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AN APPROACH TO SOLVING MULTIPLE CRITERIA MACROECONOMIC POLICY PROBLEMS AND AN APPLICATION

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In this paper we propose an approach to solving multiple criteria macroeconomic policy problems. As an example we report how a given policy problem was solved by three decision-makers using an existing econometric model.

1. Introduction

During the past few decades efforts have been made to develop econometric models for analyzing macroeconomic policy problems in several countries. Typical policy problems are, for instance, whether and by how much different categories of taxes and other income transfers should be increased or decreased, what kind of exchange rate policies should be followed, etc. The value of a simultaneous equation econometric model lies in the fact that it helps to account for the complex interrelationships existing among different variables and sectors of the economy. Once such a model has been constructed, a computer simulation approach can be used for generating and comparing different alternative policies and for choosing a policy considered to be the best among the alternatives. This approach does not require an explicit preference function of the decision-maker, but his preferences are implicitly present in the selection of values for the target variables (see Tinbergen (14,15)).Computer simulation is, however, an inefficient method of finding the best policy decisions and optimization models have been proposed as an alternative for solving these problems. In the optimization approach a preference function is optimized subject to a set of constraints which represent economic interrelationships among the variables and describe the possible values of the instrument variables (= decision variables, parameter variables, parameters). The purpose of the optimization process is to select the best solution (in terms of an overall preference function) from the set of feasible solutions.

Recent advances in multiple criteria optimization have made it possible not to require explicit knowledge of the decision-maker's preference function in terms of the objectives prior to solving the problem. Instead, as we shall demonstrate in this paper, the decision-maker's preferences can be identified by a procedure which simultaneously leads to choosing an "optimal" solution. The practical value of an optimization procedure depends, of course, on the ability of the underlying model to describe the phenomena under study, i.e., the word optimum refers to the mathematical "play process" and not necessarily to the "real process". In order to have a realistic formulation of a macroeconomic policy problem we have in the following resorted to an existing econometric model developed by one of us. A further version of this model is presently used by the Research Institute of the Finnish Economy for analyzing and forecasting short-term fluctuations in the Finnish economy. A linear version of this model was modified into a linear optimization model involving multiple objectives by allowing certain instrument variables to vary within a feasible range each. The problem was further formulated so as to represent, at the time of the experiments, an actual decision problem of the Finnish economy. The three decision-makers participating in the experiment were persons faced with the problem in practice.

The paper consists of five sections. In §1 we have outlined the problem. In §2 we describe some previous research on the problem and propose an approach to solving multiple criteria macroeconomic policy problems. In §3 we describe the problem representation and the underlying econometric model. In §4 we discuss an attempt to apply the optimization approach in practice. We conclude the paper by discussing some current research in §5. A description of the model of the Finnish economy employed is given in an appendix to this paper.

2. Some Previous Research and the Multicriterion Optimization Approach to Macroeconomic Policy Formulation

Let us assume that we have a linear macroeconomic model with estimated deterministic equations of the structural form

$$y = \hat{A}y + \hat{B}x,$$

where y is an n-vector of endogenous variables including the target variables, and x is an m-vector of predetermined (= lagged endogenous and exogenous) variables. The corresponding reduced form is given by

$$y = (I-\hat{A})^{-1}\hat{B}x = \hat{\pi}x.$$

Usually the exogenous variables also include a number of instrument variables which may take values from given intervals $[x_i^a, x_i^b]$, $x_i^a<x_i^b$. For the other predetermined variables $x_i^a=x_i^b$; that is, their values are fixed and the interval is reduced to a point. If the decision-maker had an explicit preference function $U(y)$: $\mathbb{R}^n \to \mathbb{R}$ defined on the values of the endogenous variables (the values of some y_i:s may, of course, have no effect on the value of U, i.e., he need not be directly interested in all endogenous variables) we would have a standard optimization problem

(A) Maximize $U(y) = U(\hat{\pi}x)$

subject to $x \in X = [x_1^a, x_1^b] \times \ldots \times [x_m^a, x_m^b]$.

Assuming that U fulfilled certain regularity conditions the problem could be solved by standard optimization methods. However, difficulties arise because the preference function is known seldom, if ever. In fact, even the existence of the preference function, and at least its time invariance, can be discussed.

