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INNOVATIVE THEORY OF ASSESSING INFLUENCE OF FACTORS ON ECONOMIC SYSTEM INDICATORS

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Abstract

Article is devoted to an actual problem of the assessment of economic indicators of external and internal disturbances affecting the factors that directly affect the formation of these indicators. The same evaluations are very important when designing various scenarios in economic systems. When planning production and management decisions, there is a need for systematic analysis of result indicators plan depending on the variations of the values for parameters and variables used. In addition to the direct account to assess indicators in different versions of source data that is in most cases very difficult, in economic theory and practice developed a tool based on the elasticity of the indicators to change affecting these factors. But the application of this instrument is interfaced with the inconveniences associated with the necessity of submitting variations influencing factors in percentage terms. In practice, as a rule, for points. The design was based on the basic idea of the sensitivity theory developed for technical systems that to assess the reaction of the system sensitivity functions are used with subsequent calculation of coefficients of influence on them. With respect to economic theory was developed systems are mathematical models and calculations by using real data, the largest holding of the Irkutsk region.

Keywords: System analysis, sensitivity, coefficient of influence.

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1. Introduction

The article is devoted to a topical problem of assessing response of economic indicators to external and internal disturbances affecting the factors that directly impact formation of these indicators. The same assessments are very important in developing various scenarios in economic systems. In planning product manufacture and making managerial decisions, it is necessary to carry out a system analysis of the resulting plan indicators depending on variations of values of the parameters used and the variables. Besides the direct calculation for assessing indicators with different variants of them initial data, which is difficult in most cases, the economic theory and practice have worked out an instrument based on using elasticity of the indicators to the change of the factors that impact them. But the use of this instrument is tied with disadvantages connected with the necessity of presenting the variants of the impacting factors in percentage rate. In practice, as a rule, to assess the indicator response, the changes of the impacting factors are set not in relative units (percent) but in absolute ones. Absence of the instruments analogical to elasticity, for assessing the response of economic indicators to changes of absolute values of the impacting factors, triggered development of the corresponding methods and models as a basis of the future theory.

The basis of the development was founded by the major idea of the theory of sensitivity, developed for technical systems, which resides in the fact that for assessment of the system response the functions of sensitivity are used with subsequent calculation of the influence coefficients. With regard to the economic systems, a theory has been developed, mathematical models have been built and calculations have been made with use of the real data of the biggest agroholding of Irkutsk Oblast. Also, a system analysis has been carried out for assessment of the discounted value of the assets depending on the factors that influence it and a group of targets connecting the present-day assets value, its expected value in the future, the assets payoff and the payoff rate.

2. Problem Statement

Evaluation of the influence of factors (parameters and variables) on indicators of the economic system is the subject of economic analysis. In current terms there is a need for its development in order to bring it to the system level. Questions of the influence of factors on the indicators of the economic system are described in many works of scientists (Fedotov, 2017; Kuznetsova & Davaasuren, 2017; Ogorodnikova, 2016; Samarukha, 2016; Shupletsov & Svetnik, 2016; Sukhodolov, 2018). Questions of the influence of coefficients on profit in organizations are considered in the works of Khitrova and Khitrova (2019), Medvedeva, 2016, Rasputina, Zhilkina, Ovanesyan, and Tyunkov, 2020.

3. Research Questions

In this article, we adhere to the definition of the system analysis given by Moiseyev (1981) in the book "Mathematical problems of system analysis": "... system analysis is a discipline dealing with problems of decision-making in conditions when the choice of alternative requires the analysis of complex information of various physical nature" (par. 2, p. 5). As a result of analytical research, not just new knowledge, but the rule of choosing a completely defined alternative should arise.

