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Experiments with the Penalty Scalarizing Function for Nonlinear Multiobjective Optimization Problem.

by

WITOLD CHMIELARZ
KRZYSZTOF CICHOCKI
ANDRZEJ STACHURSKI

Systems Research Institute
Polish Academy of Sciences
ul. Newelska 6
01-447 Warszawa, Poland

The paper presents the possible usefulness of optimization methods in the process of computer-aided decision-making and demonstrates results of computational experiments with a multicriteria model of national economy. The computer procedure which finds Pareto-optimal solutions of the model subject to given values of reference objectives is described. The method of penalty scalarizing function is used for this purpose. The results of computational experiments with this procedure are presented. Various Pareto-optimal solutions for different reference objectives are obtained.

1. Introduction

The aim of this paper is to present possible usefulness of optimization methods in the process of computer-aided decision-making and to demonstrate results of computational experiments with a multicriteria model of national economy.

The polioptimal, dynamic, national economy model formulated in [2] is investigated. It is a revised version of the model originally presented in [3]. It could be applied for analysis of the consequences of various economic decisions.

The model is to be used by a decision-maker. He usually has various goals, which often can not be achieved simultaneously. Thus, one should look for a compromise solution. The solution is obtained based on the methodology proposed by Wierzbicki [10] (see also March and Simon [5]). The decision-maker selects the appropriate solution by analysing various Pareto-optimal solutions. The Pareto-optimal solutions can be obtained by the method of minimization of scalarizing functions which depend on the aspiration levels of the decision-maker. Elaboration of the model which could be useful in the decision-making process requires the preparation of a computer program, which finds polioptimal solutions of the model for various, alternatively selected, aspiration levels of the decision-maker. In the paper we present the results of computational experience with such a program prepared for the above mentioned model described in [2]. In the program, the penalty scalarizng function defined by A. Wierzbicki [10, 11] is used.

2. Problem Formulation

2.1. Description of a Multicriteria Problem

It is assumed that there exists a set Ω of feasible decisions and a set $Q_0 \subset R^n$ of attainable points in a performance space (the space of values of the objective function). Ω is usually described by a set of constraints. If f denotes a performance function, then Q_0 is the image of Ω:

$$Q_0 = f(\Omega).$$

We assume that R^n is ordered in the usual way:

$$\forall q_1, q_2 \in R^n; \quad q_1 \leqslant q_2 \quad \text{iff } \forall i, \; q_{1i} \leqslant q_{2i} \tag{1}$$

and the norm in R^n is defined as:

$$\|q\| = \left(\sum_{i=1}^{n} \sigma_i q_i^2 \right)^{\frac{1}{2}}, \qquad q \in R^n, \tag{2}$$

where $\sigma_i > 0$ are weighting coefficients.

We describe a multicriteria problem symbolically by:

$$\min_{q \in Q_0} q \tag{3}$$

and define the solution of (3) to be any Pareto-optimal point $\hat{q} \in Q_0 \subset R^n$.

Definition 1. A point $\hat{q} \in Q_0$ is Pareto-minimal if and only if for every q, such that $q_i < \hat{q}_i$ for some index i and $q_j \leqslant \hat{q}_j, j \neq i$, the point q does not belong to the set Q_0. Equivalently:

$$\begin{gathered} \hat{q} \in Q_0 \text{ is Pareto-minimal iff} \\ Q_0 \cap \{q \in E;\; q - \hat{q} \leqslant 0\} = \{\hat{q}\}. \end{gathered} \tag{4}$$

The considered multicriteria nonlinear, dynamic optimization problem is of the form:

$$\begin{gathered} \min_u f(x, u), \text{ where } f = (f_1, \ldots, f_n), \\ f_i \colon R^{l \cdot T} \times R^{s \cdot T} \to R^1, \quad i = 1, \ldots, n \end{gathered} \tag{5}$$

subject to constraints:

$$x_{t+1}=\Phi x_t+h(u_t); \quad t=0, 1, ..., T-1 \tag{6}$$

$$x_0=\bar{x}_0 \tag{7}$$

$$g_j(x_t, u_t)\leqslant 0; \quad j=1, ..., p \tag{8}$$

$$\mathbf{u}_t \geqslant \mathbf{u} \tag{9}$$

where:

h is a linear function and function g is assumed to be nonlinear;
u_t denote control variables, $u_t \in R^s$ and $u=\{u_t\}_{t=0}^{T-1}$;
x_t denote state variables, $x_t \in R^l$ and $x=\{x(u)_t\}_{t=1}^{T}$;
Φ is a constant $1\times l$ matrix;
$u \in U_D \subset R^{s\cdot T}$, where U_D is defined by the constraints (6–9).

The function f transforms the set U_D into the set Q_0 of attainable points since the values of $x(u)$ are defined uniquely by (6), (7) for given values of u.

2.2. Penalty Scalarizing Function

A penalty scalarizing function in the performance space $-R^n$ can be defined in the following way:

$$\mathscr{J}(q;\bar{q})=\rho\,\|(q-\bar{q})_+\|^2-\|q-\bar{q}\|^2; \quad \rho>1 \tag{10}$$

In the formula (10) one can use any norm in R^n. We choose the norm defined by the expression (2) only to assure the differentiability of the functional $\mathscr{J}$ at every point and the second differentiability at almost every point.

