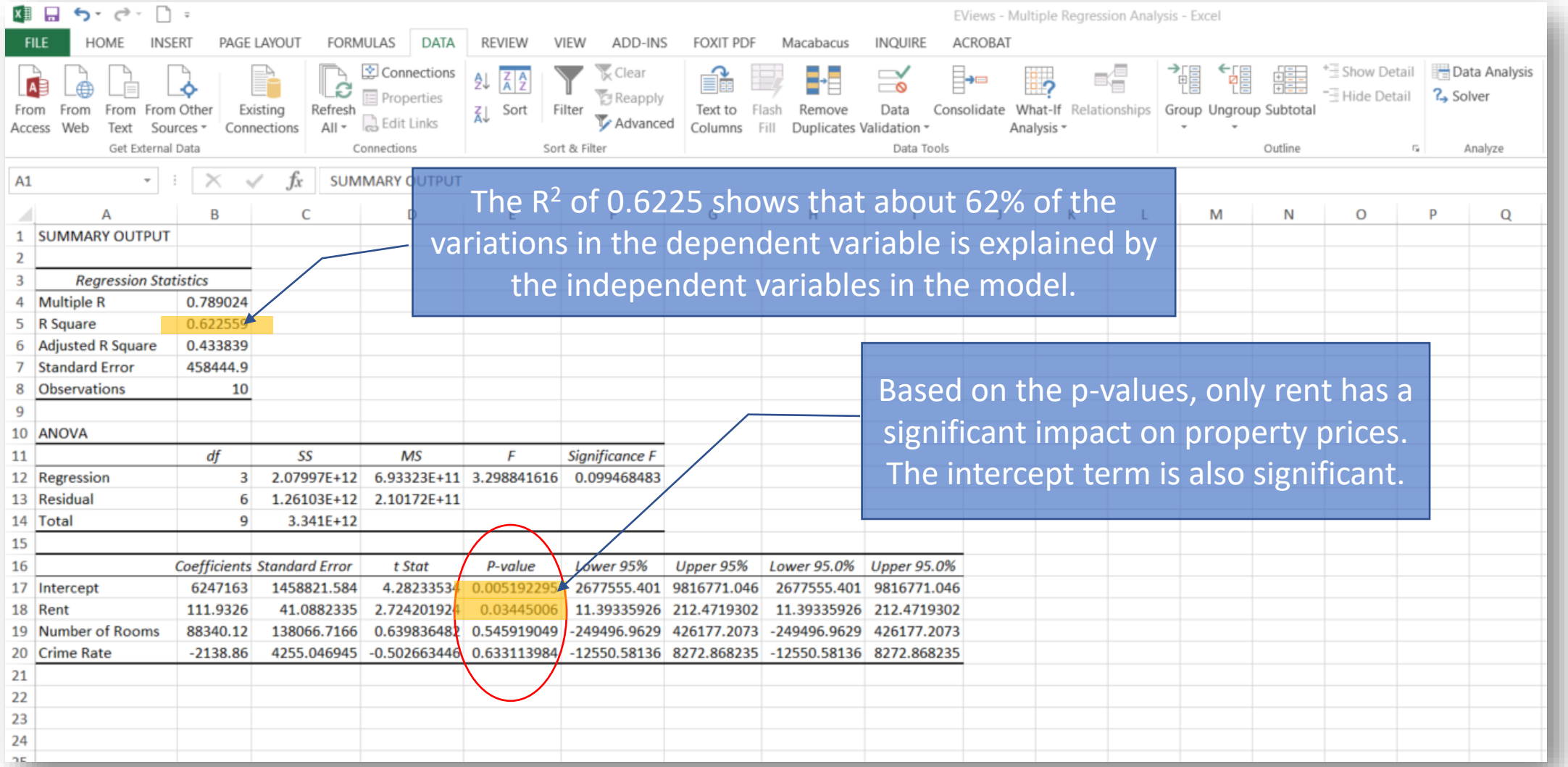
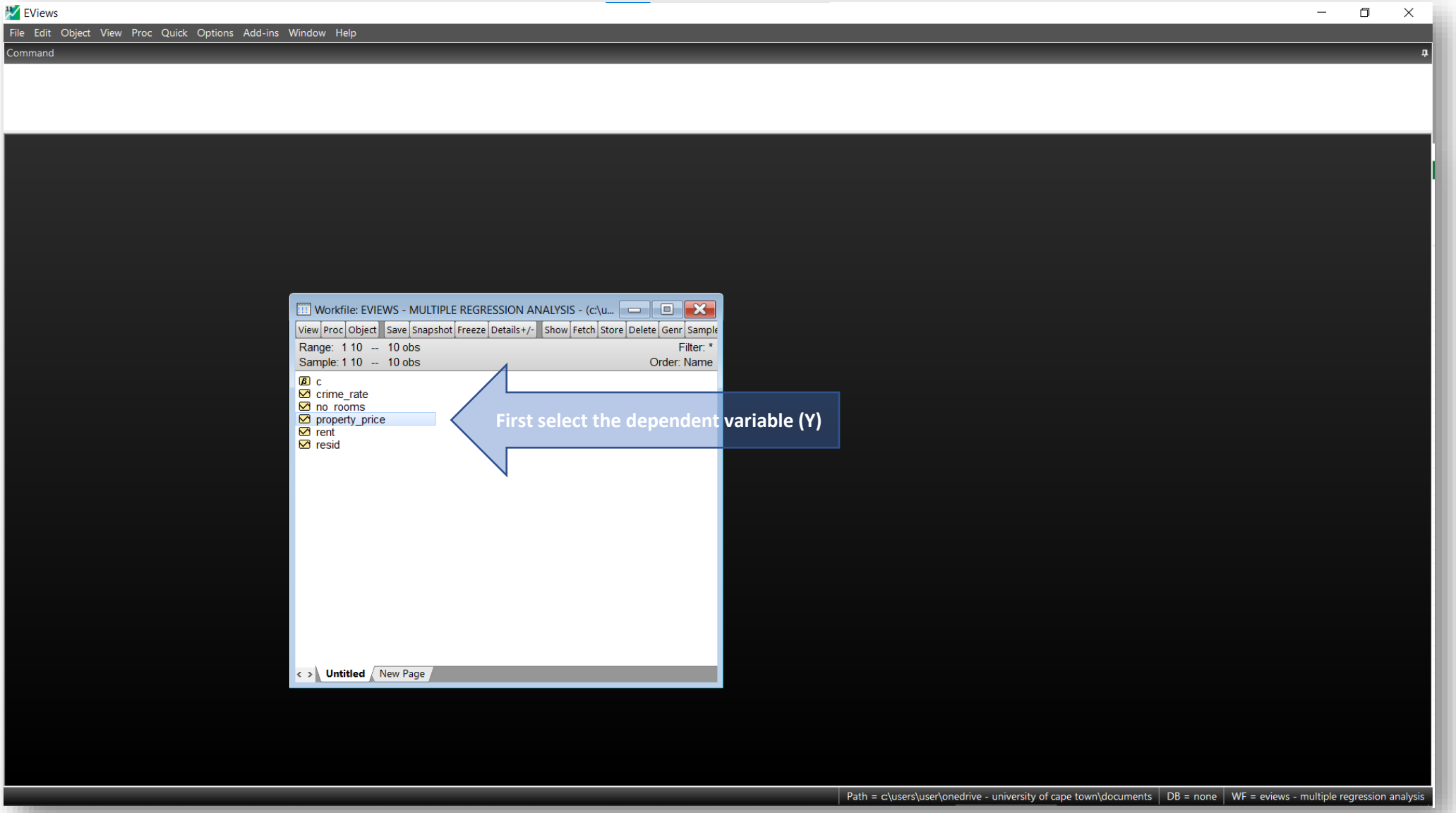