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The subject of our research within the framework of system analysis is the response of the economic system at the micro-level to the changes in its parameters and variables, which is reflected in its performance indicators. In other words, we can talk about the sensitivity of the economic system indicators to external and internal disturbances. The sensitivity of systems of various physical nature has probably been studied since ancient times. But only at the turn of the 19th and 20th centuries the first scientific publications devoted to this problem appeared. We make no pretense to historical accuracy but refer to well-known scientific works. At the present time, the theory of sensitivity, as an independent scientific discipline, has been formed for technical systems. For the first time the sensitivity problem of automatic control systems was formulated in the work of Bode (1948). The development of this theory is associated with the name of the Soviet scientist Bykhovsky (1964). The methods of the theory of sensitivity have one goal - determination of the criteria for the sensitivity of the process being studied to a change in its parameters (Taran, Brudnik, & Kofanov, 1968). These criteria are usually called influence factors. And the problem of the theory of sensitivity with respect to production systems can be defined as the development of methods for determining the coefficients of the influence of the system parameters on its parameters (Taran et al.,1968). Let's note especially that the sensitivity theory applied to technical systems was developed as a tool on the basis of knowledge of the quantitative criterion of the sensitivity of the system to changing its parameters, allowing purposefully changing the parameters of the system so that its quality criterion rushed to the necessary extremum, thereby optimizing its work (Taran et al.,1968). But, for the sake of justice, it should be noted that for the first time the problem of sensitivity in the scientific literature was raised in relation to economic systems. Thus, in analyzing the demand and prices for products presented in a competitive market, the famous British economist Alfred Marshall first introduced the concept of demand elasticity in economic theory in 1890 (Dolan & Domnenko, 1994). The concept of elasticity is always associated with two quantities, one of which is the indicator being studied, and the other is an influencing factor. For example, the elasticity of demand from the price or supply. The coefficient of elasticity is a quantitative measure of the sensitivity of the indicator to the change in the influencing factor (Fisher, Dornbush, & Shmalenzi, 1993). If we consider a function as an independent variable, then, as is known, the elasticity of a function is the limit of the ratio of the relative increment of the function y to the relative increment of the variable x with:

$$E_x(y) = \lim_{\Delta x \to 0} \left(\frac{\Delta y}{y} : \frac{\Delta x}{x} \right) = \frac{x}{y} \lim_{\Delta x \to 0} \frac{\Delta y}{\Delta x} = \frac{x}{y} \cdot y' \quad . \qquad (1)$$

The elasticity of the function shows approximately how much the function will change as the independent variable x changes by 1%. This is a measure of the response of one variable to another. Much more often in practice, the sensitivity of economic indicators is estimated by directly recalculating the value of the indicator at single given values of the influencing factors. This is associated with a large expenditure of time and labor, and possibly with a computer program that allows you to perform the appropriate calculations, which is not always the case. But the most important obstacle that does not allow to apply in practice methods for assessing the sensitivity of economic indicators is that the data in the management information system are relevant, i.e. corresponding to the current state of the system and changing them in order to assess the influence of these or other factors is absolutely impossible. For these purposes, special methods and models are created on the basis of which computer programs are developed.

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4. Purpose of the Study

The use of elasticity coefficients to assess the influence of various factors on economic indicators is associated with the inconvenience connected with the need to represent the variations of the influencing factors in the percentage calculation. In practice, as a rule, to assess the reaction of an indicator, the changes in influencing factors are set not in relative units (percent), but in absolute ones. The absence of tools, similar to elasticity, for assessing the reaction of economic indicators to changes in the absolute values of influencing factors, served as an impetus for the development of appropriate methods and models, as the basis for the future theory.

5. Research Methods

The search for possible analogs led us to the theory of sensitivity, developed for technical systems. Within the framework of this theory, a tool for analyzing the influence of various factors on the criterion of the quality of the functioning of the system under study as a function of sensitivity has been developed. Sensitivity functions are the partial derivatives of the quality criterion for the parameters calculated for certain values of the initial conditions. Using these functions, the coefficients of influence are calculated. Therefore, as a method of estimating the reaction of an economic indicator to the variations of influencing factors, we also borrowed the method of calculating the coefficients of influence.

