

**MINISTRY OF EDUCATION AND SCIENCE,
YOUTH AND SPORTS OF UKRAINE**

KHARKIV NATIONAL UNIVERSITY OF ECONOMICS

**Guidelines to practical tasks
in the educational discipline
"ECONOMETRICS"**

**for full-time students of preparation direction
6.030601 "Management"**

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Затверджено на засіданні кафедри економіки, організації та планування діяльності підприємства.

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The content of practical tasks, guidelines to their fulfillment and questions to consolidate knowledge in the given educational discipline are presented.

It is recommended for full-time students of preparation direction 6.030601 "Management".

Наведено зміст практичних завдань, методичні рекомендації до їх виконання і питання для закріплення знань з даної навчальної дисципліни.

Рекомендовано для студентів напряму підготовки 6.030601 "Менеджмент" денної форми навчання.

Introduction

The results of the commercial activities of enterprises are affected by a large number of factors and phenomena. This effect is varied: some factors and phenomena have a major impact, others are weaker, and the others are not affected. To develop an effective policy we must be able to assess the relationship between the factors and phenomena themselves, and their impact on the results of business enterprises.

Mathematical methods are essential to select and formalize the relationship between economic indicators, to assess the form and parameters of their dependencies. Accordingly, the production manager should know and be able to use this method.

Also, the future manager should know the features of economy, organization and production planning, taken into account when developing mathematical models of economic activity.

Most current methods for the study of economic processes and phenomena use econometrics. Therefore, an expert on management should know the principles of construction and analysis of econometric models able to quantitatively justify and solve problems that arise in modern conditions. To solve economic problems by means of econometric methods for the production, a manager must also use personal computer and specialized application software packages.

The purpose of the discipline "Economics" is the formation of future managers' theoretical knowledge and practical skills in econometrics, use of methods that optimize task management, organization and production planning. The task of the discipline is the application of econometrics to test economic theories on factual and quantitative optimal solutions.

The subject of the discipline is economic-mathematical methods and tools for the study of economic phenomena and processes occurring at macro- and micro levels.

"Econometrics" is taught after the students have learnt the subjects "Higher and Applied Mathematics", "Operations Research". This links the disciplines of mathematical cycle with economic sciences, prior to the study of professional disciplines which is the basis for economic research.

The discipline consists of lectures, laboratory studies, independent work.

Discipline "Econometrics" is taught within the preparation direction 6.030601 "Management" for full-time study.

1. Plans of laboratory studies

Themes of laboratory studies. Fixing lecture provisions are made in the laboratory studies. Laboratory studies are the form of academic classes, where students are organized for a detailed analysis of some theoretical discipline. For this purpose situational objectives and guidelines for their implementation are given. Successful problem solving requires the use of batch programs.

During laboratory studies the students' skills of econometric methods of application for solving specific economic problems are formed. At laboratory studies each student performs his individual tasks. For their successful implementation the previous lecture material on a particular theme must be read, and used in the tasks performance of using software. All tasks are performed with the help of the program Excel.

The academic discipline considers three practical problems:

The first two tasks are on the theme "General linear and econometric nonlinear models".

The second is theme 3: "The production function and flexibility".

The third is theme 4 "Variance analysis in the economy."

The list of laboratory studies is presented in Table 1.

Table 1

List of themes for modules laboratory studies

Task	Laboratory studies themes	Hours	References
1	2	3	4
Module 1. Investigation of static relationships of economic processes			
Task 1. Justification of building model of costs depending on two factors	Laboratory studies 1. To ground model depending on the value of home life. Build the schedule and cost model. Determine the model parameters using Excel.	2	References: main: [2; 3; 4]; ancillary: [2; 3]

Table 1 (the ending)

1	2	3	4
	Laboratory studies 2. To assess the relationship indicators. To evaluate the accuracy of the model. To make conclusions.	2	References: main: [1; 3; 4]; ancillary: [2; 3]
	Laboratory studies 3. Plot of dependent indicators. To build a model depending on parameters. To determine model parameters.	2	References: main: [2; 3; 4]; ancillary: [1; 2; 3]
	Laboratory studies 4. To determine model parameters. To assess the impact of factors on the dependent variable. To evaluate the accuracy of models.	2	References: main: [3; 4]; ancillary: [2; 3]
Total for Module 1		8	
Module 2. Investigation of relationship dynamics in the ranks			
Task 2. Justification of model production function: dependence of rubber growth on car production growth and growth of income per capita	Laboratory studies 5. To chart the growth rate depending on factors of rubber production.	2	References: main: [1; 3; 4]; ancillary: [2; 3]
	Laboratory studies 6. To determine model parameters. To assess the impact of factors.	2	References: main: [2; 3; 4]; ancillary: [1; 2; 3]
	Laboratory studies 7. Rate elasticity. Protection objectives.	2	References: main: [2; 3; 4]; ancillary: [1; 2; 3]
Task 3. Assessment of impact factors using analysis of variance.	Laboratory studies 8. To identify indicators for variation ANOVA.	2	References: main: [3; 4]; ancillary: [2; 3]
	Laboratory studies 9. To identify and assess the magnitude and variance of each factor using the F-criterion.	2	References: main: [2; 3; 4]; ancillary: [3]
Total for Module 2		9	
Total		17	

Module 1. Investigation of static relationships of economic processes

Task 1. Justification of building model of costs depending on two factors

Table 2

Data for task 1

№	The cost of building (Y), thousand \$	Useful life in years (X1)	Building area in thousand square meters (X2)
1	2	3	4
1	360	20	2,34
2	320	18	2,36
3	421	33	2,36
4	360	23	2,38
5	450	33	2,38
6	410	58	2,41
7	380	34	2,42
8	501	42	2,42
9	460	41	2,44
10	382	22	2,45
11	590	62	2,45
12	427	51	2,47
13	390	25	2,48
14	480	48	2,52
15	540	42	2,64
16	560	48	2,68
17	610	74	2,76
18	500	72	2,68
19	440	30	2,52
20	390	22	2,54
21	460	45	2,46
22	510	60	2,59
23	452	24	2,61
24	302	15	2,55
25	440	34	2,56
26	520	47	2,56
27	580	55	2,69

