Economic Models for Planning and Policy Making

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I. Numerical Models

Like plans themselves, numerical models applied to planning and programming can be differentiated according to:

(i) the time horizon,

(ii) the scale of sectoral-economic disaggregation,

(iii) organizational-administrative criteria, and

(iv) regional criteria.

Other classification criteria could also be accepted: those based on the character of target variables, on the number of instruments, on the mathematical properties of the models, etc.

(a) Overall central models

Aggregated and simplified macro-models

These models analyse the basic inter-connexions between the rate of national income, consumption, investment, foreign trade and the labour force. They help in formulating possible variants of development strategy in long-term programmes and medium-term plan. They are based on the use of overall coefficients characterizing the structure of the economy in varying degrees of detail (labour productivity, capital-output ratio, capital-labour ratio, etc.).

Macro-economic models may serve the central planner as a medium for his active role in designing the original outline of the development strategy

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for application at sectoral levels. But the model-building exercise, worked out independently at the centre, may be treated not only as an instrument of preliminary choice among alternative strategies, but also as a first set of internally consistent macro-directives for the working out of further, more detailed, versions of the programme or plan. In this way the exercise becomes an instrument for logical control in planning and counter-planning procedures, and helps to create a rational sequence of plan-building processes.

For such aggregate and simplified models, only a fairly simple set of aggregative variables is needed. For example, the model builder can start with a desired rate of growth of national income per head, and compute as a tentative target the required level of total national income, given a forecast of total population growth.

Short-term aggregated macro-models

Aggregated macro-models have also been developed for the formulation of short-term, or "conjunctural" policy. Perhaps the best-known example in western Europe is that developed by the Netherlands Central Planning Bureau. This is essentially an annual forecasting model which is used to present alternative forecasts under alternative policy assumption.The dependent variables in the "reaction" equations of the model concern the major aggregates of private final expenditure, the demand for labour and for imports, factors determining price formation (including wages), and the volume of liquidities.

Disaggregated simplified macro-models

This approach centres on the use of input-output, or activity, models of production. In the simplest version, the input-output model of production is the only formal part of the model. Exogenous estimates of final deliveries to private and public consumption, investment in stocks and fixed capital and exports—sometimes also of compe titive imports—are used in conjunction with such a model to determine the implied levels of production and empolyment in the various industrial branches, structural imports, real incomes of wage- and salary-earners, etc. In more developed versions, partial models of other aspects of the economic structure may be grafted on to the production model.

As an example of this type of model the model used in preparing the annual national budget in Norway may be mentioned. This model consists of an input-output model with about 150 production sectors and a model determining deliveries to private consumption from each of the major production sectors. These latter deliveries are assumed to be functions of incomes and relative prices. Exogenous estimates are made of changes in gross investment, government consumption, tax rates, certain items of private consumption, exports from each sector, and gross production in a limited number of sectors where production is assumed to depend on supply conditions. Exogenous estimates are also made of wage and productivity changes in all sectors, price changes in sectors with strong foreign competition and changes in profit rates in other sectors.

(b) Developed interbranch optimization macro-models and their connexion with sectoral models

The aggregated simplified models are appropriate for any organization of the planning system. Within any system, they help to formulate the first version of macro-directives, but are no more than a first step in elaborating more detailed plans either on the central or the sectoral level.

Attempts have been made to enlarge the field of practical application of mathematical methods by constructing macro-models for medium-term plans encompassing up to 300～400 branches or product groups. If such a models is used in conjunction with mathematical methods of planning and counter-planning connecting the macro-model with sectoral models, it can give the central authority a new and powerful instrument for the construction of better central plan-directives.

The problems encountered in constructing better developed macro-models for long- and medium-term plans are now engaging the attention of planners. One of the most advanced experimental works in this field is the Hungarian "two-level model" for the medium-term plan. This is a multi-sector macro-model covering the whole complex of investment, technical development, production, import and export plans, and international financing.