	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q
1	SUMMARY OUTPUT																
2																	
3	*Regression Statistics*																
4	Multiple R	0.789024															
5	R Square	0.622559															
6	Adjusted R Square	0.433839															
7	Standard Error	458444.9															
8	Observations	10															
9																	
10	ANOVA																
11		*df*	*SS*	*MS*	*F*	*Significance F*											
12	Regression	3	2.07997E+12	6.93323E+11	3.298841616	0.099468483											
13	Residual	6	1.26103E+12	2.10172E+11													
14	Total	9	3.341E+12														
15																	
16		*Coefficients*	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*								
17	Intercept	6247163	1458821.584	4.282335341	0.005192295	2677555.401	9816771.046	2677555.401	9816771.046								
18	Rent	111.9326	41.0882335	2.724201924	0.03445006	11.39335926	212.4719302	11.39335926	212.4719302								
19	Number of Rooms	88340.12	138066.7166	0.639836482	0.545919049	-249496.9629	426177.2073	-249496.9629	426177.2073								
20	Crime Rate	-2138.86	4255.046945	-0.502663446	0.633113984	-12550.58136	8272.868235	-12550.58136	8272.868235								
21																	
22																	
23																	
24																	

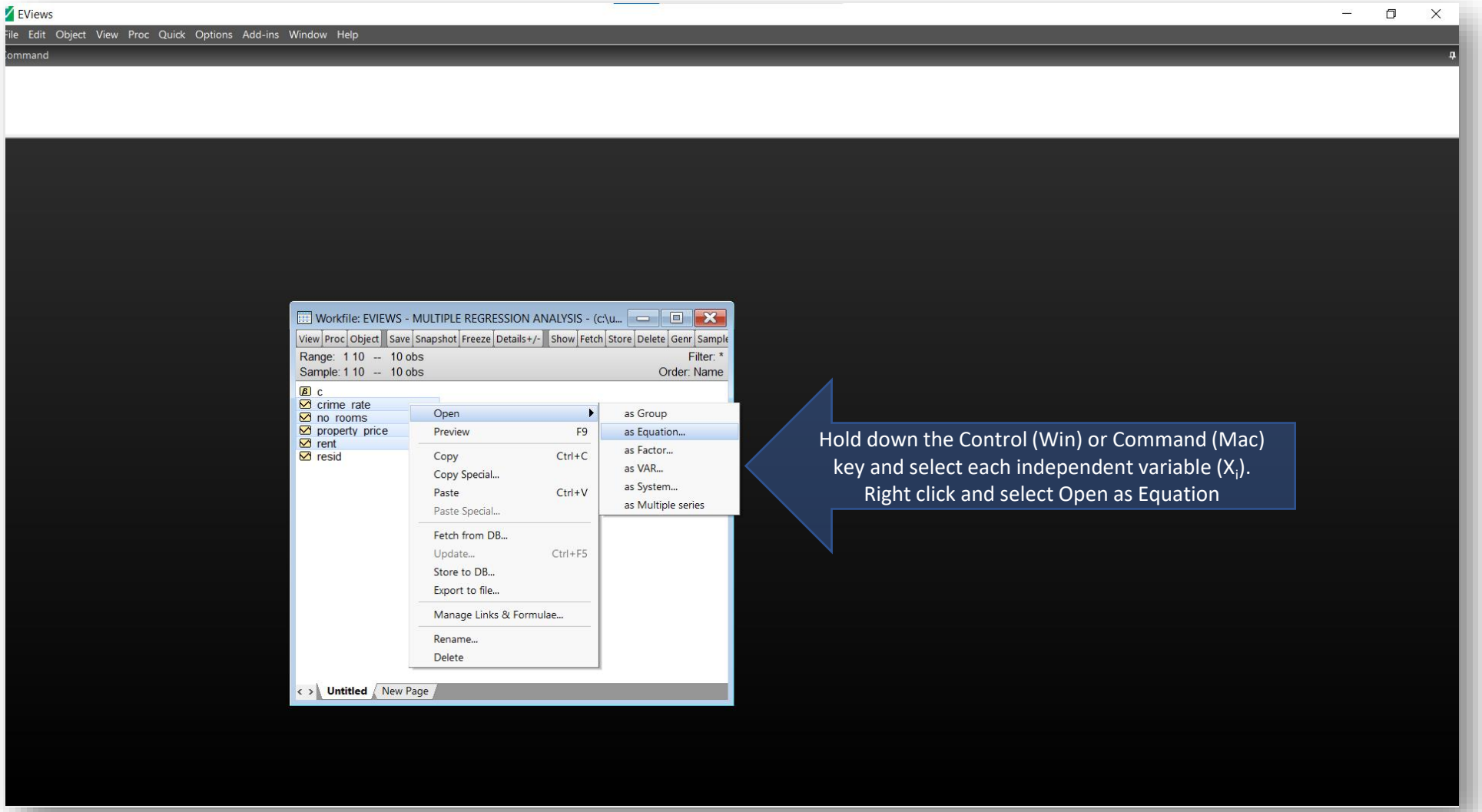
The R^2 of 0.6225 shows that about 62% of the variations in the dependent variable is explained by the independent variables in the model.

Based on the p-values, only rent has a significant impact on property prices. The intercept term is also significant.

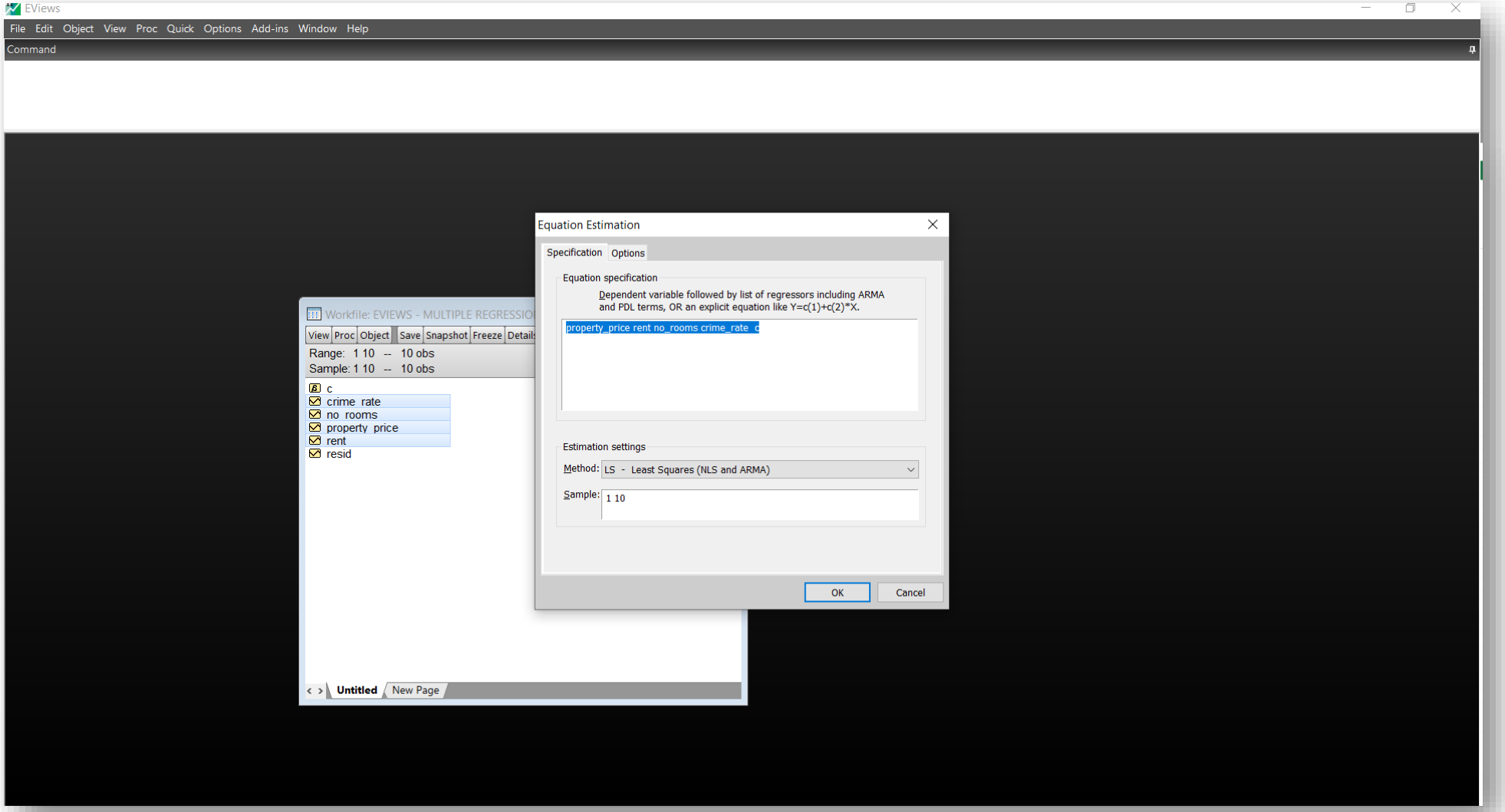
Example 1a (Answer – EViews)



Example 1a (Answer – EViews)



Example 1a (Answer – EViews)



Example 1a (Answer – EViews)

Equation: UNTITLED Workfile: EVIEWS - MULTIPLE ...