Table 2 (the ending)

1	2	3	4
28	500	42	2,57
29	540	57	2,75
30	428	38	2,62
31	540	31	2,61
32	500	43	2,62
33	560	68	2,64
34	600	36	2,78
35	540	37	2,74
36	430	40	2,66
37	480	47	2,65
38	680	75	2,89
39	703	61	3,22
40	620	43	3,02
41	580	68	2,68
42	621	43	3,11
43	620	55	2,78
44	660	45	2,71
45	580	41	2,72
46	720	63	3,24
47	650	71	2,75
48	680	60	3,21
49	580	55	2,77
50	640	51	2,98

1. The decision model is to determine the numerical values of the parameters of the function. Parameters of the correlation model can be defined in various ways: the method of the least squares point method, graphical method, linear programming techniques and others. The most popular method of the least squares. The method consists of the following: find the parameters of the equation, which minimizes the sum of squared deviations of the calculated values of the dependent variable from their actual values:

$$Z = \sum(Y - Y_t) \rightarrow \min.$$

For a linear function of the form $y = a + b X$ a system of equations has the form:

$$\begin{aligned} \sum Y &= aN + b\sum X; \\ \sum YX &= a\sum X + b\sum X^2. \end{aligned}$$

The resulting system is a system of normal equations.

Non-linear forms are solved as well, but we need to introduce additional variables that cause the system to a linear form. After building the system it is necessary to solve the equations by one of the known methods, for example, by the method of Gauss.

For the pair model, there are formulas that are convenient for storing, obtained by substitution:

$$\begin{aligned} b &= D_{yx}/D_{xx}; & a &= (\sum Y - a\sum X) / N; \\ D_{yx} &= \sum YX - (\sum X\sum Y) / N; & D_{xx} &= \sum X^2 - (\sum X)^2 / N. \end{aligned}$$

The value of the dependent variable (Y) in the model is given. To do this, we substitute the actual values of technical parameters (X) into the model (1). Check the correctness of the calculations $\sum Y = \sum Y_t$.

2. Evaluation of results solve the problem by using qualitative and quantitative analysis. Qualitative analysis is to verify compliance with the direction and nature of the influence of individual factors on the dependent variable. Quantitative analysis is: the search for indicators of closeness of the connection. Under the crowding to the correlation analysis means the weight of explainable variability and has its variability. In mathematical statistics, the variability indices are measured by the dispersion and given by:

$$\sigma_y^2 = \sum (Y - \bar{Y})^2 / N.$$

There are two measures by which the strength of links are estimated: the correlation ratio $\eta_{y/x}^2$ and the correlation coefficient r.

Correlation ratio $\eta_{y/x}^2$ is a proportion of explainable variability, i.e. variability of the dependent variable due to this factor, an argument.

Correlation ratio ($\eta_{y/x}^2$) changes from zero to unity, the value is positive, the higher the ratio, the stronger the effect of X on Y:

$$\eta_{y/x}^2 = 1 - \sum (Y - y_t)^2 / \sum (Y - \bar{Y})^2.$$

Correlation ratio is calculated to measure all forms of communications. The square root of the correlation ratio is called the index of correlation $\eta_{y/x}$.

The correlation coefficient r is a second indicator to assess the closeness of the connection. It varies from -1 to +1. When the coefficient is zero ($r = 0$), then there is no correlation (no linear relationship), but there may be a statistical or nonlinear (functional) dependence. If $r = +1$, there is the functional relationship. The correlation coefficient does not characterize any

relationship between X and Y, and the degree of closeness of a linear relationship between the indicators.

In the equation of the regression coefficient "b" shows how much X has changed in the middle. The value of "c" depends on the dimensional units X and Y.

Standardized regression coefficient is the correlation coefficient. Formula for calculating the correlation coefficient is:

$$r = b \times \sigma_x / \sigma_y; \quad r = \frac{D_{yx}}{\sqrt{D_{xx} D_{yy}}}$$

The sign of the correlation coefficient coincides with the sign of regression "b" and if the growth is an increase in the X of Y, then the correlation coefficient and the parameter "a" are positive, if X decreases with increasing V, the correlation coefficient and the parameter "c" will be negative.

A correlation coefficient in linear dependence shows measure of a closeness of the connection. The square of the correlation coefficient r^2 is the coefficient of determination and shows how much Y will change if X changes.

The nonlinear dependence of the magnitude of the correlation coefficient may be much smaller than the theoretical correlation ratio. The correlation coefficient can be close to zero, even when the correlation coefficient is close to unity.

The correlation coefficient allows us to characterize the degree of approximation to the correlation study and evaluate the closeness of the linear connection. For the linear dependence of primarily the correlation coefficient is used. If the coefficient of determination is equal to the correlation ratio ($|r^2 - \eta^2| < 0,1$), then the linear form of communication is chosen correctly. The differences between these indicators do not lie in a different form of calculation, but in a different form of communication.

3. When solving problems we use the data and the results are applied to the entire data set. Is this possible? Yes.

This method is applied in all kinds of scientific activity. The problem is that the pattern is found in the sample. You need to check whether there is a connection in the general population.

The determination of connection materiality is carried out using various criteria. Consider one of them – a criterion Z' Fisher.