Several applications of linear programming to macroeconomic policy problems have been reported. Among the first was the study of Van Eijk and Sandee (17). A linear preference function was constructed for the decision-maker by "imaginary interviewing" and optimized subject to a set of econometric constraints. Later applications have been reported by Eckaus and Parik (2), Kornai (8) and MacEwan (9), among others. Effective solution methods exist for linear programming problems and a wide range of sensitivity analyses can be performed.

In the approach proposed by Theil (13) a quadratic preference function allowing for decreasing marginal rates of substitution between any two variables is constructed. A desirable combination of target and instrument variable values is specified by the decision-maker and the "closest" realizable decision is found. Van den Bogaard and Theil (16) report on an application to the United States economy.

Spivey and Tamura (12) criticize the assumptions of the Theil procedure and propose an approach based on a variant of linear programming for solving the problem. It permits both overattainment and underattainment of any target variable, to be weighted either equally or differently in the preference function. As an example they use Klein's Model I of the United States economy (Klein (6)).

Pindyck (10) and Livesey (7) formulate the macroeconomic policy problem as a problem in optimal control theory and demonstrate that optimal control theory can be used for solving the problem and analyzing the dynamic properties of the model.

The approaches discussed above can all be criticized on the score of the assumption that the decision-maker is able to construct an overall preference function carried over the time period for which he is planning. Recent research in multiple criteria decision-making suggests that this assumption can be relaxed by using iterative procedures if the decision-maker is able to provide certain local information about his preferences at each cycle. Such approaches have been developed, among others, by Geoffrion, Dyer and Feinberg (5) and Zionts and Wallenius (23). Using either of the approaches a sequence of target vectors y, $\{y^1, y^2, \ldots, y^N\}$, is generated, which the decision-maker can influence in accordance with his preferences, such that for all $k \in \{1, \ldots, N\}$: $y^k = \hat{\pi} x^k$, $x^k \in X = [x_1^a, x_1^b] \times \ldots \times [x_m^a, x_m^b]$. The process is terminated for some N, when the decision-maker does not want to change any component of y^N. Such y^N is called the <u>optimal target vector</u>, $y^N = \hat{y}$, and it satisfies $\forall$ k: $1 \leq k \leq N$: $\hat{y} \succsim y^k$; that is, y is preferred to alternative solutions. If certain assumptions concerning the stability and form of the decision-maker's preference function U are made, it can further be shown that this procedure leads to an optimum solution of the maximization problem (A). For this to be true the preference function need not be a linear function of the instrument variables. It suffices that the relationship is concave. As such formulation (A) is, of course, more general than the linear programming formulation, which assumes that we can estimate (e.g. by employing fictitious questions) the decision-maker's preference function and that it is linear. (A) is also more general than the approach proposed by Spivey and Tamura (12).

3. Problem Representation

In this section we provide a brief description of the problem. A summary of the model employed is given in an appendix to this paper and more detailed information may be found in Vartia (18). The model is constructed using the Dutch short-term annual model as a starting point and adapted to the circumstances prevailing in Finland (see e.g. Verdoorn, Post and Goslinga (20)). As usual with short-term models, the emphasis is on the demand side and no explicit production function is included in the model. The model is based on annual percentage changes and consists of 12 behavioral equations for the volumes and prices of the main expenditure categories, for imports, labor input, unemployment and the wage rate. In addition, the model has a number of equations defining other endogenous variables. The exogenous variables of the model include usual policy variables, such as incidence of indirect taxes, income transfers, public expenditure and changes in the exchange rate, which were taken as instrument variables for the problem. Monetary policy instruments have not been incorporated in the model. The model has been estimated using data for the years 1951-1970.

The econometric simulation model was expanded to an annual optimization model involving multiple objectives by taking some of the endogenous variables as target variables and by allowing certain instrument variables to vary within feasible bounds. For target variables we selected four traditional aggregate variables relating to the internal and external equilibrium of the economy: the percentage change in gross domestic product, unemployment, the rate of inflation (measured by consumer prices) and the balance of trade.[1]

Values for the lagged endogenous and fixed exogenous variables were obtained from the latest "Economic Prospects in Finland", RIFE (3), and they reflect the situation in the Finnish economy at the time our experiments were carried out. Bounds for the four instrument variables were determined by us. If the optimization model were used on a more permanent basis, it would be natural to let the decision-maker himself determine the bounds defining the set of feasible solutions. In our study the volume of public expenditure was allowed to deviate from the "most probable" value (forecast at the time of the experiments in "Economic Prospects in Finland") by ± 5 %, the incidence of indirect taxes and the total income transfers by ± 10 %; and a change in exchange rate from - 2 % to 8 % was allowed.