This macro-model approach, as exemplified by the Hungarian experiment, though comprehensive, is not complete. It covers the most important sectors but not every sector, the major investment projects but not the whole of investment. Other models embracing the whole enconomy—both the more aggregated models, and the various static and dynamic input-output models can be used to complement the two-level planning approach, or as tools in designing plans for a more limited scope of policy.

Some of the basic requirements for developed, optimizing macro-models are as follows:

The *first* requirement is the formulation of a set of alternative preference functions. Possible alternative formulations are:

(i) maximization of consumption over the period of the plan, assuming a given rate of investment and minimum growth of consumption in the consecutive intermediate stages; constraints for, *inter alia*, foreign trade and labor are given;

(ii) maximization of a fixed structure; constraints on, *inter alia*, foreign trade and labor are given;

(iii) maximization of foreign currency earnings, final production for domestic use being given, together with constraints on, *inter alia*, foreign trade and labor;

(iv) minimization of costs under given lower limits on final home production and the current balance of foreign trade; constraints, *inter alia*, for foreign trade and labor are given. Two possible sub-variants are applied:

(a) minimization of labor costs, investment outlays being given;

(b) minimization of the sum of labor costs and investment outlays.

Secondly, there are the structural and balancing constraints.

These are:

(i) input-output balance equations for materials;

(ii) conditions relating the increase in productive capacities in time with investment outlays in time;

(iii) labor equations relating the level of employment with the level of production;

(iv) foreign trade balances relating exports, and currency balances and taking into account foreign supply- and demand-limitations;

(v) financial balances, e.g. relating consumers' money incomes with the supply of goods for consumption.

Third come the statistical requirements. The application of models to planning is limited by computational problems. It is also limited by the quantity and organization of statistical data. In particular, aggregation often leads to the explicit or implicit assumption of stable coefficients.

Finally, it should be said that the process of multi-sectoral model-building has to be adapted to the existing organizational structure of the economy. The divergences between a statistically or economically convenient subdivision of sectors and branches on the administrative and organizational economic structure on the other, are bound to create problems for the model builder. Yet for the application of a plan in practice it is essential that the subdivisions of the economy for which targets and modes of behavior are proposed in the plan should be identified with specific agencies and groups of decision-making units. The design of the subdivision of the model must as far as possible be organically related to the organizational structure of the administration and of the economy.

(c) Partial models—sectoral, regional and specific purpose modes

These models encompass only one sector(or a branch within the sector) or one region, or one aspect of economic policy, and can therefore answer more detailed questions. The problems of aggregation and data processing are more acute in regional models than in sectoral ones, simply because the necessary data for regional analysis are so often lacking.

All these partial models require the existence of a set of directives and of central parameters from the central planner. Here two approaches are possible:

(i) the central planner fixes quantitative limits for sectoral targets and for sectoral resources; or

(ii) the central planner fixes quantitative limits for sectoral targets and shadow (accounting) prices for the evaluation of resources; or the exercise must be conducted in terms of market prices.

Models can be constructed to solve such problems as:

(a) special problems of financial or monetary policy,

(b) the structure of final production,

(c) the choice of techniques,

(d) the optimal use of existing capacities,

(e) the allocation of sectoral investment funds among branches,

(f) the geographical allocation of regional investment funds,

(g) the location of enterprises within a region,

(h) problems of interregional commodity flows, etc.

The following preference functions are usually applied in partial models:

(a) maximization of final production under some limitations on changes in its internal structure,

(b) maximization of profits under the same limitations,

(c) minimization of outlays, given final demand,

(d) maximization of foreign currency surpluses, given final demand.

The field of application of partial models is very broad. Input-output tables are used for checking the consistency of sectoral plans. Models of investment allocation within given sectors or regions are constructed. Models of optimization of investment for foreign trade, as well as models of current optimization of foreign trade, are applied in practice. Transportation models are built and used within branches and regions. Models can be built applying to financial policy, or monetary policy, or tax-policy, or income distribution, or to such problems as educational development.