It is used to test the correlation coefficient. Essence of testing is as follows. Calculate the value of:

$$Z' = 1,151 \lg (1 + |r|) / (1 - |r|) \text{ or } Z' = 1/2 \ln (1 + |r|) / (1 - |r|),$$

then the standard deviation of: $S_{Z'} = Z' / \sqrt{N-3}$

and their relationship, called quantile: $Up = Z' / S_{Z'}$.

This quintile is compared with the tabulated value for a given probability. If $Up > Ut$, then with a given probability P it is said that the link exists in the general population, and the coefficient of correlation is not zero. If $Up < Ut$, then with a given probability it can not be argued that the relationship is significant.

4. The most important element of the correlation analysis is to evaluate the results. It allows you to answer the question: can we use this model for analysis and planning? In a case of conflict variation should be identified and the causes are eliminated. The following factors may be the reason for discrepancy: the model does not include all the factors that allow the selection of source material error, the set of heterogeneous, incorrectly chosen form of communication.

Qualitative analysis is used to check compliance with directions of the nature of individual factors influence on the dependent variable and the estimation accuracy of the calculations made by the model. For this calculated residual variability (measured in the same units as Y):

$$\sigma_{err} = \sqrt{\frac{\sum (Y - Y_t)^2}{N}}.$$

To obtain the relative magnitude of the oscillation of the coefficient of variation, the residual variability is divided by the average value of the dependent variable: $V = (\pm \sigma_{err} / \bar{Y}) \times 100$. If the variability of the calculated values of Ur of the actual y (ie, V) does not exceed 5-10%, we believe that the resulting model can be used. If the variability is more, the model does not take into account certain factors, and accounting for them in the model will lead to the construction of multi-factor correlation model.

5. Parameters of the model $Y_t = B_0 + B_1 \times X_1 + B_2 \times X_2$ are determined by the method of the least squares by solving a system of equations:

$$\sum Y = B_0 N + B_1 \sum X_1 + B_2 \sum X_2$$

$$\sum Y X_1 = B_0 \sum X_1 + B_1 \sum X_1^2 + B_2 \sum X_2 X_1$$

$$\sum Y X_2 = B_0 \sum X_2 + B_1 \sum X_1 X_2 + B_2 \sum X_2^2$$

To determine the parameters B_0, B_1, B_2 pre-calculated values:

Dy_{x_j} и $Dx_i x_j$ ($j = 1, 2, i = 1, 2$)

$$Dy_{x_1} = \sum YX_1 - \frac{\sum Y \sum X_1}{N},$$

$$Dy_{x_2} = \sum YX_2 - \frac{\sum Y \sum X_2}{N},$$

$$Dx_1 x_2 = \sum X_1 X_2 - \frac{\sum X_1 \sum X_2}{N},$$

$$Dx_1 x_1 = \sum X_1^2 - \frac{\sum X_1 \sum X_1}{N},$$

$$Dx_2 x_2 = \sum X_2^2 - \frac{\sum X_2 \sum X_2}{N},$$

$$Dy_y = \sum Y^2 - \frac{\sum Y \sum Y}{N},$$

$$\bar{Y} = \frac{\sum Y}{N},$$

$$\bar{X}_1 = \frac{\sum X_1}{N},$$

$$\bar{X}_2 = \frac{\sum X_2}{N}.$$

$$B_1 = \frac{Dy_{x_1} - \frac{Dx_1 x_2 Dy_{x_2}}{Dx_2 x_2}}{Dx_1 x_1 - \frac{(Dx_1 x_2)^2}{Dx_2 x_2}},$$

$$B_2 = \frac{Dy_{x_2} - \frac{Dx_1 x_2 Dy_{x_1}}{Dx_1 x_1}}{Dx_2 x_2 - \frac{(Dx_1 x_2)^2}{Dx_1 x_1}},$$

$$B_0 = \bar{Y} - B_1 \bar{X}_1 - B_2 \bar{X}_2.$$

6. The coefficient of multiple correlation $R_{y \cdot x_1 x_2}$:

$$R_{y \cdot x_1 x_2} = \frac{1}{\sigma_y \sqrt{N}} \sqrt{B_1 Dy_{x_1} + B_2 Dy_{x_2}},$$

$$\sigma_y = \sqrt{\frac{\sum (Y - \bar{Y})^2}{N}}.$$

7. Coefficient of partial correlation (r_{p_i}) and test it on materiality by Fisher's Z' (check the influence of X^2):

$$R_p = r_{yx2.x1} = \sqrt{1 - \frac{1 - R_{y.x_1x_2}^2}{1 - r_{y.x_1}^2}}, \quad r_{y.x_1} \text{ taken from the pair model:}$$

$$U_p = \frac{Z'}{S_{Z'}}$$

$$S_{Z'} = \frac{1}{\sqrt{N - 3 - g}};$$

where g is a number of factors remaining in the model.

8. Calculation of the residual variability:

$$\sigma_{err} = \sigma_y \sqrt{1 - R^2}$$

and coefficient of variation:

$$V = \frac{\sigma_{err}}{\bar{Y}} 100.$$

9. The elasticity of the influence of the i-th factor is given by:

$$E_{X_i} = Y' \frac{X_i}{Y},$$

where Y' is the first derivative of the function.

$$E_{X_i} = b_i \sum X_i / \sum Y.$$

Module 2. Investigation of relationship dynamics in the ranks

Task 2. Justification of model production function: dependence of rubber growth on car production growth and growth of income per capita.

The content of the job. To develop the optimal strategy it is necessary to know the production of rubber, where most macroeconomic performance depends significantly on the amount of its release. Preliminary analysis shows that the strongest influence on the production of rubber have such indicators as production of automobiles and per capita income. To establish an econometric relationship between these parameters collected the data on the production of rubber (V), the production of automobiles (X_1) and per

capita income (X_2) is given (Table 1) in the form of an index (%) to account for inflation.

