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An approach to solving multiple criteria macroeconomic policy problems and an application

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RESUME

Dans ce cahier, les auteurs présentent une approche multicritère et interac-
tive pour évaluer des problèmes de politique économique utilisant des
SUMMARY

In this paper we propose an interactive multiple criteria optimization approach to solve problems associated with macroeconomic policy. In contrast with classical optimization methods no explicit knowledge of the decision-maker's preference function in terms of the objectives is required. The first part of the study consists of an experiment to test the applicability of the approach to economic policy. Three high-level knowledgable decision-makers participated in it and used the GEOFFRION multiple criteria method to solve the problem. The reactions of the decision-makers were favorable and one of them expressed his willingness to continue the implementation work at the Confederation of Finnish Industries. Because the decision-makers experienced some difficulty in using the GEOFFRION procedure, the ZIONTS and WALLENIUS method was implemented for the UNIVAC 1108 time-sharing system as well. The system has now been used for one year for optimizing economic policy and simulating the impact of certain major governmental decisions.
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AN APPROACH TO SOLVING MULTIPLE CRITERIA MACROECONOMIC POLICY PROBLEMS AND AN APPLICATION

In this paper we propose an approach to solving multiple criteria macroeconomic policy problems and report on an application using an existing econometric model.
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 the relationships among the variables and describe
into a linear optimization model involving multiple objectives
\[ y = (I - \hat{A})^{-1} \hat{B} x = \hat{x}. \]

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

\[
\text{(A)} \quad \text{Maximize } U(y) = U(\hat{x})
\]

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.

Many previous approaches to optimizing macroeconomic policy problems exist. They include the classical studies of
variations by Eckaus and Parik (3), Kornai (12), MacEwan (15), Roskamp (17), Spivey and Tamura (18), Van Eijk and Sandee (23), Zeleny and Cochrane (30), among others. An interview approach to identifying a decision-maker's preference function has been developed by Frisch (7,8). For some related research see Johansen (10,11). The use of optimal control theory has been proposed by Chow (1), Pindyck (16) and Livesey (13,14). An extensive survey of the theory of quantitative economic policy is provided by Fox, Sengupta and Thorbecke (6). Until recently, however, relatively little has been done in trying to use such methods in practice.

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 (9) and Zionts and Wallenius (31). 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 $k \in \{1, \ldots, N\}$: $y^k = \xi^k x^k$, $x^k \cdot x = [x_1^a, x_1^b, \ldots, x_m^a, x_m^b]$. The process is terminated for some $N$, when the decision-maker
does not want to change \( y \) any more. Such \( y^N \) is called the optimal target vector, \( y^N = y \), and it satisfies \( \forall k: 1 \leq k \leq N; y_k \geq y^k \). 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 optimal 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 (18) or Theil (19).

3. Problem Representation

In this section we provide a brief description of the problem. A summary of the model currently employed is given in an appendix to this paper and more detailed information may be found in Vartia (24). 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 (26)). 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 13 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. Neither monetary policy instruments
nor an endogenous block for the public sector have 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", ETLA (4), and they were kept up-to-date to
reflect the situation in the Finnish economy each time
the model was used. In the earlier experiments bounds for
the instrument variables were determined by us. When the
optimization model was used on a more permanent basis, it
was natural to let the decision-maker himself determine the bounds defining the set of feasible solutions.

A linear version of the model presented in (24) was used in the application. Nonlinear models have often to be linearized, because linear systems allow of much easier estimation and solution techniques. However, in our case little was lost by linearizing the model, since the difference between the two versions concerns only a number of definitional equations which in the original version incorporate certain cross products. We also emphasize that, although our model is linear in percentage changes of variables, it is, obviously, nonlinear in terms of the absolute values of the variables. Different versions of the model have been used at the Research Institute of the Finnish Economy for a period of three years for forecasting and analyzing economic fluctuations, and the results have been found useful. For additional tests of the accuracy of the model we refer to (24).