If $\bar{q} \in \hat{Q}_0-\{q \in R^n; q\geqslant 0\}$, where $\hat{Q}_0 \subset Q_0$ is the set of Pareto-optimal points, then $\hat{q}=\arg\min_{q\in Q_0} \mathscr{J}(q,\bar{q})$ is Pareto-minimal.

If $\bar{q} \in \hat{Q}_0$ then $\hat{q}=\arg\min_{q\in Q_0} \mathscr{J}(q,\bar{q})$ is Pareto-minimal and $\hat{q}=\bar{q}$.

If $\bar{q} \in \operatorname{int} \hat{Q}_0$ then $\hat{q}=\arg\min_{q\in Q_0} \mathscr{J}(q,\bar{q})$ is not necessarily Pareto-minimal (it is only Pareto ε-minimal with $\varepsilon\leqslant(1/\rho)$).

Changing $\bar{q} \in R^n$ one can achieve any point $q \in \hat{Q}_0$ (see [10, 11]).

For the problem (5–9) the scalarizing penalty function (10) assumes the form:

$$\mathscr{J}(u;\bar{f})=\rho \sum_{i=1}^{n} \sigma_i\,[\max(0, f_i(x(u), u)-\bar{f}_i)]^2+ \\ -\sum_{i=1}^{n} \sigma_i\,(f_i(x(u), u)-\bar{f}_i)^2, \tag{11}$$

where $\bar{f}_i$ are the reference objectives.

After scalarization one has to solve the optimization problem with one performance criterion (11) subject to the constraints (6–9).

3. Description of Optimization Procedure

The optimization problem (11), (6–9) is solved with the help of the modified version of the augmented Lagrangian method. The constraints (8) are included into the augmented Lagrange functional $L(u, Z, \eta)$, ([1, 7]):

$$L(u, Z, \eta) = \mathscr{J}(u; \bar{f}) + \\ + \frac{1}{2\eta} \sum_{j=1}^{p} [\max(0, Z_j + \eta \cdot g_j(x(u), u))]^2 - \frac{1}{2\eta} \sum_{j=1}^{p} Z_j^2 . \quad (12)$$

Where $\eta > 0$ is a penalty parameter, while $Z \in R^p$ denotes a shifting parameter. Then, the augmented Lagrangian is minimized subject to the constraints (6), (7) and (9). The values of penalty parameter η and shifting parameter Z are changed according to the commonly used rules (see [1, 4, 7]).

The constraint minimization problem (12), (6), (7), (9) with constant values of η and Z is solved in the control space (for details see [4]). The adjoint equations are introduced to derive the gradient of the augmented Lagrangian with respect to control variables.

We used the modified conjugate gradient method. The modification consists in the projection of a search descent direction on a subset of active constraints from the set (9).

4. Formulation of the Model

It is assumed that the formulation of the model should ensure a compromise between the following phenomena: maximization of consumption and maximization of capital stocks in each sector of the economy and minimization of the foreign debt level for the economy as a whole over a considered time period.

Therefore, the model's objective is defined as follows:

$$\text{minimize } S_t, \quad t = 1, \ldots, T \quad (13)$$

$$\text{maximize } K_{tj}, \quad t = 1, \ldots, T; \quad j = 1, \ldots, m \quad (14)$$

$$\text{maximize } C_{tj}, \quad t = 0, \ldots, T-1, \quad j = 1, \ldots, m \quad (15)$$

where:

S_t is the level of foreign debt of the national economy at time instant t.
K_{tj} is the level of capital stocks in sector j at time t.
C_{tj} is the consumption level in sector j at time t.
T is the length of the investigated time period; m is the number of sectors in the economy.

The difference state equations (6) have the following form in the model:

$$K_{t+1} = (I - D) K_t + V_t; \quad t = 0, \ldots, T-1 \quad (16)$$

where:

D — is a diagonal matrix of depreciation coefficients of capital,
V_{tj} — is an investment level of sector j at time t.

Equation (16) describes the accumulation process of capital stocks.

$$S_{t+1}=(1+r)\,S_t+\sum_{j=1}^{m}\{((I-A+G)^{-1}\,[(B-\bar{B})\,V_t+C_t+E_t+ -M_t])_j+(HV_t)_j+M_{tj}-E_{tj}\} \tag{17}$$

where:

A — is a matrix of input-output coefficients,
M_t — is a vector of consumption imports, $M_t=(M_{t1}, ..., M_{tm})$,
E_t — is a vector of given real exports, $E_t=(E_{t1}, ..., E_{tm})$,
G — is the average propensity to import for production (diagonal matrix),
B — is a total capital coefficient investment matrix,
$\bar{B}$ — is an imported capital coefficient investment matrix,
H — is a matrix of the average propensity to import for investment in sectors.
r — is a rate of interest.

Equation (17) describes the process of accumulation of the foreign debt.

