Economic and mathematical modeling of ecological expenditure for sustainable development of united territorial communities

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SUMMARY

The paper has been proved that the current system of local finances` management does not support their sustainable development and does not introduce viable mechanisms for the effective expenditure ecological distribution inside united territorial communities (UTCs) between the settlements within them.

The following arguments have been shown: UTCs include settlements characterized by different population size and income per capita.

Due to migration processes the population size is unstable. 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.

It has been proposed to calculate the population size at certain time intervals, taking into account the expected (planned) changes of each settlement` s population within UTCs and to distribute programmed ecological expenditure within territories` sustainable development capacity.

Introduction

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. Therefore, there is a need for a balanced environmental policy in a decentralized environment.

The main task of the study is to simulate the system for united territorial communities (UTCs) expenditure ecological distribution management among settlements that comprise them, in order to create the mechanism that will ensure social justice and harmonious development.

Method

In the analysis, general-scientific methods (analysis and synthesis, induction and deduction) and special methods of phenomena and processes analysis (abstraction, econometric and econometric-mathematical modelling) have been used.

Results

Our analysis prove that the current mechanism of redistributive environmental taxation for the territories allows only certain united territorial communities (UTCs) to have the opportunity to receive their share of the tax (those having polluting companies registered on their territories).

Next problem – in Ukraine 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 in ecological sphere 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.

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.

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.

It looks as follows: $\dot{k} = lf(k) - (\alpha + \beta)k$. (1)

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:

$$f(k) = \frac{F(K, L)}{L} = F(k, l) \cdot \qquad (2)$$

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

$$\dot{L} = \alpha L, \qquad (3)$$

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

$$I = lY = \dot{K} + \beta K \text{, or } \dot{K} = lF(K, L) - \beta K \qquad (4)$$

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 (3) and (4) and obtain the equation of unknown function k having the form (2), where function f(k) is defined by formula (1). 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 $F(K, L) = \frac{K^a L^{1-a}}{L} = (\frac{K}{L})^a = k$,

are as follows: $\dot{k} = l\, k^a - (\alpha + \beta)k, 0 < a < 1$ (5)

We integrate the Bernoulli equation by the substitution method.

Let k = uv. Then $\dot{k} = \dot{u}\, v + \dot{v}\, u$ equation (5) we set as: $\dot{u}\, v + \dot{v}\, u = l\,(uv)^a - (\alpha + \beta)uv$

Or $\dot{u}\, v + u(\dot{v} + (\alpha + \beta)v) = l\, u^a\, v^a$ (6)

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 (6).

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→∝, 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.

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:

$$x(t+1) = Ax(t) \tag{7}$$

is an integral matrix A which elements obey these conditions:

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

Let us study n equation solutions (7) $x^1(t), x^2(t), ..., x^n(t)$, determined by the next initial conditions:

$$\begin{aligned} x^1(t_0) &= x_0^1 = (x_{11}^0; x_{21}^0; ...; x_{n1}^0), \\ x^2(t_0) &= x_0^2 = (x_{12}^0; x_{22}^0; ...; x_{n2}^0), \\ x^n(t_0) &= x_0^n = (x_{1n}^0; x_{2n}^0; ...; x_{nn}^0). \end{aligned} \tag{8}$$

The sum of solutions $x^1(t), x^2(t), ..., x^n(t)$ of equation (1), which obey conditions (8), 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:

$$\bar{x}(t) = C_1 x^1(t) + C_2 x^2(t) + ... + C_n x^n(t),$$

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

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

$$\begin{cases} x_1(t+1) = a_{11} x_1(t) + a_{12} x_2(t) + ... + a_{1n} x_n(t), \\ x_2(t+1) = a_{21} x_1(t) + a_{22} x_2(t) + ... + a_{2n} x_n(t), \\ .... \\ x_n(t+1) = a_{n1} x_1(t) + a_{n2} x_2(t) + ... + a_{nn} x_n(t), \end{cases} \qquad (9)$$

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

System solution (9) will be obtained in the form:

$$x_1 = \gamma_1 \lambda^t, x_2 = \gamma_2 \lambda^t, ..., x_n = \gamma_n \lambda^t, \lambda \neq 0, \qquad (10)$$

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

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.

Conclusions

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 ecological 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.