4. An Application

We performed a first test of our multiple criteria approach to solving an actual decision problem of the Finnish economy in February 1976. The experiment was successful and one of the decision-makers participating in it 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
4.2. An Experiment

A linearized version of the model presented in Vartia (24) 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 timesharing system at the Helsinki School of Economics. Some parameter values of the model were also changed so as to better reflect the current economic situation.

Three high-level knowledgeable decision-makers participated in the experiment. They 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 (9).
In an earlier work one of us had discovered that the Geoffrion, Dyer and Feinberg (9) method was relatively difficult to use (see Wallenius 27). 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 (2) was implemented. We also presented the decision-makers with a number of examples computed using different responses generated by us.

A summary of the results of the test is given in Table 1. For some additional details see (29). We note that two of the decision-makers wanted the gross domestic product to grow from the preceding year, but the third was content with a decrease in its value, since this made a considerable reduction in trade deficit possible. 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: Summary of the Results of the Iterative Decision-Making Procedure for 1976

<table>
<thead>
<tr>
<th>Criteria¹)</th>
<th>Cycle</th>
<th>GDP Increase, %</th>
<th>Inflation, %</th>
<th>Unemployment Rate, %</th>
<th>Trade Deficit Billions Fmk.</th>
</tr>
</thead>
<tbody>
<tr>
<td>First Decision-Maker</td>
<td>1</td>
<td>-2.74</td>
<td>8.16</td>
<td>3.28</td>
<td>2.24</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>0.57</td>
<td>9.00</td>
<td>2.81</td>
<td>5.27</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>1.81</td>
<td>8.88</td>
<td>2.64</td>
<td>6.54</td>
</tr>
<tr>
<td>Second Decision-Maker</td>
<td>1</td>
<td>-2.74</td>
<td>8.16</td>
<td>3.28</td>
<td>2.24</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>-0.37</td>
<td>8.27</td>
<td>2.95</td>
<td>4.55</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>0.17</td>
<td>8.29</td>
<td>2.88</td>
<td>5.08</td>
</tr>
<tr>
<td>Third Decision-Maker</td>
<td>1</td>
<td>2.00</td>
<td>10.00</td>
<td>2.50</td>
<td>6.50</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>-1.39</td>
<td>8.69</td>
<td>3.06</td>
<td>3.46</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>-1.39</td>
<td>8.69</td>
<td>3.06</td>
<td>3.46</td>
</tr>
</tbody>
</table>

¹) "Utopian" solutions obtained with one-at-a-time optimization are given in parentheses under each criterion.
region of the decision variables may not have corresponded exactly to the one thus considered relevant in the current economic situation. The decision-makers seemed to appreciate the interactive processing mode providing rapid feedback and were satisfied with the way the Geoffrion 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 advantages of the optimization framework were considered 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.
4.3. Application at the Confederation of Finnish Industries

Our intention was to implement the optimization model as a more permanent decision-making tool at the Confederation of Finnish Industries. The Confederation of Finnish Industries does not have the authority to implement the results but as an interest group of various industries it can influence the economic policy pursued. Our involvement in the project terminated by writing a detailed user’s manual (28) and by teaching some persons at the Confederation of Finnish Industries to use and update the system, so that its future use is no longer necessarily dependent on us. Prior to the application some of the equations had been reestimated and the model extended with an additional behavioral equation. In addition, net income transfers were disaggregated into a number of components, public expenditure was decomposed into public consumption and investment and total investment into private and public sector investment. The values of the predetermined variables were updated in the fall of 1976 and in the spring of 1977 in accordance with the latest "Economic Prospects in Finland", ETLA (4). In its present form the periodic updating of the model involves some labor, but it could easily be automatized so that the computer would do most of the routine work.

