1 SUSTAINABLE DEVELOPMENT MANAGEMENT OF NATURAL AND ECONOMIC SYSTEMS

1.1 MODELING OF RESOURCE DISTRIBUTION SYSTEM IN NATURAL-ECONOMIC SYSTEMS

L. Horoshkova, *Doctor of economical science, associated professor,*
Ie. Khlobystov, *Doctor of economical science, professor*
National university of «Kyiv-Mohyla academy», Ukraine

Current decentralization and reform of the administrative and territorial structure of Ukraine, the issue of overcoming inequalities and disparities of territorial development in Ukraine by building effective system of financial management for united territorial communities as basis for territories` and country`s sustainable development becomes especially relevant.

The study analyzes effectiveness of intergovernmental fiscal relations system and income distribution within united territorial communities in the context of inequalities and imbalances.

Current system of united territorial communities` expenditures. It has been shown that in the current legal framework regarding united territorial communities there are no effective guarantees of optimal, balanced budget allocation between UTCs settlements - members.

To overcome current disparities in expenditures` distribution of a UTC budget, it has been proposed to use economic and mathematical model, which allows to take into account both the dynamics of UTC per capita income and changes in its population.

In September 2015, at the United Nations Summit on Sustainable Development in New York, the Heads of states and governments agreed on Post-2015 Development Agenda defining 17 global Sustainable Development Goals as part of the 70th Anniversary Session of the UN General Assembly. On September 30, 2019, the President of Ukraine signed the Decree «On the Sustainable

Development Goals of Ukraine up to 2030». Achieving these goals, adapted to national situation, ensuring real transition of the country and its regions to the model of sustainable development requires application of all the capacity and resources, increasing efficiency of Ukrainian natural resource and socio-economic potential, overcoming inequalities and disparities in the development of territories as the main objective of public policy.

One of the main tasks of administrative and territorial reform implementation is to remodel relations and powers between administrative territorial units, to set united territorial communities (UTCs) and to grant them master rights to manage their own sustainable development. Decentralization should solve the problem of low standards of local authorities' organization, inefficient management of social development, regional disparities and inequalities. Therefore, the main task of public policy is to build the framework for the most effective use of territories` natural resource and socio-economic potential as the basis for their balanced development. As there is inequality in territories` basic terms of development, i.e. natural resources, demographic situation, socio-economic development potential, the task of the state amid process of reform is not to deepen the inequality, but to negate the disparities. The tasks could be fulfilled in case of communities` financial capability, maximum power transfer to local authorities, and opportunity to put delegated powers into practice as the basis for sustainable, balanced development of both territories and the country.

There is the needed to ensure this type of development, reforms` legal background, development of scientific principles and recommendations for the optimal use of natural resources and socio-economic development capacity in Ukraine in the context of UTCs formation and their sustainable development support when providing subregional stage of reforms.

Wollmann H. (Denmark), Andre C., Garcia C. (Finnland), Baldershrim H., Kulesza M. (Poland), Feltensteina A., Iwata S. (China) and others analyzed international experience of decentralization. Batalov O.A., Datsko O.I., Zhalilo Y.A., Marunyak E.A., Molodozhen Y.B., Murkovich L.L., Oliynyk D.I., Oliynyk

Y.B., Pavlyuk A.P., Romanova V.V., Rudenko L.G., Tobiash E.V., Chykalo I.V., Shevchenko O.V. and other Ukrainian scholars study modern aspects of solving the problems of development of territorial communities and local self-government [2-14]. Close to the topic of research on solving problems of economic security of communal (municipal) property of a territorial community, are the publications of Tobiash E.V.

Issues of social safety amid decentralization are studied by Ezcurra R., Rodriguez-Pose A. The issues of decentralization management are considered in the works of Oates W.E., relationship between centralization and decentralization by Schneider A., relationship between decentralization reforms and corruption by Arican G., Fisman R., Gatti R. Jourmard I., Giomo C., Ruśkowski E., Salachna J. conducted research referring models of local self-government, mechanism of local budgets and models of budget decentralization in European countries.

Analysis of the main publications shows that the studied problem remains completely unsolved, as in most scientific works theoretical concepts concerning management of process of united territorial communities (UTC) development amid reforming of administrative-territorial system are given mainly. There are attempts to solve the problems of resource efficiency management of UTC of a particular region without generalization for the borders of the country. Natural resources have also gone unnoticed by most authors. The results of the analysis of world and European experience of decentralization and further development of UTC do not take into account the specifics of national conditions and therefore cannot be used to build managerial system for local UTC.

The process of decentralization taking place in Ukraine is ambiguous and rather controversial. On the one hand, it is one of the recent positive achievements of Ukrainian authorities; on the other hand, there are numerous problems in its practical implementation.

Therefore, we must say that not all the tasks of the first stage of decentralization (basic reforms) have been successfully completed today. One issue was inequalities and development disparities of territories due to the

unresolved or incorrectly resolved problems.

At first glance, due to the amendments to the Budget and Tax Codes, practical steps were taken towards fiscal decentralization, significant changes in intergovernmental budgetary relations and pumping up local budgets due to the redistribution of sources of taxation between different system levels. However, more detailed analysis of the consequences of some mechanisms` implementation indicates that they impede UTCs` development, threaten their financial capacity, retain inequalities and disparities in territorial development and make it impossible to ensure country`s sustainable development.

According to the regulations of the current Budget Code of Ukraine (Articles 97, 99, 100, 102, 103-2, 103-4 and 108), UTCs budgets have direct intergovernmental fiscal relations with the state budget in the form of: basic subsidy; reverse subsidy; training subvention; medical subvention; subsidies for UTC infrastructure building; subsidies for socio-economic development of different territories; other subventions and grants, if granting and appropriate intergovernmental transfers make sense; funds from the State Regional Development Fund (SRDF) (financing for infrastructure projects). Let us provide critical analysis of some of them.