4. An Application

4.1. Design of the Experiment

A linearized version of the model presented in Vartia (18) was modified in the manner described above, so as to obtain an optimization model, and this together with the Geoffrion method assuming a monotonic preference function and a linear constraint set was implemented for the UNIVAC 1108 time-sharing system at the Helsinki School of Economics[2]. Some parameter values of the model were later changed so as to better reflect the current economic situation[3].

The three decision-makers participating in the experiment were 1) the Chief of the Bank Inspectorate, an ex-Cabinet Member, 2) the Deputy Managing Director of the Confederation of Finnish Industries and 3) a Director of the Bank of Finland. The purpose was to evaluate the applicability of our approach to macroeconomic policy formulation. Each of the decision-makers was familiar with the general characteristics and scope of the econometric model upon which the study is based. We discussed various aspects and explained the major features of our approach and the use of the method. After the starting solution the decision-maker was expected to provide two kinds of information at each cycle concerning his preferences:
1) An estimate of his marginal rates of substitution between the objectives determining the "best" direction of search.
2) Resolution of a step-size problem determining how much of a change to make. For a more complete treatment of the method the reader is referred to Geoffrion, Dyer and Feinberg (5).

In an earlier work one of us had discovered that the Geoffrion, Dyer and Feinberg (5) method was relatively difficult to use (see Wallenius (21)). This was why we decided to assist the decision-makers in several ways. A variant of the original method designed to help the decision-makers to estimate their marginal rates of substitution described in Dyer (1) was implemented. We also presented the decision-makers with a number of examples computed using different responses generated by us. Finally, we presented to the decision-makers for their information the solutions obtained by a one-at-a-time optimization of each objective (see Table 1).

4.2. Results of the Study

We initially provide a brief description of the economic situation in Finland at the time of our experiment. Finland was one of the few market economies where production did not decline during the recent deep international recession(the volume of GDP at market prices rose by 4.7 % in 1974 and by 0.1 % in 1975) and where the employment situation remained fairly good (the unemployment rate averaged 1.7 % in 1974 and 2.2 % in 1975). This was due to the strong investment activity which was to a large extent financed with foreign capital. As a consequence the country's foreign indebtedness grew quickly and rose to about a fifth of the annual gross domestic product by the end of 1975. Simultaneously the sharp rise in commodity prices had amounted to an inflationary impulse, which continued as a strong internal wage-price spiral. The rate of inflation as measured by consumer prices was 18 % in 1974 and 17.4 % in 1975,,year-on-year.

At the beginning of 1976 the continuing growth of foreign indebtedness was generally regarded as Finland's most difficult problem. To achieve the central goal of external equilibrium, it was considered advisable to strongly reduce the rate of inflation and thus ensure competitiveness in foreign trade - even at the cost of lower production and higher unemployment. Since the controlling of inflation was also necessary in itself, not many were in favor of improving price competitiveness by altering the international value of the Finnish currency, as this would have affected the rate of inflation unfavorably. Maximizing the growth of the volume of gross domestic product and reducing unemployment by the fiscal policy measures allowed by our instrument variables were in this situation in direct conflict with the minimizing of inflation and the balance of trade deficit. Changes in indirect taxation could, however, have been used effectively for reducing inflation and it would also have had some favorable effects on the level of economic activity but an unfavorable effect on the balance of trade.

The results of the test with actual decision-makers facing the policy problem described above are given in Table 1. We note that two of them wanted the gross domestic product to grow from the preceding year, but the third was content with a decrease in its value, since this enabled him to considerable reduce the trade deficit. The resulting unemployment rates represent in each case increases on the previous year's figure. The rates of inflation chosen by the three persons were close to each other and not far from the absolute minimum inflation achievable. The "optimal" balance of trade deficits varied considerably among the three persons but promised in each case an improvement on the preceding year's Fmk 7.75 billion.

