CORRELATION-REGRESSION ANALYSIS MODELS OF SOCIO-ECONOMIC PROCESSES

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Abstract: This article describes socio-economic processes correlation-regression analysis models and correlation-regression analysis models, least squares method, calculation and estimation of regression equation, elasticity coefficient, calculation of confidence intervals.

Key words: correlation, regression, economic processes, analytical models, coefficient of elasticity

Socio-economic processes of society are formed on the basis of various laws and regulations and represent various relations between market participants. In the study of these processes, economic statistics models and methods have a high place. Creating economic statistics models and using them in practice allows to determine various relationships, quantitative characteristics of economic indicators that represent them, dependence and reciprocal unity. Although the proposed economic-statistical models represent the truth somewhat simplified, it provides a strict mathematical approach in the search of the studied economic relations, evaluates the essence of the studied relations and determines how these relations are manifested. The mathematical completeness of the economic-statistical models and the accuracy of their quantitative characteristics are used not only as a means of analyzing the past period, but also as the main tool-instrument for planning the economic development in the future.

In the socio-economic field, when it comes to mutual connection of two or more indicators, they are divided into two forms of connections: functional and correlation connections.

Functional connections are known and clearly manifested in each case and in each observation. Knowing the functional relationship allows you to predict how the event will unfold. For example, using a model of the rotation trajectory of the sun and moon, it is possible to predict their eclipses in advance to the minute or to the second.

Correlational linkages, unlike functional linkages, generally and averagely and only in mass observations.

Various indicators representing economic processes are usually formed under the influence of many different factors, some of them are influenced by objective laws, others are manifested based on the conscious activities of people, taking into account different goals, and in some cases, they are manifested under pure (pure) random influences. Laws in the economy are not manifested with the same precision and immutability as in the field of technology. Therefore, correlation and regression analysis are often used to study the relationship of economic indicators.

In normal cases, correlation analysis is used to study the relationship between two indicators, where one of them is considered as an independent indicator-factor (the variable is defined by x-), and the other is a related variable (defined by u-). The existence of a connection between two variable indicators is realized not by a mathematical method, but by revealing the inner nature of the phenomenon under study and its causes based on the qualitative analysis of the data obtained as a result of observations. Thus, before performing mathematical calculations, there is a relationship between an independent indicator factor and an associated variable, and it is assumed that it is characterized by the function $U = f(x)$. The existence of connections between economic indicators is based on the science of economic theory.

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One of the main tasks of correlation and regression analysis is to analyze the existence of the connection between the studied indicators, its appearance and quantitative expression. This is done using correlation coefficient analysis.

The task of regression analysis is to determine a regression equation that quantifies the relationship between two economic indicators.

Pair regression and correlation. Paired regression represents the relationship equation of two variables u and x:

u = f(x),

where u is an independent variable (resultant sign);

x is an independent, defining variable (sign – factor).

Regression is divided into linear and non-linear.

Linear Regression: y = a + b*x+ ε will be in the form of

Nonlinear regression is divided into two classes: regression that is nonlinear with respect to the explanatory variables included in the analysis, but linear with respect to the parameters being evaluated, and nonlinear regression with respect to the parameters being evaluated.

A regression that is non-linear with respect to the explanatory variables:

- polynomials of different degrees $y = a + b_1*x + b_2*x^2 + b_3*x^3 + \varepsilon$;

- - equilateral hyperbola $y = a + \frac{b}{x} + \varepsilon$;
- A regression that is nonlinear in terms of parameters being evaluated:
- - graded $y = a*x^b*\varepsilon$;
- - indicative $y = a*b^x*\varepsilon$;
- - exponentialseal $y = e^{a+bx}*\varepsilon$.