There are the initial conditions on the state variables K and S:

$$S_0=\bar{S}_0, \tag{18}$$

$$K_0=\bar{K}_0. \tag{19}$$

The expression which appears in equality (17) $(\{I-A+G)^{-1}\,[(B-\bar{B})\,V_t+C_t+ +E_t-M_t]\})$ represents the production derived from a balance equation of the form:

$$Y_{tj}+P_{tj}=(AY_t)_j+I_{tj}+C_{tj}+E_{tj}, \tag{20}$$

where:

$$P_{tj}=(GY_t)_j+M_{tj}+(\bar{B}V_t)_j, \tag{21}$$

$$I_{tj}=(BV_t)_j, \quad j=1, ..., m \tag{22}$$

and the vector of real exports E_t is assumed to be given exogeneously.

The factor $\bar{B}_{ij}\,V_{tj}$ represents the flow of imported investment goods i to different sectors j of the economy. The term $(HV_t)_j$ in equation (17) represents the values of goods imported for investment purposes in investing sector j.

The inequalities (8) represent production possibilities constraints:

$$\{(I-A+G)^{-1}\,[(B-\bar{B})\,V_t+C_t+M_t-E_t]\}_j\leqslant F_j\,(K_{tj}, L_{tj}), \tag{23}$$

where L_{tj} is the level of employment in sector j at time t. Inequality (23) describes the fact that global production can not exceed the production possibilities $F_j\,(\cdot)$. As the function F_j we apply the constant elasticity of substitution production function — *CES*:

$$F_j\,(K_{tj}, L_{tj})=\alpha_j\,e^{\lambda_j t}\,[\delta_j\,K_{tj}^{-\rho_j}+(1-\delta_j)\,L_{tj}^{-\rho_j}]^{-\frac{\nu_j}{\rho_j}}, \quad j=1, ..., m, \tag{24}$$

where:

$\alpha_j e^{\lambda_j t}$ — parameter of technical progress,
δ_j — distribution parameter,
ρ_j — substitution parameter,
v_j — parameter of returns to scale (homogeneity degree of function F_j).

Additionally the constraint describing distribution of employment level over time is assumed in the model:

$$\sum_{j=1}^{m} L_{tj} \leqslant \bar{L}_t, \quad \forall t=1, \ldots, T-1 \tag{25}$$

where:

$\bar{L}_t$ — is the total number of employees in the economy.

The variables C_t, L_t, V_t, M_t are control variables. They are nonnegative and additionally it is assumed that the consumption can not be lower than a given subsistence level:

$$C_{tj} \geqslant \mathbf{C}_{tj} \tag{26}$$

$$L_{tj}, V_{tj}, M_{tj} \geqslant 0 \tag{27}$$

The penalty scalarizing function for our example can be formulated as:

$$\begin{aligned} J(C, V, L, M; \bar{C}, \bar{K}, \bar{S}) = \rho \Bigg\{ & \sum_{t=1}^{T} \sigma_S (\max(0, S_t - \bar{S}_t))^2 + \\ & + \sum_{t=1}^{T} \sum_{j=1}^{m} \sigma_K (\max(0, \bar{K}_{tj} - K_{tj}))^2 + \\ & + \sum_{t=0}^{T-1} \sum_{j=1}^{m} \sigma_C (\max(0, \bar{C}_{tj} - C_{tj}))^2 \Bigg\} + \Bigg\{ \sum_{t=1}^{T} \sigma_S (S_t - \bar{S}_t)^2 + \\ & + \sum_{t=1}^{T} \sum_{j=1}^{m} \sigma_K (\bar{K}_{tj} - K_{tj})^2 + \sum_{t=0}^{T-1} \sum_{j=1}^{m} \sigma_C (\bar{C}_{tj} - C_{tj})^2 \Bigg\}, \end{aligned} \tag{28}$$

where $\bar{C}$, $\bar{K}$, $\bar{S}$ are reference objectives and σ_S, σ_K, σ_C are weighting coefficients (cf. (10), (11)).

5. Analysis of Computational Results

The computations are carried out for the nine sectors of the Polish economy: (1) energy, (2) metalmachine industry, (3) chemistry, (4) construction materials and ceramics, (5) forestry and timber industry, (6) light industry, (7) food and agriculture, (8) construction, (9) services. For each sector the major growth paths of the economy: investment, employment, consumption import, consumption, foreign debt of the economy (with credits included) and capital, defined as fixed assets are calculated.

The data used are based on official statistics given in the Statistical Yearbooks of Poland [12] and materials of the Planning Institute. Data concerning foreing credits are derived from publication by I. Stankowsky [8]. Parameters of the *CES* production function are taken from M. Tylec and I. Woroniecka [9].

One can obtain any Pareto-optimal point by an appropriate minimization of the penalty scalarizing function. This can be done in two different ways:

— by changing the weighting coefficients σ_S, σ_K, σ_C, with any, not attainable reference point $\bar{q}$ given,

— by changing the reference objectives $\bar{q}$, with given values of weighting coefficients and penalty parameter ρ.

Both approaches have economic interpretation, although the second one seems to be more explicit.

In this paper the second way is used. It is done in two stages. In the first one the values of parameters σ_S, σ_K, σ_C, are selected.