Table 1: Solution of the Model for 1976

Cycle	Criteria[1)]			
	GDP increase, % (7.18)	Inflation, % (8.16)	Unemployment Rate,% (1.88)	Trade Deficit, Billions Fmk. (1.21)
First Decision-Maker				
1	-2.74	8.16	3.28	2.24
2	0.57	9.00	2.81	5.27
3	1.81	8.88	2.64	6.54
Second Decision-Maker				
1	-2.74	8.16	3.28	2.24
2	-0.37	8.27	2.95	4.55
3	0.17	8.29	2.88	5.08
Third Decision-Maker				
1	2.00	10.00	2.50	6.50
2	-1.39	8.69	3.06	3.46
3	-1.39	8.69	3.06	3.46

1) "Utopian" solutions obtained with one-at-a-time optimization are given in parentheses under each criterion.

First Decision-Maker

The first decision-maker started from a solution implying the lowest possible rate of inflation. In that case the gross domestic product decreased considerably from the preceding year and the unemployment rate rose by more than one percentage point. To obtain this solution public expenditure, net income transfers to households and indirect taxes ought to have been reduced and the currency (unit) slightly revalued. As described above our method needs information about the decision-maker's marginal rates of substitution between a reference criterion (GDP in this study) and the other objectives. To elicit this information the decision-maker was asked questions such as: "What percentage decrease in GDP would exactly compensate for a unit decrease in inflation ?" The decision-maker was willing to worsen GDP by 0.5 unit in order to reduce inflation by 1 %. Similarly, his marginal rate of substitution between GDP and unemployment was 1 and between GDP and balance of trade deficit 0.75. These responses indicate the direction in which utility mostly increases. Solutions along this direction were better in terms of GDP and unemployment, but worse in terms of inflation and the trade deficit than the starting solution. This also meant increases in public expenditure and income transfers, decreases in indirect taxes and devaluation of the currency (unit). The decision-maker was willing to proceed in this direction about half-way (of the maximum possible distance).

It was thus possible for him to secure a positive change in GDP and to hold inflation below ten per cent and unemployment below three per cent at the expense of the balance of trade deficit. This solution was considered the new starting point for the second cycle. This time the decision-maker placed more weight on the curbing of inflation by raising the marginal rate of substitution between GDP and inflation to 0.8. He also raised the marginal rate of substitution between GDP and trade deficit from 0.75 to 0.8, but did not change the rate of substitution between GDP and unemployment. The method took into account the decision-maker's responses and proposed as the new direction a set of solutions with values for inflation, GDP and unemployment somewhat better than those in the previous solution. The improvements were achievable only at the expense of the balance of trade and implied increases in public expenditure, income transfers, indirect taxes, and a revaluation of the currency unit. Because of the resulting increase in the trade deficit the decision-maker proceeded in this direction only to the extent of a quarter of the maximum distance. At the new solution the decision-maker was willing to increase the marginal rate of substitution between GDP and inflation to 1 and between GDP and trade deficit to 1.25. The new direction promised a reduction in both inflation and the trade deficit at the expense of the other objectives. However, the decision-maker was not willing to proceed in this direction at all, and considered his previous solution to be the best among the available alternatives.

Second Decision-Maker

The second decision-maker started from the same solution as the first. Yet his marginal rates of substitution among the objectives were different. He was willing to put more weight on inflation at the expense of unemployment and balance of trade deficit. This direction promised a considerable increase in GDP and a decrease in unemployment, at the expense of an increase in the balance of trade deficit. To prevent the balance of trade deficit from increasing too much he was prepared to proceed in this direction only one third of the maximum distance. At this solution the decision-maker put more weight on inflation and balance of trade deficit, but the changes were too small to alter the direction and the search was terminated.

Third Decision-Maker

Our procedure includes a method for testing the feasibility of the starting solution, and this method was used by the third decision-maker. He started from a solution with much emphasis on GDP and unemployment and less on the balance of trade deficit. Then he set the largest weight on the balance of trade deficit and equal rates of substitution between GDP and inflation and between GDP and unemployment. The responses were used to generate a solution which turned out to be the one from which the others had started. The decision-maker was willing to proceed in this direction to the extent of three quarters of the distance, resulting in a clearly negative GDP. At this new solution he raised the relative weight of unemployment, but did not change the other weights. However, this did not produce any changes in the direction and the decision-maker terminated the exercise at the previous solution[4].