Constructing a regression equation leads to estimation of its parameters. The least squares equation is used to estimate the regression equation, which is linear in terms of parameters. Least squares allows to obtain such estimates of the parameters, in which the sum of the squares of the difference of the actual values of the resulting sign from the theoretical ux values is minimal, i.e.

$$\sum (y - y_x)^2 \to \min .$$

For linear and linearizable nonlinear equations, the following system is solved with respect to a and b:

$$\begin{cases} na + b\sum x = \sum y, \\ a\sum x + b\sum x^2 = \sum yx. \end{cases}$$

The following formulas derived from this system can be used:

$$a = \bar{y} - b \cdot \bar{x}, \quad b = \frac{\operatorname{cov}(x, y)}{\sigma_x^2} = \frac{\overline{y * x} - \bar{y} \cdot \bar{x}}{\overline{x^2} - \bar{x}^2}.$$

The linear coefficient of the pair correlation - r_{xy}, evaluates the strength of connection (density) of the studied phenomena, for linear regression ($-1 \le r_{xy} \le 1$):

$$r_{xy} = b\frac{\sigma_x}{\sigma_y} = \frac{\operatorname{cov}(x, y)}{\sigma_x \sigma_y} = \frac{\overline{yx} - \bar{y} \cdot \bar{x}}{\sigma_x \sigma_y},$$

and correlation index – r_{xu} for nonlinear regression ($0 \le p_{xy} \le 1$):

$$p_{xy} = \sqrt{1 - \frac{\sigma_{oct}^2}{\sigma_y^2}} = \sqrt{1 - \frac{\sum (y - \hat{y}_x)^2}{\sum (y - \bar{y})^2}}.$$

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The quality of the built model was assessed by the coefficient of determination and the average error approximation.

The average error approximation is the average deviation of the calculated values from the true ones:

$$\overline{A} = \frac{1}{n}\sum\left|\frac{y-y_x}{y}\right|\cdot 100\%.$$

The possible range of the average error approximation is no more than 8-10%.

The average coefficient of elasticity shows how much the resulting indicator will change from its average value in general when the factor x changes by one percent from its average value:

$$\overline{Э} = f'(x)\frac{\overline{x}}{\overline{y}}.$$

The task of analysis of variance is to analyze the variance of the associated variable:

$$\sum(y-\overline{y})^2 = \sum(\hat{y}_x-\overline{y})^2 + \sum(y-\hat{y}_x)^2.$$

here $\sum(y-\overline{y})^2$ total sum of squares of deviations;

$\sum(\hat{y}_x-\overline{y})^2$ the square of the sum of deviations associated with the regression (identified or associated with the factors);

$\sum\left(y-\hat{y}_x\right)^2$ - of the square of the residual sum of deviations.

The coefficient of determination (index) R2 characterizes the share of the variance explaining the regression in the total variance of the resulting indicator u:

$$R^2 = \frac{\sum(\hat{y}_x-\overline{y})^2}{\sum\left(y-\overline{y}\right)^2}.$$

The coefficient of determination is the square of the correlation coefficient or index.

Evaluating the quality of the regression equation consists in conducting the F-test to check the statistical insignificance of the N0 hypothesis - the regression equation and the indicator of the strength of association. For this, the true Fkhaqi and the critical (in the table) Fjadv Fisher criteria - F are compared. In this case, it is determined from the ratio of the calculated Fkhaki factor and residual variance values for one degree of freedom:

$$F_{õõàê} \quad \frac{\sum(\hat{y}_x-\overline{y})^2/m}{\sum\left(y-\hat{y}_x\right)^2/(n-m-1)} = \frac{r_{xy}^2}{1-r_{xy}^2}(n-2),$$

where n is the number of units in the set; m – x is the number of parameters in the variable.

F_{jadv} is the maximum value that the criterion α- can take under the influence of random factors with a given degree of freedom and degree of essence. Significance level is the probability of rejecting the correct hypothesis in the event that it is true. Usually α is taken to be 0.05 or 0.01.

If $F_{jadv} < F_{khaqi}$, then the hypothesis about the random nature of the evaluated characteristics N0 is rejected and their statistical significance and reliability are recognized. If $F_{jadv} > F_{khaqi}$, then N_0 is not rejected and the statistical insignificance, unreliability of the regression equation is recognized.