View | Proc | Object | Print | Name | Freeze | Estimate | Forecast | Stats | Resids

Dependent Variable: PROPERTY_PRICE
Method: Least Squares
Date: 10/20/22 Time: 13:48
Sample: 1 10
Included observations: 10

Variable	Coefficient	Std. Error	t-Statistic	Prob.
RENT	111.9326	41.08823	2.724202	0.0345
NO_ROOMS	88340.12	138066.7	0.639836	0.5459
CRIME_RATE	-2138.857	4255.047	-0.502663	0.6331
C	6247163.	1458822.	4.282335	0.0052

R-squared	0.622559	Mean dependent var	8530000.
Adjusted R-squared	0.433839	S.D. dependent var	609280.1
S.E. of regression	458444.9	Akaike info criterion	29.19824
Sum squared resid	1.26E+12	Schwarz criterion	29.31928
Log likelihood	-141.9912	Hannan-Quinn criter.	29.06547
F-statistic	3.298842	Durbin-Watson stat	2.392055
Prob(F-statistic)	0.099468		

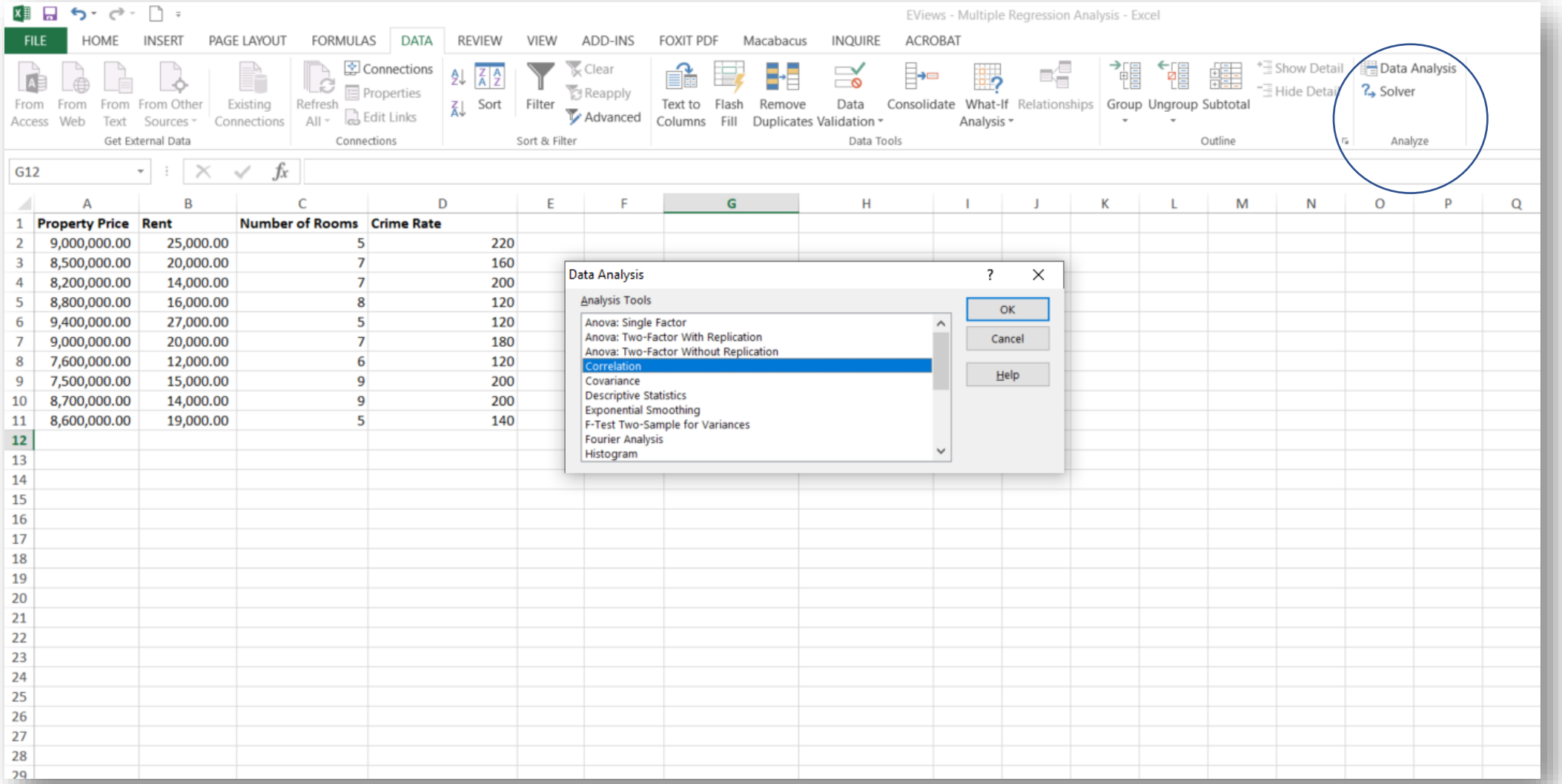
Example 1b (Answer)

- **The R^2 of 0.6225 shows that about 62% of the variations in the dependent variable is explained by the independent variables in the model.**

- **Based on the p-values, only rent has a significant impact on property prices.**

- **Although both crime and number of rooms have the expected sign, the p-value indicates that the relationship is not statistically significant.**

Example 1c (Answer – Excel)



Property Price	Rent	Number of Rooms	Crime Rate
9,000,000.00	25,000.00	5	220
8,500,000.00	20,000.00	7	160
8,200,000.00	14,000.00	7	200
8,800,000.00	16,000.00	8	120
9,400,000.00	27,000.00	5	120
9,000,000.00	20,000.00	7	180
7,600,000.00	12,000.00	6	120
7,500,000.00	15,000.00	9	200
8,700,000.00	14,000.00	9	200
8,600,000.00	19,000.00	5	140