Some Reactions of the Decision-Makers

The decision-makers considered the results yielded by the model and the relationships among the objectives realistic, with the possible exception that both the unemployment rate and the rate of inflation were, in their opinion, somewhat low when fixed values were given for the other objectives. This can at least in part be explained by the fact that the model was not used for forecasting but for optimization purposes, and the feasible region of the decision variables may not have corresponded exactly to the one considered relevant in the current economic situation. Furthermore, one of the decision-makers insisted on excluding the possibility of exchange rate changes. As mentioned above the possibility of setting bounds for instrument variables by the decision-maker can easily be incorporated. The decision-makers seemed to be satisfied with the way the method worked, with the exception that the estimation of the marginal rates of substitution among the objectives (despite the assistance provided) was not considered simple enough.

The decision-makers considered the advantages of the optimization framework to be the following:

1. The model would provide information about the relationships between the objectives and between the objectives and policy instruments.
2. The decision-makers would better learn their preferences in terms of the objectives.
3. The optimization framework would indicate which are feasible and which are infeasible targets for economic policy.

Also, the possibility of using this kind of "policy formulation game" as a pedagogic instrument for different groups of decision-makers was considered a fruitful application.

5. Conclusion

In this paper we have described work in process to implement an optimization procedure for formulating macroeconomic policy decisions in Finland. Three experienced decision-makers who used the procedure to solve the problem for 1976 seemed to be satisfied with the way the method operated, except for the difficulty of providing certain kinds of information required by the method, and felt that the approach would be valuable in helping decision-makers to understand their preferences in terms of multiple objectives.

One of the decision-makers participating in the study expressed his willingness to continue the implementation work at the Confederation of Finnish Industries to install the optimization model as a more permanent decision-making tool. For that purpose a one-year project has been initiated in the fall of 1976. The planning horizon in the experiment was one year but plans have been made to extend it because the consequences of policy formulation for one year are visible also in the longer run. Because the decision-makers experienced some difficulty in using the optimization model, we intend to implement the method developed by Zionts and Wallenius (23) as well. There is reason to believe that this method is easier to use than the current method, as it is based only on yes or no questions on certain feasible tradeoffs presented to the decision-maker.

Appendix: A Model of the Finnish Economy

In the following list of variables all exogenous variables are underlined. Unless otherwise stated, capital letters stand for value and small letters for volume. Absolute variables are denoted by the symbol (~); all other variables denote percentage changes from the previous year. Because no confusion is expected to arise, the subscript t denoting time has been dropped. Thus, for instance, C_t is abbreviated C and C_{t-1} (the lagged value) C_{-1}.

a	labor input in the private sector
c, C	private consumption
d, D	total demand
d', D'	total demand less inventory changes
De	devaluation percentage
$\tilde{E}$	balance of trade deficit
$\underline{F}$	depreciation
$\underline{g}$, G	public expenditure
H	unit labor cost
i, I	private fixed investment
K	gross profits per total sales
m, M	imports
m_g, M_g	commodity imports
$\underline{m}_s$, $\underline{M}_s$	imports of services
$\underline{m}_w$	weighted growth of industrial production in ten OECD countries (export demand variable)
n, N	inventory changes

$\underline{O}$	income transfers
p_c	consumption prices
p_d	price of total demand
$p_{d'}$	price of total demand less inventory changes
p_g	price of public expenditure
p_i	investment prices
$\underline{p}_m$	import prices
$\underline{p}_{mg}$	prices of commodity imports
p_x	export prices
p_{xg}	prices of commodity exports
$\underline{p}'_x$	prices of competing exports
p_y	price index of gross domestic product
T_i	indirect taxes minus subsidies
$\underline{T}'_i$	incidence of indirect taxes minus subsidies
$\tilde{U}$	unemployment rate
w	wage rate
W	wage bill in the private sector
$(W+Z)^D$	disposable income of households
x, X	exports
x_e, $\underline{X}_e$	bilateral commodity exports
x_g, X_g	exports of goods
x_{gw}, X_{gw}	multilateral commodity exports
$\underline{x}_s$, $\underline{X}_s$	exports of services
y, Y	gross domestic product at market prices
y'	gross domestic product less inventories
Z	nonlabor income

Desiderata:

1. Change in the volume of gross domestic product (y) as big as possible.
2. Inflation (p_c) as small as possible.
3. Unemployment rate ($\tilde{U}$) as small as possible.
4. Balance of trade deficit ($\tilde{E}$) as small as possible.

