Models, Simulations and Games

1. Introduction

Ministers of finance, the heads of central banks, members of missions and government agencies often take pride in distinguishing themselves as practical men, in contrast with academic economists and most members of research and planning institutes.

Practicality, role and purpose are often confused. What is practical for one purpose may spell disaster for another. The basic nature of a modern economy is such that it requires a considerable division of labor in decisionmaking, planning, basic data gathering and research. All or these processes are necessary. In general they are provided by diverse groups with only a lose interlinkage among them. Successful economic policy depends to a great extent upon the optimum coordination of these different activities. Much of the conflict among individuals and organization hinges upon the problem that what is regarded as practical, relevant and important by the data gatherer or researcher may be regarded as a waste of time by the decisionmaker and vice versa.

In this paper we wish to differentiate seven different activities and to discuss the role of the new and growing methodology in model construction, simulation and gaming in providing a way of increasing the amount of coordination, recognition of different problems and needs and mutual respect among individuals who differ fundamentally not only in their positions and goals, but often in personalities and sociopsychological viewpoints.

A national economic decision system involves:

1. Political decisionmaking and goal setting (PDM)
2. Administrative decisionmaking and implementation (ADM)
3. Data gathering and storage (DGS)
4. Data processing (in context of its projected use) (DP)
5. Planning (PL)
6. Research (R)
7. Teaching, training and recruiting (TTR)
When a country has been through a period of crises, such as many years of bad administration, or confused and ineffective top decision-making it is possible that great gains can be made by the setting of goals and by direct improvement of administration. However the very success of moves of this variety will make further success highly dependent upon the coordination with other groups. Although for some brief periods of development coordination may be neither necessary nor optimal, this is the exception, not the rule.

Figure 1 is meant to be suggestive of the primary interrelationships that exist among the different functional groups. It should not be regarded as a specific institutional structure. Depending upon the country, the availability of personnel, historical accident and so forth, the institutional details of organization will vary. However the basic roles remain.

Political decisionmaking and goal setting must be tuned to the realities and pressures of the moment. This is a far cry from the interests of most researchers. For this reason there is, in general, very little need for much direct communication between political decisionmakers and economic theorists. The lack of need for direct communication however should not be confused with needs for indirect communication. Lord Keynes observed that the influence of the theories of economists long since dead on everyday policy making is enormous. I am not advocating that the only operationally useful economist is a dead economist, however today's theorizing will be of poorer quality and dubious use if it is linked too closely to value oriented desicionmaking.
Possibly one of the most difficult parts of an economy to characterize adequately is the administrative decisionmaking and implementation system. The dreams of the politician and reformer together with the hopes and visions of the academics and theorists are transformed into administrative reality together with its attendant telephone calls, message sending, conferences and generation of documents.

The inertia of large bureaucracies is such that they often take on a dynamics of their own. Their importance to the facilitating of affairs is so large and their goals, methods of promotion and recruitment, so internalized that in the short run and to a certain extent in the long run the power of political decisionmaking in considerably limited by administrative realities which cannot be cured by *housecleaning*. Because once one has cleaned house and ridded oneself of the bureaucratic structure, usually there are not enough trained individuals to administer the system.

Data gathering and data processing are separated as activities in order to stress some important differences in function and in level of decisionmaking. It is really not possible to separate completely the gathering of data from thinking about the uses and the value of information. For most purposes processed data contains considerably more usable information than raw data. Furthermore it is in general not economic to gather enormous quantities of raw data without subjecting them immediately to refinement. The type of refinement will depend upon the ultimate uses. The design of the refinement process cannot be left to the data gathering group alone; but must be done in coordination with those directly concerned with data processing and with the preparation of information to be used for planning, administrative decisionmaking and research.

In most countries and large organizations the data gathering group, be they called the bureau of statistics, the census or the statistical office, is not particularly a major center of power, even if it has the largest computer establishment in the country. The gathering of basic statistics is a service function. It will be done well if those who need information are sufficiently coordinated with the data gathering to provide the guidelines and criteria for preliminary refinement. Otherwise, without this coordination the data-gatherers must second-guess the needs of the users or bury themselves in unworkably large collections of numbers that scarcely, if ever, are processed. Routine data-gathering is not exciting work. Frequently, for this reason, it is overlooked when funds are being allocated to improve the information network. It is our belief that the
marginal value productivity of investment in quality control and administrative procedures at the point of data gathering may be enormously high.