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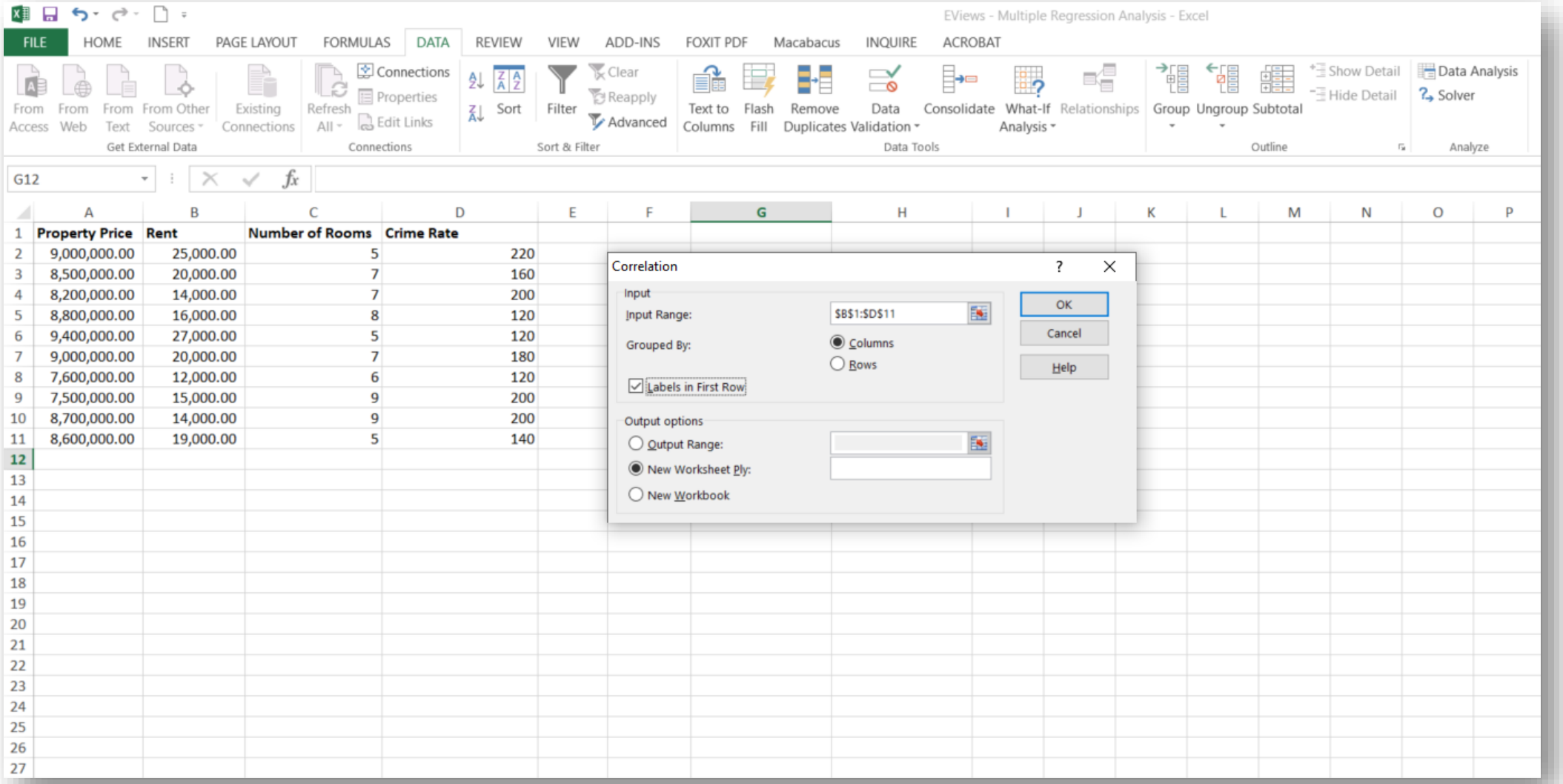

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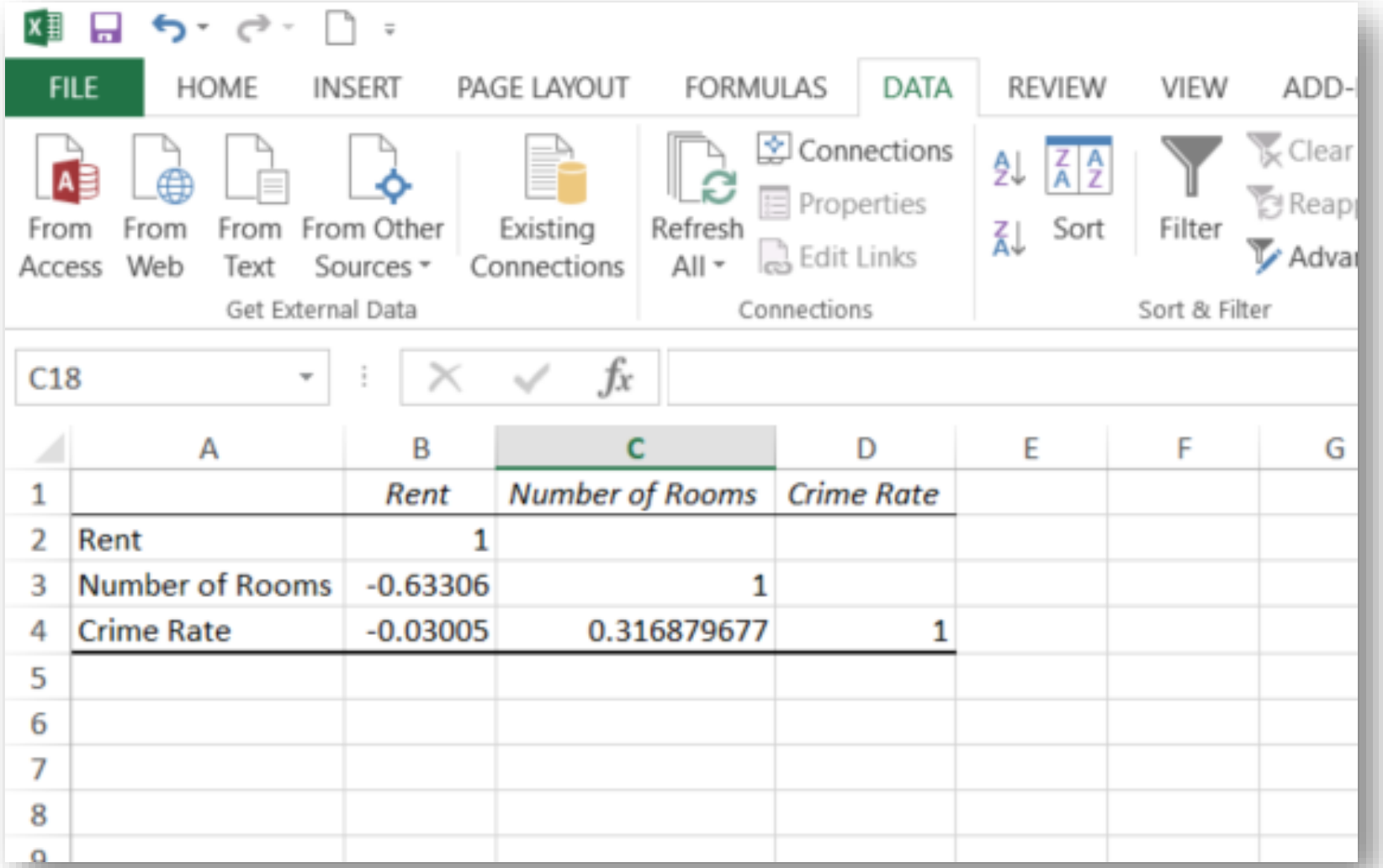
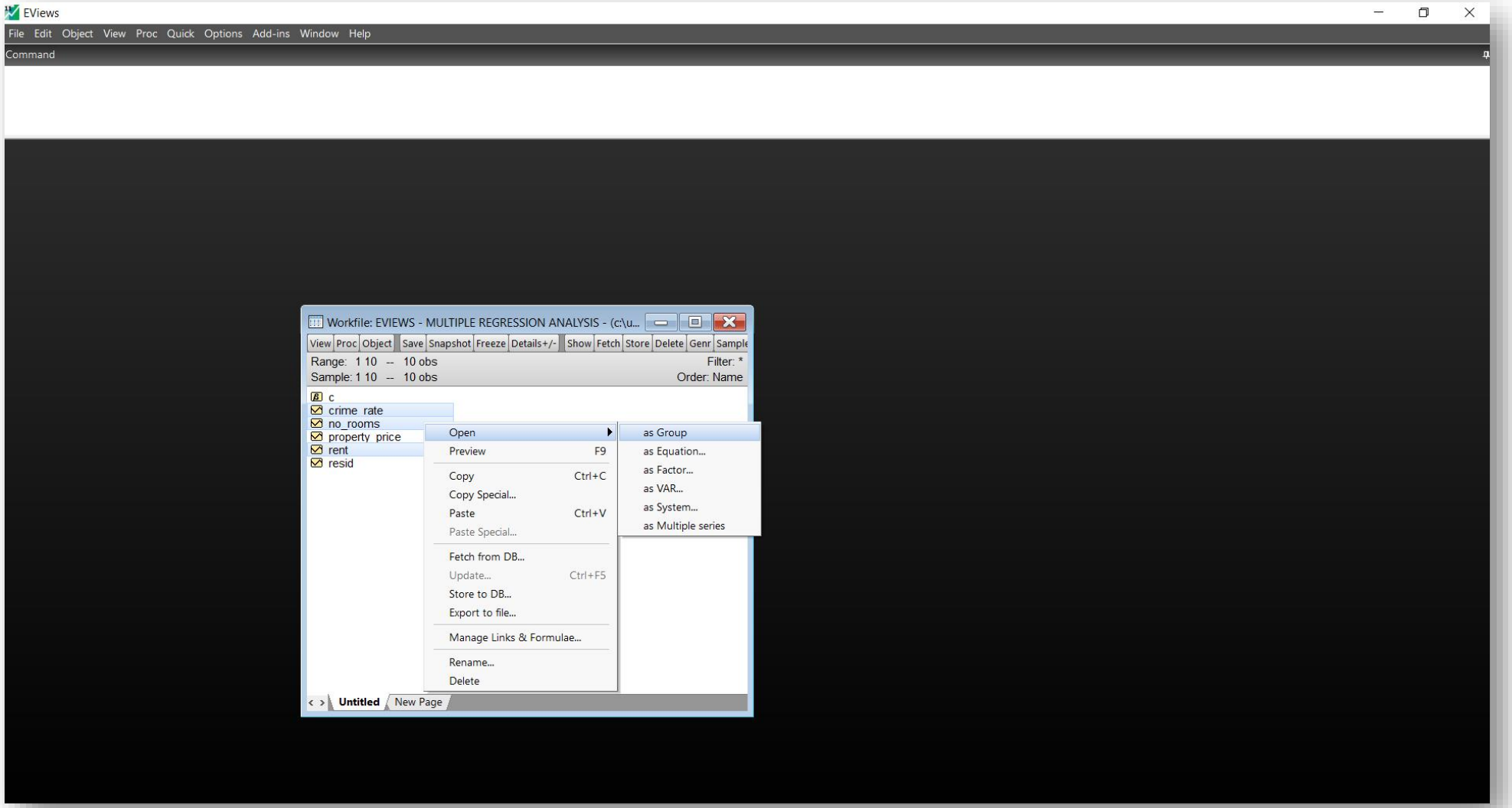
Example 1c (Answer – Excel)