In the second stage, which must follow the first one, variations of reference objectives take place. The above described first stage is realized in three substeps of the following interactive procedure of utilization of the penalty scalarizing function while the second one is simply its fourth step:

1° Select $\bar{q}$ based on previous numerical experiments.

2° Find experimentally "the best" parameter ρ with some approximate values of weighting coefficients σ.

3° Determine experimentally "the best" values of σ with constant value of ρ, evaluated in the previous step.

4° Analyse different alternatives for various reference objectives.

The real values of performance variables are assumed as the initial reference values $\bar{q}$ in step 1°. They are needed only for analytical purposes. Previously obtained numerical results, described e.g. — in [2] justify such selection. From this experiments follow also, in the second step, the chosen values of σ_S, σ_K, σ_C. Usually the initial choice should be the result of the user's experience and knowledge about the nature of the economic problem and the solution method applied.

Consistently with the second step of the procedure we start with the numerical selection of penalty parameter ρ. The experiments have been carried out for $\rho=$ $=2$, 10, 50, 100, 500 and 10 000. The most suitable values of ρ can be selected separately for:

1. the consumption trajectory — $\rho=50$ (Fig. 1)
2. the capital stock trajectory — $\rho=50$ (Fig. 3)
3. the investment trajectory — $\rho=500$ (Fig. 2)
4. the foreign debt trajectory — $\rho=100$ (Fig. 4)

The best selection is defined as such, for which the sum of deviations (computed for every year of the considered time period) of the model trajectory and the real one is minimum. We have chosen the value $\rho=100$ for further computations. In the third step of the procedure the weighting coefficients σ_C, σ_K, σ_S are changed. They

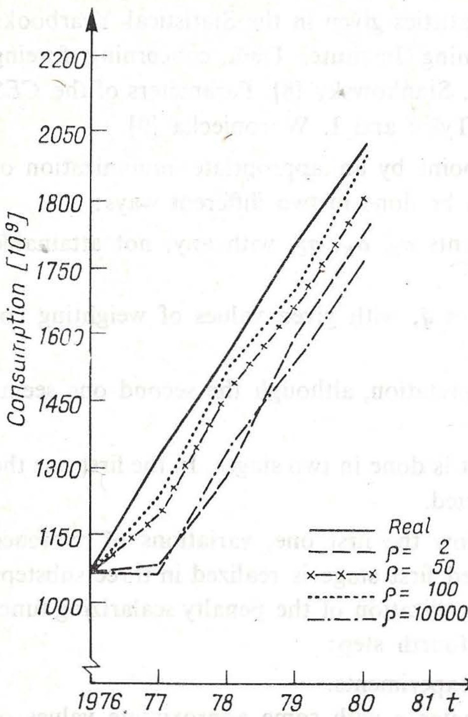

Fig. 1. Changes in trajectories of consumption with changes of parameter ρ in metalmachinery sector.

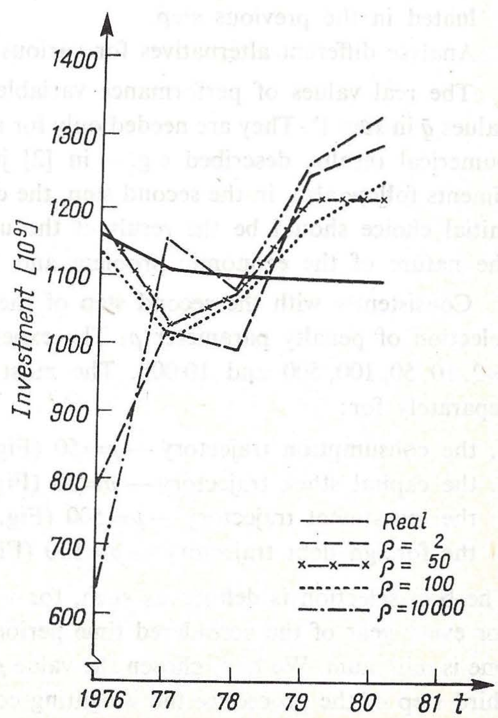

Fig. 2. Changes in trajectories of investment with changes of parameter ρ in metalmachinery sector.

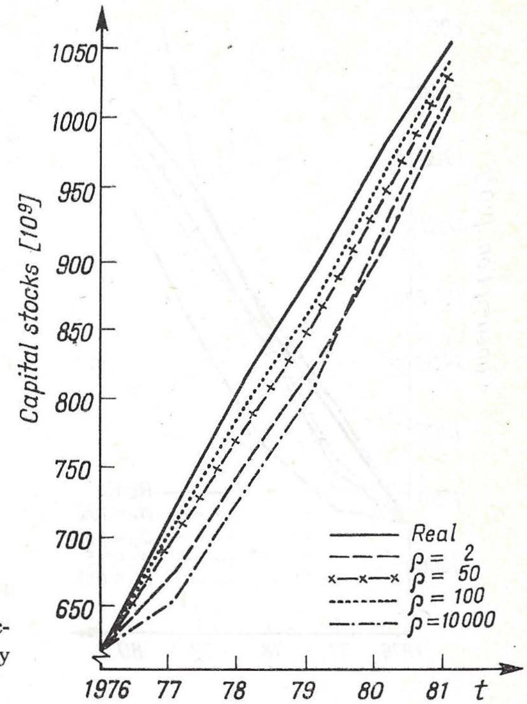

Fig. 3. Influence of parameter ρ on trajectories of capital stock in metalmachinery sector.

