Environmental expenditure modelling for sustainable development strategies creation and implementation

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SUMMARY

The level of development of the economic mechanism of regulation and stimulation in environmental management on the basis of nature protection funding indicators has been assessed. The correlation between environmental tax revenues in the budget and the dynamics of environmental protection expenditures has been studied. It has been proved that the dynamics of environmental tax revenue in budget does not coincide with the dynamics of environmental protection expenditures. The necessity of methodological approaches development to substantiate effective lines of national policy implementation in the field of environmental protection, as well as recommendations on their scientific support based on the proposed economic and mathematical model providing the balance between environmental revenues in the budget and environmental protection expenditures has been proved. It has been confirmed that it is possible to achieve environmental policy sustainability both at the national and local level by using differential stabilization, in which government environmental demand management (needs for environmental expenditures or budget environmental protection expenditures) is associated with the rate of change of revenue (budget revenues from environmental tax and other fees).

Introduction

In the context of comprehensive reform in Ukraine, decentralizing governance, public administration reform and regional policy are important. The Strategy for Sustainable Development "Ukraine 2020" contains the list of planned reforms and national development programmes. The document defines key prerequisites for the progressive national economy development, namely the tasks of ensuring sustainable, dynamic economic growth in environmentally friendly and safe way.

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

Territorial development, as well as of branches of the national economy and all economic entities can ensure national sustainable development only if material and spiritual needs of the population are met in accordance with world quality standards, effective application of environmental, economic and natural capacity, its preservation and reproduction. That is why the issue of sustainable development framework design focusing on its environmental component needs theoretical research and practical substantiation. The assessment criterion for the efficiency level of the economic mechanism for environmental management regulation and fostering can indirectly be the indicators of environmental funding. The basic assessment criterion for the environmental expenditures in Ukraine is primarily their share on state expenditure, which during 2006-2009 was 0.91 – 0,98%, during 2010-2014 – 0,67 – 1,11%, during 2015–2017 – 0,75 – 0,81%. Compared to the indicators of 2002 – 2004 (1,2 – 1,3%), there is noticeable contraction of environmental funding. The dynamics of environmental protection expenditures in consolidated budget of Ukraine indicates their annual growth (except for 2014), but the growth rate during 2016 - 2017 slowed down amounting to 113.12% and 117.49%, respectively. The growth rates of expenditures are insignificant, if the inflation impact is offset. That is the sign of environmental expenditures stagnation. The situation is typical for the state budget too. Besides, expenditures in 2017 decreased. As for the local budgets, their growth rates have accelerated since 2015, in 2015 and 2017 they boosted significantly. In our opinion, this is due to the processes of decentralizing governance. There is reason to believe that the established communities have more balanced approach to environmental policy and environmental matters funding.

The study results are presented in Figure 1. Environmental tax rates increased during 2014 – 2018; they were risen on 01.04.2014, 01.01.2016, 01.01.2017 and 01.01.2018. The maxima on the curve of dynamics of environmental tax growth rates correspond to these periods.

As one can see from the figure, the dynamics of environmental tax revenues to the budget do not coincide with the dynamics of environmental protection expenditures budget. It is illogical situation, because according to the analysis, about 75% of the tax is paid to the state budget by big businesses, which discharge pollutants. For instance by metallurgical plants like PJSC " ArcelorMittal Kryvyi Rih ", PJSC " ILYICH IRON AND STEEL WORKS", PJSC " Dneprovsky Integrated Iron&Steel Works named after Dzershinsky ", enterprise of PJSC "Cherkasykhimvolokno", the DTEK Group enterprises and others. Thus, government receives the taxpayers' money and directs it to environmental protection with a delay of at least one year. This indicates the environmental policy`s regulatory imperfections at the national and territorial levels. Unfortunately, in the context of decentralizing governance (since 2015), the situation has not improved, which illustrates low efficiency of the national environmental policy as for its territories. 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). Given this, there is a need to develop methodological approaches to determine the rationale for effective implementation of national environmental policy and recommendations for its scientific support, development of the set of measures for their implementation and improvement of current legal framework. It is clear that precautionary approach application enables significant savings due to even small environmental investments. Continuous investment support of environmental issue requires governmental guarantees of environmental protection expenditures, implementation of regional preventive measures with high environmental risk, support of businesses implementing innovations. We believe that synergetic effect during environmental policy implementation could be achieved, if the dynamics of environmental tax revenues in budgets will coincide with the corresponding dynamics of environmental protection expenditures. Thus, there is a need to build economic-mathematical model that would ensure higher environmental policy efficiency in the country and its regions, including UTCs. To our mind, the model should be based on the possibility of coherence between environmental taxes revenues and environmental protection fees and expenditures. That is, these flows must be balanced. Thus, the need to design territorial communities` expenditure management ecological policy is of particular importance.