To assess the statistical significance of regression and correlation coefficients, Student's t-test and confidence intervals for each indicator were calculated. The N0 hypothesis is put forward about the random nature of the indicators, that is, that they are very little different from zero. Assessment of the significance of regression and correlation coefficients is carried out by comparing their value with the value of a random variable using the Student's t-test:

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$$t_b = \frac{b}{m_b}; \quad t_a = \frac{a}{m_a}; \quad t_r = \frac{r}{m_r}.$$

Random errors of linear regression parameters and correlation coefficients are determined by the following formula:

$$m_b = \sqrt{\frac{\sum (y - y_x)^2 / (n-2)}{\sum (x - \bar{x})^2}} = \sqrt{\frac{S_{oct}^2}{\sum (x - \bar{x})^2}} = \frac{S_{oct}}{\sigma_x \sqrt{n}};$$

$$m_a = \sqrt{\frac{\sum (y - y_x)^2}{(n-2)} \cdot \frac{\sum x^2}{n \sum (x - \bar{x})^2}} = \sqrt{S_{oct}^2 \frac{\sum x^2}{n^2 \sigma_x^2}} = S_{oct} \frac{\sqrt{\sum x^2}}{n \sigma_x};$$

$$m_{r_{xy}} = \sqrt{\frac{1 - r_{xy}^2}{n-2}}.$$

True and critical (in the table) values of Student's t-statistics - $t_{жадв}$ and - $t_{хақи}$ By comparison, the hypothesis N0 is accepted or rejected.

The relationship between Fisher's F-test and Student's t-statistic is expressed by the following equation.

$$t_r^2 = t_b^2 = \sqrt{F}$$

If $t_{жадв} < t_{хақи}$, then N_0 is negated, that is, a, b, and r_{xy} different from zero are not random and are formed under the influence of a constant factor x. If $t_{жадв} > t_{хақи}$ then the N_0 hypothesis is not rejected and the random nature of the formation of a, b and r_{xy} is recognized.

To determine the confidence interval for each indicator, the margin of error - Δ is determined:

$$\Delta_a = t_{таба} m_a, \quad \Delta_b = t_{табл} m_b.$$

The formula for calculating confidence intervals is as follows:

$$\gamma_a \quad a \pm \Delta_a; \quad \gamma_{a_{\min}} = a - \Delta_a; \quad \gamma_{a_{\max}} = a + \Delta_a;$$

$$\gamma_b = b + \Delta_b; \quad \gamma_{b_{\min}} - \Delta_b; \quad \gamma_{b_{\max}} = b + \Delta_b.$$

If zero falls on the border of the confidence interval, that is, if the lower limit is negative, and the upper one is positive, then the evaluated parameter is considered null, because it cannot take both positive and negative values at the same time.

Result indicator y_p The predictive value of the regression equation y_x =a +b*x га x_p is determined by putting the corresponding prediction (forecast) values of The mean standard error of the prediction m_{yx} is calculated as:

$$m_{y_x} = \sigma_{ocm} \cdot \sqrt{1 + \frac{1}{n} + \frac{(x_p - \bar{x})^2}{\sum (x - \bar{x})^2}},$$

here $\sigma_{ocm} = \sqrt{\frac{\sum (y - y_x)^2}{n - m - 1}};$

and confidence intervals of the prediction are drawn:

$$\gamma_{y_p} = y_p \pm \Delta_{y_p}; \gamma_{y_{p\min}} = y_p - \Delta_{y_p}; \gamma_{y_{p\max}} = y_p - \Delta_{y_p}; \text{ бу ерда } \Delta_{y_p} = t_{жадв} \cdot m_{y_p}.$$

1- **Example 1. The values of the following two signs are known for seven regions of the republic**:

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Regions	Food costs in total costs, % U	Average daily wage of one worker, thousand soums.x
1	68.8	45.1
2	61.2	59.0
3	59.9	57.2
4	56.7	61.8
5	55.0	58.8
6	54.3	47.2
7	49.3	55.2

It is required: 1. Determine the parameters characterizing the connection of indicators U and x for the following functions:

a) linear;

b) level;

c) indicative;

g) equilateral hyperbola.