Let the function be known, where $y = f(x)$ is the exponent, and x is the vector of the influencing factors. Then the sensitivity of the indicator to the change of the i-factor can be expressed in terms of the sensitivity function $f(\boldsymbol{x_i})$, and the change in the value of the exponent (increment) is $-\boldsymbol{dy_i}$, corresponding to the change (increment) of the factor- $d\boldsymbol{x_i}$ value through the influence coefficient.

$$f(\boldsymbol{x_i})=\frac{\partial y}{\partial x_i}, \qquad \boldsymbol{dy_i} = \frac{\partial y}{\partial x_i} d\boldsymbol{x_i} \text{ i=1,2,…..n .} \qquad (2)$$

Thus, the coefficient of influence shows the change in the value of the indicator in absolute expression when the factor is changed by 1 unit.

As noted above, this is sufficient to solve problems in technical systems. But, for economic systems, this is not enough for a number of reasons. In economic systems, the sensitivity assessment is needed not so much to rank the influencing factors on its indicators, but for their further use with the purpose of analyzing the various scenarios of its functioning, predicting the values of its integral indicators for making the best decisions. In addition, in most cases it is necessary to evaluate the simultaneous influence of various factors on the integral index. And this requires, from a mathematical point of view, the calculation of the so-called total differential for the analyzed indicator.

Therefore, we will develop further the theory of sensitivity for its application in economic systems.

By integral indicators we mean indicators characterizing the generally accepted economic characteristics of the economy, such as profit, profitability, breakeven parameters of the whole production, and others.

Let us first consider the problem of estimating the partial indices, by which we will understand the indicators, generally accepted in the economy, that characterize the same quantities, but as applied to individual objects. For example, the profit and profitability of the production of a particular product will

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be private indicators, and the profit and profitability of the entire production of all products will be an integral indicator.

Each partial exponent is a function of many factors - $y_i = f(X)$, i = 1,2, ..., where X is a vector of influencing factors. The sensitivity function of this indicator, for each factor, $f(x_i)$ is presented in the formula under the number (2). And to assess the magnitude of the increment of the indicator under the influence of all factors, it is necessary to calculate its total differential, i.e.

$$dy_i = \frac{\partial y_i}{\partial x_1} dx_1 + \frac{\partial y_i}{\partial x_2} dx_2 + \ldots \frac{\partial y_i}{\partial x_m} dx_m, \; i=1,2,\ldots..n . \qquad (3)$$

Thus, by specifying the magnitude of the absolute increment of each factor, the corresponding increment of the analyzed indicator can be calculated from formula (3). Here we must especially emphasize the most important property of the total differential, which consists of the fact that "the differentials of variables connected by some functional dependence (finite equation) are connected with each other always linearly" [7, p. 305]. This means that even in the case when the indicator is related, with the factors influencing it, by a nonlinear dependence, the increment of the indicator with changing factors is always found as the sum of the changed values of factors multiplied by the corresponding influence factors. The importance of this circumstance cannot be overestimated. It is of interest to compare the two instruments for assessing the influence of various factors on economic indicators, using the elasticity coefficients and the coefficients of influence proposed by us. We analyze the change in profit from price variation, specific variable costs, the number of products produced and the total amount of fixed costs. To this end, we will compose the corresponding sensitivity functions to calculate the values of the influence coefficients.

Profit the difference between revenue from sales and total cost of production of a certain number of products. Let P_i– be the unit price of the ith product; Q_i– be the number of produced i-th product; VC_i be unit variable costs in the production of the i-th product; FC is the total amount of fixed costs in the production of all products; n is the number of types of products.