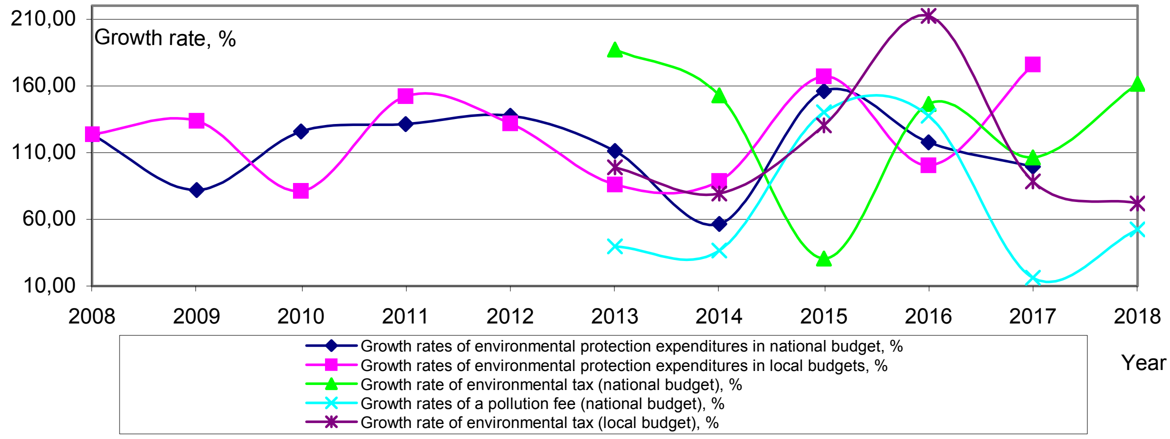

Figure 1 *Growth rates of expenditures in national and local budgets, a pollution fee, environmental tax transferred to national and local budgets*

In our opinion, taking into consideration previous positive experience, the process of policy-making has to be grounded on mathematical tools known as Phillips' stabilization model [4, 5].
Assume as input data three basic options of governmental ecological expenditure policy (витрати на охорону навколишнього середовища) $G^*(t)$:
a) Proportional stabilization policy with government ecological expenditure. In this case, the government ecological expenditure is described by equation:

$$G^*(t) = -\gamma_p \cdot U(t), \tag{1}$$

where $U(t)$ – income, generated by the cumulative money transferred from environmental protection fees and expenditures;
b) Derivative stabilization ecological policy: government ecological expenditure adjustments correlate with the rate of ecological income change (environmental protection fees and expenditures) (the derivative is used). In this case the government ecological expenditure is:

$$G^*(t) = -\gamma_d \cdot \frac{dY}{dt} \cdot \tag{2}$$

c) Integral stabilization ecological policy: government ecological expenditure is proportional to the ecological income deficit generated and accumulated. In this case the government ecological expenditure is:

$$G^*(t) = -\gamma_i \int_0^t U(\tau) \cdot d\tau \,, \tag{3}$$

In all three cases, the coefficients of proportionality $\gamma_p, \gamma_d, \gamma_i$ – are coefficients with given values (coefficients of proportionality). There is difference $G^*(t) - G(t)$, between potential public ecological expenditure $G^*(t)$ and actual $G(t)$, which affects the economic system and should be eliminated for the sake of stabilization. We assume $\beta < 0$ – is a coefficient, which indicates the speed of response to state decision-making (reaction coefficient). Then decisions about state ecological expenditure $G(t)$ are determined as solution of first order linear differential equation:

$$\frac{dG(t)}{dt} + \beta \cdot G(t) = \beta \cdot G^*(t), \tag{4}$$

where $G^*(t)$ is determined by one of the policy options (a – c) or their combination aiming to balance demand and supply of ecological income (екологічні надходження до бюджету та екологічні витрати).

The use of the Phillips model only with the multiplier, without the accelerator, i.e. the coefficient of proportionality of the induced ecological investment to the rate of ecological income change $\frac{dY}{dt}$, aggregated ecological demand $Y_c(t)$, with government ecological expenditure becomes:

$$Y_c(t) = cY(t) + G(t) + C_0 + I_0, \tag{5}$$

where $0 < c < 1$ – propensity to ecological consume; C_0 – ecological consumption; I_0 – autonomous ecological investment.

The supply ecological resources in this case is made of equation:

$$\frac{dY}{dt} = \alpha\left(Y_c(t) - Y(t)\right). \tag{6}$$

We make the mathematical model of economic stabilization ecological policy and calculate its effect. Substituting into equation (6) for $Y_c(t)$ its values from correlation (5), we obtain:

$$\frac{dY}{dt} = -\alpha s Y(t) + \alpha G(t) + \alpha A, \tag{7}$$

where $s = 1 - c$ – propensity to ecological save (rate of accumulation) ($1/s = \mu$ – the Keynesian multiplier); $A = C_0 + I_0$ (investment is const.).