In the initial stages of the project we used the Geoffrion, Dyer and Feinberg method (9), but because the decision-makers experienced some difficulty in using it we subsequently
switched to the method developed by Zionts and Wallenius (31). Both methods are fully interactive and the system allows the user to execute programs in a conversational manner. In the Zionts and Wallenius method the decision-maker is only requested to provide answers to yes and no questions regarding certain tradeoffs that he likes or dislikes. His answers are used to construct sets of consistent weights for the objectives and to find the associated Pareto-optimal solutions. If such solutions are not appealing, the method generates efficient neighboring solutions and poses them to the decision-maker for his evaluation. The procedure is terminated when a reasonably good solution has been found. Two versions of the method were programmed: one assuming linear preferences and another assuming concave preferences in terms of the objectives. Because there was no reason to believe that the decision-makers' preferences would be linear the more general version was used most of the time. No test of concavity of the preference function was made. It is, however, a common assumption in economic theory and seemed reasonable in our context as well. For further details the reader is referred to (31).

The model naturally generates economic forecasts when fixed values are given for all exogenous variables and various test runs are performed to assure the user of the realism of the results. The model has also been used for investigating the impact of certain major governmental policy decisions in 1977 with given fixed instrument variables. When the model is used for optimization purposes, it is important that the specification of the bounds of the instrument variables by
the decision-maker corresponds to the relevant region in
the current economic situation. In practice a reasonable
approach seems to be to start with loose bounds and, as
new information becomes available, modify the feasible
space accordingly. Furthermore, different aspects of the
system such as the problem representation and the important
representation of the system are discussed.
Representing a first application of the general version of the Zionts and Wallenius optimization procedure, the tests provide us with some useful information about its performance. The procedure seemed generally to function well, its ease of use was appreciated and it was not sensitive to inconsistent responses by the decision-maker. On average, approximately four question sessions and ten responses were required for finding the neighborhood containing the optimal solution. The cost of a run was
<table>
<thead>
<tr>
<th>Criteria:</th>
<th>Solution 1</th>
<th>Proposed Tradeoff 1</th>
<th>Proposed Tradeoff 2</th>
<th>Solution 2</th>
<th>Proposed Tradeoff 3</th>
<th>Proposed Tradeoff 4</th>
<th>Proposed Tradeoff 5</th>
<th>Solution 3</th>
<th>Solution</th>
</tr>
</thead>
<tbody>
<tr>
<td>GDP, %</td>
<td>2.73</td>
<td>.2005</td>
<td>.0728</td>
<td>3.90</td>
<td>.2053</td>
<td>.2501</td>
<td>-.3139</td>
<td>3.90</td>
<td>4.00</td>
</tr>
<tr>
<td>UNEMPLOYMENT, %</td>
<td>4.75</td>
<td>-.0333</td>
<td>-.0109</td>
<td>4.57</td>
<td>-.0333</td>
<td>-.0394</td>
<td>.0486</td>
<td>4.57</td>
<td>4.56</td>
</tr>
<tr>
<td>TRADE DEFICIT, Billions Fmk</td>
<td>1.46</td>
<td>.1013</td>
<td>.0388</td>
<td>2.48</td>
<td>.1013</td>
<td>.2634</td>
<td>-.3130</td>
<td>2.48</td>
<td>2.58</td>
</tr>
</tbody>
</table>

Decision-Maker's response:

