

Assessment and Forecast of the Efficiency of Use of the Financial Resources of Amalgamated Territorial Communities in the Context of European Integration

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Abstract

The task of forecasting in economics is fulfilled by developing a variety of econometric models. The complexity of actual relations between the economic indices requires improvement of the existing and creation of new methods of modeling. That diversity is limited by the current set of elementary mathematical functions, whereas some of them cannot be applied in economics. At the beginning of the 21st century, it was proposed to use the functions of complex variable in economics. Due to their properties, which differ from the functions of real variables, they describe relations between the economic indices in a different way. Particularly, exponential presentation of a complex variable provides easy assessment of the relations between the economic index, presenting the real part of the complex number and the index, which describes its imaginary part. The trigonometric representation of the complex variable provides a more precise assessment of the studied econometric indices. Basing on the theory of the functions of complex variable, the authors of the article make assessment of the efficiency of funds use by the communities in Lviv region. In particular, the relation of the dynamics of income per one resident and the costs for maintenance of the managerial apparatus in terms of one resident in each of the amalgamated territorial community is considered as a function of complex variable. Using the statistical data, the authors have developed modules of complex variables and their arguments, which demonstrate the dynamics of relations between those components. The work also presents developed exponential functions of complex variable with the real coefficients, which have high approximation properties and can be used to make forecast of the efficient use of funds of each ATC in the future. The methodology can be used not only for assessment of the efficiency of funds use by amalgamated territorial communities, but also for evaluation of the general activity of communities, as well as for the analysis and forecast of production processes and planning on different enterprises.

Keywords: complex numbers, economic and mathematical modeling, nonlinear models, territorial communities, Lviv region, social development, efficiency of the use of funds.

1. Introduction

Development of local government requires an effective mechanism of use of the financial resources of local budgets and satisfaction of various needs of population at the regional level. The efficient use of the resource potential of amalgamated territorial communities is closely connected with application of the economic analysis. Some of the most developed methods of economic analysis include economic and mathematical methods, which are mainly developed due to improvement of the existing methods and models. New directions of development of the instrumental base of the economic

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analysis emerge not very often. The main reserve of that process is observed in the use of the directions of modern mathematics, which, because of different reasons, have not been used in the economic and mathematical modeling. One of those directions is represented by the theory of the functions of complex variable, which has not been widely used in economics.

The problems of the efficient use of the financial funds of amalgamated territorial communities in Ukraine were studied by N. Kulchytska, L. Dermanska, T. Yakovets [11], O. Nezdoimynoha [15], K. Pavliuk [16], R. Khirivskiy, H. Cherevko, I. Yatsiv, T. Pasichnyk, L. Petryshyn, L. Kucher [5, 25]. The issues, related with development of the territorial communities in context of implementation of the policy of sustainable development, and the problems of decentralization are considered in the works by Y. Petrusenko, A. Vorontsova, O. Ponomarenko, K. Derbenov [18], A. Korbutiak, Z. Lysenko, N. Sokrovol'ska, A. Oleksyn, E. Yuriy [7], the business potential and business-model of rural territories development are concerned in the researches by M. Strussová [22], O. Prokopchuk, T. Usyuk [20], M. Babych [2], V. Chemerys, V. Dushka, V. Maksym, D. Solomonko [3], I. Kravchuk, A. Rakovich [9]. The issues, related with financial support of sustainable development of Ukrainian agricultural sector and rural areas in the context of European integration are considered in the works by E. Kirieieva et al. [6], O. Kravchenko et al. [8], A. Kucher [10]; the role of public investment policy and responsible investment in sustainable development financing and budgetary revenue structure at central level of public administration are concerned in the researches by A. Plastun et al. [19], N. Reková [21]. In those works, as well as in the most cases of economic and mathematical modeling, the researchers mostly use the methods and models, which describe and study the behavior of a set of indices, whereas do not reveal the casual relations [4, 26, 12, 17]. In the simplest case, they use the trends, considering the simple principle, i.e. it is assumed that because of inertia, which is particular for the economic systems, the established tendencies will continue in the forecasted future.

Nevertheless, in practice, the expectation is often not justified, and thus the accuracy of the forecasts, made by means of such models, is not very high. However, it is worth mentioning that they are the most popular models of forecasting, widely used in the economic practice and in the science of forecasting.