Practical experience shows that the construction and application of partial models must be strictly connected with the fields of competence of the administrative agencies responsible for the questions which the model-building procedure is designed to answer. Only then can the model analysis became a workable tool of importance in practical decision-making.

In general, it can be said that the purpose of the investigations now going on in several countries into the field of application of numerical models is not to define a single programme which would then be unequivocally recommended for execution, but continuously to work out plan variants and their consequences, keeping the data of the model up to date. The mathematical model should thus become a permanent tool of continuous planning.

II. Non-Numerical Algebraic Models

A non-numerical model, formulated in algebraic terms and representing the economic structure in the abstract, is used to analyse the functioning of the system and the properties of the optimal solution. On the basis of this analysis it becomes possible to formulate decision criteria for specific decision units. These decision criteria depend on central parameters determined by overall balances. The central parameters will typically be "shadow prices" for certain basic commodities, a "shadow rate of interest", and "shadow exchange rates" for trade with particular foreign markets. They might also be the prices, for example, of labor or capital goods. The purpose of these central parameters is to provide a guide for partial optimization superior to that provided by the existing structure of prices. The central parameters are intended both for the guidance of the separate decision units in drawing up their planning proposals, and (after revision in the course of the iterative process of drawing up the plan) for their guidance in the actual conduct of their affairs in carrying out the plan.

The non-numerical model lays down the parameters for a numerical solution to be found by specific decision unit, not the solution itself. The non-numerical model may then be used as a basis for constructing a system of numerical models and traditional planning and decision-making procedures.

Such a system may embrace one central and several subordinated decision-making units, all adopting the patterns of behavior and observing the decision criteria indicated by the analysis of the non-numerical model.

The method seems particularly applicable for planning and management over fairly short periods, when production capacities are given, and attention is focused on the efficient use of these capacities and on the choice among existing techniques of production and foregn trade. The level and structure of profit maximization, which contain a set of central parameters, i.e. marginal rates of exchange(expressing the scarcity of foreign currencies in the overall solution) and shadow (accounting) prices of basic commodities (also expressing their scarcities in the overall commodity balance). Once it has received these central parameters, every enterprise or group of enterprises can construct a short-run optimization model and solve it numerically, using methods of operational research, or can optimize its structure of production and the geographical allocation of its exports and imports by simple traditional planning techniques.

The non-numerical model approach can also be used for longer-term planning and management. In the dynamic longer-term model, changes of productive capacities through investment are introduced, and the time factor is taken into account. Beginning by evaluating possible variants of the desired level and structure of final demand, the central planner works out an outline of an overall strategy of development, based on the exploration of future possibilities and formulates plan directives for the executive level. The longer the time horizon, the larger the field of manoeuvre, but at the same time the more the elements of uncertainty. Here various approaches are possible: general dynamized models expressing the time schedule of activities (dynamic multi-stage models) on the one hand, or simpler single-phase solutions for consecutive years on the other.

The choice of preference function determines the solution of the model. This choice belongs to the category of value-judgements and is made on general political, social and economic considerations. The role of the model builder, on the basis of the algebraic analysis of the properties of the optimal solution, is to elaborate the system for translating general criteria into partial criteria for executive levels, consistently with the preferences of the central planning authority. The basic and complex question reappears: how to decompose or disaggregate the overall optimization model into partial models corresponding to the lower levels of decision-making.

At this point the approach may be different from that accepted in the short-run model. First, the necessity for disaggregation is much less in long-term than in short-run planning, and it is therefore more acceptable to operate with aggregates. Secondly, the use of existing market prices, or of shadow prices, expressing present scarcities and present preferences, must be excluded for rational long-term optimization. New shadow prices expressing future preferences and scarcities should be introduced into the optimization procedure. Reliance on purely static analysis of the existing structure is of no use: new central parameters must be estimated or computed. If the scope of planning activities requires the cooperation of lower administrative units, then the central planning authority must formulate plan directives and consider the resources required to implement them. These formulations may take the shape either of quantitative constraints on targets and resources, or of shadow prices for the evaluation of resources.