Behavioral equations:

Domestic expenditure:

$$(1)\ c = .365((W+Z)^D - p_c)) + .435((W+Z)^D + C))_{-1} - 2.407\Delta\tilde{U} + 2.389$$

$$(2)\ i = 3.169\Delta y'_{-3/4} + .355Z + .582Z_{-1} - .756p_i - .466$$

$$(3)\ N = .321\Delta d'_{-1/2} + .037\Delta p_{mg} - .369N_{-1} + .685$$

Foreign sector:

$$(4)\ x_{gw} = 2.338m_w - .520(p_{xg} - p_x') - .828(p_{xg} - p_x')_{-1} - .308(p_{xg} - p_x')_{-2} - 3.172$$

$$(5)\ m_g = 1.924d' + 3.074N + .594(p_y - p_{mg})_{-1/3} + .334\Delta d' - 3.868$$

Labor input and unemployment:

$$(6)\ a = .638y + .151y_{-1} + .102K - 2.376$$

$$(7)\ \Delta\tilde{U} = - .219a + .398$$

Wages and prices:

(8) $w = .562p_c + .900(y-a)_{-1/2} - .846\Delta\tilde{U} + .4(w_{-1} - .562p_{c-1}$

$+ .846\Delta\tilde{U}_{-1}) + .074$

(9) $p_c = .362H + .164p_{mg} + .207T_i' + 2.084$

(10) $p_i = .363H + .255p_{mg} + .155p_{i-1} + 1.086$

(11) $p_{xg} = .780p_x' + .189H + .069p_{mg} + .3(p_{xg} - .189H - .069p_{mg})_{-1}$

$- .297$

(12) $p_g = .766H + .088p_{mg} + .118p_{g-1} + 1.679$

Definitional equations:

(13) $C = c + p_c$

(14) $I = i + p_i$

(15) $G = g + p_g$

(16) $X_{gw} = x_{gw} + p_{xg}$

(17) $M_g = m_g + p_{mg}$

(18) $X_e = x_e + p_{xg}$

(19) $X = x + p_x$

(20) $Y = y + p_y$

(21) $d' = .468c + .152i + .219x + .162g$

$$(22)\quad D' = .452C + .155I + .217X + .175G$$

$$(23)\quad d = .452c + .147i + .966n + .211x + .156g$$

$$(24)\quad D = .433C + .149I + .958N + .208X + .168G$$

$$(25)\quad y' = 1.260d' - .260m$$

$$(26)\quad y = 1.249d - .249m$$

$$(27)\quad Y = 1.250D - .250M$$

$$(28)\quad x_g = .824x_{gw} + .176x_e$$

$$(29)\quad X_g = .824X_{gw} + .176X_e$$

$$(30)\quad x = .819x_g + .181x_s$$

$$(31)\quad X = .826X_g + .174X_s$$

$$(32)\quad m = .885m_g + .115m_s$$

$$(33)\quad M = .872M_g + .128M_s$$

$$(34)\quad H = w - (y-a)_{-1/2}$$

$$(35)\quad K = p_{d'} - .325w - .093T_i' - .210p_m$$

$$(36)\quad W = a + w$$

$$(37)\quad Z = 3.167D - .985W - .288T_i - .637M - .256F$$

$$(38)\quad (W+Z)^D = .625W + .634Z + 1.259\ O$$

$$(39)\quad T_i = D' + T_i'$$

$$(40)\quad \tilde{E} = .28m_g + .28p_{mg} - .202X_g + \tilde{E}_{-1}$$

The following bounds were set for the instrument variables: public expenditure [-2, 8], incidence of indirect taxes [-15.8, 4.2], income transfers [-14, 6], and devaluation percentage [-2, 8].

In order to take into account the effect of eventual exchange rate changes on exogenous foreign trade variables the following equations were used (variables with the bar represent forecast values of the exogenous variables excluding the effect of exchange rate changes):

(41) $p_m = \bar{p}_m + De$

(42) $p'_x = \bar{p}_{x'} + De$

(43) $p_{mg} = \bar{p}_{mg} + De$

(44) $M_s = \bar{M}_s + De$

(45) $X_e = \bar{X}_e + De$

(46) $X_s = \bar{X}_s + De$

References

(1) Dyer, J. S., "A Time-Sharing Computer Program for the Solution of the Multiple Criteria Problem", Management Science, Vol. 19, No. 12 (August 1973), pp. 1379-1383.