In the attempts to obtain better economic forecasts, scientists develop the models, in which the expected index is calculated using the instruments of the regression analysis [12, 14, 25]. Such models are developed on the most adequate preconditions, because only having detected and described the cause and effect relations of a complicated object, one can understand the peculiarities of its behavior and make a more accurate forecast. However, in economics, such approach does not always work in a proper way, i.e. any assumed index depicts the economic phenomenon, which is a result of actions and interaction of many factors of different nature. Thus, the impact of such factors is very complex, and often has nonlinear character with a time delay.

The so-called analysis of economics on the base of complex variables is one of the promising directions to solve the problems of economic forecasting [13, 23].

According to S. Svetunkov, the complex variables have specific properties, differing from the functions of real variables, and thus describe the relations between the

economic indices in a different way [24]. Particularly, on the example of the theory of production functions, he proved that use of the complex variables greatly expanded the instruments of the economic analysis of production processes.

Thus, to study the efficiency of use of the funds of amalgamated territorial communities in Lviv region, the authors of the work choose the methodology of complex variables.

2. Materials and Methods

The aim of the article is to make assessment and forecast of efficiency of use of financial resources of amalgamated territorial communities of the region in context of the European integration.

A complex number is a number, which consists of two parts, particularly real and imaginary. In algebraic form, the complex number z looks like:

$$z = z_r + iz_i, \quad (1)$$

where z_r – stands for a real part, iz_i – stands for an imaginary part, z_r , z_i – stand for real numbers, i – stands for an imaginary one (number, which satisfies the equality $i^2 = -1$).

A complex number is a normal mathematical abstraction, similar to, for example, rational or irrational number. In different technical sciences, particularly in physics and in electric engineering, the complex numbers are used rather actively. However, presentation of variables in the real and imaginary parts of a complex number is explained by some laws. For instance, in electrical engineering, it is considered that the value of the active capacity should refer to the real part, whereas reactive – to the imaginary one. In economics, there are no such conceptual correspondences to the real and imaginary parts of a complex variable. Nevertheless, presentation of economic components in the form of a complex index secures investigating different aspects as an integrity.

3. Results

The econometric model of complex variables in the general form can be presented as a regressive dependence of the complex econometric index y on one or several complex variables x_j :

$$y = f(x_j) + \varepsilon, \quad (2)$$

Here, y – stands for a complex of resultant economic index, which consists of a real y_r and imaginary y_i parts; x_j – stands for a complex economic factor (or factors), which is considered as a reason of the dynamics y and consists of a real and imaginary part; ε – stands for the approximation deviation.

It is important that by means of the imaginary one, it is possible to combine two (or more) economic indices into one complex index.

As far as the complex variable can be presented not only in arithmetic form, but also in

$$y = y_r + iy_i = Re^{iQ} \quad (3)$$

a trigonometric one

$$y = R \cos Q + iR \sin Q, \quad (4)$$

its additional characteristics include a module of the complex variable:

$$R = \sqrt{y_r^2 + y_i^2}, \quad (5)$$

and its argument:

$$Q = \arctg \frac{y_i}{y_r}, \quad (6)$$

Before using the above-mentioned complex variables in the models, it is necessary to consider a set of conditions of their use:

1. Economic indices, which are consolidated into one complex variable, should include two characteristics of one process of phenomenon, i.e. depict different sides of that phenomenon. Thus, there should be a relation both between the variables and between the real and imaginary parts of each variable.
2. The indices should be of the same dimension.
3. Random values should be normally distributed.

To study the efficiency of use of the funds of amalgamated territorial communities in Lviv region by the method of complex variable, the authors of the work consider the dynamics of income per one resident (y_r) and spending for maintenance of the managerial apparatus on a per one resident basis (y_i).

The first index characterizes the financial potential of ATC, capability to supply the community by means of resources, which are generated on its territory. The second index demonstrates the “cost” of one employee of the managerial apparatus of the ATC for each resident of the community (on per a year basis). Those data are presented in the Table 1.