In 2014, the Verkhovna Rada of Ukraine adopted amendments to the Budget Code. The balancing system was replaced by fiscal equalization system, which means horizontal equalization of territorial depending on per capita income achieved due to the introduction of basic and reverse subsidy. According to the Budget Code, a basic subsidy is defined as a transfer provided from the state budget to local budgets for horizontal equalization of territories` taxability. A reverse subsidy is funds transferred to state budget from local budgets for horizontal equalization of territories` taxability (Article 96 of the Budget Code).

Authorities of the Ministry of Regional Development consider that there used to be a balancing system to ensure each level`s budgetary liabilities by their expenditure with the income capacity. That is, balancing of local budgets was carried out based on necessary expenditures to support public sector according to

the formulaic approach. Expenditures delegated by the state were calculated, then incomes were defined and if expenditures exceeded incomes, the equalization subsidy covered the difference.

Experts of the Ministry of Regional Development emphasize the advantages of current budgetary relations management model. Firstly, there is expenditure-based equalization but not income-based; secondly, equalization is set only for personal income tax (exception regional budgets); it forms the basis for the taxability index of corresponding budget. It is also stressed that this is national tax and other income sources are not involved in the equalization process.

This approach is not without significant financial and economic managerial disadvantages. Firstly, reverse subsidy depends on UTC budget`s taxability index, which in turn is determined by personal income tax (PIT). PIT is major budget income generating source in local budgets` structure. Its share in all local budgets of Ukraine is 56% of total income excluding transfers, and 55% of UTCs in particular. As the share of PIT accumulated by UTCs is quite significant - 60%, partial funds withdrawal from this source of income may adversely affect UTCs financial position.

Secondly, new equalization mechanism does not solve the main problem – revitalization of the activity providing level playing field for national UTCs financial capacity. Thus, financially capable communities will increase their capacity and transfer some of their incomes to the State budget in the form of a reverse subsidy. At the same time, disadvantaged communities will receive funds from the State budget in the form of a basic subsidy. This mechanism does not support financial sustainability of the vast majority of UTCs, but pose a threat to the financial position of UTCs able to increase their income independently.

According to the information about local budgets` creditworthiness and stability published by the Ministry of Regional Development (based on the analysis of territorial communities` financial indicators), basic subsidy negatively affects UTCs sustainable development if its ratio to own revenues is more than 50% (calculated by division of basic subsidy to total own incomes and basic

subsidy). Basic subsidy within 20-30% is considered to be uncritical for a budget. However, according to the analysis, there have been any procedures initiated by the state regarding steadily subsidized UTCs during the reform period.

Moreover, similar standards for the reverse subsidy (at least formal ones) have not been developed. This is a significant failure as the reverse subsidy directly affects stability of local budgets and financial capacity of UTCs. We applied economic and mathematical modelling and proposed a corresponding model.

It was proposed to determine allowable limits of reverse subsidy correlated to UTC per capita income growth rate. It was proved that to describe the dynamics of UTC income it is expedient to use not the exponential law (hard model), but the logistic model (soft model). It was offered to determine safe limits of UTC financial position`s adjustment with the help of the logistic model ensuring sustainable development. Conditions for the external impact on UTC system in the form of reverse subsidy were shaped. Safe limits for its amounts` adjustments were defined as well. It was proved that 50% of UTC income is critical amount of the reverse subsidy. The estimated allowable amount of the reverse subsidy is no more than 25% of UTC income.

The analysis of reverse subsidy`s to UTC income ratio over time was made to prove the conclusions regarding the deterring effect of reverse subsidies and current inequality of UTCs development in Ukraine. It showed that Honcharivska UTC (Chernihiv region); Verbkivska UTC (Dnipropetrovsk region) and Bogdanivska UTC (Dnipropetrovsk region) occupied first places during 2016 – 2018s. Besides, it is noteworthy that reverse subsidies for these communities increased from 2016 to 2018: in Verbkivska UTC (Dnipropetrovsk region) – from 15.92 to 19.9% and 24.9%; in Bogdanivska UTC (Dnipropetrovsk region) – from 13.9% to 19.1% and 23.4%. In Honcharivska UTC (Chernihiv region) – from 25.8% in 2017, form 25.8% to 29.3% in 2018. Honcharivska UTC was set in 2016 so its budget in 2016 had no subsidies.

Average income per capita growth rate analysis for these communities during 2015 – 2017s demonstrated the following results: Verbkivska UTC - 946.22% (2016/2015), 25.98% (2017/2016); Bogdanivska UTC - 632.95% (2016/2015), 24.50% (2017/2016).

Thus, the comparison of own per capita income analysis` results for these communities during 2015 – 2017s showed that the growth rate of community income was distributed as follows: Verbkivska UTC (Dnipropetrovsk region) - 946.22% (2016/2015), 25.98% (2017/2016); Bogdanivska UTC (Dnipropetrovsk region) – 632.95% (2016/2015), 24.50% (2017/2016). That is, exponential income growth was only in the first year (2015). In 2016, income growth rates declined substantially, similar dynamics were observed in the first half of 2018 and came closer to logistical pattern. Meantime, during 2016 – 2017s the reverse subsidy expanded. Reverse subsidies almost reached 25% level calculated as safe for united territorial communities. Their further growth threatens gradual crisis for UTCs.

We also conducted analysis of basic granting and the reverse subsidy withdrawal based on the results of the first half of 2018, by regions of the country (Table 1).

The results indicate that among the regions of Ukraine there are those with a significant part of UTCs receiving a basic subsidy, which has reached or on the threshold. Among them are Lviv, Volyn, Chernivtsi, Ivano-Frankivsk, Ternopil, and Rivno regions. Besides, it was found out that most communities receive a basic subsidy of 30 - 50% in Lviv, Ivano-Frankivsk, Ternopil, and Rivno regions. At the same time, it should be noted that the level of reverse subsidies is quite high - from 18.8% to 29.3% in Poltava, Dnipropetrovsk, Chernihiv, Mykolaiv, Sumy, and Kyiv regions. The level of basic subsidy is quite low here - from 21.8% to 34.7%.