Revenue from sales of all products (TR) will be:

$$TR = \sum_{i=1}^{n} P_i Q_i. \qquad (4)$$

total cost (TC), respectively:

$$TC = FC + \sum_{i=1}^{n} VC_i Q_i., \qquad (5)$$

a, profit (GP) –

$$GP = TR - TC = \sum_{1=i}^{n} P_i Q_i - FC - \sum_{i=1}^{n} VC_i Q_i. \qquad (6)$$

Let us now compose the functions of profit sensitivity from:

prices per unit of output –

$$K_i^P = \frac{\partial GP}{\partial P_i} = Q_i, \qquad i = \overline{1,n} ; \qquad (7)$$

quantity of products –

$$K_i^Q = \frac{\partial GP}{\partial Q_i} = P_i - VC_i, \qquad i = \overline{1,n} ; \qquad (8)$$

specific variable costs –

$$K_i^{VC_i} = \frac{\partial GP}{\partial VC_i} = -Q_i, \qquad i = \overline{1,n} ; \qquad (9)$$

From the total amount of fixed costs –

$$K_i^{FC} = \frac{\partial GP}{\partial FC} = -1, \qquad i = \overline{1,n} . \qquad (10)$$

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6. Findings

Table 1 shows the results of calculations of the elasticity coefficients and the effect of the factors considered on profit according to the data of the largest agro-holding of the Irkutsk Oblast, the Belorechenskoye refinery for one of the past months.

Table 01. Calculation of the coefficients of influence and elasticity on profit

Name of products	Price per one. rubles / pcs.	Specific variable costs, rubles / pcs.	Number of products, pcs..	The total amount of fixed costs, tb.	Factors of influence on profit from:				Coefficients of profit elasticity from:			
					Price list	Specific variable costs	Quantities of output	Total amount of fixed costs	Price list	Specific variable costs	Quantities of output	Total amount of fixed costs
П1	29.45	21.99	7750	44 799	7750	-7750	7.46	-1	17.517	-13.078	4.44	-3.44
П2	16.47	7.06	12400	90 435	12400	-12400	9.41	-1	7.7645	-3.3263	4.4382	-3.44
П3	29.25	22.06	10230	57 016	10230	-10230	7.19	-1	18.045	-13.606	4.4382	-3.44
П4	16.67	13.13	4030	11 050	4030	-4030	3.54	-1	20.897	-16.458	4.4382	-3.44
П5	29.61	22.13	13640	79 037	13640	-13640	7.48	-1	17.569	-13.131	4.4382	-3.44
П6	17.04	12.99	5270	16 511	5270	-5270	4.04	-1	18.695	-14.256	4.4382	-3.44
П7	29.50	22.09	9300	53 367	9300	-9300	7.41	-1	17.675	-13.237	4.4382	-3.44
П8	16.49	13.09	3720	9 796	3720	-3720	3.40	-1	21.531	-17.093	4.4382	-3.44
П9	29.68	22.13	9920	58 056	9920	-9920	7.55	-1	17.437	-12.999	4.4382	-3.44
П10	16.45	12.85	4030	11 249	4030	-4030	3.60	-1	20.262	-15.823	4.4382	-3.44
П11	29.01	21.88	7750	42 808	7750	-7750	7.13	-1	18.058	-13.619	4.4382	-3.44
П12	22.39	17.56	46500	173 836	46500	-46500	4.83	-1	20.59	-16.152	4.4382	-3.44
П13	19.50	12.30	50220	280 085	50220	-50220	7.20	-1	12.018	-7.5801	4.4382	-3.44
П14	20.91	14.43	118420	594 337	118420	-118420	6.48	-1	14.325	-9.8864	4.4382	-3.44
П15	13.17	9.33	93000	276 723	93000	-93000	3.84	-1	15.213	-10.775	4.4382	-3.44
П16	15.89	11.39	74400	259 270	74400	-74400	4.50	-1	15.678	-11.239	4.4382	-3.44
П17	29.65	21.93	136400	816 254	136400	-136400	7.72	-1	17.035	-12.597	4.4382	-3.44
П18	16.59	13.66	37200	84 392	37200	-37200	2.93	-1	25.136	-20.698	4.4382	-3.44
П19	14.47	20.75	31000	0	31000	-31000	-6.28	-1	-2..3028	3.3028	1	0
П20	16.20	11.44	7440	27 415	7440	-7440	4.76	-1	15.116	-10.678	4.4382	-3.44
П21	17.52	12.73	6200	22 990	6200	-6200	4.79	-1	16.241	-11.802	4.4382	-3.44
П22	14.84	6.73	27900	175 262	27900	-27900	8.11	-1	8.1224	-3.6842	4.4382	-3.44
П23	29.29	22.03	23250	130 832	23250	-23250	7.26	-1	17.896	-13.458	4.4382	-3.44
П24	18.92	16.49	65100	122 302	65100	-65100	2.43	-1	34.617	-30.179	4.4382	-3.44
П25	20.40	18.70	44640	58 669	44640	-44640	1.70	-1	53.368	-48.93	4.4382	-3.44
П26	18.57	11.91	105400	543 552	105400	-105400	6.66	-1	12.377	-7.9392	4.4382	-3.44