2. Each model average error approximation $\overline{A}$ вLet α be estimated by Fisher's criterion F.

Solution: 1. Linear regression y=a+b*x to calculate the parameters, it is necessary to solve the system of normal equations with respect to a and b:

$$\begin{cases} na + b\sum x = \sum y, \\ a\sum x + b\sum x^2 = \sum yx. \end{cases}$$

According to the information provided ∑y, ∑x, ∑yx, $\sum x^2$, $\sum y^2$ are considered.

	y	x	yx	x2	y2	ypac	y-ypac	A_i
1	68,8	45,1	3102,88	2034,01	4733,44	61,095	7,705	10.9
2	61,2	59	3610,8	3481	3745,44	56,23	4,97	7.7
3	59,9	57,2	3426,28	3271,84	3588,01	56,86	3,04	4.7
4	56,7	61,8	3504,06	3819,24	3214,89	55,25	1,45	2.1
5	55	58,8	3234	3457,44	3025	56,3	-1,3	2.7
6	54,3	47,2	2562,96	2227,84	2948,49	60,36	-6,06	11.4
7	49,3	55,2	2721,36	3047,04	2430,49	57,56	-8,26	17.2
Total	405.2	384.3	22162.34	21338.41	23685.76	405.2	0.0	56.7
Average value	57.89	54.90	3166.05	3048.34	3383.68	x	x	8.1
σ	5.74	5.86	x	x	x	x	x	x
σ^2	32.92	34.34	x	x	x	x	x	x

$$b = \frac{\overline{yx} - \overline{y}\,\overline{x}}{\sigma_x^2} = \frac{3166.05 - 57.89*54.9}{5.86^2} = -0.35, \quad a = \overline{y - b*x} = 57.89 + 0.35*54.9 = 76.88$$

Regression equation: $y_x = 76.88 - 0.35*x$. An increase in the average daily wage by 1 ruble leads to a decrease in the share of food purchasing expenses by an average of 0.35% points.

We calculate the linear coefficient of pair correlation:

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$$r_{xy} = b\frac{\sigma_x}{\sigma_y} = -0.35 \cdot \frac{5.86}{5.74} = -0.357.$$

There is a connection and it is inverse.

We determine the coefficient of determination:

$$r_{xy}^2 = (-0.35)^2 = 0.127.$$

The fluctuation of the result is determined by the variation of the x-factor of 12.7%.

We determine the theoretical (calculated) values of ux by putting the actual values of x into the regression equation. We find the value of the average error of approximation ¯A-:

$$\overline{A} = \frac{1}{n}\sum A_i = \frac{1}{n}\sum |y - y_x| \cdot 100\% = \frac{56{,}7 \cdot 100\%}{7} = 8{,}1\%.$$

Calculated values differ (outlier) on average by 8.1% from the actual values.

Now we calculate the criterion F:

$$F_{хаки} = \frac{0{,}127}{0{,}873} \cdot 5 = 0.7,$$

Criterion $1 \leq F \leq \infty$ for being F^{-1} should be considered.

The obtained value N_0 indicates that the hypothesis should be accepted, the nature of the detected connection is random, and the parameters of the equation and the indicator of the density of connection are statistically insignificant.

1b. Before constructing the level model, it is necessary to perform the process of linearizing the variables. In the example, linearization is done by logarithmizing both sides of the equation:

$$\lg y = \lg a + b \lg x; \quad Y = C + b \cdot X$$

in this Y=lgy, X=lgx, C=lga.

We use the above information for calculation.