In our opinion, results obtained prove ineffectiveness of the current mechanism of intergovernmental budgetary regulation as it forms the basis for inequalities of UTCs development characteristics, which may threaten territorial and national sustainable development. As we can see, current mechanism forms the

framework when some regions of the country make no effort to work without basic subsidies. Meanwhile, regions having stable indicators of their economic development find out that reverse subsidy slows down further development of their potential, as it withdraws part of funds from UTC budget.

Table 1 – Quantitative indices of basic granting and the reverse subsidy withdrawal based on the results of the first half of 2018

Region	Number of UTCs on 01.07. 2018.	Number of UTCs with basic granting	Maximum basic subsidy, %	Number of UTCs withdrawing reverse subsidy	Maximum reverse subsidy, %
Dnipropetrovsk	56	38	34,7	9	24,9
Zhytomyr	45	36	39,8	7	17,5
Volyn	40	33	61,7	7	23,5
Ternopil	40	36	50,1	2	14,7
Poltava	39	17	22,4	14	19,7
Khmelnytskyi	39	34	41,7	4	15,5
Chernihiv	37	21	22,6	8	29,3
Zaporizhzhia	36	32	45,2	2	8,7
Lviv	35	31	55,8	4	6,0
Vinnytsia	34	22	41,0	9	11,4
Mykolaiv	28	22	36,9	5	20,8
Sumy	28	18	26,4	4	18,8
Kherson	26	24	42,7	1	4,5
Cherkasy	26	18	21,8	4	21,2
Chernivtsi	26	25	53,0	1	4,3
Odessa	25	20	37,7	3	4,4
Rivno	25	22	49,3	2	7,8
Ivano-Frankivsk	23	22	59,0	1	9,6
Kirovohrad	13	4	19,8	6	15,6
Kharkiv	12	9	18,0	2	18,7
Donetsk	9	3	48,0	4	8,9
Kyiv	9	4	8,2	4	21,6
Luhansk	8	6	45,7	1	8,1
Zakarpattia	6	3	43,6	3	0,8

Thus, implementation of reverse and basic subsidies creates inequality in UTCs development and their ability to ensure financial capacity and self-sufficiency as one of the main tasks of decentralization reforms.

Other types of subsidies are not without their disadvantages too as they also lead to social inequality in UTCs development.

UTCs have one exclusive subsidy type – for UTC infrastructure building, imposed in 2016 in accordance with the resolution of the Cabinet of Ministers of Ukraine «Some issues of granting a subsidy from the state budget to local budgets for the formation of infrastructure of the united territorial communities» of 16.03.2016, No. 200. It covers 10 main forms funding: a) development of project, urban planning and design documentation; b) quality improvement of administrative services, including setting and modernization of Administrative Service Centres (ASCs), of acquisition of equipment and software; c) formation of modern systems of community management organization, i.e communication networks, databases, public warning systems; d) reconstruction, reorganization and repurposing of budgetary institutions buildings applying obligatory energy efficient technologies; e) new construction, reconstruction and capital improvement of streets, roads, bridges, communal property transfers; f) acquisition of school transport, special purpose vehicles and their accessories for public utilities, fire and special rescue equipment and fire-fighting equipment, specialized medical transport for healthcare institutions; g) new construction, reconstruction and capital improvement of water supply and drainage system facilities, waste management units and remediation of landfills, etc; h) other activities with public utilities to ensure adequate security and civil defence level; i) meeting budgetary accounts payable according to the legal procedure under the program «State budget subsidy to local budgets to build UTCs infrastructure»; j) construction, reconstruction, repair and maintenance of local roads, streets and roads of communal property in settlements, as well as repairs of streets and roads that are constituent roads of national significance (co-financing on contractual basis).

The amount of subsidy to build UTCs infrastructure is specified one, which depends on UTC area and its rural population. Therefore, inequalities may arise from both rural and urban settlements in some UTCs. The last have to seek resources for infrastructure development from their own sources. This situation is unfair, as rural residents cannot be restricted to use infrastructure of cities where they, for example, work. Their development funding is not covered by this subsidy.

Other two subsidies - for the activities, which support socio-economic development of individual territories and funds of the State Fund of Regional Development - depend on the decisions of special Commission of the corresponding ministry, which is the main manager of these funds. This indicates subjectivism of the granting process, which can also lead to inequality in their distribution between UTCs.

Therefore, these shortcomings of state financing mechanisms of UTCs development should be improved because they cause inequalities in UTCs development in Ukraine and prevent sustainable development of the country.

These disadvantages can be attributed to UTCs inequalities within districts and country as a whole. There are also some unresolved issues regarding allocation of resources between settlements within one UTC.

Resource management is the basis for complex systems performance. To analyze and evaluate the quality of management, they use the category of production and resource capacity, which characterizes the maximum capacity of the accumulated and prepared for processing natural, material, technical, labour, financial and information resources to meet the needs of society and individual citizens. .

However, there is the law of scarce resources. According to this law, available resources do not always fully satisfy all the needs and desires of people.

At the state level, society must choose products for manufacturing, taking into account opportunities and available resources to balance supply and demand. Besides, there are vital goods and services that are of social importance and the state must ensure their supply all citizens without exception.

There is similar issue of resource supply at the mezolevel. Each territory is characterized by its specific production and resource potential, and thus by its industrial specialization. At the administrative-territorial level, as well as at the state level, there is a need to supply population with vital goods and services, regardless of abundancy or scarcity of certain resources.

Resource potential (ownership right and right of disposition of resources) and the level of rational, effective management are the main determinants of building capable UTCs amid current decentralization.

The ability to manage a community depends essentially on rational and efficient managerial processes impact tangible and intangible benefits making.

It was emphasized in «The methodology of capable communities formation» (Methodology, 2015) that: capable territorial community is a territorial community of villages (settlements, cities), which, as a result of voluntary association, are able to provide, on their own or through appropriate local governments, can maintain adequate level of service supply, in particular in the fields of education, culture, health, social protection, utilities, taking into account human resources, financial support and infrastructure development of corresponding administrative-territorial unit.