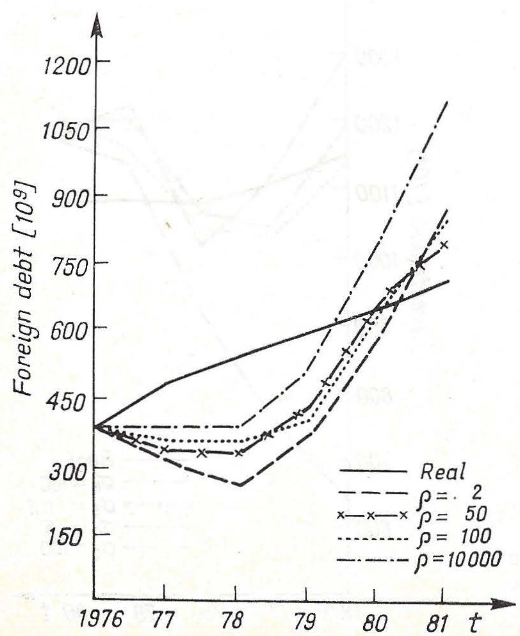

Fig. 4. Influence of parameter ρ on trajectories of capital debt.

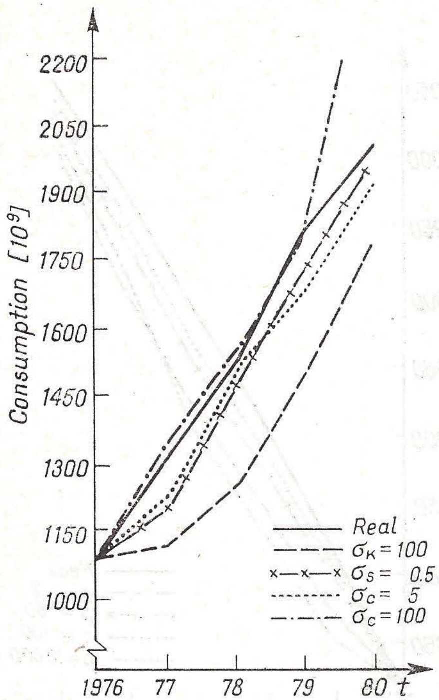

Fig. 5. Influence of weighting coefficient σ on consumption trajectory in metalmachinery sector.

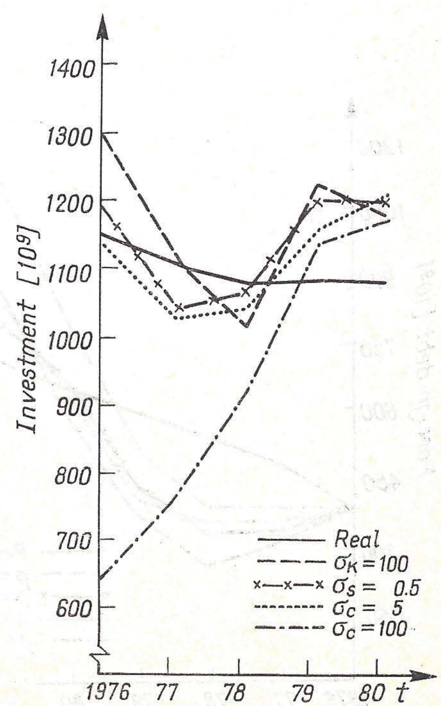

Fig. 6. Influence of weighting coefficient σ on investment trajectory in metalmachinery sector.

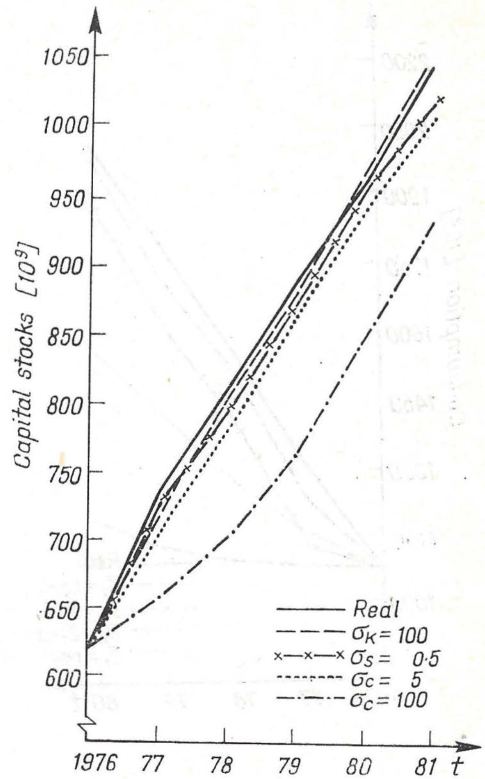

Fig. 7. The dependence of the capital stock on weighting coefficient σ in metalmachinery sector