Table 1: Principal figures of the amalgamated territorial communities

ATC in Lviv region	Years					
	2017		2018		2019	
	Personal income per one resident, (%)	Share of spending in the personal resources, used for maintenance of the managerial apparatus, (%)	Personal income per one resident, (%)	Share of spending in the personal resources, used for maintenance of the managerial apparatus, (%)	Personal income per one resident, (%)	Share of spending in the personal resources, used for maintenance of the managerial apparatus, (%)
Babyrna	35.21	25.70	12.37	51.30	6.71	61.20
Biskovychi	13.19	38.60	6.09	52.00	3.37	44.20
Vilshanyk	4.88	75.30	3.35	78.60	0.97	82.10
Volia Baranetska	4.67	68.90	3.03	85.90	0.79	87.10
Hnizdychiv	17.17	26.90	8.25	23.00	7.26	22.40
Hrabovets	14.43	60.00	7.38	58.40	4.68	55.60
Davydiv	38.71	24.80	18.29	30.40	17.11	23.60
Dubliany	17.63	34.20	7.55	35.30	4.51	39.90
Zhovtantsi	26.81	20.90	13.20	21.40	10.14	20.70
Zabolotsti	20.46	28.90	11.36	26.70	12.37	26.90
Lukiv	5.10	55.90	2.95	69.20	0.93	64.80
Mizhenets	8.33	60.10	4.15	74.50	1.20	86.10

Mostyska	26.43	15.40	9.61	21.80	6.40	20.70
Nyzhankovychi	14.67	35.30	6.21	52.90	3.86	46.30
Novyi Kalyniv	28.91	30.30	12.49	35.80	9.98	34.40
Nove Misto	4.61	53.00	2.75	62.30	0.52	60.60
Novi Strilyshcha	21.85	38.10	9.73	39.70	5.03	43.00
Sudova Vyshnia	12.65	28.50	7.04	34.90	4.30	34.60
Trostanets	42.75	16.90	16.30	23.00	11.25	27.00
Khodoriv	20.62	18.20	8.50	24.60	6.25	21.70
Chukva	8.53	58.50	4.70	64.80	2.57	59.20
Shehyni	34.90	25.80	15.86	32.50	12.69	27.80

Source: The Table is composed on the base of the data of the communities and electronic resource [1].

The Table 1 demonstrates that reduction of values of the module (1) can happen in the variant of reduction of at least one of its economic components. Stability of the module, under the growth of one index, confirms a reduction of another one. It can be diagnosed by the argument dynamics. Reduction of the argument confirms that the fraction numerator (2) decreases as compared to the denominator.

The Table 2 proves that the argument does not go up only in Davydiv and Zabolotsti ATC. Thus, in all other communities, spending for maintenance of the managerial apparatus increases faster than the personal income per one resident of the ATC. It confirms an inefficient use of the funds of the ATC.

Table 2: Argument of the indices of spending for maintenance of the managerial apparatus relating to the personal funds in the amalgamated territorial communities in Lviv region

ATC in Lviv region	Years			ATC in Lviv region	Years		
	2017	2018	2019		2017	2018	2018
Babyna	0.6305	1.3341	1.4615	Mizhenets	1.4331	1.5151	1.5569
Biskovychi	1.2415	1.4543	1.4946	Mostyska	0.5276	1.1556	1.2709
Vilshanyk	1.5060	1.5282	1.5589	Nyzhankovychi	1.1769	1.4539	1.4875
Volia Baranetska	1.5032	1.5356	1.5618	Novyi Kalyniv	0.8089	1.2350	1.2885
Hnizdychiv	1.0028	1.2265	1.2572	Nove Misto	1.4840	1.5267	1.5622
Hrabovets	1.3348	1.4452	1.4868	Novi Strilyshcha	1.0501	1.3304	1.4544
Davydiv	0.5698	1.0292	0.9434	Sudova Vyshnia	1.1531	1.3716	1.4471
Dubliany	1.0948	1.3602	1.4584	Trostanets	0.3764	0.9542	1.1761
Zhovtantsi	0.6622	1.0182	1.1153	Khodoriv	0.7232	1.2381	1.2906
Zabolotsti	0.9548	1.1684	1.1399	Chukva	1.4261	1.4984	1.5274
Lukiv	1.4797	1.5282	1.5564	Shehyni	0.6366	1.1168	1.1427

Source: Composed by the authors using the formula (6).