The purpose of the job. With the production functions of the linier form:

$$Y = B_0 + B_1 X_1 + B_2 X_2$$

and power:

$$Y = B_0 \times X_1^{B_1} \times X_2^{B_2}$$

assess the impact on the elasticity of the rubber production such factors as the production of automobiles (X_1) and per capita income (X_2).

The order of the job.

1. Construct the graphs of Y on X_1 and X_2 , and Y on select models as a function of $Y = B_0 + B_1 X_1 + B_2 X_2$.

2. To solve the model by the least squares.

3. For the model:

a) evaluate the impact of all factors with the multiple correlation coefficient;

b) test the effect of X_1 : calculate the pair correlation coefficient r_{y,x_2} ; determine the coefficient of partial correlation and test it on materiality;

c) test the effect of X_2 : calculate the pair correlation coefficient r_{y,x_1} ; determine the coefficient of partial correlation and test it on materiality;

d) to assess the reliability of the model using the coefficient of variation;

d) determine the influence of the elasticity of factors.

4. To draw up conclusions.

Task 3. Assessment of impact factors using analysis of variance.

The content of the job. A large company has a network of shops, and is interested in increasing sales revenue, which depends on many factors: products quality, customer habits, location of stores, the presence of a number of competitors, as well as a properly designed and conducted marketing policy.

Fluctuations in the size of sales of certain goods depending on a day of a week and the shops location given in Table 4. In this setting we study two-factor model: one factor (A) is a day of a week, the second (B) is a location of the store.

Data for task 2

N	Y	X1	X2
1	90,2	128,7	98,7
2	125,2	128,1	106,4
3	94,7	78,7	100,7
4	102,2	79,6	101,2
5	104,4	139,2	102,9
6	90,5	89,4	99,3
7	121,9	140	104,7
8	92,3	72,1	102,4
9	100,1	103,2	100,3
10	91,6	68,5	99,3
11	117,3	129,1	102,7
12	93,8	117	100,1
13	96,5	81,7	101,4
14	110,6	123,1	103,2
15	101,1	108,6	102
16	108	110,1	105,3
17	119	103,2	106,4
18	108,4	103,4	107,1
19	115,5	106,5	108,3
20	125,4	108,6	110,8

N	Y	X1	X2
1	108,2	154,4	118,4
2	150,2	153,7	127,7
3	113,6	94,4	120,8
4	122,6	95,5	121,4
5	125,3	167,0	123,5
6	108,6	107,3	119,2
7	146,3	168,0	125,6
8	110,8	86,5	122,9
9	120,1	123,8	120,4
10	109,9	82,2	119,2
11	140,8	154,9	123,2
12	112,6	140,4	120,1
13	115,8	98,0	121,7
14	132,7	147,7	123,8
15	121,3	130,3	122,4
16	129,6	132,1	126,4
17	142,8	123,8	127,7
18	130,1	124,1	128,5
19	138,6	127,8	130,0
20	150,5	130,3	133,0

N	Y	X1	X2
1	2	3	4
1	97,42	139	106,6
2	135,2	138,3	114,9
3	102,3	85	108,8
4	110,4	85,97	109,3
5	112,8	150,3	111,1
6	97,74	96,55	107,2
7	131,7	151,2	113,1
8	99,68	77,87	110,6
9	108,1	111,5	108,3
10	98,93	73,98	107,2
11	126,7	139,4	110,9
12	101,3	126,4	108,1

N	Y	X1	X2
1	2	3	4
1	114,6	163,4	125,3
2	159,0	162,7	135,1
3	120,3	99,9	127,9
4	129,8	101,1	128,5
5	132,6	176,8	130,7
6	114,9	113,5	126,1
7	154,8	177,8	133,0
8	117,2	91,6	130,0
9	127,1	131,1	127,4
10	116,3	87,0	126,1
11	149,0	164,0	130,4
12	119,1	148,6	127,1

Table 3 (to be continued)

1	2	3	4
13	104,2	88,24	109,5
14	119,4	132,9	111,5
15	109,2	117,3	110,2
16	116,6	118,9	113,7
17	128,5	111,5	114,9
18	117,1	111,7	115,7
19	124,7	115	117
20	135,4	117,3	119,7

1	2	3	4
13	122,6	103,8	128,8
14	140,5	156,3	131,1
15	128,4	137,9	129,5
16	137,2	139,8	133,7
17	151,1	131,1	135,1
18	137,7	131,3	136,0
19	146,7	135,3	137,5
20	159,3	137,9	140,7

N	Y	X1	X2
1	105,5	150,6	115,5
2	146,5	149,9	124,5
3	110,8	92,08	117,8
4	119,6	93,13	118,4
5	122,1	162,9	120,4
6	105,9	104,6	116,2
7	142,6	163,8	122,5
8	108	84,36	119,8
9	117,1	120,7	117,4
10	107,2	80,15	116,2
11	137,2	151	120,2
12	109,7	136,9	117,1
13	112,9	95,59	118,6
14	129,4	144	120,7
15	118,3	127,1	119,3
16	126,4	128,8	123,2
17	139,2	120,7	124,5
18	126,8	121	125,3
19	135,1	124,6	126,7
20	146,7	127,1	129,6

N	Y	X1	X2
1	127,2	181,5	139,2
2	176,5	180,6	150,0
3	133,5	111,0	142,0
4	144,1	112,2	142,7
5	147,2	196,3	145,1
6	127,6	126,1	140,0
7	171,9	197,4	147,6
8	130,1	101,7	144,4
9	141,1	145,5	141,4
10	129,2	96,6	140,0
11	165,4	182,0	144,8
12	132,3	165,0	141,1
13	136,1	115,2	143,0
14	155,9	173,6	145,5
15	142,6	153,1	143,8
16	152,3	155,2	148,5
17	167,8	145,5	150,0
18	152,8	145,8	151,0
19	162,9	150,2	152,7
20	176,8	153,1	156,2