Differentiating (5) we obtain:

$$\frac{dYc}{dt} = c\frac{dY}{dt} + \frac{dG}{dt}. \tag{8}$$

We add equation (8) to equation (5) and multiply the sum by β (reaction coefficient), then we obtain:

$$\frac{dYc}{dt} + \beta Yc = c\frac{dY}{dt} + \beta c Y(t) + \beta G(t) + \beta A \,. \tag{9}$$

Substituting into (8) for $\frac{dG}{dt}$ its value from (4), we obtain:

$$\frac{dY_c}{dt} + \beta Y_c(t) = c\frac{dY}{dt} + \beta c Y(t) + \beta G^*(t) + \beta A \,. \tag{10}$$

From equation (6)

$$Y_c(t) = \frac{1}{\alpha}\left(\frac{dY}{dt} + \alpha Y(t)\right), \tag{11}$$

obtain

$$\frac{dY_c}{dt} = \frac{1}{\alpha}\left(\frac{d^2Y}{dt^2} + \alpha\frac{dY}{dt}\right). \tag{12}$$

Substitute the expressions (11), (12) into the ratio (10):

$$\frac{1}{\alpha}\left(\frac{d^2Y}{dt^2} + \alpha\frac{dY}{dt}\right) + \frac{\beta}{\alpha}\left(\frac{dY}{dt} + \alpha Y(t)\right) = c\frac{dY}{dt}\beta G^*(t) + \beta A \,. \tag{13}$$

or

$$\frac{d^2Y}{dt^2} + (\beta + \alpha s)\frac{dY}{dt} + \alpha\beta_s Y(t) = \beta\alpha G^*(t) + \beta\alpha A \,. \tag{14}$$

Relevant characteristic equation for the equation (14) can be shown to be:

$$\lambda^2 + (\beta + \alpha s)\lambda + \alpha\beta s = 0. \tag{15}$$

And has the roots $\lambda_1 = -\beta$, $\lambda_2 = -\alpha s$.

Thus, general solution of the relevant homogeneous equation becomes:

$$Y^0(t) = C_{1e}^{-\beta_t} + C_{2e}^{-\alpha s t}, \tag{16}$$

where C_1, C_2 – arbitrary constants. We have $Y^0(t) \to 0$ with $t \to \infty$.
We analyze peculiarities of the policy of derivative stability.
Its equation (5) becomes:

$$\frac{d^2Y}{dt^2} + (\beta + \alpha s)\frac{dY}{dt} + \alpha\beta(s + \gamma_p)Y(t) = \alpha\beta A \, . \tag{17}$$

The equation (17) general solution is obtained as $Y(t) = Y^0(t) + Y^*$.
We use trial and error method to find partial solution:

$$Y^* = \frac{A}{s + \gamma_\rho} \, . \tag{18}$$

To find general solution $Y^0(t)$ of the relevant homogeneous equation we make the characteristic equation:

$$\lambda^2 + (\beta + \alpha s)\lambda + \alpha\beta(s + \gamma_\rho) = 0 \, . \tag{19}$$

To find the roots of the equation (19) we find the discriminant:

$$D = (\beta + \alpha s)^2 - 4\alpha\chi(s + \gamma_\rho) = (\beta - \alpha s)^2 - 4\alpha\beta\gamma_\rho \, . \tag{20}$$

If D = 0, then $\gamma_\rho = \frac{(\beta - \alpha s)^2}{4\alpha\beta}$ and $\lambda_1 = \gamma_2 = \frac{\beta + \alpha s}{2}$, where $Y^0(t) = (C_1 t + C_2)e^{\frac{\beta + \alpha s}{2}e}$, C_1, C_2 are arbitrary constants. If $t \to \infty$ we obtain: $Y^0(t) \to 0$ *a* $Y(t) \to Y^* = \frac{A}{s + \gamma_\rho}$, so the development process is being stabilized. If $D < 0$, then $\gamma_\rho > \frac{(\beta - \alpha s)^2}{4\alpha\beta}$, and roots $\lambda_{1,2}$ are complex-conjugate, also oscillations take place. In this case $Y(t) = e - \frac{(\beta + \alpha s)}{2}(C_1 \cos \varphi \, t) + C_2 s \, \alpha \, t)$, and if $t \to \infty$ we obtain: $Y^0(t) \to 0$.

There are damped oscillations and the process is tend to stabilize. Thus, application of differential stabilization policy means that government environmental demand management (needs for environmental expenditures or budget environmental protection expenditures) is associated with the rate of change of revenue (budget revenues from environmental taxes and other fees), i.e. the use of a derivative.

Conclusions

The level of development of the economic mechanism of regulation and stimulation in environmental management on the basis of nature protection funding indicators has been assessed. The analysis of dynamics of total environmental protection expenditure change has been made. The correlation between environmental tax revenues in the budget and the dynamics of environmental protection expenditures has been studied. It has been proved that the dynamics of environmental tax revenue in budget does not coincide with the dynamics of environmental protection expenditures. This indicates the imperfection of environmental policy`s regulatory mechanisms both at the state and territorial level. The necessity of methodological approaches development to substantiate effective lines of national policy implementation in the field of environmental protection, as well as recommendations on their scientific support based on the proposed economic and mathematical model providing the balance between environmental revenues in the budget and environmental protection expenditures has been proved. It has been confirmed that it is possible to achieve environmental policy sustainability both at the national and local level by using differential stabilization, in which government environmental demand management (needs for environmental expenditures or budget environmental protection expenditures) is associated with the rate of change of revenue (budget revenues from environmental tax and other fees).