In the same way that metallic ore is frequently refined and rerefined before it reaches its final user, so must data be converted into relevant information. The first refining is at the point of collection. Transportation of the crude material in bulk is too expensive and for this reason the design of questionnaires, formats and samples are so important.

After the preliminary data processing associated with data gathering has been done, then data processing associated with the preparation of information for specialized users is called for. This involves a far higher level of decisionmaking than is involved in the first refinement. In particular there must be close cooperation in the selection of the criteria for data reduction and the methods for checking for compatibility of data. Furthermore at this point, consideration must be given to both consistency and completeness of the information base.

What information is to be stored for several years, how is it to be stored, where and in what form for data retrieval? The nature and location of data banks are critical to the functioning of an information system.

The information needs of administrative decisionmakers, planners and researchers are considerably different. In particular the tradeoff between speed and accuracy in the different uses is critical. Accurate information supplied in a month's time may be excellent for the researcher but of no use to the decisionmaker.

The planning function will almost always be under more pressures than any other part of the system because in order for it to function in a healthy manner it must have a direct interface with the political decisionmakers, with data processing and with research. This role tends to produce split personalities among the planners. They always run the danger of being captured by the day by day operations of the political decisionmakers and thereby lose much of their value to their masters as they may fail to fulfill the important role of providing an objective evaluation of the effect of projected policies.

A good planning group must be aware of the current thinking of researchers and it must constantly be examining the feasibility and the value of the application of new methodology. It plays the role of broker or retailer between the decisionmakers and the researcher. At the same time the planners must be directly concerned with improving the flow
of information which enables them both to advise decisionmakers and evaluate projects in a manner that meets professional standards.

Neither short nor long range planning is a day to day operation. It needs an objectivity and an attitude that easily might inhibit an individual from simultaneously being able to make short term decisions. Nevertheless a planner must differ considerably from a researcher. He must perform his work in the context of the economic and political realities and in the full understanding of the needs of the decisionmakers.

The researcher is a short run luxury and a long run necessity to the healthy decisionmaking system. He is vital both to the growth of new knowledge and to the transmission of existing knowledge. It is not difficult for a system to run for several years with poor research, bad universities and an exodus of research-oriented graduate students. Such a system however is living off capital and cannot maintain such a mode indefinitely.

At the same time as a good decision system needs the long run products of the researcher in the form of new theories and methodologies and well trained students, the researcher needs to interact with the planners and data processors. A research worker need not be practical in the same sense as a decisionmaker must be practical. However good research calls for testing ideas against reality. For example the concepts of unemployment, capital and money (to name three among many) are all extremely subtle. The subtleties are usually of little interest to the decisionmaker. However they are critical to accurate planning and of great importance in the design of categories for data gathering. The researcher needs to be able to obtain data to check his theories and he is in a position to benefit from interchanges with planners who are in a position to offer him criticism in a spirit and manner that he can accept. Often (although there are exceptions) an attempted dialogue between a decisionmaker and a researcher might as well be carried on in different languages. Each one believing that the other's views are irrelevant to his concept of reality.

The health of a group of institutions depends not only upon their ability to remain flexible with respect to new knowledge and changing conditions; it also depends upon the opportunities to recruit and promote new talent. Here once more the role of researchers in research institutions and the universities is of considerable importance. There must be enough opportunity and challenge to locate, attract and motivate potential talent.

A sketch has been presented of seven different roles relevant to economic decisionmaking. We now turn to the consideration of some new techniques and methodology, specifically to consider their role in increasing
the coordination among the different roles and improving the overall performance of the system.

2. Models, Simulation and Gaming

Verbal, diagramtic and mathematical models have been familiar to economists at all levels for many years. The advent of the high speed digital computer, however, has introduced new possibilities in economic decisionmaking, planning, data processing and research. In particular models of economic process can now be translated into computer programs and those programs can be run to produce future contingent histories. The existence of computer programs now makes it possible to estimate the parameters of equations portraying economic or other behavior. Without the computer, although some of the statistical methods were known and were regarded as logically applicable, they were obviously technologically inapplicable owing to costs in time, money and error checking.