Our analysis prove that there is no effective guarantee of optimal, balanced distribution of resources among UTCs settlements - members in the legal framework for united territorial communities. This problem arises first of all in UTCs, which consist of settlements with different population and different per capita income.

Thus there are some shortcoming.

The first corresponds to the fact that as single council of UTCs is formed by equal and direct elections, the number of representatives of each settlement depends on its population. That is, settlements as UTC centres may have decision-making advantages by the population size.

The second problem is that per capita income does not always depend on population size for settlements; more priority is given to natural resources

abundancy, valuable land or big profitable business. It can also lead to uneven use of funds, in particular for the development of settlements.

The third problem is that fair, balanced expenditures and subsidies distribution is possible if there is reliable information on the number of UTCs residents. The information is practically absent, since UTC formation is preceded by the elections announced by the Central Election Commission (CEC), based on information about residents official registration in settlements. Practice shows that the place of registration does not always coincide with the place of residence. In addition, there is a pendulum labour migration in the process of job search between settlements. That is, there are those who work in another locality leaving every morning and returning in the evening. There are those who work during a week, there are also seasonal jobs. Thus, the number of settlements` residents fluctuates. In this case, the traditional approach is that the distribution of necessary expenditures between settlements will not be effective, since it is based on the place of registration without taking into account temporary migration. In turn, settlements accumulating additional workforce every morning must be provided with appropriate infrastructure (transport, catering, etc.). Transport infrastructure between settlements of such communities also needs additional attention.

To plan UTCs and their settlements development (provision of public goods, capital expenditure, level of income, provision of resources and goods, etc.), it is necessary to take into account the population size and potential changes over a period of time.

To simulate the described situation we apply the system of linear homogeneous difference equations. Let us assume that UTC comprises $n \geq 2$ settlements $D_1, D_2, ..., D_n$ and there is the following migration between them: for all $i \neq j$ is the same part a_{ij} of residents of a settlement D_j goes to settlement D_i, and part a_{ji} of residents of a settlement D_j migrates to D_i, but part a_{ji} stays in it. Let $x_i(t)$ be residents of settlement D_i in t –period. Then,

$$x_1(t+1) = a_{i1}x_1(t) + a_{i2}x_2(t) + ... + a_{in}x_n(t),$$

since for vector $x(t)=(x_1(t);x_2(t);....;x_n(t))$ we obtain the system of discretized equations:

$$x(t+1)=Ax(t) \tag{1}$$

is an integral matrix A which elements obey these conditions:

$$0 \le a_{ij} \le 1,\ a_{1j}+a_{2j}+.....+a_{nj}=1,\quad j=\overline{1,n.}$$

Let us study *n* equation solutions (1) $x^1(t), x^2(t),...., x^n(t),$ determined by the next initial conditions:

$$\begin{gathered} x^1(t_0)=x_0^1=(x_{11}^0;x_{21}^0;...;x_{n1}^0), \\ x^2(t_0)=x_0^2=(x_{12}^0;x_{22}^0;...;x_{n2}^0), \\ x^n(t_0)=x_0^n=(x_{1n}^0;x_{2n}^0;...;x_{nn}^0). \end{gathered} \tag{2}$$

The sum of solutions $x^1(t), x^2(t),...., x^n(t)$ of equation (1), which obey conditions (2), are called fundamental system of solutions if the determinant does not equal zero:

$$|X(t_0)|=\begin{vmatrix} x_{11}^0 & x_{12}^0 & \cdots & x_{1n}^0 \\ x_{21}^0 & x_{22}^0 & \cdots & x_{2n}^0 \\ \cdots & \cdots & \cdots & \cdots \\ x_{n1}^0 & x_{n2}^0 & \cdots & x_{nn}^0 \end{vmatrix} \neq 0.$$

If $x^1(t), x^2(t),...., x^n(t)$ is a fundamental system of solutions of equation (1), then any solution $\bar{x}(t)$ of rhis equation can be presented as:

$$\bar{x}(t)=C_1x^1(t)+C_2x^2(t)+...+C_nx^n(t),$$

where $C_1, C_2,...., C_n$ - constants.

Let us apply the system of linear homogeneous difference equations with fixed factors:

$$\begin{cases} x_1(t+1)=a_{11}x_1(t)+a_{12}x_2(t)+.....+a_{1n}x_n(t), \\ x_2(t+1)=a_{21}x_1(t)+a_{22}x_2(t)+.....+a_{2n}x_n(t), \\ ..... \\ x_n(t+1)=a_{n1}x_1(t)+a_{n2}x_2(t)+.....+a_{nn}x_n(t), \end{cases} \tag{3}$$

where $a_{ji}, i, j=1,n,$ - real constants.

System solution (3) will be obtained in the form:

$$x_1 = \gamma_1 \lambda^t, x_2 = \gamma_2 \lambda^t, ..., x_n = \gamma_n \lambda^t, \lambda \neq 0, \quad (4)$$

where $\gamma_1, \gamma_2, ..., \gamma_n$ and γ - numbers, which have to be determined.

Let us substitute expression (4) into system (3) after reduction of λ^t and obtain:

$$\begin{cases} (a_{11} - \lambda)\gamma_1 + a_{12}\gamma_2 + ... + a_{1n}\gamma_n = 0 \\ (a_{21} - \lambda)\gamma_1 + a_{22}\gamma_2 + ... + a_{2n}\gamma_n = 0 \\ ..... \\ (a_{n1} - \lambda)\gamma_1 + a_{n2}\gamma_2 + ... + a_{nn}\gamma_n = 0 \end{cases} \quad (5)$$

System (5) has zero solution if its determinant equals zero, which is necessary and sufficient:

$$\begin{vmatrix} a_{11} - \lambda & a_{12} & ... & a_{12} \\ a_{21} & a_{22} - \lambda & ... & a_{2n} \\ ..... & & & \\ a_{n1} & a_{n2} & ... & a_{nn} - \lambda \end{vmatrix} = 0. \quad (6)$$

Equation (6) is called characteristical for system (3).