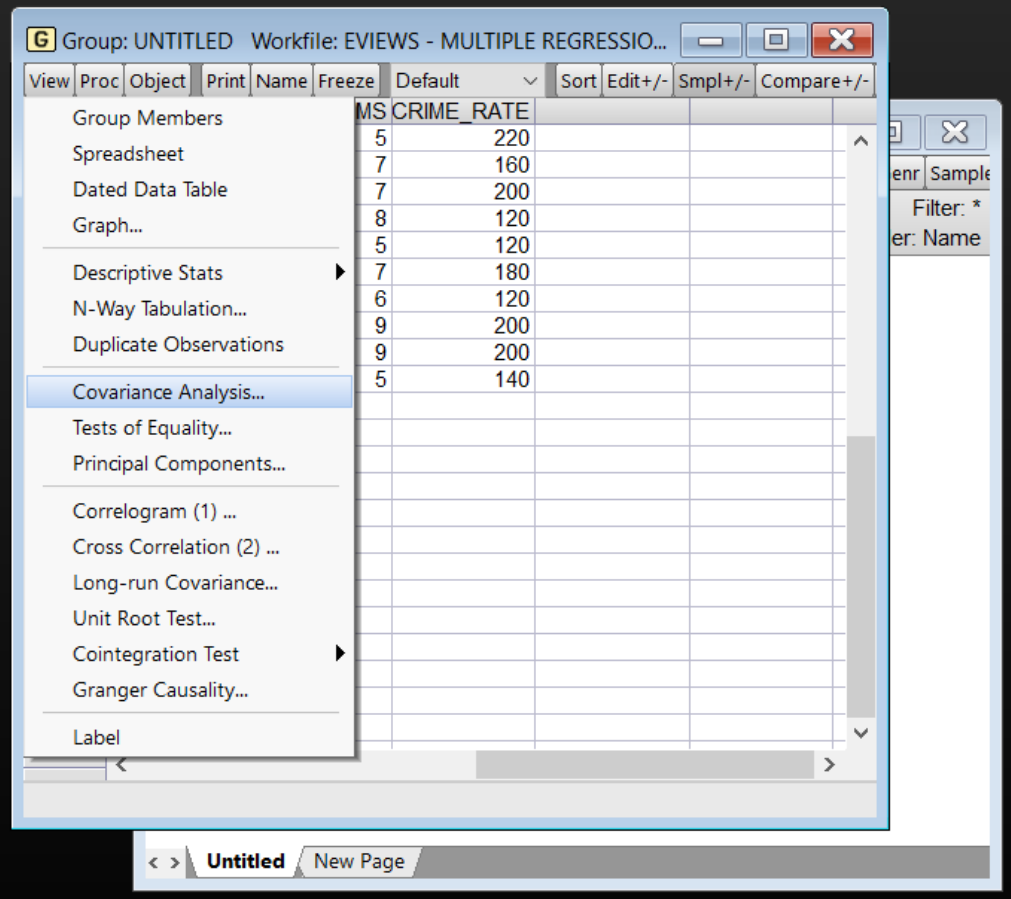


	A	B	C	D	E	F	G
1		*Rent*	*Number of Rooms*	*Crime Rate*			
2	Rent	1					
3	Number of Rooms	-0.63306	1				
4	Crime Rate	-0.03005	0.316879677	1			
5							
6							
7							
8							

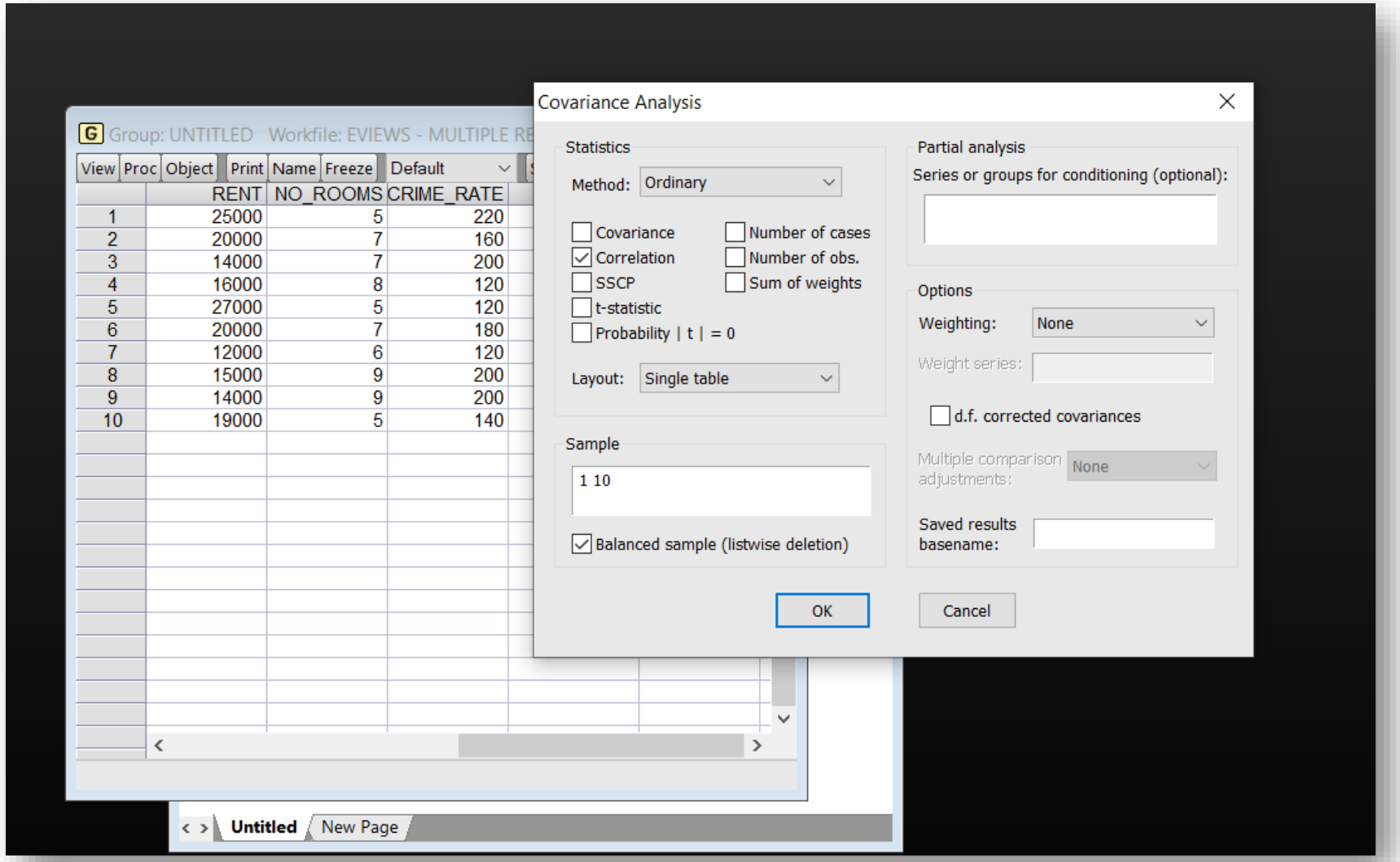
Example 1c (Answer – EViews)