New techniques of data storage and retrieval have totally changed the scope of economic data processing. Although we have not yet seen the growth of large data banks, they will undoubtedly come into being. Even more important than the technical details of data bank organization are the institutional implications and the new possibilities for the coordination of research, planning and decisionmaking all working in concert on the same information system.

The high speed digital computer together with modern communications has completely changed the scope the information network in a modern economy.

Now speed in gathering and processing data is not, by itself enough. Methods for controlling and organizing the great new flood of data need to be found. Economic and other models serve as methods to supervise and organize information. They provide checks on compatibility of units of measurement, logical consistency and completeness of the supply of information for specific purposes.

It would be naive to believe that it is easy to build an economic model of sufficient accuracy that it is possible to use its outputs with great confidence for short or long range planning. A model however is a concept made explicit. It provides a way for checking to see if one's perception of the problem at hand is plausible and logical. A simulation enables us to connect a model to a data source.

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A good model contains within itself both a view of the environment and a set of relevant questions. A model is an abstraction, it is a partial representation of reality. It selects what is deemed to be of importance. Thus a model is a data organizing device. It makes data gathering and processing easier because it is usually considerably easier find something if you know what you are looking for.

The decisionmakers will not usually be served directly by a simulation. The benefit at this level comes through an improved information system and through the possibility of operational gaming: this latter point is discussed below.

Figure 2 indicates the organizational value of coordinated work on simulation. In particular one would expect that the planning agencies

General Simulation = GS
Special Simulation = SS
Operational Games = OG
Experimental Games = EG

 Statistical Search Methods = SSM
Technological Information = ETC
Economic Theory = ET
would build special simulations for their own purposes while at the same
time they would work in concert with researchers and the data processing
and gathering agencies on some common models dedicated to fulfilling
their important but different purposes in concert. The three purpose are
as follows. First, to supply the planners with constantly improving basic
economic models which can be used in parallel with their other methods
of prediction. Second to provide the guidelines for data gathering and
processing. And third, to provide researchers with the data base and the
mechanism for testing their theories and improving their methodologies
in a context that is operational yet not in the main stream of deci­sionmaking.

The word gaming has been used in the title of this section. What does it mean and where does it fit into the economic decisionmaking process?
It has been noted that a simulation is a dynamic manifestation of a model. It is possible to trace out the behavior path of the system through time. In
such a model the relations can be classified into three different categories
such as behavioral, control and accounting.

An extremely simple example of a macroeconomic model which can
be run as a simulation is provided to illustrate the different types of
relations and to indicate the meaning and possible uses of gaming. For
ease we take the four equations version of the Samuelson multiplier-ac­celerator model.

\[
\begin{align*}
(1) \quad Y_t &= G_t + I_t + C_t \quad \text{(accounting relation)} \\
(2) \quad C_t &= Y_{t-1} \quad \text{(behavior relation)} \\
(3) \quad I_t &= (C_t - C_{t-1}) \quad \text{(behavior relation)} \\
(4) \quad G_{t-k} \quad \text{(control relation)}
\end{align*}
\]

where,

\[
\begin{align*}
Y_t &= \text{Gross National Product in time } t \\
G_t &= \text{Government spending in time } t \\
C_t &= \text{Consumption in time } t \\
I_t &= \text{Private investment in time } t
\end{align*}
\]

The behavior equations in this system are meant to be based upon
observation and insight. It is a matter of observation, data gathering and
processing, econometrics and economic theory to check on their accuracy.

**MODELS, SIMULATIONS AND GAMES**
The first equation is an accounting identity. This calls for both routine National Income Accounting and a survey by the users (planning and research) to determine if the definitional scheme is optimal for the purposes for which it is used.

The last equation is a control relation. The government has options. It can change the size of k, or it can make its policy depend upon unemployment levels or other features of society.

A decision maker may wish to explore alternatives. If he has a sufficient degree of trust in the abilities of his planning group he may wish to explore the effects of changes in policy.

A simulation may be used as an operational game when a decision-maker is called upon to experiment with alternative policies. In an operational game certain relations and variables are set by policy makers. If there is only one policy-maker setting the variables there is no conflict of interest. If there is more than one (as in international trade) then there may well be conflict.

Operational gaming is a technique to help to establish a better dialogue between decisionmakers, planners and other technical staff. It helps to link decision making to a background of knowledge and information by helping to make more explicit the goals, interests and alternatives that need to be considered.