To plan UTC future development based on its residents distribution between settlements it is necessary to study vector behavior $x(t)$ when $t \to \infty$. To do this, we need to look for a complementary solution to the system (1).

Let us consider the case when UTC comprises three settlements, that is n = 3.

We assume that $a_{21} = \alpha_1, \quad a_{31} = \alpha_2, \quad a_{12} = \beta_1, \quad a_{32} = \beta_2, \quad a_{13} = \beta_1, \quad a_{23} = \beta_3.$

Then matrix A will be:

$$A = \begin{pmatrix} 1 - \alpha_1 - \alpha_2 & \beta_1 & \beta_1 \\ \alpha_1 & 1 - \beta - \beta_2 & \beta_3 \\ \alpha_2 & \beta_2 & 1 - \beta_1 - \beta_3 \end{pmatrix}.$$

We obtain for system (1) with the matrix A complementary solution.

Characteristical numbers of matrix A are found from the equation

$$\begin{vmatrix} 1-\alpha_1-\alpha_2-\lambda & \beta_1 & \beta_1 \\ \alpha_1 & 1-\beta_1-\beta_2-\lambda & \beta_3 \\ \alpha_2 & \beta_2 & 1-\beta_1-\beta_3-\lambda \end{vmatrix} = 0,$$

or

$$(1-\lambda-\alpha_1-\alpha_2)(1-\lambda-\beta_1-\beta_2)(1-\lambda-\beta_1-\beta_3)+$$
$$+\alpha_1\beta_2\beta_1+\beta_1\beta_3\alpha_2-(1-\lambda-\beta_1-\beta_2)\alpha_2\beta_1-$$
$$-(1-\lambda-\alpha_1-\alpha_2)\beta_2\beta_3-(1-\lambda-\beta_1-\beta_3)\alpha_1\beta_1=0.$$

The last equation can be written as

$$(1-\lambda)^3-(1-\lambda)^2-(\alpha_1+\alpha_2+2\beta_1+\beta_2+\beta_3)+$$
$$+(1-\lambda)((\alpha_1+\alpha_2)(\beta_1+\beta_2)+(\alpha_1+\alpha_2)(\beta_1+\beta_3)+)$$
$$+(\beta_1+\beta_2)(\beta_1+\beta_3)-\alpha_2\beta_1-\beta_2\beta_3-\alpha_1\beta_1=0.$$

The we obtain $\lambda_1=1$, *a* the other two roots are from equation $(\lambda-1)^2+(\lambda-1)(\alpha_1+\alpha_2+2\beta_1+\beta_2+\beta_3)+(\alpha_1+\alpha_2+\beta_1)(\beta_1+\beta_2+\beta_3)=0$

These roots are $\lambda=1-\alpha_1-\alpha_2-\beta_1$ і $\lambda_3=1-\beta_1-\beta_2-\beta_3$. We build system for each root (5). When $\lambda_1=1$ it is

$$\begin{cases} (-\alpha_1-\alpha_2)\gamma_1+\beta_1\gamma_2+\beta_1\gamma_3=0, \\ \alpha_1\gamma_1-(\beta_1+\beta_2)\gamma_2+\beta_3\gamma_3=0, \\ \{\alpha_2\gamma_1+\beta_2\gamma_2-(\beta_1+\beta_3)\gamma_3=0. \end{cases}$$

Subtracting from the second equation of the system multiplied by α_2, third equation, multiplied by α_1, we obtain:

$$(-\alpha_2\beta_1-\alpha_2\beta_2-\alpha_1\beta_2)\gamma_2+(\alpha_2\beta_3+\alpha_1\beta_3+\alpha_1\beta_1)\gamma_3=0.$$

We think that $\gamma_3=\alpha_2\beta_1+\alpha_2\beta_2+\alpha_1\beta_2$,we have: $\gamma_2=\alpha_2\beta_3+\alpha_1\beta_3+\alpha_1\beta_1$. We substitute these values γ_2 and γ_3 to the first equation of the system and obtain: $\gamma_1=\beta_1\beta_2+\beta_1^2+\beta_1\beta_3$.

Substituting system (5) $\lambda_2=1-\alpha_1-\alpha_2-\beta_1$, we have:

$$\begin{cases} \beta_1\gamma_1+\beta_1\gamma_2+\beta_1\gamma_3=0, \\ \alpha_1\gamma_1+(\alpha_1+\alpha_2-\beta_2)\gamma_2+\beta_3\gamma_3=0, \\ \alpha_2\gamma_1+\beta_2\gamma_2+(\alpha_1+\alpha_2-\beta_3)\gamma_3=0. \end{cases}$$

Multiplying the second equation of the system by α_2, and the third by α_1 and subtracting the obtained equation, we have:

$$\left(-\alpha_1\beta_2 + \alpha_1\alpha_2 + \alpha_2^2 - \beta_2\alpha_2\right)\gamma_2 + \left(\beta_3\alpha_1 - \alpha_1^2 - \alpha_1\alpha_2 + \beta_3\alpha_2\right)\lambda_3 = 0,$$

then if $\gamma_2 = \alpha_1^2 - \alpha_1\beta_3 + \alpha_1\alpha_2 - \alpha_2\beta_3,$ we obtain:

$$\gamma_3 = \alpha_1\alpha_2 - \alpha_1\beta_2 + \alpha_2^2 - \beta_2\alpha_2.$$

Then

$$\gamma_1 = (\alpha_1 + \alpha_2)(\beta_3 + \beta_2 - \alpha_1 - \alpha_2).$$

For $\lambda_3 = 1 - \beta_1 - \beta_2 - \beta_3$ we have:

$$\begin{cases} \left(-\alpha_1 - \alpha_2 + \beta_1 + \beta_2 + \beta_3\right)\gamma_1 + \beta_1\gamma_2 + \beta_1\gamma_3 = 0. \\ \alpha_1\gamma_1 + \beta_3\gamma_2 + \beta_3\gamma_3 = 0. \\ \alpha_2\gamma_1 + \beta_2\gamma_2 + \beta_2\gamma_2 = 0. \end{cases}$$