<table>
<thead>
<tr>
<th>Instruments:</th>
<th>&quot;NO&quot;</th>
<th>&quot;YES&quot;</th>
<th>&quot;PREFERRED&quot;</th>
<th>&quot;NO&quot;</th>
<th>&quot;DON'T KNOW&quot;</th>
<th>&quot;NO&quot;</th>
<th>&quot;NOT PREFERRED&quot;</th>
<th>&quot;PREFERRED&quot;</th>
</tr>
</thead>
<tbody>
<tr>
<td>PUBLIC CONSUMPTION, %</td>
<td>U T</td>
<td>U I</td>
<td>U T</td>
<td>U T</td>
<td>N I</td>
<td>N I</td>
<td>N U</td>
<td>N I</td>
</tr>
<tr>
<td>PUBLIC INVESTMENTS, %</td>
<td>I O</td>
<td>I D</td>
<td>I O</td>
<td>I O</td>
<td>I BR</td>
<td>I R</td>
<td>I R</td>
<td>I R</td>
</tr>
<tr>
<td>PUBLIC EXPENDITURE, %</td>
<td>T N</td>
<td>T I</td>
<td>T N</td>
<td>T N</td>
<td>T L E</td>
<td>T E</td>
<td>T E</td>
<td>T E</td>
</tr>
<tr>
<td>INDIRECT TAXES, %</td>
<td>D E</td>
<td>D E</td>
<td>I C</td>
<td>I C</td>
<td>I T</td>
<td>I T</td>
<td>I T</td>
<td>I T</td>
</tr>
<tr>
<td>DIRECT TAXES of households, %</td>
<td>2.0</td>
<td>2.0</td>
<td>6.5</td>
<td>6.5</td>
<td>6.5</td>
<td>6.5</td>
<td>6.5</td>
<td>6.5</td>
</tr>
<tr>
<td>OTHER INCOME TRANSFERS to</td>
<td>3.5</td>
<td>3.5</td>
<td>2.0</td>
<td>2.0</td>
<td>2.0</td>
<td>2.0</td>
<td>2.0</td>
<td>2.0</td>
</tr>
<tr>
<td>the public sector, %</td>
<td>0.2</td>
<td>0.2</td>
<td>0.2</td>
<td>0.2</td>
<td>0.2</td>
<td>0.2</td>
<td>0.2</td>
<td>0.2</td>
</tr>
<tr>
<td>INCOME TRANSFERS to households, %</td>
<td>1.5</td>
<td>1.5</td>
<td>2.5</td>
<td>2.5</td>
<td>2.5</td>
<td>2.5</td>
<td>2.5</td>
<td>2.5</td>
</tr>
<tr>
<td>DEVALUATION, %</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>
list of the values of the other variables and, if desired, the associated aggregate balance of resources and expenditure at each iteration. The next step requires the decision-maker to respond to certain efficient tradeoff questions concerning feasible changes in the values of the objectives. More specifically, the decision-maker was asked whether he was willing to accept an increase in GDP of .2005 %, an increase in inflation of .1925 %, a decrease in unemployment of .0333 %, and an increase in trade deficit of Fmk .1013 billion corresponding to a unit devaluation of the currency. The response was negative. The second question corresponding to a unit decrease in indirect taxes involved an increase in GDP of .0728 %, a decrease in inflation of .2202 %, a decrease in unemployment of .0109 %, and an increase in trade deficit of Fmk .0388 billion. The trade was found attractive. A solution consistent with these two responses was generated and posed to the decision-maker for his evaluation. (See Table 2). The solution essentially promised an increase in GDP and decreases in inflation and unemployment at the expense of an increase in trade deficit and implied decreases in indirect and direct taxation and other income transfers to the public sector. The general version of the Zions and Wallenius procedure requires a strict utility increase at each iteration and thus the decision-maker was asked to compare the first and the second solution. The latter solution was found more appealing and the process was continued from there. Three questions as described in Table 2 were posed to the decision-maker, but none of them was liked. However, some doubt was expressed about the fourth
question and the decision-maker was advised to respond "I don't know." Obviously, the solution consistent with the three most recent responses remained unaltered. In such a case we generate neighboring solutions to the previous solution corresponding to yes and I don't know responses. This time there was only one such solution providing a slight improvement in GDP at the expense of a corresponding increase in trade deficit (solution 4), which meant an increase in public expenditure. The new solution was not only preferred to the previous solution, but it was also considered satisfactory by the decision-maker. After evaluating the neighboring solutions the process was terminated by printing the associated aggregate balance of resources and expenditure. By comparing the optimal solution with the starting solution we can see that by increasing public investment and income transfers to households and decreasing indirect and direct taxes of households GDP can be increased and the inflation and the unemployment rates decreased at the expense of an increment of a billion Fmk in trade deficit. No devaluation would be required.