It must be stressed that although operational gaming is an aid to communication it is not a substitute for debate and other verbal processes. If a popular expression such as Amazon Highway catches the popular imagination the merits of such a venture can better be challenged by arguing that the Great Amazon Highway has already been built (it is called the Amazon River), than by simulation, cost effectiveness or operational gaming.

The right name is often more effective than cost analysis. Prime Minister Churchill referred to the “soft underbelly of Europe”. He was talking about the mountain ranges of France, Italy and Greece.

3. Types of Models, Simulations and Games

Consistency is often useful, but by no means always necessary. Decision-makers usually understand this far more easily than do pedants.

There are many different questions that we want to ask concerning our economic system. The models that best answer them are different
and are often not consistent with each other. To this day, few inflation models are consistent with general equilibrium price models or technical production models of an economy.

The question to be answered should do much to determine the model. It is a safe rule to assume that there are few models which can be used to answer many questions. The general purpose economic model may easily be an illusion. General purpose can rapidly change into no purpose. This does not imply that large and complex models should not be built. Sometimes questions are complex and require complex answers. However the spirit of model building should be guided by the specification of purpose.

A general macroeconomic model of a whole economy is best used for teaching training, data organization, testing econometric methods and encouraging research than it is for forecasting and planning.

Most economists do not think in terms of systems science, whereas many decisionmakers think implicitly in terms of systems, though not necessarily in terms of science. For this reason large macroeconomic models can easily be misused. Their main virtue is in establishing a common language and joint work among planners, cost effectiveness groups, data processors and gatherers and researchers. The publishing of economic forecasts based on these large models, if not taken _cum grano salis_, can be dangerous. The recent results of the Brookings, Wharton and other models as were reported in _Business Week_ in the Spring of 1970, did not further the image of large scale model builders. Much of the value of the 200 odd equations of the Brookings model lies undoubtedly in the work and the economic analysis done to obtain them and _not_ in the overall model.

Specific purpose models are probably of more immediate value than general macromodels. The smaller the scope of the question, the more feasible it is to investigate it in depth. A partial list of areas in which formal economic modeling is fruitful includes

- Banking
- Taxation and the fiscal system
- International trade
- Production: production functions
  - input-output tables
  - special industry studies
Socioeconomic simulations: distribution of income models
education
health services
demographic models

Microeconomic models: transportation models
irrigation and power models
agricultural sectors
structure of industry models
urban development

Not all of the models are necessarily simulations, but virtually all stand to benefit from computerization and automated data handling of one form or the other.

Simulations are in general sequential models, where the relations are formulated in terms of difference or differential equations.

A second type mathematical model familiar to the economist is one which involves simultaneous relationships. A simple example is provided by considering the interaction of linear supply and demand schedules. Suppose that we have a supply and demand given by \( s_t = a + bp_t \) and \( q_t = c = dp_t \). If we assume that there is a market mechanism which brings about a price which equates supply and demand, then we can find \( p_t \) and \( s_t = p_t \) by solving the three equations.

Operations with industrial input-output tables also calls for the solving of simultaneous systems. Sometimes it is necessary to include simultaneous relations in a simulation. It has been argued that in economic life simultaneity is not needed because, by the use of a sufficiently fine grid on the time increment, the error introduced by assuming the existence of a lag will be so small that it can be safely ignored. Thus if \( \Delta t = t - (t - l) \) is small enough

\[ s_t = a + bp_t \]

or

\[ q_t = c + dp_t \]

will give approximately the same results. This is certainly not mathematically sound in any general way, but for many situations of economic interest may be sufficiently true. It is almost always bound to be false if the time increment is large. The natural time units for most economic simulations are the week, month, quarter, or year. In general it is very
difficult to obtain large masses of data on a weekly basis. If decisions are frequent but, say, a quarterly or yearly time scale is used, the errors introduced in replacing an equation such as $C_t = Y_t$ by $C_t = Y_{t-1}$ may be large.

An important distinction among economic models is whether they are presented as explicit optimizing processes, or in terms of behavior systems which may or may not be based upon optimization.

Most of basic microeconomic theory is founded upon explicit maximization. Macroeconomic models and theory have behavioral relations which, in general, are only implicitly explained by optimizing principles.