	Y	X	YX	Y^2	X^2	y_x	$y-y_x$	$(y-y_x)^2$	A_i
1	1,8376	1,6542	3,0398	3,3768	2,7364	61,0	7,8	60,8	11,3
2	1,7868	1,7709	3,1642	3,1927	3,1361	56,3	4,9	24,0	8,0
3	1,7774	1,7574	3,1236	3,1592	3,0885	56,8	3,1	9,6	5,2
4	1,7536	1,7910	3,1407	3,0751	3,2077	55,5	1,2	1,4	2,1
5	1,7404	1,7694	3,0795	3,0290	3,1308	56,3	-1,3	1,7	2,4
6	1,7348	1,6739	2,9039	3,0095	2,8019	60,2	-5,9	34,8	10,9
7	1,6928	1,7419	2,9487	2,8656	3,0342	57,4	-8,1	65,5	15,4
Total	12,3234	12,1587	21,4003	21,7078	21,1355	403,5	1,7	197,9	56,3
Average value	1,7605	1,7370	3,0572	3,1011	3,0194	x	x	28,27	8,0
σ	0,0425	0,0484	x	x	x	x	x	x	x
σ^2	0,0018	0,0023	x	x	x	x	x	x	x

We calculate the values S and b of the equation:

$$b = \frac{\overline{YX} - \overline{Y} \cdot \overline{X}}{\sigma_X^2} = \frac{3{,}0572 - 1{,}7605 \cdot 1{,}7370}{0{,}0484^2} = -0{,}298;$$

$$C = \overline{Y} - b \cdot \overline{X} = 1{,}7605 - 0{,}298 \cdot 1{,}7370 = 1{,}278.$$

We form a linear equation: Y_x =2,278 -0,298*X.

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We create it by powering it: $y_x = 10^{2,278} * x^{-0,298} = 189,7 * x^{-0.298}$.

Putting the actual values of x into this equation, we get the theoretical values of the resulting ux. We calculate the following indicators for them: connection density - correlation index r_{xu} and average error of approximation – A_i:

$$\rho_{xy} = \sqrt{1 - \frac{\sum (y - y_x)^2}{\sum (y - \bar{y})^2}} = \sqrt{1 - \frac{28.27}{32.92}} = 0.3758, ... \bar{A} = 8.0\%.$$

The characteristics of the level model show that they represent the correlation somewhat better than linear function indicators.

1 v. The equation of the exponential curve $y = a * b^x$ The process of linearizing the variables in the logarithm of both sides of the equation is followed by:

$$\lg y = \lg a - x \cdot \lg b; \quad Y = C + B * x,$$

in this Y = lgy, C = lga, B = lgb.

We use the following table to perform the calculations.

	Y	x	Yx	Y^2	X^2	y_x	$y-y_x$	$(y-y_x)^2$	A_i
1	1,8376	45,1	82,8758	3,3768	2034,01	60,7	8,1	65,61	11,8
2	1,7868	59,0	105,4212	3,1927	3481,00	56,4	4,8	23,04	7,8
3	1,7774	57,2	101,6673	3,1592	3271,84	56,9	3,0	9,00	5,0
4	1,7536	61,8	108,3725	3,0751	3819,24,	55,5	1,2	1,44	2,1
5	1,7404	58,8	102,3355	3,0290	3457,44	56,4	-1,4	1,96	2,5
6	1,7348	47,2	81,8826	3,0095	2227,84	60,0	-5,7	32,49	10,5
7	1,6928	55,2	93,4426	2,8656	3047,04	57,5	-8,2	67,24	16,6
Total	12,3234	384,3	675,9974	21,7078	21338,41	403,4	-1,8	200,78	56,3
Average value	1,7605	54,9	96,5711	3,1011	3048,34	x	x	28,68	8,0
σ	0,0425	5,86	x	x	x	x	x	x	x
σ^2	0,0018	34,3396	x	x	x	x	x	x	x

We calculate the values \u200b\u200bof the regression parameters a and b:

$$b = \frac{\overline{Y \cdot x} - \overline{Y} \cdot \overline{x}}{\sigma_x^2} = \frac{96{,}5711 - 1{,}7605 \cdot 54{,}9}{5{,}86^2} = -0{,}0023,$$

$$a = \bar{Y} - b \cdot \bar{x} = 1{,}7605 + 0{,}0023 \cdot 54{,}9 = 1{,}887.$$

We form the following linear equation: $Y_x = 1{,}887 - 0{,}0023 * x$.