The experience of scientific researches demonstrates that nonlinear models are the most effective for solution of the economic problems [7]. The exponential production function of complex variable with real coefficients [11] is one of the simplest forms of nonlinear complex-number models of production functions. It has the following form:

$$y_r + iy_i = (a_0 + ia_1)t^{(b_0+ib_1)} \quad (7)$$

To find the unknown parameters (a_0 , a_1 , b_0 , b_1) of the model (7), the authors of the research use the methodology of assessment of the parameters of nonlinear models of

complex variable with complex coefficients. Thus, the equation (7) should be first brought to the linear form by taking the natural logarithm of the left and right part of the model. It results in obtaining of the following linear equation:

$$\ln(y_r + iy_i) = \ln(a_0 + ia_1) + (b_0 + ib_1) \ln t \tag{8}$$

Having applied the method of the smallest squares for calculation of the coefficients of the present model, the researchers obtain a system of equations of the following kind:

$$\begin{aligned} a_0 n + b_0 \sum_t x_{rt} - b_1 \sum_t x_{it} &= \sum_t y_{rt} \\ a_1 n + b_0 \sum_t x_{it} + b_1 \sum_t x_{rt} &= \sum_t y_{it} \end{aligned} \tag{9}$$

$$\begin{aligned} a_0 \sum_t x_{rt} + a_1 \sum_t x_{it} + b_0 \sum_t (x_{rt}^2 + x_{it}^2) &= \sum_t y_{rt} x_{rt} + \sum_t y_{it} x_{it} \\ -a_0 \sum_t x_{it} + a_1 \sum_t x_{rt} + b_1 \sum_t (x_{rt}^2 + x_{it}^2) &= \sum_t y_{it} x_{rt} + \sum_t y_{rt} x_{it} \end{aligned} \tag{10}$$

which results in calculation of the coefficients figures by the formulas:

$$\begin{aligned} a_0 &= \frac{\sum_t (x_{rt}^2 + x_{it}^2) \cdot \sum_t y_{rt} - \sum_t x_{rt} \cdot \left(\sum_t y_{rt} x_{rt} + \sum_t y_{it} x_{it} \right) + \sum_t x_{it} \cdot \left(\sum_t y_{it} x_{rt} + \sum_t y_{rt} x_{it} \right)}{D} \\ a_1 &= \frac{\sum_t (x_{rt}^2 + x_{it}^2) \cdot \sum_t y_{it} - \sum_t x_{it} \cdot \left(\sum_t y_{it} x_{rt} + \sum_t y_{rt} x_{it} \right) - \sum_t x_{rt} \cdot \left(\sum_t y_{rt} x_{rt} + \sum_t y_{it} x_{it} \right)}{D} \\ b_0 &= \frac{n \cdot \left(\sum_t y_{rt} x_{rt} + \sum_t y_{it} x_{it} \right) - \sum_t x_{rt} \cdot \sum_t y_{rt} - \sum_t x_{it} \cdot \sum_t y_{it}}{D} \\ b_1 &= \frac{n \cdot \left(\sum_t y_{it} x_{rt} + \sum_t y_{rt} x_{it} \right) + \sum_t x_{it} \cdot \sum_t y_{rt} - \sum_t x_{rt} \cdot \sum_t y_{it}}{D} \end{aligned} \tag{11}$$

where:

$$D = n \sum_t (x_{rt}^2 + x_{it}^2) - \left(\sum_t x_{rt} \right)^2 - \left(\sum_t x_{it} \right)^2, \tag{12}$$

n – stands for the number of samples.

Using the (11) and data of the Table 1, the authors have composed regression models of the trends of each of the considered ATC and obtained the following results (Table 3).

Table 3: Parameters of the developed models for the ATC in Lviv region

ATC	Coefficients			
	a_0	a_1	b_0	b_1
Babyna	0.425243	0.08235	0.310068	0.784295
Biskovychi	0.087327	0.418714	0.106309	0.238647
Vilshanyk	0.262326	-0.705280	0.075053	0.046425
Volia Baranetska	0.247898	-0.657530	0.22256	0.052649
Hnizdychiv	0.261685	0.172418	-0.28828	0.241368
Hrabovets	0.038642	0.618335	-0.08917	0.140649
Davydiv	0.395898	-0.239800	-0.41027	0.374851
Dubliany	0.203644	0.316637	0.024705	0.336540
Zhovtantsi	0.321088	-0.096740	-0.3624	0.423351