Use of the Model for Simulation Purposes

The model can flexibly be used for simulating the impact of major economic policy decisions by giving fixed values for the instrument variables. Thus e.g. when the Finnish
yen was devalued in April 1977 by 5.7%. the impact

was simulated using the model for the year 1977 simultaneously...
would at the same time increase by Fmk 500 million. The program does not seem to have any major impact on the employment situation, nor does it increase exports much.

Table 3: Changes in the Aggregate Balance of Resources and Expenditure Due to the Governmental Program to Stimulate the Economy

<table>
<thead>
<tr>
<th>Category</th>
<th>Annual Change (percentage)</th>
<th>Absolute Changes Billions Fmk.</th>
</tr>
</thead>
<tbody>
<tr>
<td>GDP (mp)</td>
<td>0.9 0.8 1.7</td>
<td>1.9</td>
</tr>
<tr>
<td>IMPORTS</td>
<td>0.7 4.5 5.2</td>
<td>1.6</td>
</tr>
<tr>
<td>TOTAL RESOURCES</td>
<td>0.9 1.6 2.5</td>
<td>3.5</td>
</tr>
<tr>
<td>EXPORTS</td>
<td>0.3 4.1 4.4</td>
<td>1.3</td>
</tr>
<tr>
<td>INVESTMENTS</td>
<td>0.8 1.2 3.0</td>
<td>0.6</td>
</tr>
<tr>
<td>- private</td>
<td>0.9 1.4 3.3</td>
<td>0.6</td>
</tr>
<tr>
<td>- public</td>
<td>0 0.3 0.3</td>
<td>0</td>
</tr>
<tr>
<td>CONSUMPTION</td>
<td>0.8 1.0 1.7</td>
<td>1.3</td>
</tr>
<tr>
<td>- private</td>
<td>0.9 0.9 1.9</td>
<td>1.1</td>
</tr>
<tr>
<td>- public</td>
<td>0 0.8 0.8</td>
<td>0.2</td>
</tr>
<tr>
<td>INVENTORY CHANGES</td>
<td></td>
<td>0.3</td>
</tr>
<tr>
<td>TOTAL DEMAND</td>
<td>0.9 1.6 2.5</td>
<td>3.5</td>
</tr>
<tr>
<td>TRADE DEFICIT</td>
<td></td>
<td>0.5</td>
</tr>
<tr>
<td>UNEMPLOYMENT (%)</td>
<td></td>
<td>-0.2</td>
</tr>
</tbody>
</table>
would at the same time increase by Fmk 500 million. The program does not seem to have any major impact on the employment situation, nor does it increase exports much.

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<table>
<thead>
<tr>
<th></th>
<th>Annual Change (percentage)</th>
<th>Absolute Changes Billions Fmk.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Vol.</td>
<td>Price</td>
</tr>
<tr>
<td>GDP (mp)</td>
<td>0.9</td>
<td>0.8</td>
</tr>
<tr>
<td>IMPORTS</td>
<td>0.7</td>
<td>4.5</td>
</tr>
<tr>
<td>TOTAL RESOURCES</td>
<td>0.9</td>
<td>1.6</td>
</tr>
<tr>
<td>EXPORTS</td>
<td>0.3</td>
<td>4.1</td>
</tr>
<tr>
<td>INVESTMENTS</td>
<td>0.8</td>
<td>1.2</td>
</tr>
<tr>
<td>- private</td>
<td>0.9</td>
<td>1.4</td>
</tr>
<tr>
<td>- public</td>
<td>0</td>
<td>0.3</td>
</tr>
<tr>
<td>CONSUMPTION</td>
<td>0.8</td>
<td>1.0</td>
</tr>
<tr>
<td>- private</td>
<td>0.9</td>
<td>0.9</td>
</tr>
<tr>
<td>- public</td>
<td>0</td>
<td>0.8</td>
</tr>
</tbody>
</table>
In this paper we have described work in process to implement an optimization model for formulating macroeconomic policy decisions in Finland. One of three experienced decision-makers who experimentally used the model to solve the problem for 1976 felt that the approach would be valuable in providing decision-makers with relevant quantitative information and was willing to continue and finance the implementation work at the Confederation of Finnish Industries. The system has now been used for one year for optimizing economic policy and simulating certain major governmental decisions. It is also expected that the system will be used in the future. It has been agreed, among other things, that a seminar will be arranged in the near future by the Confederation of Finnish Industries at which some leading Finnish decision-makers will be invited to use it.