N	Y	X1	X2
1	2	3	4
1	114	162,6	124,7
2	158,2	161,9	134,4
3	119,7	99,45	127,2
4	129,1	100,6	127,9

N	Y	X1	X2
1	2	3	4
1	134,0	191,2	146,7
2	186,0	190,3	158,1
3	140,7	116,9	149,6
4	151,9	118,3	150,4

Table 3 (to be continued)

1	2	3	4
5	131,9	175,9	130
6	114,4	113	125,5
7	154	176,9	132,3
8	116,6	91,11	129,4
9	126,5	130,4	126,7
10	115,7	86,56	125,5
11	148,2	163,1	129,8
12	118,5	147,8	126,5
13	121,9	103,2	128,1
14	139,8	155,5	130,4
15	127,7	137,2	128,9
16	136,5	139,1	133,1
17	150,4	130,4	134,4
18	137	130,7	135,3
19	145,9	134,6	136,8
20	158,5	137,2	140

1	2	3	4
5	155,1	206,8	152,9
6	134,5	132,8	147,5
7	181,1	208,0	155,6
8	137,1	107,1	152,2
9	148,7	153,3	149,0
10	136,1	101,8	147,5
11	174,3	191,8	152,6
12	139,4	173,9	148,7
13	143,4	121,4	150,7
14	164,3	182,9	153,3
15	150,2	161,4	151,6
16	160,5	163,6	156,5
17	176,8	153,3	158,1
18	161,1	153,6	159,1
19	171,6	158,2	160,9
20	186,3	161,4	164,6

N	Y	X1	X2
1	112,8	160,9	123,4
2	156,5	160,1	133
3	118,4	98,38	125,9
4	127,8	99,5	126,5
5	130,5	174	128,6
6	113,1	111,8	124,1
7	152,4	175	130,9
8	115,4	90,13	128
9	125,1	129	125,4
10	114,5	85,63	124,1
11	146,6	161,4	128,4
12	117,3	146,3	125,1
13	120,6	102,1	126,8
14	138,3	153,9	129
15	126,4	135,8	127,5
16	135	137,6	131,6
17	148,8	129	133
18	135,5	129,3	133,9
19	144,4	133,1	135,4
20	156,8	135,8	138,5

N	Y	X1	X2
1	135,3	193,1	148,1
2	187,8	192,2	159,6
3	142,1	118,1	151,1
4	153,3	119,4	151,8
5	156,6	208,8	154,4
6	135,8	134,1	149,0
7	182,9	210,0	157,1
8	138,5	108,2	153,6
9	150,2	154,8	150,5
10	137,4	102,8	149,0
11	176,0	193,7	154,1
12	140,7	175,5	150,2
13	144,8	122,6	152,1
14	165,9	184,7	154,8
15	151,7	162,9	153,0
16	162,0	165,2	158,0
17	178,5	154,8	159,6
18	162,6	155,1	160,7
19	173,3	159,8	162,5
20	188,1	162,9	166,2

Table 3 (to be continued)

N	Y	X1	X2
1	121,8	173,7	133,2
2	169	172,9	143,6
3	127,8	106,2	135,9
4	138	107,5	136,6
5	140,9	187,9	138,9
6	122,2	120,7	134,1
7	164,6	189	141,3
8	124,6	97,34	138,2
9	135,1	139,3	135,4
10	123,7	92,48	134,1
11	158,4	174,3	138,6
12	126,6	158	135,1
13	130,3	110,3	136,9
14	149,3	166,2	139,3
15	136,5	146,6	137,7
16	145,8	148,6	142,2
17	160,7	139,3	143,6
18	146,3	139,6	144,6
19	155,9	143,8	146,2
20	169,3	146,6	149,6

N	Y	X1	X2
1	143,2	204,3	156,7
2	198,8	203,4	168,9
3	150,3	124,9	159,9
4	162,2	126,4	160,7
5	165,7	221,0	163,4
6	143,7	141,9	157,6
7	193,5	222,3	166,2
8	146,5	114,5	162,6
9	158,9	163,8	159,2
10	145,4	108,7	157,6
11	186,2	204,9	163,0
12	148,9	185,7	158,9
13	153,2	129,7	161,0
14	175,6	195,4	163,8
15	160,5	172,4	161,9
16	171,5	174,8	167,2
17	188,9	163,8	168,9
18	172,1	164,1	170,0
19	183,4	169,1	171,9
20	199,1	172,4	175,9

N	Y	X1	X2
1	2	3	4
1	78,47	112	85,87
2	108,9	111,4	92,57
3	82,39	68,47	87,61
4	88,91	69,25	88,04
5	90,83	121,1	89,52
6	78,74	77,78	86,39
7	106,1	121,8	91,09
8	80,3	62,73	89,09
9	87,09	89,78	87,26
10	79,69	59,6	86,39
11	102,1	112,3	89,35
12	81,61	101,8	87,09
13	83,96	71,08	88,22
14	96,22	107,1	89,78
15	87,96	94,48	88,74

N	Y	X1	X2
1	2	3	4
1	94,2	134,4	103,0
2	130,7	133,7	111,1
3	98,9	82,2	105,1
4	106,7	83,1	105,7
5	109,0	145,3	107,4
6	94,5	93,3	103,7
7	127,3	146,2	109,3
8	96,4	75,3	106,9
9	104,5	107,7	104,7
10	95,6	71,5	103,7
11	122,5	134,8	107,2
12	97,9	122,1	104,5
13	100,7	85,3	105,9
14	115,5	128,5	107,7
15	105,5	113,4	106,5

Table 3 (the ending)