(2) Eckaus, R. S. and Parik, K. S., Planning for Growth, MIT Press, Massachusetts, 1968.

(3) "Economic Prospects in Finland", Research Institute of the Finnish Economy, Helsinki, Autumn 1975.

(4) Fox, K., Sengupta, J. and Thorbecke, E., The Theory of Quantitative Economic Policy with Applications to Economic Growth, Stabilization and Planning, 2nd ed., Amsterdam 1973.

(5) Geoffrion, A.M., Dyer, J. S. and Feinberg, A., "An Interactive Approach for Multicriterion Optimization with an Application to the Operation of an Academic Department", Management Science, Vol. 19, No. 4 (December 1972), pp. 357-368.

(6) Klein, L. R., Economic Fluctuations in the United States 1921-1941, Cowles Commission Monograph No. 11, John Wiley & Sons, New York, 1950.

(7) Livesey, D.A.,"Feasible Directions in Economic Policy", Paper presented at the European Meeting of the Econometric Society, Helsinki, August 23-27, 1976.

(8) Kornai, J., Mathematical Planning of Structural Decisions, Amsterdam, 1967.

(9) MacEwan, A., Development Alternatives in Pakistan, Harvard University Press, Cambridge, Mass., 1971.

(10) Pindyck, R. S., Optimal Planning for Economic Stabilization, North Holland Publishing Company, Amsterdam, 1973.

(11) Roskamp, K., "Multiple Fiscal Policy Objectives and Optimal Budget: A Programming Approach", Proceedings of the Leningrad Congress, International Institute of Public Finance, Paris, 1971.

(12) Spivey, W. A. and Tamura, H., "Goal Programming in Econometrics", Naval Research Logistics Quarterly, Vol. 17, No. 1 (March 1970), pp. 183-192.

(13) Theil, H., Optimal Decision Rules for Government and Industry, Rand McNally & Co., Chicago, 1964.

(14) Tinbergen, J., On the Theory of Economic Policy, Contributions to Economic Analysis, North Holland Publishing Company, Amsterdam, 1952.

(15) Tinbergen, J., Economic Policy, Principles and Design, North Holland Publishing Company, Amsterdam, 1956.

(16) Van den Bogaard, P. J. M. and Theil, H., "Macrodynamic Policy-Making: An Application of Strategy and Certainty Equivalence Concepts to the Economy of the United States 1933-1936", Metroeconomica, Vol. 11, 1959.

(17) Van Eijk, C. J. and Sandee, J., "Quantitative Determination of an Optimum Economic Policy", Econometrica, Vol. 27, 1959.

(18) Vartia, P., An Econometric Model for Analyzing and Forecasting Short-Term Fluctuations in the Finnish Economy, Helsinki, 1974.

(19) Vartia P., "Malli ei ole mekaano", Kansantaloudellinen Aikakauskirja, 1975: 1, pp. 66-70.

(20) Verdoorn, P.J., Post, J. J. and Goslinga, S.S., The Re-Estimation of the Annual Model, Central Planning Bureau, the Hague, 1970.

(21) Wallenius, J., "Comparative Evaluation of Some Interactive Approaches to Multicriterion Optimization", Management Science, Vol. 21, No. 12 (August 1975), pp. 1387-1396.

(22) Zeleny, M. and Cochrane, J. L., "A Priori and A Posteriori Goals in Macroeconomic Policy Making", in Multiple Criteria Decision Making, ed. Cochrane, J. and Zeleny, M., Columbia, South Carolina, 1973.

(23) Zionts, S. and Wallenius, J., "An Interactive Programming Method for Solving the Multiple Criteria Problem", Management Science, Vol. 22, No. 6 (February 1976), pp. 652-663.

Footnotes

1 At the end of 1975 the Economic Council, chaired by the Prime Minister, set these four objectives as the most important criteria in evaluating macroeconomic policy decisions in Finland in 1976.

2 For a similar application of the Geoffrion method, see Geoffrion, Dyer and Feinberg (5).

3 For methods of manipulating the solutions of the model and for ways of combining outside information with an existing model, see Vartia (18,19).

4 The Geoffrion method was implemented using a linear programming algorithm in which case the direction-finding problem always generates a corner solution. For a set of marginal rates of substitution which are "close" to each other the implied direction may thus remain unaltered. We intend to have a more general implementation in the future.