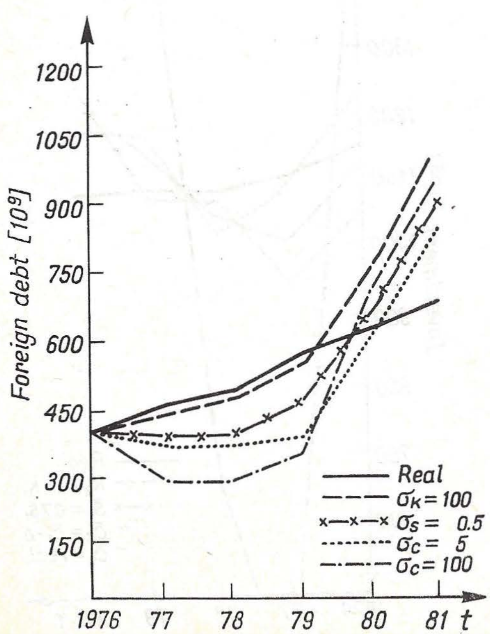

Fig. 8. The dependence of the foreign debt on weighting coefficient σ.

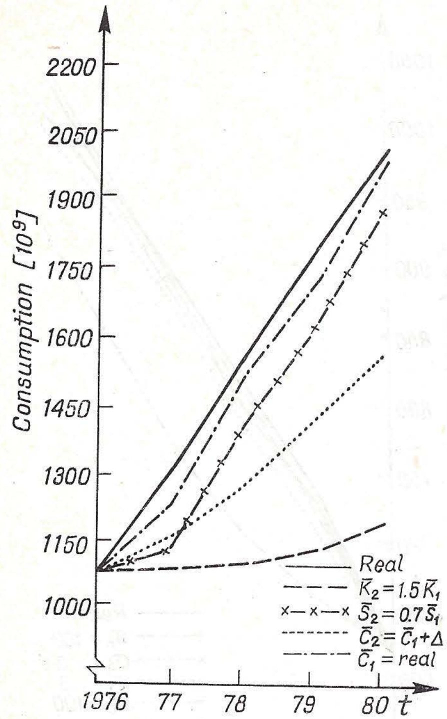

Fig. 9. Changes in trajectories of consumption with changes of reference objectives in metal-machinery sector, $\Delta < 0$; $\bar{S}_1$, $\bar{K}_1$=reał.

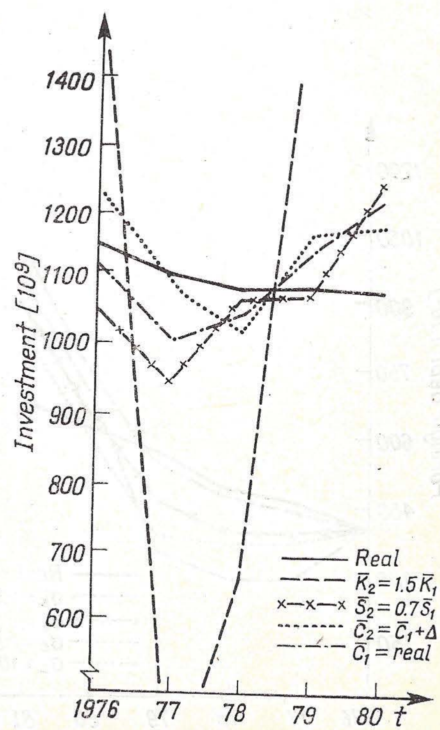

Fig. 10. The dependence of the investment path in metalmachinery sector on reference objectives, $\Delta < 0$; $\bar{S}_1$, $\bar{K}_1$=real.

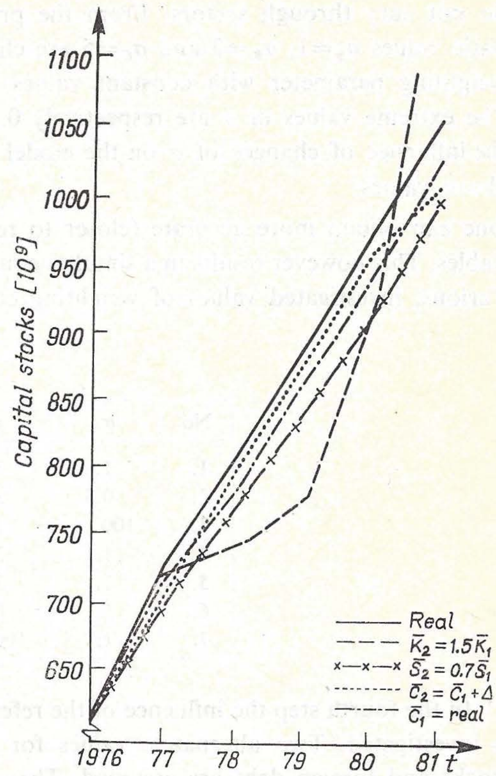

Fig. 11. The dependence of the capital stock on reference objectives in metalmachinery sector.