1	2	3	4
16	93,96	95,79	91,61
17	103,5	89,78	92,57
18	94,31	89,96	93,18
19	100,5	92,66	94,22
20	109,1	94,48	96,4

1	2	3	4
16	112,8	114,9	109,9
17	124,2	107,7	111,1
18	113,2	107,9	111,8
19	120,6	111,2	113,1
20	130,9	113,4	115,7

N	Y	X1	X2
1	84,75	120,9	92,74
2	117,6	120,4	99,97
3	88,98	73,95	94,62
4	96,03	74,79	95,09
5	98,09	130,8	96,68
6	85,03	84	93,3
7	114,5	131,5	98,38
8	86,73	67,75	96,22
9	94,05	96,97	94,24
10	86,07	64,36	93,3
11	110,2	121,3	96,5
12	88,13	109,9	94,05
13	90,67	76,77	95,28
14	103,9	115,7	96,97
15	94,99	102	95,84
16	101,5	103,4	98,94
17	111,8	96,97	99,97
18	101,9	97,15	100,6
19	108,5	100,1	101,8
20	117,8	102	104,1

N	Y	X1	X2
1	99,7	142,2	109,1
2	138,3	141,5	117,6
3	104,6	87,0	111,3
4	112,9	88,0	111,8
5	115,4	153,8	113,7
6	100,0	98,8	109,7
7	134,7	154,7	115,7
8	102,0	79,7	113,1
9	110,6	114,0	110,8
10	101,2	75,7	109,7
11	129,6	142,6	113,5
12	103,6	129,3	110,6
13	106,6	90,3	112,0
14	122,2	136,0	114,0
15	111,7	120,0	112,7
16	119,3	121,6	116,3
17	131,5	114,0	117,6
18	119,8	114,2	118,3
19	127,6	117,7	119,7
20	138,6	120,0	122,4

The purpose of the job. Assess the effect of location of the store and a day of a week on the fluctuations in revenue from the sale of specific products using analysis of variance.

Tables 4 and 5 show the raw data and the choice of option assignment. The order of the job.

1. To calculate the variation of the total sales revenue and the factors.
2. To determine the variance of the factors to assess materiality variance with the Fisher F-test (Table 6).
3. To calculate the net variance of the factors and provide an economic analysis of the results of problem solution.

Table 4

The deviations of actual revenue from the planned one

Days	Shops numbers										
	1	2	3	4	5	6	7	8	9	10	11
1	1	-1	0	0	-1	1	0	1	1	0	1
2	1	-2	1	1	0	2	1	3	1	-2	-1
3	2	0	2	1	-2	3	2	4	2	-3	-2
4	2	-3	3	2	-3	4	5	6	3	-4	-5
5	4	-6	5	7	-4	6	6	7	4	-5	-7
6	5	-6	6	6	-7	7	7	4	6	-7	-6

Table 5

Data for task 3

Variant	Shops numbers	Variant	Shops numbers
1	1, 2, 3, 4, 5	15	6, 7, 8, 9, 10
2	2, 3, 4, 5, 6	16	7, 8, 9, 10, 11
3	3, 4, 5, 6, 7	17	4, 5, 9, 10, 11
4	1, 2, 4, 5, 6	18	6, 7, 9, 10, 11
5	1, 3, 4, 5, 6	19	6, 8, 9, 10, 11
6	1, 2, 5, 6, 7	20	5, 7, 8, 10, 11
7	1, 2, 4, 5, 8	21	1, 2, 7, 10, 11
8	2, 4, 5, 6, 8	22	5, 7, 8, 9, 10
9	2, 3, 5, 6, 7	23	4, 7, 8, 9, 10
10	1, 2, 3, 6, 7	24	3, 7, 8, 9, 10
11	1, 4, 5, 6, 7	25	2, 7, 8, 9, 10
12	1, 4, 5, 6, 10	26	1, 7, 8, 9, 10
13	1, 3, 5, 7, 9	27	1, 3, 5, 8, 10
14	1, 3, 5, 6, 7	28	2, 3, 6, 7, 8

Table 6

The values of the criterion F-Fisher at 0.95

Kerr	The number of degrees of freedom for the greater variation of (Kf)									
	1	2	3	4	5	11	14	20	30	60
1	161,4	199,5	215,7	224,6	230,2	243	245	248	250	252
2	18,51	19,00	19,16	19,25	19,3	19,33	19,35	19,37	19,38	19,48
3	10,13	9,55	9,28	9,117	9,014	8,941	8,887	8,845	8,812	8,58
4	7,709	6,944	6,591	6,388	6,256	6,163	6,094	6,041	5,999	26,35
5	6,608	5,786	5,410	5,192	5,050	4,950	4,876	4,818	4,773	4,44
6	5,987	5,143	4,757	4,534	4,387	4,287	4,207	4,147	4,099	9,24
7	5,591	4,737	4,347	4,120	3,972	3,866	3,787	3,726	3,677	3,32
8	5,318	4,459	4,066	3,838	3,688	3,581	3,501	3,438	3,388	5,85
9	5,117	4,257	3,863	3,633	3,482	3,374	3,293	3,230	3,179	2,80
10	4,965	4,103	3,708	3,478	3,326	3,217	3,136	3,072	3,020	4,51
11	4,84	3,982	3,587	3,357	3,204	3,095	3,012	2,948	2,896	2,50
12	4,474	3,885	3,490	3,259	3,106	2,996	2,913	2,849	2,796	3,80
13	4,667	3,806	3,411	3,179	3,025	2,915	2,832	2,767	2,714	2,32
14	4,600	3,739	3,344	3,112	2,958	2,848	2,764	2,699	2,646	3,37
15	4,543	3,682	3,287	3,056	2,901	2,791	2,707	2,641	2,588	2,18
16	4,494	3,634	3,239	3,007	2,852	2,741	2,657	2,591	2,538	3,07
17	4,451	3,592	3,197	2,965	2,810	2,699	2,614	2,548	2,494	2,08
18	4,414	3,555	3,160	2,928	2,773	2,661	2,577	2,510	2,456	2,86
19	4,381	3,522	3,127	2,895	2,74	2,628	2,544	2,477	2,423	2,00
20	4,351	3,493	3,098	2,866	2,711	2,599	2,514	2,447	2,393	2,70
21	4,242	3,385	2,991	2,759	2,603	2,490	2,405	2,337	2,282	1,93
22	8,02	4,87	4,04	3,65	3,40	3,24	3,07	2,88	2,58	2,58
23	4,28	3,03	2,64	2,45	2,32	2,24	2,14	2,4	1,96	1,88
24	7,88	4,76	3,94	3,54	3,30	3,14	2,97	2,78	2,62	2,49
25	4,24	2,99	2,60	2,41	2,28	2,20	2,11	2,00	1,92	1,84
26	7,77	4,68	3,86	3,46	3,21	3,05	2,89	2,70	2,54	2,40
27	4,21	2,96	2,57	2,37	2,25	2,16	2,18	1,97	1,88	1,80
28	7,68	4,60	3,79	3,39	3,14	2,98	2,83	2,63	2,45	2,33
29	4,18	2,93	2,54	2,35	2,22	2,14	2,05	1,94	1,85	1,77
30	7,60	4,54	3,73	3,33	3,08	2,92	2,77	2,57	2,41	2,27