We express it in simple form by exponentiating the resulting equation:

$Y_x = 10^{16887} * 10^{-060023x}$ $_x = 77{,}1 * 0.9947^x$.

Correlation index of bond strength (density). ρ_{xy} we evaluate through:

$$\rho_{xy} = \sqrt{1 - \frac{\sum (y - y_x)^2}{\sum (y - \bar{y})^2}} = \sqrt{1 - \frac{28{,}27}{32{,}92}} 0{,}3589.$$

The connection is weak. The average error of approximation shows that the error is high, but within a sufficient limit. The exponential function represents the relationship being studied slightly worse than the rank function.

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1g. Equilateral hyperbola equation $y = a + b\frac{1}{x}$ is linearized by the following substitution: $y = a + bz$.

We use the following table to perform the calculations:

	y	z	yz	z^2	y^2	y_x	$y-y_x$	$(y-y_x)^2$	A_i
1	68,8	0,0222	1,5255	0,000492	4733,44	61,8	7,0	49,00	10,2
2	61,2	0,0169	1,0373	0,000287	3745,44	56,3	4,9	24,01	8,0
3	59,9	0,0175	1,0472	0,000306	3588,01	56,9	3,0	9,00	5,0
4	56,7	0,0162	0,9175	0,000262	3214,89	55,5	1,2	1,44	2,1
5	55	0,0170	0,9354	0,000289	3025,00	56,4	-1,4	1,96	2,5
6	54,3	0,0212	1,1504	0,000449	2948,49	60,8	-6,5	42,25	12,0
7	49,3	0,0181	0,8931	0,000328	2430,49	57,5	-8,2	67,24	16,6
Total	405,2	0,1291	7,5064	0,002413	23685,76	405,2	0,0	194,90	56,5
Average value	57,9	0,0184	1,0723	0,000345	3383,68	x	x	27,84	8,1
σ	5,74	0,002145	x	x	x	x	x	x	x
σ^2	32,9476	0,000005	x	x	x	x	x	x	x

The values of parameters a and b of the regression were formed:

$$a = \bar{y} - b \cdot \bar{z} = 57{,}89 - 1051{,}4 \cdot 0{,}0184 = 38{,}5;$$

$$b = \frac{\overline{y \cdot z} - \bar{y} \cdot \bar{z}}{\sigma_z^2} = \frac{1{,}0723 - 57{,}9 \cdot 0.0184}{0{,}002145^2} = 1051{,}4.$$

The resulting equation will look like this: $y_x = 38{,}5 + 1051{,}4 \cdot \frac{1}{x}$.

Correlation index: $\rho_{xy} = \sqrt{1 - \frac{27{,}84}{32{,}92}} = 0{,}3944$. A The average error of approximation A=8.1%.

The estimate of the strongest bond density was obtained by the equilateral hyperbola equation: ρ_{xy}=0б3944(compared to linear, rank, exponential regressions). A – enough remains.

2. $F_{хаки} = \frac{\rho_{yx}^2}{1-\rho_{xy}^2} \cdot \frac{n-m-1}{m} = \frac{0{,}1555}{0{,}8445} \cdot 5 = 0{,}92$, бунда $F_{жадв}=5{,}5 > F_{хақи}, \alpha=0{,}05$.

It follows that the N_0 hypothesis about the statistical insignificance of the parameters of this equation is accepted. Such a result can be explained by the rather low density of the identified connections, the small number of observations.

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