If the system described in this paper is used for regular
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 (\(\cdot\)); 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) \(C_{-1}\).

CONSUMPTION

- \(c, C\): total consumption
- \(cpr, Cpr\): private consumption
- \(cg, Cg\): public consumption
- \(pc\): price of total consumption
- \(pcpr\): price of private consumption
- \(pcg\): price of public consumption

INVESTMENTS

- \(i, I\): total investments
- \(ipr, Ipr\): private investments
- \(ias\): private investments in housing
- \(iasc\): other private investments
- \(ig, Ig\): public investments
- \(N\): inventory changes
- \(pi\): price of total investments
- \(pipr\): price of private investments
- \(pig\): price of public investments
FOREIGN TRADE

Imports
m, M total imports
mg, Mg commodity imports
ms, Ms imports of services
pm price of total imports
pml price of commodity imports

Exports
mx weighted growth of industrial production in ten OECD countries (export demand variable)
x,X total exports
xE, XE bilateral commodity exports
xg, Xg commodity exports
xgw, Xgw multilateral commodity exports
xs, Xs exports of services
px price of total exports
pxcom price of competing exports
pxg price of commodity exports

Others
E trade deficit
S factor income from abroad (net)

SALARIES
H wage increases exceeding profitability
k1 effects of employers' contribution to social security
W total wage bill (inc. social security)
Ws total wage bill (exc. social security)
wI wage rate

LABOR INPUT

all total labor input
U unemployment rate
### INCOME VARIABLES

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>K</td>
<td>profit margin</td>
</tr>
<tr>
<td>NI</td>
<td>national income</td>
</tr>
<tr>
<td>$o_{1}$</td>
<td>public sector income from property and enterprises</td>
</tr>
<tr>
<td>WZD</td>
<td>disposable income of households</td>
</tr>
<tr>
<td>$z_{10}$</td>
<td>nonlabor income</td>
</tr>
</tbody>
</table>

### SAVING

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>$o_{4}$</td>
<td>corporate saving</td>
</tr>
</tbody>
</table>

### TAXATION

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>$o_{3}$</td>
<td>direct corporate taxes</td>
</tr>
<tr>
<td>$o_{5}$</td>
<td>direct taxes of households</td>
</tr>
<tr>
<td>Ti</td>
<td>indirect taxes minus subsidies</td>
</tr>
<tr>
<td>TiDN</td>
<td>incidence of indirect taxes minus subsidies</td>
</tr>
</tbody>
</table>

### INCOME TRANSFERS

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Description</th>
</tr>
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<tbody>
<tr>
<td>$o_{6}$</td>
<td>other income transfers from households to the public sector</td>
</tr>
<tr>
<td>$o_{7}$</td>
<td>income transfers from the public sector to households</td>
</tr>
<tr>
<td>$o_{8}$</td>
<td>income transfers of households abroad</td>
</tr>
<tr>
<td>$o_{9}$</td>
<td>income transfers from abroad to households</td>
</tr>
<tr>
<td>$o_{10}$</td>
<td>net income transfers of households</td>
</tr>
</tbody>
</table>