After multiplication of the second equation by α_2 , and the third by α_1 and subtracting we obtain: $(\beta_3\alpha_2 - \alpha_1\beta_2)\gamma_2 + (\alpha_2\beta_3 - \alpha_1\beta_2)\gamma_3 = 0.$

We consider that $\gamma_2 = \alpha_2\beta_3 - \alpha_1\beta_2,$ then we have:

$$\gamma_3 = \alpha_1\beta_2 - \beta_3\alpha_2.$$

Obtain from the first equation: $\gamma_1 = 0$

The fundamental system of solution is presented as: for $\lambda_1 = 1$

$$\begin{cases} x_{11} = \beta_1\beta_2 + \beta_1^2 + \beta_1\beta_3, \\ x_{21} = \alpha_2\beta_3 + \alpha_1\beta_3 + \alpha_1\beta_1, \\ x_{31} = \alpha_2\beta_1 + \alpha_2\beta_2 + \alpha_1\beta_2; \end{cases}$$

for $\lambda_2 = 1 - \alpha_1 - \alpha_2 - \beta_1$

$$\begin{cases} x_{12} = (\alpha_1 + \alpha_2)(\beta_3 + \beta_2 - \alpha_1 - \alpha_2)(1 - \alpha_1 - \alpha_2 - \beta_1)^t, \\ x_{22} = \left(\alpha_1^2 - \alpha_1\beta_3 + \alpha_1\alpha_2 - \alpha_2\beta_3\right)(1 - \alpha_1 - \alpha_2 - \beta_1)^t, \\ x_{32} = \left(\alpha_1\alpha_2 - \alpha_1\beta_2 + \alpha_2^2 - \beta_2\alpha_2\right)(1 - \alpha_1 - \alpha_2 - \beta_1)^t; \end{cases}$$

for $\lambda_3 = 1 - \beta_1 - \beta_2 - \beta_3$

$$x_{13} = 0,$$

$$x_{23} = (\alpha_2\beta_3 - \alpha_1\beta_2)(1 - \beta_1 - \beta_2 - \beta_3)^t,$$

$$x_{33} = (\alpha_1\beta_2 - \beta_3\alpha_2)(1-\beta_1-\beta_2-\beta_3)^t.$$

Complementary system solution is:

$$x_1 = C_1(\beta_1\beta_2 + \beta_1^2 + \beta_1\beta_3) + C_2(\alpha_1+\alpha_2)(\beta_3+\beta_2-\alpha_1-\alpha_2)(1-\alpha_1-\alpha_2-\beta_1)^t,$$

$$x_2 = C_1(\alpha_2\beta_3 + \alpha_1\beta_3 + \alpha_1\beta_1) + C_2(\alpha_1^2 - \alpha_1\beta_3 + \alpha_1\alpha_2 - \alpha_2\beta_3)^t +$$

$$+ C_3(\alpha_2\beta_3 - \alpha_1\beta_2)(1-\beta_1-\beta_2-\beta_3)^t.$$

$$x_3 = C_1(\alpha_2\beta_1 + \alpha_2\beta_2 + \alpha_1\beta_2) + C_2(\alpha_1\alpha_2 - \alpha_1\beta_2 + \alpha_2^2 - \beta_2\alpha_2)(1-\alpha_1-\alpha_2-\beta_1)^t +$$

$$+ C_3(\alpha_1\beta_2 - \beta_3\alpha_2)(1-\beta_1-\beta_2-\beta_3)^t$$

Therefore, based on these equations, it is possible to calculate population size at certain time intervals (the beginning t = 0). Taking into account the expected (planned) changes in each settlement`s population size in UTC territory, it is possible to distribute planned expenditure for providing public goods.

This allows to form the financial revenue distribution models that make up UTCs budgets and to take into account in territorial development strategies and projects such components as: budget revenue dynamics, territorial peculiarities and development determinants, employment rates and migration capacity.

The decentralization process has intensely started since 2015. During the initial stage separate territorial communities were organized, which started the integration process to form UTCs during 2016-2017. Unfortunately, the deceleration of the UTCs formation started in 2017 due to the inefficient regulation of UTCs consolidation. Intensification of decentralization process started only in 2018. It is found impossible to illustrate practical facets of the model in retrospect, which stems from: population size data is out-of-date as the last population census was held in 2001 n Ukraine; official statistics does not take into account circular (short-term) migration inside one country, its regions and certain settlements; population registration in Ukraine includes not the residence but the registration place, which sometimes do not coincide. Total public goods cannot be accurately estimated as actual consumption data is approximate, expert one. As the first stage of reforms is finished by the end of 2019, the purpose of our study was to build economic and mathematical model of financial resource management for public

goods provision during the next phase of reforms. By now the decision to improve decentralization reform frame has been made. The accent is transferred from basic to sub-regional level aimed at UTCs and regions consolidation, considerable reduction in their number. The model proposed by us was built just for the second phase of reforms, which have to be intensified in Ukraine by 2020. Thus, the main tasks of UTCs formation in the nearest future are setting of ration measures and sustainability of territories development. To do this we propose economic and mathematical modelling of UTC formation in certain territorial measures.

Assume that in system (1) matrix A is

$$A=\begin{pmatrix} 0,4 & 0,1 & 0,1 \\ 0,4 & 0,8 & 0,3 \\ 0,2 & 0,1 & 0,6 \end{pmatrix}$$

Let us find the law of population distribution in three settlements for this case.