Example 1c (Answer – EViews)

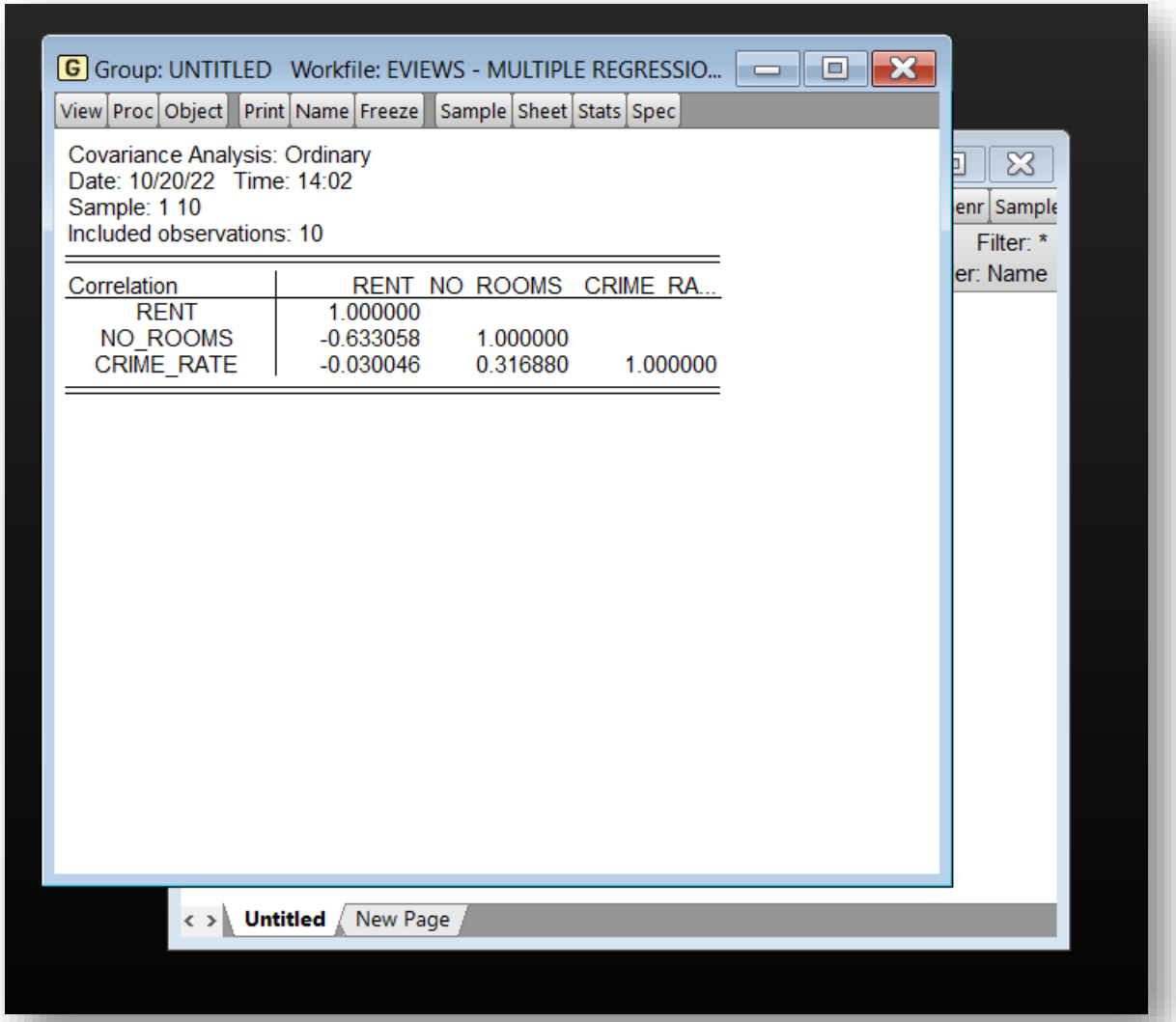


Example 1c (Answer – EViews)



	RENT	NO_ROOMS	CRIME_RATE
1	25000	5	220
2	20000	7	160
3	14000	7	200
4	16000	8	120
5	27000	5	120
6	20000	7	180
7	12000	6	120
8	15000	9	200
9	14000	9	200
10	19000	5	140

Example 1c (Answer – EViews)



Correlation	RENT	NO_ROOMS	CRIME_RA...
RENT	1.000000		
NO_ROOMS	-0.633058	1.000000	
CRIME_RATE	-0.030046	0.316880	1.000000

Example 1c (Answer – EViews)

Covariance Analysis: Ordinary
Date: 10/20/22 Time: 14:02
Sample: 1 10
Included observations: 10

Correlation	RENT	NO ROOMS	CRIME RA...
RENT	1.000000		
NO ROOMS	-0.633058	1.000000	
CRIME RATE	-0.030046	0.316880	1.000000

- **Since none of the correlations between the independent variables exceeds 0.80, there is no concern about multicollinearity in the model.**

Example 2

a) **Using the data available here (Example 2), estimate a multiple regression equation to show how Inflation, Listed Property Returns and Direct Property Returns impact House Prices in South Africa.**

b) **Comment on the following:**
   - ❑ **Regression coefficients and p-values**
   - ❑ **Adjusted coefficient of determination (R^2)**

c) **Test for multicollinearity among the independent variables.**

Example 2a and 2b (Answer - Excel)

Regression Statistics	
Multiple R	0.69021348
R Square	0.476394648
Adjusted R Square	0.214591972
Standard Error	1.367500097
Observations	10

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	3	10.20866091	3.402887	1.819671	0.243904409
Residual	6	11.22033909	1.870057		
Total	9	21.429			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	-1.79876325	3.099184136	-0.5804	0.582771	-9.38219364	5.784667139	-9.382193642	5.784667139
SA_CPI	1.121024876	0.568263364	1.972721	0.095988	-0.26946548	2.511515235	-0.269465484	2.511515235
SAPY	-0.0146462	0.032693814	-0.44798	0.669889	-0.09464508	0.06535268	-0.094645084	0.06535268
IPD_SA	0.110944268	0.090843585	1.221267	0.267791	-0.11134198	0.333230512	-0.111341975	0.333230512

Example 2a and 2b (Answer - EViews)

Dependent Variable: SA_HPI
Method: Least Squares
Date: 10/21/22 Time: 07:11
Sample: 2010 2019
Included observations: 10

Variable	Coefficient	Std. Error	t-Statistic	Prob.
SA_CPI	1.121025	0.568263	1.972721	0.0960
SAPY	-0.014646	0.032694	-0.447981	0.6699
IPD_SA	0.110944	0.090844	1.221267	0.2678
C	-1.798763	3.099184	-0.580399	0.5828

R-squared	0.476395	Mean dependent var	4.910000
Adjusted R-squared	0.214592	S.D. dependent var	1.543049
S.E. of regression	1.367500	Akaike info criterion	3.753020
Sum squared resid	11.22034	Schwarz criterion	3.874054
Log likelihood	-14.76510	Hannan-Quinn criter.	3.620246
F-statistic	1.819671	Durbin-Watson stat	1.901171
Prob(F-statistic)	0.243904		

Example 2b (Answer)

- **The R^2 of 0.4764 shows that about 48% of the variations in the dependent variable is explained by the independent variables in the model.**

- **Based on the p-values, only CPI Inflation has a significant impact on house prices (at 10% significance level).**

Example 2c (Answer - Excel)

	SA_CPI	*SAPY*	*IPD_SA*
SA_CPI	1		
SAPY	0.350621645	1	
IPD_SA	0.040619897	0.397195625	1

Example 2c (Answer - EViews)

Covariance Analysis: Ordinary
Date: 10/21/22 Time: 07:25
Sample: 2010 2019
Included observations: 10

Correlation	IPD_SA	SA_CPI	SAPY
IPD_SA	1.000000		
SA_CPI	0.040620	1.000000	
SAPY	0.397196	0.350622	1.000000

None of the independent variables are highly correlated, so there's likely no multicollinearity between the independent variables.

