Economic and Mathematical Model for Optimization for Environmental Fee Payments

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Abstract. The article reviews the main methodological approaches to constructing an economic and mathematical model that would make it possible to optimize environmental fees payable by companies.

The article presents a method of constructing an economic and mathematical model for optimizing environmental fee payments. The main factors of the model are delivery of production targets, evaluation of equipment performance in terms of capacity load, equipment health and utilization efficiency, and environmental pollution. For the purpose of this research problem, the minimization of costs caused by negative environmental impacts is viewed as an optimization criterion.

The application of the proposed economic and mathematical model makes it possible not only to determine differential environmental fee payment limits, but also to compute the optimum structure of production that would generate a permanent income for the company.

The proposed method of environmental and economic analysis can comprehensively solve several problems: that of determining the optimum amount of environmental fees to be paid for natural resources use; an objective assessment of production equipment by volume and type of pollutants; identification of costly pollutants, which should enable the company to reduce its negative environmental impacts and environmental costs.

1. First Section

Economic and mathematical methods are considered to be the most effective way of evaluating current environmental conservation costs. The methods make it possible to address the strategic problem of cutting business costs. One has to bear it in mind that within a certain allowance, fees for the use of natural resources are included in production costs and are therefore recoverable. Companies pay environmental pollution fees exceeding the cap out their profits [6].

In Russian science, the use of mathematical modelling in economics as a tool for assessing production and business operations has been studied by V.S. Nemchinov [17] and M.A. Gataulin [8]. The problem of economic and environmental analysis of production processes has been covered by T.L. Nedorezov [16], M.A. Gonopolsky [10], A.S. Cheshev [4], and G.A. Yanev [20].

However, in the majority of the above studies, fees for the use of natural resources are calculated on the basis of output. The approaches did not take into account the wear and tear of production equipment in use.
2 Method
The article presents a method of estimating the amount of emission fees that takes into account equipment characteristics (on the basis of an economic and mathematical model constructed for the machine building company Amursky Metallist).

The mathematical problem was set with a condition that cost optimization is conducted, ensuring that emission limits are complied with:

\[
\begin{align*}
    &\sum_{j} a_j x_j \leq A_i, \\
    &B^0_{jk} \leq \sum_{j} \beta_{jk} x_j \geq B^1_{jk}, \\
    &\sum_{j} c_j x_j \leq S_i, \\
    &F(x)_{\text{min}} = \sum_{j} f_j x_j,
\end{align*}
\]

where

- \(x_j\) is the target number of units of production equipment \(j\);
- \(a_j\) is the quantity of the emitted pollutant \(i\) from the polluting source \(j\);
- \(\beta_{jk}\) is the manufacturing capability of the equipment \(j\) for the product \(k\);
- \(c_j\) is the production worthiness coefficient of the equipment \(j\);
- \(A_i\) are the standards for permissible emissions of the pollutant \(j\) within the set allowance;
- \(B^0_{jk}, B^1_{jk}\) are the manufacturing capability limits of the production equipment \(j\) for the product \(k\);
- \(S_i\) is the actual number of units of the production equipment \(j\);
- \(f_j\) is the sum total of environmental fees for the polluting source \(j\).

The economic and mathematical model makes it possible to determine the amount of fees for air pollution and identify the most expensive pollutants for the company. The constructed model can be further elaborated by taking into account the specific features of production processes in a company that match its business concept.

3. Results
The economic and mathematical analysis performed by the author shows that the emissions of air pollutants exceed the set standards by an average of 8.8 tonnes depending on the available production equipment. The results of the modeling indicates that the ensuing excess costs could be reduced by 50%, or RUB5.653 thousand purely by optimizing the amount of emissions in line with the set standards provided that production equipment operates at full capacity.

| Indicators                                           | Actual  | Modelled | Growth, % |
|------------------------------------------------------|---------|----------|-----------|
| Pollutant emissions, tonnes                          | 180.74  | 192.44   | 106.5     |
| Total amount of emitted pollutions, tonnes           | 447.67  | 459.37   | 102.6     |
| Current environmental conservation costs, thousand roubles | 495.3   | 495.3    | 100       |
| Environmental fees and charges for the excess use of natural resources, thousand roubles | 11.054  | 5.401    | 48.9      |
| Total costs per tonne of emitted pollutants, thousand roubles | 1.138   | 1.090    | 95.8      |
The economic and mathematical model takes into account the condition of the production equipment provided it operates at full capacity. The cost of polluting emissions is estimated in the course of the problem solving process as a shadow price that shows that airborne emissions of benzpyrene and petroleum products are the "costliest" for Amursky Metallist in terms of minimization of environmental fees.

For example, 1 gram of benzpyrene emissions costs the company RUB143,641, while 1 kg of petroleum products RUB8,678. It has to be also noted that by reducing benzol emissions by 1 kg would enable the company to save RUB4,311; and by cutting manganese emissions by 1 kg it would save RUB2,616. In the course of dual analysis the lowest and highest limits of emissions were calculated within which the sum total of environmental conservation payments would not exceed RUB5,401 thousand.

The obtained shadow prices also make it possible to conclude that the company should consider renewing the following types of equipment in order to reduce environmental pollution and better environmental safety.

For example, an increase in the workload of the blast room would increase environmental fees by RUB34.38; of the electric arc steel-making furnace DSP-1,5 by RUB28.8, of the daily fuel tank by RUB16.44, of the tool grinders by RUB16.47, and of the sand dryer by RUB14.96.

4. Conclusion
The proposed method of environmental and economic analysis can comprehensively solve several problems. First of all, it enables one to determine the optimum amount of environmental fees to be paid for natural resources use. Second, it delivers an objective assessment of production equipment by volume and type of pollutants. Third, it helps identify costly pollutants and assess production equipment from this perspective, thus enabling the company to reduce its negative environmental impacts and environmental conservation payments.

5. References
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