Characteristical equation is

$$\begin{vmatrix} 0,4-\lambda & 0,1 & 0,1 \\ 0,4 & 0,8-\lambda & 0,3 \\ 0,2 & 0,1 & 0,6-\lambda \end{vmatrix}=0$$

or $\lambda^3-1,8\lambda+0,95\lambda-0,15=0.$ Its roots are $\lambda_1=1,\ \lambda_2=0,3,\ \lambda_3=0,5.$

For $\lambda_1=1$ we have the system (5):

$$\begin{cases} -0,6\gamma_1+0,1\gamma_2+0,1\gamma_3=0, \\ 0,4\gamma_1-0,2\gamma_2+0,3\gamma_3=0, \\ 0,2\gamma_1+0,1\gamma_2-0,4\gamma_3=0, \end{cases}$$

Then $\gamma_1=0,5,\quad \gamma_2=2,2,\quad \gamma_3=0,8.$

For $\lambda_2=0,3$ from system

$$\begin{cases} 0,1\gamma_1+0,1\gamma_2+0,1\gamma_3=0 \\ 0,4\gamma_1+0,5\gamma_2+0,3\gamma_3=0 \\ 0,2\gamma_1+0,1\gamma_2+0,3\gamma_3=0 \end{cases}$$

obtain: $\gamma_1=-2,\quad \gamma_2=1,\quad \gamma_3=1.$

System

$$\begin{cases} -0,1\gamma_1 + 0,1\gamma_2 + 0,1\gamma_3 = 0, \\ 0,4\gamma_1 + 0,3\gamma_2 + 0,3\gamma_3 = 0, \\ 0,2\gamma_1 + 0,1\gamma_2 + 0,1\gamma_3 = 0, \end{cases}$$

If $\lambda_3 = 0,5$, we obtain the following solution: $\gamma_1 = 0$, $\gamma_2 = 1, \gamma_3 = -1$.

Fundamental system of solution is the following:

For $\lambda_1 = 1$

$$\chi_{11} = 0,5,\ \chi_{21} = 2,2,\ \chi_{31} = 0,8;$$

for $\lambda_2 = 0,3$

$$\chi_{12} = -2(0,3)^t,\ \chi_{22} = (0,3)^t,\ \chi_{32} = (0,3)^t;$$

for $\lambda_3 = 0,5$

$$\chi_{13} = 0,\ \chi_{23} = (0,5)^t,\ \chi_{33} = -(0,5)^t.$$

Thus, we obtain:

$$\chi_1(t) = 0,5C_1 - 2C_2(0,3)^t,$$

$$\chi_2(t) = 2,2C_1 + C_2(0,3)^t + C_3(0,5)^t,$$

$$\chi_3(t) = 0,8C_1 + C_2(0,3)^t - C_3(0,5)^t.$$

This is complementary solution of this model.

Thus the obtained equations describe the dynamics of the population size changes in three settlements of UTCs and can be used for UTCs financial resource distribution planning aimed at certain settlements development.

We believe that there is another problem with the inefficiency of allocating both of UTCs budget expenditures to individual settlements and consideration of external migration, above all - labour migration outside the country. In regions with significant external labour migration (emigration), the actual population size does not always coincide with that taken into account by CEC when setting a UTC. It is also not possible to take into account the current system of expenditures and other financial resources (subsidies) distribution from the State budget.

Therefore, there is a need to build a mechanism for fair distribution of UTCs budget.

There is experience in solving this problem. Thus, in the EU, there is a principle of harmonious development, enshrined in the Treaty on the Functioning of the EU. It means distribution of the majority of budget to less developed territories. This approach, in our opinion, poses threat of these settlements affiliation with UTCs or the emergence of communities that would prefer subsidized development instead of creating conditions for their own financial capacity.

Another opposite approach is economic liberalism. It provides dependency of budget expenditures on each participant contribution. The negative experience with this approach is already known in the USA. Due to the threat of social injustice, there are already more and more municipalities separating the rest of the territory, along with the richest districts and, accordingly, their incomes, leaving a gap in the financing of total expenditures. However, this approach will encourage communities to seek new opportunities to earn money.

That is why, it is advisable to use differential approach for the formation of budget expenditures, taking into account their peculiarities based on social justice principles for UTCs` population.

We consider that it is possible to take into account the mentioned shortcomings in distribution of resources between UTCs settlements applying equation of the economic growth model by R. Solow.

We consider that the neoclassical R. Solow model could be used to solve the problem. Set of determinants causes the model`s application as the basis for fair mechanism for income generation and distribution among UTC residents. First, within the Solow model, mechanisms of economic growth flat-rates have been found out, which is the key to UTCs sustainable development. Second, the Solow model was developed for a closed economy in which domestic investment equals domestic savings and there is no international trade. In our opinion, economic conditions for UTC functioning can be considered equal to a closed economy. This conclusion is based on the fact that the main task of decentralization is to create financially viable, self-sufficient communities, so their financial capacity should be

formed similarly to the closed economy – mainly from their own sources and available resources. Third, the Solow model reveals the mechanism of savings`, investment`s and population growth`s impact on living standards and the dynamics, which fully meets the task set by us. Fourth, capital accumulation is a key element of neoclassical Solow growth model, which is important for UTCs. Moreover, the neoclassical approach is radically different from the New Keynesian one. The model uses the Cobb–Douglas production function, in which the factors of production are non-substitutable, which is considered as a disadvantage of the model. Taking into account the task to ensure fair income distribution between UTC settlements based on the actual population, the factors of capital and population are not non-substitutable, they must be coherent.

It looks as follows:

$$\dot{k} = lf(k) - (\alpha + \beta)k \tag{7}$$

Let us find the solution of R. Solow model equation for Cobb-Douglas macroeconomic production function:

$F(K,L) = K^a L^{1-a}, 0 < a < 1$

Let $Y = F(K,L)$ be total UTC income, that is own income, infrastructure subsidy and basic / reverse subsidy.

F – homogeneous first-order production function described by equation:

$F(tK, tL) = tF(K, L)$

where K – UTC income;

L – UTC population.

Let us introduce index $k = K/L$, which is equal to UTC own income to UTC total population ratio, so we have index of own income per capita for UTC.

Then capital productivity is:

$$f(k) = \frac{F(K,L)}{L} = F(k,l). \tag{8}$$

We assume that we have a natural increase in UTC population over period of time:

$$\dot{L} = \alpha L \tag{9}$$

where α - coefficient (growth rate)of UTC population.

UTC investments (capital expenditures) are used to increase own resources (income) and depreciation of fixed capital, i.e

$I = \dot{K} + \beta K$, where β - depreciation rate (share of capital expenditures).