### OTHERS

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>d, D</td>
<td>total demand</td>
</tr>
<tr>
<td>$dn$, $DN$</td>
<td>total demand minus inventory changes</td>
</tr>
<tr>
<td>pdn</td>
<td>price of total demand minus inventory changes</td>
</tr>
<tr>
<td>F</td>
<td>depreciation</td>
</tr>
<tr>
<td>g, G</td>
<td>public expenditure</td>
</tr>
<tr>
<td>pg</td>
<td>price of public expenditure</td>
</tr>
<tr>
<td>$o_{2}$</td>
<td>interest on public debt</td>
</tr>
<tr>
<td>$y$, $Y$</td>
<td>gross domestic product at market prices</td>
</tr>
<tr>
<td>yn</td>
<td>gross domestic product minus inventories</td>
</tr>
</tbody>
</table>
py    price index of gross domestic product
Ynfc  net domestic product at factor prices

Desiderata:
1. Change in the volume of gross domestic product (y) as big as possible.
2. Inflation (pc) as small as possible.
3. Unemployment rate (U) as small as possible.
4. Trade deficit (F) as small as possible.

Behavioral equations:

Domestic expenditure:

1. cpr = .365(WZD - pcpr) + .435(WZD - Cpr) \_1 - 2.407\_U + 2.389
2. iasc = 3.111\Delta y_n -3/4 + .527Z_{10} + .487Z_{10} -1 - .573\Delta ppr - .916
3. N = .321\Delta d_n -1/2 + .037\Delta pmg - .369N_{-1} + .695

Foreign sector:

4. xgw = 2.338mw - .520(pxg - pxcom) - .828(pxg - pxcom) \_1
   \_ - .308(pxg - pxcom) \_2 - 3.172
5. mg = 1.924dn + 3.074N + .594(py - pmg) \_1 -1/3 + .334\Delta d_n - 3.868

Labor input and unemployment:

6. uII = .549y + .060y_{-1} + .049K - .881
7. U = -.287uII + \_U_{-1} + .879

Wages and prices:

8. wI = .562pcpr + .9(y - uII) \_1/2 - .846U + .4(wI - .562pcpr
   \_ + .846U) \_1 + .074
9. \( \text{pcpr} = 0.362H + 0.164\text{pmg} + 0.207\text{TiDN} + 2.084 \)

10. \( \text{pcg} = 0.757H + 0.060\text{pmg} + 0.090\text{pcg}_1 + 2.486 \)

11. \( \text{pipr} = 0.363H + 0.255\text{pmg} + 0.155\text{pipr}_1 + 1.086 \)

12. \( \text{pig} = 0.812H + 0.208\text{pmg} + 0.136\text{pig}_1 - 0.254 \)

13. \( \text{pxg} = 0.189H + 0.780\text{pxcom} + 0.069\text{pmg} + 0.3(\text{pxg} - 0.189H - 0.069\text{pmg})_1 - 0.297 \)

Definitional equations:

14. \( \text{Cpr} = \text{cpr} + \text{pcpr} \)

15. \( \text{Ipr} = \text{ipr} + \text{pipr} \)

16. \( \text{ipr} = (\text{tiasc/tipr})_1\text{iasc} + (\text{tias/tipr})_1\text{ias} \)

17. \( \text{G} = (\text{tCg/tG})_1\text{Cg} + (\text{tIg/tG})_1\text{Ig} \)

18. \( \text{Xgw} = \text{xgw} + \text{pxg} \)

19. \( \text{Mg} = \text{mg} + \text{pmg} \)