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П27	19.71	14.15	74400	320 713	74400	-74400	5.56	-1	15.721	-11.283	4.4382	-3.44
П28	4.97	2.16	31000	67 445	31000	-31000	2.81	-1	7.8542	-3.416	4.4382	-3.44
П29	56.37	98.90	12500	0	12500	-12500	-42.52	-1	-1.3258	2.3258	1	0
П30	325.00	498.28	200	0	200	-200	-173.28	-1	-1,8756	2.8756	1	0
П31	17.29	11.73	31000	133 366	31000	-31000	5.55	-1	13,814	-9.3759	4.4382	-3.44
П32	33.17	25.42	24800	148 977	24800	-24800	7.75	-1	18,985	-14.547	4.4382	-3.44
П33	37.98	30.39	24800	145 737	24800	-24800	7.59	-1	22,221	-17.783	4.4382	-3.44
П34	40.99	32.81	24800	157 154	24800	-24800	8.18	-1	22,24	-17.802	4.4382	-3.44
П35	28.14	21.96	3906	18 693	3906	-3906	6.18	-1	20.217	-15.778	4.4382	-3.44
П36	25.18	15.19	13640	105 578	13640	-13640	9.99	-1	11.185	-6.7467	4.4382	-3.44
П37	27.23	20.24	177733	962 276	177733	-177733	6.99	-1	17.289	-12.851	4.4382	-3.44
П38	26.78	21.80	65100	250 980	65100	-65100	4.98	-1	23.883	-19.445	4.4382	-3.44
П39	30.41	26.55	682000	2 041 142	682000	-682000	3.86	-1	34.935	-30.497	4.4382	-3.44
П40	19.10	16.39	31000	65 131	31000	-31000	2.71	-1	31.257	-26.819	4.4382	-3.44
П41	36.40	30.97	31000	130 305	31000	-31000	5.43	-1	29.774	-25.336	4.4382	-3.44
П42	31.85	28.67	393700	969 905	393700	-393700	3.18	-1	44.451	-40.013	4.4382	-3.44
П43	14.42	11.04	19220	50 320	19220	-19220	3.38	-1	18.937	-14.499	4.4382	-3.44
П44	15.66	13.34	22320	40 008	22320	-22320	2.31	-1	30.029	-25.591	4.4382	-3.44
П45	1627	14.40	7440	10 763	7440	-7440	1.87	-1	38.659	-34.221	4.4382	-3.44
П46	31.51	26.77	31000	113 937	31000	-31000	4.74	-1	29.477	-25.039	4.4382	-3.44
П47	27.50	20.58	4340	23 251	4340	-4340	6.92	-1	17.649	-13.211	4.4382	-3.44
П48	33.47	32.06	130200	141 872	130200	-130200	1.41	-1	105.61	-101.17	4.4382	-3.44
П49	52.95	52.90	16120	562	16120	-16120	0.05	-1	5221.8	-5217.4	4.4382	-3.44
П50	23.78	23.73	206150	7 154	206150	-206150	0.04	-1	2355.8	-2351.3	4.4382	-3.44
П51	52.44	52.40	26040	807	26040	-26040	0.04	-1	5818.5	-5814.1	4.4382	-3.44
П52	27.52	27.42	46500	3 602	46500	-46500	0.10	-1	1221.4	-1217	4.4382	-3.44
П53	50.94	50.84	155000	11 527	155000	-155000	0.10	-1	2354.9	-2350.4	4.4382	-3.44
П54	33.27	22.29	139000	1 18803	139000	-139000	10.98	-1	13.452	-9.014	4.4382	-3.44
П55	34.69	30.38	275000	917 131	275000	-275000	4.31	-1	35.759	-31.32	4.4382	-3.44
П56	35.00	17.15	27280	377 232	27280	-27280	17.85	-1	8.7024	-4.2642	4.4382	-3.44
П57	18.50	9.27	26660	190 515	26660	-26660	9.22	-1	8.9008	-4.4625	4.4382	-3.44
П58	19.50	9.81	71920	539 970	71920	-71920	9.69	-1	8.93	-4.4918	4.4382	-3.44
П59	15.00	8.94	260090	1 220 631	260090	-260090	6.06	-1	10.989	-6.551	4.4382	-3.44
П60	15.00	7.76	45260	253 757	45260	-45260	7.24	-1	9.1987	-4.7604	4.4382	-3.44

