idolizes growth to a mature society; by which he does not mean stopping growth here and now, but working toward what he calls a "gentle saturation".

Gabor does not underestimate the magnitude of the social changes which are needed, but unlike those afflicted with the doomsday syndrome, he does not want to force the pace of change. "Stopping the machinery" of society is, he says, "not enough; any fool can do it and there are enough fools busy doing it." He puts in a plea for the value of computer simulation. Well and good; but it is a pity that such a distinguished scientist as Gabor apparently accepts, without challenge, the naive and sometimes downright nonsensical inputs included in the exercise sponsored by the Club of Rome. The computer is a very promising instrument for planning and prediction; but if you feed it with nonsense it will excrete nonsense. It will be a great misfortune if the use of computers as an aid to the prediction of social change is discredited.

ERIC ASHBY

A Model of Doom

The Limits to Growth. By Donella H. Meadows, Dennis L. Meadows, Jørgen Randers and William W. Behrens III. Pp. 250. (Universe Books: New York, 1972.) $2.75.

IN *The Limits to Growth* Professor Meadows and his colleagues describe a computer simulation of certain global physical stocks, namely population, pollution, land, agricultural, industrial and service capital, and non-renewable resources, and the flows associated with them in the period 1900–2100. This book portends disaster from which only a policy of zero growth will save us. The population vector distinguishes three age groups, the other variables apparently being scalars. These variables are linked by equations, with coefficients representing what the authors believe to be the important effects.

Professor Meadows says that every assumption made is written in a precise form so that it is open to inspection and criticism by all, though unfortunately not in *The Limits to Growth*. This is a popular account of the model, the technical report on which is not yet available. The book is clearly written, however, and a sincere attempt is made to deal with the issues honestly, revealing rather than obscuring the difficulties. The methodology is familiar from Professor Forrester's books *Industrial Dynamics, Urban Dynamics* and *World Dynamics*. Professor Meadows does not follow Professor Forrester in ignoring empirical evidence and relying only on his intuition. He draws on whatever estimates he has been able to find of specific effects, such as the relation between GNP *per capita* and steel consumption. Here, for example, he uses a very rough fit of a logistic curve to data on steel from a cross section of countries in 1968, to justify similar global behaviour on all resources over time, thus taking a very restricted view of changes in technology. Where he has not been able to find an estimate such as the effect of pollution on life expectancy he has made it up, in this case choosing that relation which shows the most apocalyptic effect—namely a negligible effect until high levels of pollution are reached, when the effect increases rapidly.

Overall, the treatment of population builds in persistent tendencies to exponential growth in developing countries rather than a large stepwise growth such as is nearing completion in the developed countries. On resources the book does not always distinguish clearly between manufacturing output, tonnage of raw materials absorbed, and sometimes even "economic growth", thus denying itself the tools to analyse effectively the problems and possibilities of technical change, substitution, and re-cycling processes. The cost of dealing with pollution is exaggerated.

The model is not estimated by a statistical analysis of data, even where, as in the case of population, a good deal of data is available. Professor Meadows justifies this course of action by arguing that the model is not intended as a forecasting model, but as a demonstration of the dynamic behaviour to be expected. He demonstrates the sensitivity of this behaviour to changes in coefficient values and some changes in model structure, producing variations on the theme of disaster. But provided poles are kept well clear of stability boundaries in variations of coefficients and structure, the dynamics of any model are to the uninitiated surprisingly insensitive to "assumptions". The test is whether the broad structure is right. In estimating systems, even where albeit noisy data are available, it is often exceedingly difficult to test statistically whether a specific long term effect is there or not. There is no serious attempt at the validation of this model. There is no element of open loop adaptive control, that is "learning", in the model, let alone closed loop adaptive control, that is "experiment". It thus takes a rather poor view of our intelligence and adaptability. There is no attempt to learn from experience in the modelling of complex systems in economics, with the sterility of theoretical growth models which use only "stylized facts" and not empirical data, nor from the many pitfalls in econometrics. Even here decision models are only now beginning to be explored.

Professor Meadows is disarmingly ready to admit the imperfections of his model, claiming only that it is better than all other world models available today. Since decisions in conflict with the results of his model simulations are being made by policy makers in the light of inferior models, mental or written, Professor Meadows felt obliged to publish this popular account for a wider community than scientists, before scientists, social as well as physical, have seen a technical description of the work. The fallacy in this position is to suppose that the decision process in human society is the result of a single model in the mind of any one man, or system, or organization. The decision process is the result of feedback loops with many models constantly modified by experience of many kinds, the performance of the whole being far beyond the capacity of any part because of the manifold interactions and feedbacks from experience. This is why the world has been able to get by so far without Professor Meadows's model. The overall models of man and nature that have been used, the political, religious, and philosophical systems of mankind, have dealt with a rather wider range of phenomena. There may well be a role for simple global material flow models, even of the simplicity of that in this book, but to have any practical implications for policy they will have to be more firmly based in reality, and better linked with the more complex systems behaviour models which man has found necessary throughout history[1].

JEREMY BRAY

[1] Bray, J., *The Politics of the Environment* (Fabian Society, London, 1972).

Chinese Directory

Directory of Selected Scientific Institutions in Mainland China. Prepared by Surveys and Research Corporation. (Hoover Institution Series 96.) Pp. xxii +469. (Hoover Institution: Stanford, California, June 1971.) $19.50.

THE aim of this directory is to provide, for the first time, detailed information on nearly 500 of the more prominent institutions of the People's Republic of China that are "engaged in scientific research and other activities". It covers the basic fields of physical, biological, medical, agricultural and engineering sciences. A concise introduction describes the organization and management of science and technology in China followed by a short users guide. The directory proper is grouped under five broad sections: the academies, other government agencies,