Guidelines for Task 3.

The overall process variability (V) for two-factor analysis (factors A and B) can be decomposed into variability of reasons:

$$V = V_A + V_B + V_{err},$$

where V_A is variability by a factor A (day);

V_B is variability due to factor V (store location);

V_{err} is residual variability due to other factors.

Variability is determined by the following formulas.

Total:

$$V = \sum_{I=1}^n \sum_{J=1}^P X_{ij}^2 - \frac{T^2}{N}.$$

Variability by a factor A:

$$V_A = \frac{\sum_{J=1}^P A_J^2}{n} - \frac{T^2}{N}.$$

Variability by a factor B:

$$V_B = \frac{\sum_{i=1}^n B_i^2}{P} - \frac{T^2}{N}.$$

Residual variability:

$$V_{OC} = V - (V_A + V_B);$$

where $T = \sum A_j = \sum B_i$;

n is options factor A (the number of columns);

p is variations in the factors (number of lines of source data).

Dispersion of factors is determined by the following formulas.

Total variance:

$$S^2 = \frac{V}{np - 1}.$$

Dispersion factor A:

$$S^2_A = \frac{V_A}{p - 1}.$$

Dispersion factor B:

$$S^2_B = \frac{V_B}{n - 1}.$$

Residual variance:

$$S^2_{err} = \frac{V_{err}}{(n - 1)(p - 1)}.$$

The net variance of factor A is equal to:

$$\sigma^2_A = (S^2_A - S^2_{\text{err}}) \frac{1}{p-1}.$$

The net variance of factor B is equal to:

$$\sigma^2_B = (S^2_B - S^2_{\text{err}}) \frac{1}{n-1}.$$

Residual:

$$\sigma^2_{\text{err}} = S^2_{\text{err}}.$$

Total net variance:

$$\sigma^2 = \sigma^2_A + \sigma^2_B + \sigma^2_{\text{err}}.$$

2. Independent work of students

For successful learning of the discipline it is necessary to conduct independent work of students in the form of lectures, preparation of practical tasks, design tasks, organization and self-learning knowledge.

Questions for self-learning.

Module 1. Investigation of static relationships of economic processes

1. Mathematical modelling as a method of scientific knowledge of economic phenomena and processes.

2. Manufacturing as a complex system.

3. Features of production.

4. Statistical validation criteria for significance.

5. The standardized model.

6. Cobb-Douglas.

7. Features of static and dynamic models.

8. Disperse analysis in economics

9. The use of F-criterion.

10. Using analysis of variance to assess the significance of regression coefficients.

11. What is meant by marginalisation and conditioning in the process of model reduction within the dynamic modelling tradition?

12. Having derived a model for the exchange rate s_t as a function of the interest rate differential r_t and performed the following regression

$$s_t = a + b r_t + e_t,$$

where e_t is an error term. How would you check the presence of serial correlation in the error term and how would you deal with it?

13. Explain what recursive estimation is and how it would be used to assess the stability of this equation.

14. Define the term's weak stationarity, integrated of order one and uniform mixing. How would you assess the stationarity of a variable X .

15. Suppose X was the US stock market index and your data period was from 1920 – 1938 (to include the stock market crash). How would the testing procedure for stationarity be affected?

16. If both the Dollar/Sterling exchange rate (E) and the Yen/Dollar exchange rate (Y) were $I(1)$ but there was in fact no relationship between the two variables, what would you expect the result of performing the following regression be:

$$E_t = a + bY_t + v_t.$$

17. Suppose both X and Y are $I(1)$ variables which are generated by the following true system:

$$X_t = a + bY_t + e_t$$

$$Y_t = Y_{t-1} + v_t,$$

where e and v are stationary error processes.

18. Define the common stochastic trend underlying this model.

19. What is the integrating vector?

20. Explain the relationship between the number of integrating vectors in a system and the number of stochastic trends.

21. What is the importance of the Granger Representation theorem to practical modelling?

22. Suppose we are estimating a model for the return on a bond r_t of the form,

$$r_t = a + br_{t-1} + e_t,$$

where e is an error term.

23. Explain the difference between the conditional variance and the unconditional variance. Which of the two is more relevant for financial decision making?

24. If we suspect that the variance of e changes systematically through time what would the consequences for standard OLS estimation be?

25. Define the exponentially weighted moving average time series forecasting approach and give examples of commonly used versions of this model.