20. \( \text{D} = (\text{tCpr/tD})_1\text{Cpr} + (\text{tIpr/tD})_1\text{Ipr} + (\text{tDN/tD})_1 \)
29. \( Ti = DN \times Ti_{DN} \)
30. \( x_E = XE - px \)
31. \( x_g = (txg/wx)_1xg + (tx/tx)_1xg \)
32. \( x = (txg/tx)_1xg + (txs/tx)_1xs \)
33. \( X_g = (txg/wxg)_1Xg + (tx/txg)_1XE \)
34. \( X = (txg/tx)_1Xg + (txs/tx)_1xs \)
35. \( X = x + px \)
36. \( m = (tmg/tm)_1mg + (tm/tm)_1ms \)
37. \( M = (tmg/tM)_1mg + (tm/tM)_1Ms \)
38. \( y_n = (tdn/tn)_1dn - (tm/tn)_1m \)
39. \( d = (tcp/ttd)_1cpr + (tigr/td)_1ipr + (tdn/td)_1N + (tg/td)_1g + (tx/td)_1x \)
40. \( y = (td/ty)_1d - (tm/ty)_1m \)
41. \( Y = (td/ty)_1d - (tm/ty)_1M \)
42. \( Y = py + y \)
43. \( Y_{nfc} = (ty/y_{nfc})_1Y - (tF/y_{nfc})_1F - (tT/y_{nfc})_1Ti \)
44. \( N_{I} = (y_{nfc}/tNI)_1Y_{nfc} + (y_{nfc}/tNI)_1S \)
45. \( Z_{10} = (tNI/tz10)_1NI - (tW/tz10)_1W \)
46. \( c = (tcp/tc)_1cpr + (tcg/ct)_1cg \)
47. \( i = (tip/ti)_1ipr + (tip/ti)_1ig \)
48. \( C_g = cg + pcg \)
49. \( I_g = ig + pig \)
50. \( C = (tC/pr/tc)_1Cpr + (tCg/tC)_1Cg \)
51. \( I = (tip/ti)_1ipr + (tIg/tI)_1ig \)
52. \( C = c + pc \)
53. \( I = i + pi \)
54. \( G = g + pg \)
55. \( O_{10} = -0.1 -0.2 -0.3 -0.4 -0.5 -0.6 -0.7 -0.8 +0.9 \)
56. \( \bar{x} = \bar{x}_{g-1} + \frac{M_g}{100} \bar{x}_{g-1} - \frac{X_g}{100} X_g \)
57. \( g = (tcm/tg)_1cg + (tig/tg)_1ig \)
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):

58. \( \bar{pm} = \bar{pm} + De \)
59. \( \bar{pxcom} = \bar{pxcom} + De \)
60. \( \bar{pmg} = \bar{pmg} + De \)
61. \( \bar{Ms} = \bar{Ms} + De \)
62. \( \bar{Xe} = \bar{Xe} + De \)
63. \( \bar{Xs} = \bar{Xs} + De \)
References


(4) "Economic Prospects in Finland", Research Institute of the Finnish Economy, (ETLA), Bi-Annual Publication, Helsinki.


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 Equation (14) of the original model, for instance, reads 
   \[ C_{pr} = c_{pr} + p_{cpr} + 0.01c_{pr} \times p_{cpr}, \]
   for which the first two terms with small changes in \( c_{pr} \) and \( p_{cpr} \) give a reasonably good approximation. For different versions of the model see Vartia (24).

3 The Geoffrion method was implemented using a linear programming algorithm in which case the direction-finding problem always generates a corner solution. One of the reasons for using the Geoffrion method in the experiment was that we had available a workable computer program embodying the method.

4 For methods of manipulating the solutions of the model and for ways of combining outside information with an existing model, see Vartia (24, 25).

5 As consultants to the Confederation of Finnish Industries Hannele and Jyrki Wallenius assume the responsibility for the results reported in section 4.3, but wish to thank the Research Institute of the Finnish Economy for making the model available. During the project we were responsible directly to the Deputy Managing Director.
6 A definition of an efficient neighboring solution and the procedure for identifying them is given in (31).

7 The necessary FORTRAN programs were developed by Mr. Matti Sihto, Helsinki Technical University.