For example, theories of money and inflation often incorporate equations which describe the amount of liquid funds kept for transactions or for speculation.

It is usually hinted that these equations represent optimizing behavior, however when examined more closely it is difficult to decide how much the equation reflects habit, custom or convention and how much it mirrors optimization.

Large economic simulations and operational games deal with one type of optimization via the manipulation of policy relations and variables. The policy-oriented decisionmaker is interested in how the system behaves not in why it behaves in that manner.

4. Models and Accounting Schemes

The invention by the north Italians of double-entry accounting, the growth of national income accounting, the development of input-output data gathering are key examples of the importance of a conceptual scheme for the control and interpretation of data.

At the level of operations a government can probably function quite well with no knowledge of say the accelerator with distributed lags however it no longer can function without the national accounts.

No accounting scheme is completely general. Each accounting scheme provides an important set of benchmarks for its users. The intelligent user, however, is the master and not the slave of his accounting system. He knows that even for the purposes of his profession the scheme will not satisfy all needs. The blind use of formal models based upon an accounting system that was designed as a guide and as an aid to the perceptive can only lead to disaster. Aids to thought are not substitutes for all thought.
At the level of policy and microeconomics, corporate accounting provides an excellent example of the possibilities for the use and misuse of a data organizing scheme. In the United States of America considerable fortunes have been made and lost on the differences in the interpretation of depreciation reserves, on what are the profits of an insurance company or what is the rate of growth of a firm expanding by mergers.

As the needs of a country expand so do the needs for specialized accounting schemes. In particular a social income accounting scheme, no matter how crude would be a considerable step in organization of information gathering for the construction of measures of welfare. Noise, pollution, queues, delays in bureaucratic processes, crime patterns and so forth are difficult to characterize and to measure, but it is not impossible to do so.

The improvement of accounting schemes, data sources and theoretical models is a highly interlinked feedback process. Simulation models and explicit maximizing models have been noted. However it is important to appreciate that verbal diagramatic and graphical treatments of economic problems are also models. The disadvantage of verbal and diagramatic arguments is that they are not precise and tend to be qualitative.

When a concept is well defined and clear, then a formal mathematical or computer model is easy to build and may even be of use in prediction and planning. When the concept is not clear the premature construction of a completely nonverbal model can be dangerous.

Spoken and written language is not precise. This is often an advantage in considering alternatives in decisionmaking because it does not too quickly exclude alternative interpretations of the same words. Communication is usually best achieved if there exists a method for clarifying goals and problems by successive approximation. This often calls for conferences, debate and written and graphical presentations. These methods serve to interlink models, decisionmaking and the improvements in models and decisionmaking. Thus verbal treatment of economic problems and formal models must coexist and reinforce each other.

5. On Decision Systems, Information and Specialization

The modern economic revolution is a revolution in command and control systems; in communication and information networks. The industrial revolution first saw a great growth in power sources and a new division of labor come into being together with the growth of techniques for the
management of large industrial enterprises. As society has become more complex a new and critical division of labor has become necessary. It is the division of tasks in decisionmaking, planning, producing and evaluating information.

The techniques for coordinating the different tasks in a decision-making information system have lagged behind the growth of the specialities. The need for the division of labor is great but the need for coordination and systems design is greater.

Coordination must be improved among independent groups working on different sectors.

Coordination must also be improved among those with considerably different goals and time horizons. In particular this means universities with more or less the same time horizons such as central and development banks and the investment controlling groups in the public and private and research institutes, banks, planning departments and those who set economic policy.

Automated data handling and processing is becoming a fact of modern economic life. Computer techniques alone will not solve the many organizational problems which lie ahead.

There is no single technique or theory that will provide the correct amalgam of Politics, Administration, Science and Technology. It is suggested, however, that a practical step in the right direction can be taken by using econometric and simulation models to provide a means for coordinating work in planning, data processing and theory. Furthermore, this work can be supplemented by the use of operational gaming to help improve communication at the decisionmaking level.

This is the first of a series of three articles on simulation and model building in Brazil. The second article will review the existing models of the Brazilian economy and evaluate some of their properties. The third paper will describe a new model of the economy of Brazil developed by the Fundação Getúlio Vargas and the Pontifícia Universidade Católica in cooperation with a number of other administrative, data gathering, planning, research, and teaching institutions in Brazil.
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