26. Explain the problem of spurious regression and relate it to the question of stationarity of the data.

27. Define the terms ergodic, stationary, non-stationary and integrated.

Module 2. Investigation of relationship dynamics in the ranks

28. Aitken method.

29. Correlogram of stationary and nonstationary processes.

30. Multicollinearity economic data.

31. The method of principal components.

32. Models of scientific progress.

33. 2-step method of the least squares.

34. Recursive system of simultaneous equations.

35. Characteristics of different measurement scales.

36. Criteria for independence indicators.

37. Specialized software.

38. Characteristics of different programs.

39. How would you test the stationarity?

40. When do non-stationary data not give rise to the problems of a spurious regression?

41. What is meant by marginalisation and conditioning in the process of model reduction within the dynamic modelling tradition?

42. Having derived a model for the exchange rate s_t as a function of the interest rate differential r_t and performed the following regression:

$$s_t = a + b r_t + e_t,$$

where e_t is an error term. How would you check the presence of serial correlation in the error term and how would you deal with it?

43. Explain what recursive estimation is and how it would be used to assess the stability of this equation.

44. Is the conditional or unconditional variance a more appropriate measure of uncertainty?

45. What are the problems in using this framework to model covariance terms between assets?

46. Suppose both X and Y are variables which are generated by the following true system

$$X_t = a + bY_t + e_t$$

$$Y_t = Y_{t-1} + v_t,$$

where e and v are stationary error processes.

47. Define the common stochastic trend underlying this model.

48. What is the cointegrating vector?

49. Explain the relationship between the number of cointegrating vectors in a system and the number of stochastic trends.

50. What are the properties of the OLS estimate of the parameter b ? How do these properties vary from that of a spurious regression?

51. How would you assess the possibility that two series such as X and Y actually do cointegrate?

52. What is meant by stationarity? What is an integrated variable?

53. Explain the relationship between stationarity and a spurious regression, why does the OLS estimator give such bad results?

54. How would you assess the stationarity of a variable?

55. Outline the process of model reduction which is a central part of the LSE econometric tradition.

56. How is testing used to assess the validity of a model?

57. What is the Encompassing principal?

58. What is the rational for an Error Correction Model?

3. Test questions for self-diagnosis

Module 1. Investigation of static relationships of economic processes

1. Explain the purpose of the discipline "Econometrics."
2. Define the subject and object of the discipline "Econometrics."
3. The role of Econometrics in improving production efficiency.
4. Define the concept of production system.
5. Formulate the basic properties of the system.

6. What are the main stages of economic problems solutions by using economic and mathematical methods?
7. Advantages and disadvantages of modelling method.
8. Econometric models and stages of construction.
9. Characterization of econometric models.
10. Stages of building econometric models.
11. The main problems of econometric methods in laboratory studies.
12. The essence of correlation and regression.
13. Types of correlation and regression relationships.
14. Stages of construction of correlation (regression) model.
15. The method of the least squares.
16. Mnemonic rule of building a system of equations.
17. Methods of calculating the parameters of correlation (regression) model.
18. Calculation of the studied variable with the correlation (regression) model.
19. Estimation of the accuracy of correlation (regression) model.
20. Evaluation of relationship indicators.
21. What is the relationship between correlation coefficient and correlation ratio.
22. The range of correlation coefficient.
23. What does the correlation coefficient show?
24. How can the correlation coefficient be calculated?
25. The range of changes of correlation ratio.
26. What does correlative relation show?
27. How is the significance of correlation coefficient tested?
28. What is quintile for normal distribution?
29. Value quintile for different probabilities.
30. How to build a multifactor model.
31. Evaluate the impact of factors on the variable.
32. The range of changes of multiple correlation coefficient.
33. How to estimate the net impact of factors on the variable.
34. What is the correlation coefficient frequency?
35. Range of frequent changes in the coefficient of correlation.
36. Methods of assessing the net impact factors.
37. The method of direct account.
38. The method of pair correlations.

39. What is a production function?
40. How to build a production function?
41. What is a Cobb-Douglas?
42. What is elasticity?
43. How to estimate the elasticity of indicators?
44. How can the elasticity be estimated by dependency indicators?
45. What is a variance analysis?
46. What is the variation of parameters and how is it calculated?
47. How is the variance calculated?
48. What is the F-Fisher criterion?
49. How is the analysis of variance used?
50. Methods of variance analysis.
51. What is the number of degrees?
52. Features of using the analysis of variance.

Module 2. Investigation of relationship dynamics in the ranks

53. What is a homoscedasticity?
54. What is a heteroscedasticity?
55. How does heteroscedasticity affect the measurement of parameters?
56. Generalized method of the least squares.
57. The method of Aitken and its peculiarities.
58. How to estimate the parameters of linear econometric models with heteroscedasticity tests?
59. The concept of multicollinearity.
60. The impact of multicollinearity on estimation of model parameters.
61. The method of Ferrar-Hlober.
62. The essence of the principal components method.
63. What is an autocorrelation?
64. Methods for determining the autocorrelation.
65. What is the autocorrelation function?
66. What is Correlogram?
67. Correlogram to identify different types of economic processes.
68. What is an auto regressive model?
69. The concept of lag and lagged variables.
70. Distribution by lag model.

71. What is a system of simultaneous structural equations?
72. How to make the transition to the reduced form?
73. The relationship of structural and reduced forms.
74. The concept of identification.
75. What are strictly identified systems of equations?
76. What is a system of equations?
77. How to estimate the parameters of the system of simultaneous equations?
78. 2 step-method of the least squares.
79. Recursive system of simultaneous equations.
80. The concept of measurement scale.
81. Criteria for independence indicators.
82. Specialized software packages and features.

4. Recommended bibliography

4.1. Main

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