Which of the two basic theoretical approaches(aggregation or decomposition), or what combination of them,will in practice best conduce to optimization in long- and short-term planning and management remains to be seen. The answer to this question seems to be of crucial importance for the formulation of rational principles and procedures for planning and management.

Annex A: Kalecki's Model

In Prof. Kalecki's general model the basic relationships determining the rate of growth of national income are as follows:

$$\frac{\Delta y}{y}=\frac{1}{m}\frac{I}{y}-a+u$$

'where

y—annual national income

Δy—annual increment of national income both calculated in gross terms (i.e. without deduction of depreciation) and at constant prices.

m—marginal capital/output ratio

I—annual gross expenditure on productive investment at constant prices.

a—capacity reducing coefficient (related to annual replacement of worn-out fixed captial)

u—coeefficient expressing the annual increment of national income due to factors other than investment (better utilization of fixed capital, etc.)

When this model is used in perspective planning, it is assumed, first, that there is no accrual of foreign credit, so that the necessity of balancing foreign trade is paramount; and, second, that the increment of output yielded by better utilization of fixed capital (i.e.$u=a$). It follows that in the long-term analysis of basic relationships the increase in output is treated as a function of productive investment only.

$$\frac{\Delta y}{y}=\frac{1}{m}\frac{I}{y}$$

Annex B: Stone's Cambridge Model

The model developed at Cambridge University by R. Stone, J. A. C. Brown and others is as follows:

(1) $q=Aq+h+x-m$

(2) $n=\hat{a}_3 q$

(3) $\beta=i'(x-m-n)$

where

q—vector of gross outputs

h—vector of home final demands

A—matrix of fixed input coefficients

x—vector of exports

m—vector of competitive imports, all classified by commodity type

n—vector of non-competitive imports classified by industry of use

$\hat{a}_3$—matrix of non-cempetitive import coefficients

β—external balance of goods and services

All figures are in £ million at 1960 prices.

Equation (1) expresses the equality between supplies (q) and demands ($Aq+h+x-m$) for commodities. The use of matrix A implies proportionality between inputs and outputs. Equation (2) relates non-competitive imports to production of commodities, by simple proportionalities of the input-output type. Equcation (3) merely says that the external balance of goods and services is equal to the difference between exports and imports.

Annex C: The Traditional Method of Strategy-Building

(1) $P=P_0+\Delta P(\Delta E,I,T)$

(2) $N_w=h(N)$

(3) $E=h(N_w)$

(4) $Z=E.b$

(5) $E=E_a+E_n$

(6) $Z_n = g(P_n, T_n)$

$$E_n = \frac{Z_n}{b_n}$$

(7) $Z_a = g(P_a, T_a)$

$$E_a = \frac{Z_a}{b_a}$$

(8) $Z_a + Z_n = E_a b_a + E_n b_n$

(9) $I = K_k + IK_k + M_k$

(10) $I = S + D + L$

(11) $S = g(Y)$

(12) $P + M = PA + C + I + X$

(13) $P^{mb} = f(P^b) = g(I)$

(14) $P_c + M_c = C + X_c$

$$P_k + M_k = I + X_k$$

where

P—production

P_0—production in base year

E—employment

ΔE—increase in employment

I—gross investment

N_w—population of working-age

N—total pouplation

Z—labor inputs

b—average working time

E_a, E_n—employment of the agricultural and non-agricultural sectors respectively

Z_a, Z_n—labor input of the respective sectors

P_a, P_n—production of the respective sectors

T_a, T_n—techniques of the respective sectors

b_a, b_n—average working time of the respective sectors

K_k—existing capacity for producing capital goods

IK_k—technically possible increment of capacity for producing capital goods

S—home savings

D—depreciation

L—foreign loans (net)

Y—national income

M—imports

C—consumption

X—exports

A—matrix of current coefficients

P^{mb}—production of building materials

P^b—production of construction sector

P_c, P_k—production of the consumer and capital goods sectors respectively

M_c, M_k—imports of the respective sectors

X_c, X_k—exports of the respective sectors