Then if l – rate of investment, then

$I = lY = \dot{K} + \beta K$,

or

$$\dot{K} = lF(K, L) - \beta K \tag{10}$$

According to the own income per capita definition *k*, we have $lnk = lnK - lnL$. We differentiate this equation by *t*, and obtain:

$$\frac{\dot{k}}{k} = \frac{\dot{K}}{K} - \frac{\dot{L}}{L}.$$

We substitute into the last ratio equations (9) and (10) and obtain the equation of unknown function *k* having the form (8), where function *f(k)* is defined by formula (7). This first-order nonlinear differential equation to own income per capita has simple economic interpretation: net own income increment is the difference between gross own income and steady-state own income.

Equations of R. Solow model for Cobb-Douglas production function take into account

$$F(K, L) = \frac{K^a L^{1-a}}{L} = \left(\frac{K}{L}\right)^a = k,$$

are as follows:

$$\dot{k} = l k^a - (\alpha + \beta)k, 0 < a < 1 \tag{11}$$

We integrate the Bernoulli equation by the substitution method.

Let $k = uv$. Then

$\dot{k} = \dot{u}v + \dot{v}u$

equation (11) we set as:

$\dot{u}v + \dot{v}u = l(uv)^a - (\alpha + \beta)uv$

or

$$\dot{u}v + u(\dot{v} + (\alpha + \beta)v) = l\,u^a v^a \qquad (12)$$

Taking into account that one of the unknown functions, such as *v*, can be arbitrarily chosen (because only derivative *uv* must meet original equation), we take any partial equation solutions for *v*

$\dot{v} + (\alpha + \beta)v) = 0$, which turns to zero coefficient of *u* in equation (12).

Obtain:

$\frac{dv}{dt} = -(\alpha + \beta)v$.

After integration, we get: $\ln|v| = -(\alpha + \beta)v$ or $v = e^{-(\alpha+\beta)t}$ (we do not introduce continuous integration because only a partial solution of the auxiliary equation is required). To calculate u we have equations

$\dot{u}v = l\,u^a v^a$

or

$\dot{u}\,e^{-(\alpha+\beta)t} = l\,u^a e^{-a(\alpha+\beta)t}$.

We divide variables and obtain:

$\frac{du}{u^a} = l\,e^{(\alpha+\beta)(1-a)t}\,dt$,

then

$\frac{u^{-a+1}}{1-a} = l\,\frac{1}{(1+a)(\alpha+\beta)}\,e^{(\alpha+\beta)(1-a)t} + \frac{C}{1-a}$

or

$u = (\frac{l}{(\alpha+\beta)}\,e^{(\alpha+\beta)(1-a)t} + C)^{\frac{1}{1-a}}$.

Then

$k = (\frac{l}{(\alpha+\beta)}\,e^{(\alpha+\beta)(1-a)t} + C)^{\frac{1}{1-a}}\,e^{-(\alpha+\beta)t} =$

$$= (\frac{l}{(\alpha+\beta)} + C\,e^{-(1-a)(\alpha+\beta)t})^{\frac{1}{1-a}}.$$

When t$\to\infty$, own income per capita is:

$$k \to (\frac{l}{(\alpha+\beta)})^{(1-a)^{-1}}.$$

Thus, we have proposed the model that simultaneously take into account the capital expenditures growth rate and changes in population, if UTC per capita income and gross income rise. If necessary, it is advisable to build this function for average UTC indices, and then to determine the expenditures for each UTC`s settlement taking into account its change in population in case its per capita income meets UTC average.

Similar calculations can be further made within the region to assess the level of financial autonomy of both UTC and region in general. Comparison of regional indicators (in terms of districts) will allow to estimate the level of sustainable development of a territory (region). It will also make it possible to compare these parameters between different regions.

The paper analyzes the effectiveness of intergovernmental relations and income distribution system within united territorial communities in the context of inequalities and imbalances as a threat to sustainable development of territories and the country.

The analysis fiscal equalization system introduced in 2014 instead of income and expenditures balancing system made it possible to conclude that the current system is also not without drawbacks. The main ones are: a reverse subsidy determined by personal income tax negatively affects UTCs financial position, since PIT is the main source of community income. It has been proposed to determine the maximum allowable limits of reverse subsidy correlated to per capita income growth rate of UTCs. A so-called soft model, in the form of a logistic curve, has been proposed to describe the dynamics of UTCs own income. Secure limits of external impact, such as a reverse subsidy, on UTCs financial position have been determined.

It has been proved that current mechanism of intergovernmental budget regulation causes inequality of UTCs development because funds in the form of reverse subsidies are being withdrawn from self-sufficient, financially capable communities. Nevertheless, there are UTCs in Ukraine that have been receiving a basic subsidy for a long time, which does not encourage them to support their self-sufficiency. Implementation of this mechanism creates imbalances in regional development funding.

Current system of united territorial communities` expenditures, which includes financing of education, culture, health care, social protection, utilities, infrastructure development have been analysed in the study. It has been shown that current legal framework regarding united territorial communities there are no efficient guarantees of optimal, balanced budget distribution between UTCs settlements - members.

Distribution issues have been identified, namely: UTCs include settlements with different population size, different per capita income; there is volatility of population caused by migration processes of different duration. Therefore, the need to build mechanism for efficient UTCs budget distribution based on the real needs and capabilities of communities has been proved. Foreign experience does not have effective mechanisms for budgets expenditures distribution, especially when we take into account Ukrainian specifics. Different UTCs can be dramatically different in terms of their capability and potential, even in one administrative region. Therefore, distribution of communities` financial resources should be as efficient as possible and independent of shortsighted decision-making.

To overcome existing disparities in UTCs budget expenditures distribution, it has been proposed to apply economic and mathematical model based on the first-order differential equation, which allows to take into account simultaneously the dynamics of UTC per capita income and its population change.

Application of the proposed models has practical significance as it provides opportunity to increase public policy efficiency to affect inequalities and

imbalances as a principle for harmonious development of the country and its territories.

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