Group Task 1

a) **Using multiple regression analysis, show how foreign investment in the property market is impacted by the following: Crude oil prices, interest rates, gross national product, purchasing power of local currency and consumer debt. The data for the dependent and independent variables is available here .**

b) **Comment on the following:**

- ❑ **Regression coefficients and p-values**
- ❑ **Adjusted coefficient of determination (R^2)**

c) **Test for multicollinearity among the independent variables.**

Example 3a and 3b (Answer - Excel)

Regression Statistics	
Multiple R	0.998830462
R Square	0.997662291
Adjusted R Squ	0.994857041
Standard Error	5.157833042
Observations	12

ANOVA

	df	SS	MS	F	Significance F
Regression	6	56767.23379	9461.21	355.641	2.0738E-06
Residual	5	133.0162084	26.6032		
Total	11	56900.25			

	Coefficients	Standard Error	t Stat	P-value	Lower 95%	Upper 95%	Lower 95.0%	Upper 95.0%
Intercept	-392.1282593	115.9639686	-3.38147	0.01964	-690.22313	-94.0333881	-690.22313	-94.03338808
CRUDE	0.154497787	1.108344013	0.1394	0.89458	-2.6945912	3.00358677	-2.6945912	3.003586774
INTEREST	-0.962686789	3.838882369	-0.25077	0.81197	-10.830848	8.9054745	-10.8308481	8.905474499
DJIA	0.014832228	0.014612963	1.015	0.35667	-0.0227316	0.05239605	-0.02273159	0.052396045
GNP	0.152991984	0.036540162	4.18695	0.0086	0.05906251	0.24692146	0.059062508	0.246921461
PURCHASE	121.7238464	52.68912254	2.31023	0.06889	-13.717855	257.165548	-13.717855	257.1655477
CONSUMER	-0.280273727	0.133258537	-2.10323	0.08939	-0.6228257	0.06227825	-0.6228257	0.062278248

Example 3a and 3b (Answer - EViews)

Dependent Variable: FOREIGN_Y
Method: Least Squares
Date: 10/21/22 Time: 06:38
Sample: 1976 1987
Included observations: 12

Variable	Coefficient	Std. Error	t-Statistic	Prob.
CONSUMER	-0.280274	0.133259	-2.103233	0.0894
CRUDE	0.154498	1.108344	0.139395	0.8946
DJIA	0.014832	0.014613	1.015005	0.3567
GNP	0.152992	0.036540	4.186954	0.0086
INTEREST	-0.962687	3.838882	-0.250773	0.8120
PURCHASE	121.7238	52.68912	2.310227	0.0689
C	-392.1283	115.9640	-3.381466	0.0196

R-squared	0.997662	Mean dependent var	118.2500
Adjusted R-squared	0.994857	S.D. dependent var	71.92183
S.E. of regression	5.157833	Akaike info criterion	6.410108
Sum squared resid	133.0162	Schwarz criterion	6.692970
Log likelihood	-31.46065	Hannan-Quinn criter.	6.305382
F-statistic	355.6411	Durbin-Watson stat	2.670833
Prob(F-statistic)	0.000002		

Example 3b (Answer)

- **The R^2 of 0.9988 shows that nearly all (0.9988%) of the variations in the dependent variable is explained by the independent variables in the model.**

- **The results show that GNP, PURCHASING POWER and CONSUMER DEBT have a statistically significant effect on foreign investments in properties.**

Example 3c (Answer - Excel)

	CRUDE	INTEREST	DJIA	GNP	PURCHASE	CONSUMER
CRUDE	1					
INTEREST	0.969380679	1				
DJIA	-0.146106092	-0.300973798	1			
GNP	0.37480369	0.227548657	0.80659	1		
PURCHASE	-0.619665891	-0.48812024	-0.60792	-0.95052	1	
CONSUMER	0.152950564	0.003861288	0.88363	0.96958	-0.8545451	1

Example 3c (Answer - EViews)

Covariance Analysis: Ordinary
Date: 10/21/22 Time: 06:56
Sample: 1976 1987
Included observations: 12

Correlation	CONSUMER	CRUDE	DJIA	GNP	INTEREST	PURCHASE
CONSUMER	1.000000					
CRUDE	0.152951	1.000000				
DJIA	0.883626	-0.146106	1.000000			
GNP	0.969579	0.374804	0.806587	1.000000		
INTEREST	0.003861	0.969381	-0.300974	0.227549	1.000000	
PURCHASE	-0.854545	-0.619666	-0.607922	-0.950515	-0.488120	1.000000

Consumer debt is highly correlated with DJIA, GNP and Purchase. GNP is highly correlated with Purchase. INTEREST is also highly correlated with CRUDE. These high correlations point to the presence of multicollinearity in the multiple regression model.

Group Task 2

a) **You have determined that the following factors impact the performance of retail outlets: size of the property (X_1), inventory (X_2), amount spent on advertising (X_3), size of sales district (X_4), number of competing stores in district (X_5). You have compiled the data for the dependent and independent variables (See here).**

b) **Comment on the following:**
   - ❑ **Regression coefficients and p-values**
   - ❑ **Adjusted coefficient of determination (R^2)**

c) **Test for multicollinearity among the independent variables.**

Example 4a and 4b (Answer - Excel)

Regression Statistics	
Multiple R	0.996583914
R Square	0.993179497
Adjusted R Square	0.991555568
Standard Error	17.64924165
Observations	27

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	5	952538.9415	190508	611.59	5.39731E-22
Residual	21	6541.410344	311.496		
Total	26	959080.3519			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	-18.85941416	30.15022791	-0.62551	0.53837	-81.56024554	43.84141723	-81.56024554	43.84141723
X1	16.20157356	3.544437306	4.57099	0.00017	8.830512669	23.57263445	8.830512669	23.57263445
X2	0.174635154	0.057606068	3.03154	0.00635	0.054836778	0.294433531	0.054836778	0.294433531
X3	11.52626903	2.5321033	4.55205	0.00017	6.260471952	16.79206611	6.260471952	16.79206611
X4	13.5803129	1.770456609	7.67051	0.00000	9.898446822	17.26217897	9.898446822	17.26217897
X5	-5.31097141	1.70542654	-3.11416	0.00525	-8.857600053	-1.76434277	-8.857600053	-1.76434277

Example 4a and 4b (Answer - EViews)

Dependent Variable: Y
Method: Least Squares
Date: 10/21/22 Time: 06:28
Sample: 1 27
Included observations: 27

Variable	Coefficient	Std. Error	t-Statistic	Prob.
X1	16.20157	3.544437	4.570986	0.0002
X2	0.174635	0.057606	3.031541	0.0063
X3	11.52627	2.532103	4.552053	0.0002
X4	13.58031	1.770457	7.670514	0.0000
X5	-5.310971	1.705427	-3.114160	0.0052
C	-18.85941	30.15023	-0.625515	0.5384

R-squared	0.993179	Mean dependent var	286.5741
Adjusted R-squared	0.991556	S.D. dependent var	192.0617
S.E. of regression	17.64924	Akaike info criterion	8.772393
Sum squared resid	6541.410	Schwarz criterion	9.060356
Log likelihood	-112.4273	Hannan-Quinn criter.	8.858019
F-statistic	611.5904	Durbin-Watson stat	1.788873
Prob(F-statistic)	0.000000		

Example 4b (Answer)

- **The R^2 of 0.9988 shows that nearly all (0.9988%) of the variations in the dependent variable is explained by the independent variables in the model.**

- **The results show that GNP, PURCHASING POWER and CONSUMER DEBT have a statistically significant effect on foreign investments in properties.**

Example 4b (Answer)

- **The R^2 of 0.9988 shows that nearly all (0.9988%) of the variations in the dependent variable is explained by the independent variables in the model.**

- **Apart from the intercept term, the p-values show that all the other variables have a significant influence on annual net sales (performance) of retail outlets.**

Example 4c (Answer - Excel)

	X1	*X2*	*X3*	*X4*	*X5*
X1	1				
X2	0.843615779	1			
X3	0.748587239	0.906230646	1		
X4	0.838022882	0.863916923	0.79543	1	
X5	-0.765737791	-0.807380423	-0.84128	-0.86959	1

Example 4c (Answer - EViews)

Covariance Analysis: Ordinary
Date: 10/21/22 Time: 06:31
Sample: 1 27
Included observations: 27

Correlation	X1	X2	X3	X4	X5
X1	1.000000				
X2	0.843616	1.000000			
X3	0.748587	0.906231	1.000000		
X4	0.838023	0.863917	0.795434	1.000000	
X5	-0.765738	-0.807380	-0.841280	-0.869590	1.000000

Most of the independent variables are highly correlated, pointing to the presence of multicollinearity. The researcher should consider dropping or replacing some of the variables and re-running the regression.

