# Optimisation Problems for Planning Structural and Technological Changes

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Some results of the project "Analysis of Institutional and Technological Changes in Market and Transition Economies on the Background of the Present Financial Crisis" will be reported[1].

Input-Output Tables of Leontief, based on the principle of circularity, proved to be an essential tool to analyse economic questions. In the Leontief-type models, the technical coefficients matrix (matrix of direct costs) is supposed to be known and is calculated on the basis of statistical information from the input-output tables. It was M. V. Mikhalevich who formulated the inverse problem: how to determine the structural and technological changes that would reduce the costs of production and thus would increase the incomes of ultimate customers and make the economy more dynamic. Or, in other words, how to select or adjust technical coefficients to improve properties of the economic process. These models of M. V. Mikhalevich ([1]–[3]) can be called inverse models of the Leontief type. Inverse models of the Leontief type form a family of multi-extremal problems, where the elements of the technical coefficients matrix are unknown. These models are formulated in terms of nonlinear programming problems and include two objective functions for maximization: the ultimate incomes of consumers and the multiplier "increase of incomes – increase of production". Constraints of the models describe the conditions of non-inflationary growth of incomes and limited resources, availiable to the conduct of structural and technological transformations, and also condition of nonnegativity of new coefficients.

Let an economy contain $N$ pure industries manufacturing only one type of products; $i, j = \overline{1,N}$ be the numbers of these branches. Denote by $a_{ij}$ the value of direct production costs of the branch $i$ for manufacturing a unit of production of the branch $j$. This quantity can be expressed in both natural and cost measures depending on the information avaliable. The matrix $A = \{a_{ij}\}_{i,j=\overline{1,N}}$ is a matrix of the coefficients of direct costs. Denote by $q_i$ the share of ultimate incomes (payment for labor, social transfers, and profit) in the price of the production of the branch $i$, and vector $q = \{q_i\}_{i=\overline{1,N}}$. Possible changes of existing components of matrix $A$ and vector $q$ are denoted as $\Delta A = \{\Delta a_{ij}\}_{i,j=\overline{1,N}}$ and $\Delta q = \{\Delta q_i\}_{i=\overline{1,N}}$ respectively.

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We have to find such changes $\Delta A$ for the matrix $A$ and such changes $\Delta q$ for the vector $q$ that maximize consumer incomes and the multiplicator "increase of incomes – increase of production". So, two optimization problems are considered:

$$f_1(\Delta A, \Delta q) = \frac{(q+\Delta q)^T (E-(A+\Delta A))^{-1} h}{1-(q+\Delta q)^T (E-(A+\Delta A))^{-1}\alpha} \to \max \qquad (1)$$

$$f_2(\Delta A, \Delta q) = (q+\Delta q)^T (E-(A+\Delta A))^{-1}\alpha \to \max \qquad (2)$$

where $E$ is an identity $(N \times N)$ matrix, and $T$ means transposition. The goal function $f_1(\Delta A, \Delta q)$ corresponds to the consumer's incomes, and the goal function $f_2(\Delta A, \Delta q)$ is a multiplicator "increase of incomes – increase of production". Elements of the vectors $\alpha$ and $h$ are defined by the structure of individual consumption and the export-import balance of the branches.

The following constraints should be included into the model: the constraints that exclude the intensification of the inflation of costs; the relationships that follow from the physical meaning of the coefficients $a_{ij}$ and $q_j$; the balance of the expenses and added cost; constraints for the possible ranges of variation of the coefficients due to specific features of the technologies available; the resource constraints.

This provides tools for analysis of input-output data and integrated into the program, which is designed as open menu-driven software available for Windows. Developed software MiSTC (Mikhalevich Structural and Technological Changes) uses Lapack++ and Qt libraries and requires no special user's computer training. Numerical optimization procedures are based on Shor's $r$-algorithm [4] and its modern realizations. Other important features of the system – modularity and extensibility – facilitates quick adaptation to special user's requirements. In more details these results of the project were published in the books [3], pp. 123–129 and [5], pp. 96–110.

## References


[1] Sergienko, I.V., Mikhalevich, M.V., Stetsyuk, P.I., Koshlai, L.B., *Interindustry model of planned technological-structural changes*, Cybern. Syst. Anal. 34(3), 319-330 (1998).

[2] Sergienko, I.V., Mikhalevich, M.V., Stetsyuk, P.I., Koshlai, L.B., *Models and information technologies for decision support during structural and technological changes.* Cybern. Syst. Anal. 45(2), 187-203 (2009).

[3] Sergienko, I. V., Mikhalevich, M. V., Koshlai, L. B., *Optimization Models in a Transitional Economy.* – Springer: Optimization and its Application, Vol. 101, VIII, 334 p. (2014).

[4] Shor, N. Z., *Minimization Methods for Non-Differentiable Functions*, Springer-Verlag, Berlin, 199 p. (1985).

[5] Stetsyuk, P. (Ed.), Bortis, H., Emmenegger, J.-F., Koshlai, L., Beresovskyi, O., Bardadym, T., Pervukhina, E., Golikova, V., Osipov, K., Karpets E., Pylypovskyi, O., *Institutional and Technological Changes in Market and Transitional Economies*, Publishing House "Kyiv Mohyla Academy", Kyiv, 336 p. (2015) (In Russian), http://www.icyb.kiev.ua/file/120/books/Stetsyuk-Editor-2015.pdf