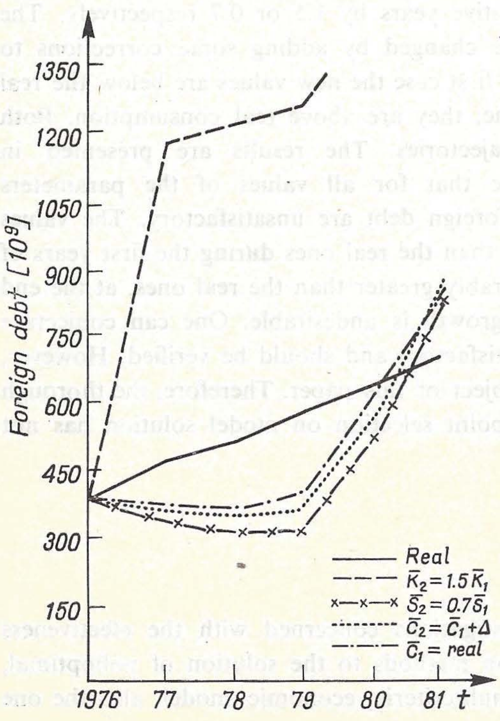

Fig. 12. Influence of reference objectives on foreign debt trajectory, $\Delta < 0$; $\bar{S}_1$, $\bar{K}_1$ = real.

do not vary through sectors. From the previous computational experiments the basic values $\sigma_S=1$, $\sigma_K=3$ and $\sigma_C=5$ are chosen. The influence of changes of one weighting parameter with constant values of the two other ones is investigated. The extreme values of σ are respectively 0.5 and 100. The figures 5 to 8 present the influence of changes of σ on the model solutions and justify the selection of the above values.

One can obtain more accurate (closer to real) trajectories for selected model variables. This however results in a simultaneous deterioration of the other trajectories. Various, investigated values of weighting coefficients are given below:

Table 1

No	σ_s	σ_k	σ_c
1.	1.	3.	5.
2.	0.5	3.	5.
3.	100	3.	5.
4.	1.	3.	0.5
5.	1.	3.	100.
6.	1.	0.5	5.
7.	1.	100.	5.

In the fourth step the influence of the reference objectives on the model solutions is investigated. Two alternative values for the aspirations trajectories of capital stocks and foreign debt are assumed. They are obtained by multiplication of the real values of the trajectory in consecutive years by 1.5 or 0.7 respectively. The desired trajectories of consumption are changed by adding some corrections to the values of the basic year 1976. In the first case the new values are below the real path of consumption, in the second one, they are above real consumption. Both cases yield nondecreasing desired trajectories. The results are presented in Fig. 9, 10, 11, 12. One can observe that for all values of the parameters and reference objectives the paths of foreign debt are unsatisfactory. The values of foreign debt in most cases are lower than the real ones during the first years of the considered time period and considerably greater than the real ones, at the end of the time period. Such exponential growth is undesirable. One can conjecture that the structure of the model is unsatisfactory and should be verified. However, verification of the model is not the subject of this paper. Therefore, the thorough analysis of the influence of reference point selection on model solution has not been presented.

6. Concluding Remarks

The paper contributes to the investigations concerned with the efectiveness of application of numerical optimization methods to the solution of polioptimal, dynamic national economy model. A multicriteria, economic model, also the one presented in the paper, can be successfully solved with the help of these methods. The model itself, when carefully elaborated, can be a very useful tod in the decision making process. The application of the penalty scalarizing function allows for generating various alternatives of economic development which can reflect different aspiration levels of the decision maker.

In fact, one can observe in figures 9–12 that we have achieved completely different solutions for different reference objectives. One can consider our attempt of application of the penalty scalarizing function to solving a nonlinear, dynamic model, successful. To the authors knowledge it is the first attempt.

The obtained Pareto-optimal solutions for the dynamic model of the Polish economy are not fully satisfactory. This is mainly due to the deficiences of the model structure and also due to inconsistency of the data. In result of these deficiences the foreign debt trajectory calculated by the model deviates too much from the real trajectory. Therefore, the model, in its present form, can not be directly applied by a decision maker.

However, the obtained introductory results seem to be encouraging. They allow to hope that it might be possible to elaborate a dynamic model useful for a decision maker.

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Eksperymenty ze skalaryzującą funkcją kary dla nieliniowego wielokryterialnego zadania optymalizacji

Praca wykazuje potencjalną użyteczność metod optymalizacji w procesie wspomaganego komputerowo podejmowania decyzji i przedstawia wyniki eksperymentów komputerowych z wielokryterialnym modelem gospodarki narodowej. Opisano procedurę komputerową, która znajduje rozwiązanie Pareto optymalne modelu odpowiadające zadanym wartościom punktów odniesienia. Dla tego celu użyto metody skalaryzującej funkcji kary. Przedstawiono wyniki eksperymentów obliczeniowych uzyskanych przy pomocy tej procedury. Osiągnięto różne rozwiązania Pareto-optymalne dla różnych punktów odniesienia.

Эксперименты со скаляризирующей функцией штрафа для нелинейной многокритериальной задачи оптимизации

В работе показана потенциальная полезность методов оптимизации в процессе принятия решений с использованием ЗВМ и представлены результаты вычислительных экспериментов с многокритериальной моделью народного хозяйства. Описана вычислительная процедура, которая находит оптимальные по Парето решения модели, соответствующие заданным значениям точек отнесения. Для этой цели используются методы скаляризирующей функции штрафа. Представлены результаты численных экспериментов, полученных с помощью этой процедуры. Получены разные оптимальные по Парето решения для разных точек отнесения.