The information generated in Table 1 convincingly shows that the coefficients of elasticity and influence have the same effect on the change in profit. From the line for P1 it follows that to change profit

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on this product, bearing in mind the elasticity of profit, the most effective is the change in price and specific variable costs, then the quantity of output and at the end of the total amount of fixed costs. The same is true if we take into account the coefficients of influence.

We show now how much more effective is the use of the coefficients of influence instead of the elasticity coefficients. The initial data correspond to product P1: the price is equal to 29.45 rubles per 1 unit; specific variable costs - 21.99 rubles; the total amount of fixed costs is 44.799 rubles; the amount of produced (or subject to production) product – 7.750 pieces. Calculate the gross profit corresponding to these data: the sum of variable costs = 21.99 * 7.750 = 170.409 rubles; total cost = 170.409 + 44.799 = 215.208 rubles; the amount of proceeds from the sale = 29.45 * 7.750 = 228.238 rubles; profit = 228.238-215.208 = 130.30 rubles. We will study how the profit will change with the increase in the quantity of the product by 1%. We start with the elasticity coefficient. The coefficient is 4.44, hence the profit will increase by 13,029.7 * 4.43825 / 100 = 578.29066 rubles. = 578.29 rubles. The figures in the calculation are accurate, because rounded off gives a slight error and distorts the exact result.

We now use the coefficient of influence. Its value is 7.46. One percent of the number of products is 78. Consequently, with an increase in the number of 78 pieces, the increase in profit will be 7.4618 * 77.5 = 578.2895 = 578.29. As follows from the above example, the calculation option with the coefficient of influence gives exactly the same result as the variant with the elasticity coefficient but it is simpler.

7. Conclusion

In practice, when solving such problems, as a rule, consider not the percentage change in the parameters, but their specific numerical values. And here the variant with coefficients of influence has undeniable advantages. Let suppose, for example, it is necessary to estimate the increase in profit for product P1 with an increase in its quantity by 200 units. For a variant with elasticity, first we need to determine how much it will be percent (200/7750) * 100 = 2.58%. Then, the value of the elasticity coefficient corresponding to 200 units is 2.58 * 4.44 = 11.45. And only now it is possible to determine the amount of profit growth for 200 units of additional quantity of products 11.45 * 13030/100 = 1.492 rubles.

For the variant with the coefficient of influence, the increment for 200 units of the additional quantity of output is 7.46 * 200 = 1.492. Comments are superfluous.

In conclusion, we note that the developed theory and the above examples do allow us to conduct a system analysis of various situations in the economic system at the micro-level, since they form the necessary and sufficient information to choose a well-defined alternative when making informed decisions in the process of managing the economic system.

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