Testing for Multicollinearity – Variance Inflation Factor

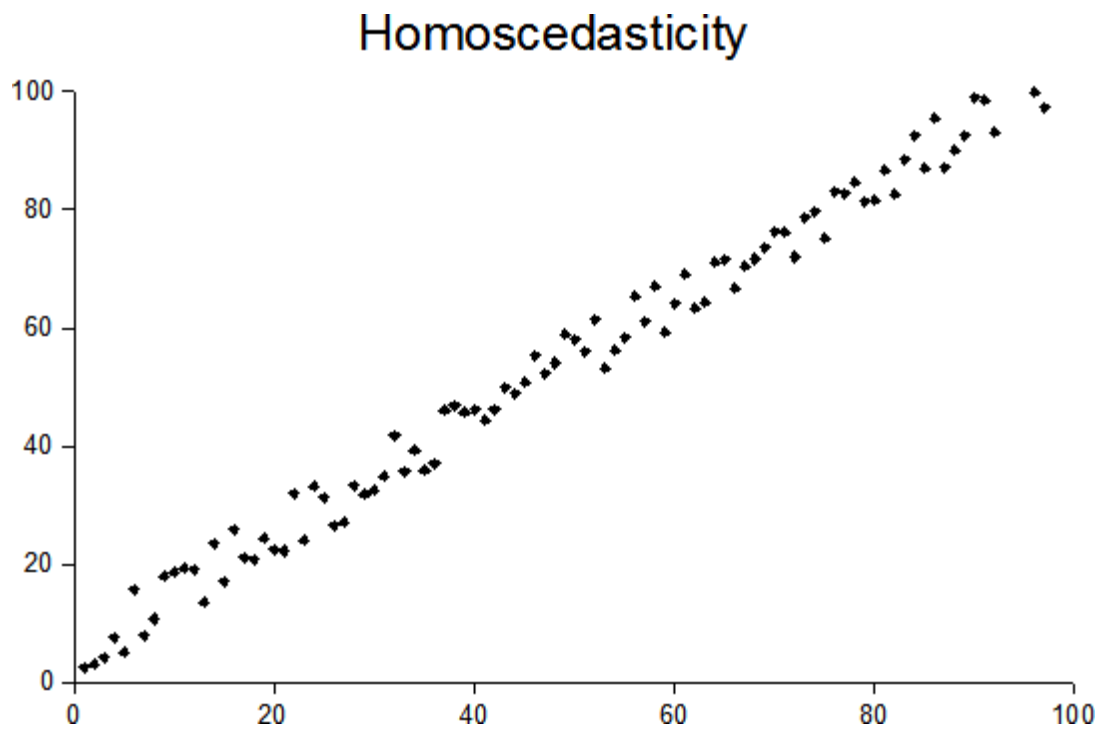
- **A VIF less than 5 indicates a low correlation of that predictor with other predictors.**
- **A VIF value between 5 and 10 indicates a moderate correlation**
- **VIF values larger than 10 are a sign for high, not tolerable correlation of model predictors (James et al. 2013).**

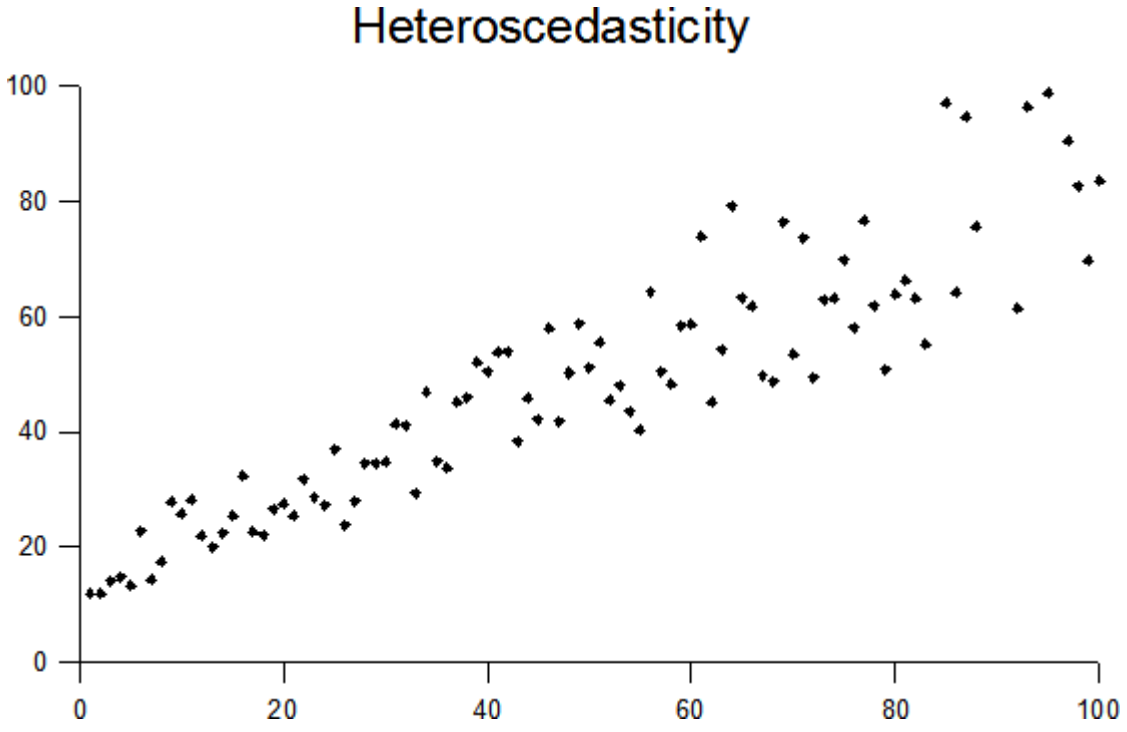
Homoscedasticity

- **Homoscedasticity describes a situation in which the error term (that is, the "noise" or random disturbance in the relationship between the independent variables and the dependent variable) is the same across all values of the independent variables.**

- **Heteroscedasticity (the violation of homoscedasticity) is present when the size of the error term differs across values of an independent variable. The impact of violating the assumption of homoscedasticity is a matter of degree, increasing as heteroscedasticity increases.**

Homoscedasticity





The easiest way to check homoscedasticity is to draw a scatterplot with the residuals against the dependent variable.

Tests of Heteroskedasticity

- **White Test for Heteroskedasticity**
- **Breusch Pagan Test for Heteroskedasticity**
- **Harvey Harvey Test for Heteroskedasticity**
- **Glejser Test of heteroskedasticity**

Test of Heteroskedasticity in EViews

- **To test for heteroskedasticity in EViews, you must first run an ordinary least squares (OLS) regression.**
  - **The heteroskedasticity test is a diagnostic that uses the residuals of the estimated model to check for non-constant variance.**

- **With your equation window open, click the View button on the toolbar.**
  - **Select Residual Diagnostics > Heteroskedasticity Tests.**
  - **Click on one of the tests, e.g. Breusch-Pagan-Godfrey to select it.**