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News and Announcements

11th IFIP Conference on System Modelling and Optimization
(Copenhagen, Denmark, July 25–29, 1983)

The aim of the conference is to discuss recent advances in the mathematical description of engineering socio-technical and socio-economic systems as well as in their optimization. The conference will be focused around the following areas:
— optimal control of systems governed by differential and integral equation ,
— stochastic modelling and control,
— mathematical programming, theory and algorithms,
— large-scale optimization problems,
— integer and combinatorial programming,
— computational complexity of algorithms,
— mathematical economics,
— modelling of energy systems,
— traffic and transportation planning,
— location and allocation models,
— uncertainty modelling of engineering systems,
— modelling of space structures,
— modelling of offshore structures,
— biomedical modelling.

Abstracts

Abstracts of papers for presentation to the conference should be submitted to the secretariat by December 31, 1982. They should be of approximately 2 pages in length and describe original unpublished results by their authors. Notification of acceptance will be delivered by March 1, 1983.

Mailing Address: Prof. P. Thoft-Christensen, 11th IFIP Conference Director, Institute of Building Technology and Structural Engineering, Aalborg University Centre, P. O. Box 159, DK-9100 Aalborg, Denmark. Telephone: International +45 8 138788.

General Information:

The conference will be held at the Technical University of Denmark (DTH), Lyngby. The conference language is English and typescripts of a selection of complete papers will be published in the Conference Proceedings.

The co-sponsor of the conference is International Federation of Operational Research Societies (IFORS).

Instructions to Authors

"Control and Cybernetics" publishes original papers which have not been published and will not be simultaneously submitted elsewhere. The preferred language of the papers is English.

No paper should exceed in the length 20 typewritten pages (210×297 mm) of the text, double spaced and with 50 mm margin on the left-hand side. Manuscripts should be submitted in duplicate, typed only on one side of the sheet of paper.

The plan and form of the submitted manuscripts is as follows:

1. The heading should include the title, full names and surnames of the authors in the alphabetic order, as well as the names and addresses of the institutions they represent. The heading should be followed by a concise summary (of approximately 15 typewritten lines).

2. Figures, photographs, tables, diagrams etc. should be enclosed to the manuscript. The texts related should be typed on a separate page.

3. All elements of mathematical formulae should be typewritten whenever possible. A special attention is to be paid towards differentiating between capital and small letters. All the Greek letters appearing in the text should be defined. Indices and exponents should be written with a special care. Round brackets should not be replaced by the inclined fraction line.

In general, elements easily confused are to be identified by the appropriate previously discussed measures or by a circled word or words explaining the element.

4. References should be listed in alphabetical order on a separate sheet. For journals the following infoımation should appear: names (including initials or first names) of all authors, full title of paper, and journal name, volume, issue, pages, year of publication. Books cited should list author(s), full title, edition, place of publication, publisher, and year. Examples are:

Lukes D. Optimal regulation of nonlinear dynamical systems. SIAM J. Control 7 (1969) 1, 75–100.

Athans M., Falb P. Optimal Control. New York, Mc Graw-Hill 1966.

Wskazówki dla autorów

W wydawnictwie „Control and Cybernetics" drukuje się prace oryginalne nie publikowane w innych czasopismach. Zalecane jest nadsyłanie artykułów w języku angielskim. W przypadku nadesłania artykułu w języku polskim Redakcja może zalecić przetłumaczenie na język angielski. Objętość artykułu nie powinna przekraczać 1 arkusza wydawniczego, czyli ok. 20 stron maszynopisu formatu A4 z zachowaniem interlinii i marginesu szerokości 5 cm z lewej strony. Prace należy składać w 2 egzemplarzach. Układ pracy i forma powinny być dostosowane do niżej podanych wskazówek.

1. W nagłówku należy podać tytuł pracy, następnie imię (imiona) i nazwisko (nazwiska) autora (autorów) w porządku alfabetycznym oraz nazwę reprezentowanej instytucji i nazwę miasta. Po tytule należy umieścić krótkie streszczenie pracy (do 15 wierszy maszynopisu). Autorów polskich obowiązuje załączenie tekstu streszczenia i tytułu pracy w języku polskim i w razie możliwości w języku rosyjskim.

2. Materiał ilustracyjny powinien być dołączony na oddzielnych stronach. Podpisy pod rysunki należy podać oddzielnie.

3. Wzory i symbole powinny być wpisane na maszynie bardzo starannie.

Szczególną uwagę należy zwrócić na wyraźne zróżnicowanie małych i dużych liter. Litery greckie powinny być objaśnione na marginesie. Szczególnie dokładnie powinny być pisane indeksy (wskaźniki) i oznaczenie potęgowe. Należy stosować nawiasy okrągłe.

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a) przy wydawnictwach zwartych (książki) — miejsce i rok wydania oraz wydawcę;

b) przy artykułach z czasopism: nazwę czasopisma, numer tomu, rok wydania i numer bieżący.

Pozycje literatury radzieckiej należy pisać alfabetem oryginalnym, czyli tzw. grażdanką.