Zabolotsti	0.323455	0.125158	-0.17628	0.183529
Lukiv	0.176331	-0.550130	0.149365	0.069823
Mizhenets	0.131004	-0.590340	0.316473	0.113335
Mostyska	0.291448	-0.084690	-0.31887	0.701265
Nyzhankovychi	0.126238	0.381610	0.209966	0.295313
Novyi Kalyniv	0.401976	0.117164	-0.14239	0.455727
Nove Misto	0.170149	-0.514500	0.130489	0.070113
Novi Strilyshcha	0.271907	0.336503	-0.02287	0.371978
Sudova Vyshnia	0.142941	0.282394	0.111336	0.272768
Trostianets	0.304389	-0.314570	-0.44323	0.739226
Khodoriv	0.276752	0.039971	-0.16863	0.540775
Chukva	0.102961	-0.595710	0.016557	0.093523
Shehyeni	0.427683	-0.094920	-0.31331	0.485649

Source: Composed by the authors.

The data demonstrate that the trends describe the established tendency and can serve as the models, which provide a reliable forecast on the general tendency of the efficiency of use of the funds of amalgamated territorial communities in Lviv region by the method of complex variable.

According to the data of the Table 3, the researchers make a forecast of the personal funds per one resident and the share of spending for maintenance of the managerial apparatus in each of the studied ATC at the end of 2020 (Table 4).

Table 4: Forecasted quantitative indices of amalgamated territorial communities for 2020

ATC in Lviv region	Personal income per one resident (%)	Share of spending in the personal resources, used for maintenance of the managerial apparatus (%)	ATC in Lviv region	Personal income per one resident (%)	Share of spending in the personal resources, used for maintenance of the managerial apparatus (%)
Babyna	0.153974	0.711776	Mizhenets	0.002835	1.331420
Biskovychi	0.000624	0.567017	Mostyska	0.106928	0.248139
Vilshanyk	0.004754	0.910242	Nyzhankovychi	0.016710	0.508756
Volia Baranetska	0.000514	1.181173	Novyi Kalyniv	0.105385	0.394315
Hnizdychiv	0.061141	0.218999	Nove Misto	0.001634	0.664728
Hrabovets	0.015757	0.631743	Novi Strilyshcha	0.059496	0.359630
Davydiv	0.161152	0.226132	Sudova Vyshnia	0.030709	0.338625
Dubliany	0.057143	0.412444	Trostianets	0.193025	0.243760
Zhovtantsi	0.155720	0.047192	Khodoriv	0.098701	0.122634
Zabolotsti	0.157981	0.273651	Chukva	0.001817	0.696763
Lukiv	0.000649	0.648957	Shehyeni	0.106556	0.264171

Source: The Table is composed by the authors using the formula (7).

4. Conclusions

Basing on the theory of the functions of complex variable, the authors of the article make assessment of the efficiency of funds use by the communities in Lviv region. In particular, the relation of the dynamics of income per one resident and the costs for maintenance of the managerial apparatus in terms of one resident in each of the amalgamated territorial community is considered as a function of complex variable. Using the statistical data, the authors have developed modules of complex variables and their arguments, which demonstrate the dynamics of relations between those components. The work also presents developed exponential functions of complex variable with the real coefficients, which have high approximation properties and can be used to make forecast of the efficient use of funds of each ATC in the future. The methodology can be used not only for assessment of the efficiency of funds use by amalgamated territorial communities, but also for evaluation of the general activity of communities, as well as for the analysis and forecast of production processes and planning on different enterprises.

It is clear that to increase the accuracy of the forecast by means of a complex trend (11), the following researches should be devoted to adaptation of the model coefficients to the conditions, which change during the time. Moreover, making forecast of the general tendency of the complex index dynamics, one should remember that the level of social and economic development of the region is the result of an active economic impact of both regional administrations and the government of Ukraine. It means that the established tendencies can significantly change any moment. Thus, the complex trends of the real argument of social and economic dynamics can be used to answer the question whether economic activity of the communities is efficient under unchanged social and economic policy. Hence, it is necessary to assess the module of the complex variable and its argument. It is argued that the developed trends are unable to answer the question of what should be done to change the situation and the tendency of the social and economic dynamics. The answer to the question can be found in application of more complicated multi-factorial models of complex variables.

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