# Modeling with scenarios: technology in north-south development

Chichilnisky, Graciela and Cole, Sam

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# MODELLING WITH SCENARIOS
## Technology in North–South development

Sam Cole and Graciela Chichilnisky

This article outlines work in progress on a study of technological choice in the context of North–South development. Its main purpose is to describe the methodology being developed in the pilot phase of the study. This is of interest because it links together a number of analytic techniques—sociopolitical scenario analysis, macroeconomic modelling, and certain microstudies. The methodological problems are general to much forecasting activity.

Most existing global modelling studies do recognise the importance of technology as a central variable, although the assumptions made about choice of technology may be criticised on several grounds (see Table 1).[1] In the main the choice of technology in the models has implicitly assumed that a Western path of development will be followed by developing nations. As Table 2 shows this is not an adequate assumption to explain important elements of development patterns.

Little attention has been paid to the interaction of social and economic factors (especially income distribution) in the technologies explored using the models. Many studies, however, show that these relationships are crucial.[2] In fact, a considerable volume of literature exists at present dealing with so-called "appropriate technologies" within developing economies.[3] These works, however, deal with questions of technology only at a microeconomic level (ie at the level of project or industry). To date there has been little attempt to integrate such studies into a formal global framework of analysis. Those global futures studies which have attempted to take account of this work do not employ macroeconomic models.[4]

Sam Cole is with the Science Policy Research Unit of Sussex University, Brighton, Sussex, UK; Graciela Chichilnisky is with the Department of Economics at Columbia University, New York, and Harvard Institute for International Development, USA. The work described in this article was carried out for a pilot project—sponsored by the UNITAR Project on the Future—entitled "Towards a model of technology for basic needs". The authors are grateful for discussions with M. Bell, J. Clark, I. Miles, P. de Seynes, J. Gershuny, R. Falk, K. Hoffman, and C. Freeman and S. Dain.

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TABLE 1. THE TREATMENT OF SOCIOPOLITICAL AND TECHNOLOGICAL FACTORS IN GLOBAL STUDIES

| Study | Relation of social and political variables to the model | Assumptions about technology |
|---|---|---|
| Limits to growth model: systems dynamics (Meadows *et al*, 1972) | A "holistic" approach with variables and sub-models dealing with selected sociological phenomena | Based on historical US experience with anticipated future diminishing returns to investment |
| World integrated model: hierarchical systems theory (Mesarovic and Pestel, 1974) | "Political" judgements are introduced as exogenous policy variables | Fixed capital–output ratios calibrated to give model internal consistency for base year |
| Fundacion Bariloche model (Herrera *et al*, 1976) | A conceptual model describes social and political aspects of the society, whose physical viability is demonstrated by the mathematical model | Cobb-Doublas production functions with exponential change parameters used to calibrate model over 1960–70 period; optimisation is used to allocate capital and labour inputs |
| UN input–output model (Leontief *et al*, 1976) | Almost no discussion of social and political factors although it is claimed that the model can be used to analyse a wide range of scenarios | Technical coefficients assumed to depend on per capita regional income; largely based on US experiences |
| RIO model (Tinbergen, 1976) | Mainly discussion of transnational political and economic institutions and desirable human goals | Qualitative sector by sector analysis of major transnational sectors |
| Science Policy Research Unit (Freeman and Jahoda, 1978) | Analysis of economic development "profiles" based on competing social theories; a construction of corresponding "images of the future" | No macroeconomic parameters assumed; specific industries and technologies considered in relation to economic profiles |

TABLE 2. INFLUENCES ON TECHNOLOGY IN SOME DEVELOPING COUNTRIES

**Algeria:** rapid industrialisation based on imported technology from a variety of sources including other developing countries (to lessen dependence) while paying less attention for the moment to rural unemployment and improvement of productivity in agriculture; attempt to achieve rapid development toward industrial socialism.

**Brazil:** peripheral capitalist society with rapid industrialisation initially through import substitution; imports of capital goods and exports of cash crops and, increasingly, manufactures; economic and social participation relatively neglected. After 1964 emphasis on attracting international capital and multinational corporations; the role of the state and state enterprises increasingly important as partners with multinational firms and domestic capital, to control labour costs and organisation, and to express nationalist aspirations as a local superpower. Attempts to create greater energy self-reliance in response to increasing demands of the economy for oil due to energy-intensive Western industrialisation and lack of domestic oil resources.

**Burma:** more or less closed socialist society rejecting Western values; agriculture largely based on traditional techniques and relatively little manufacturing.

**China:** Import, and domestic replication, of capital-intensive capital goods; consumer goods produced using domestic labour-intensive and less efficient techniques; attempt to place moral (eg non-elite participation) over material goods; this Maoist strategy is now undergoing revision.

**India:** industrialisation and modernisation programme in mixed economy currently being criticised as having led to technocratic and bureaucratic elitism, unemployment, and alienation—without reducing poverty; possible return to Ghandian principles with new (1977) government.

**South Korea:** industrialisation and modernisation programme similar to that followed in Japan with relatively equitable income distribution; initial land distribution leading to productive agriculture sector; steadily increasing capital intensity in manufacturing export sector initially labour-intensive.

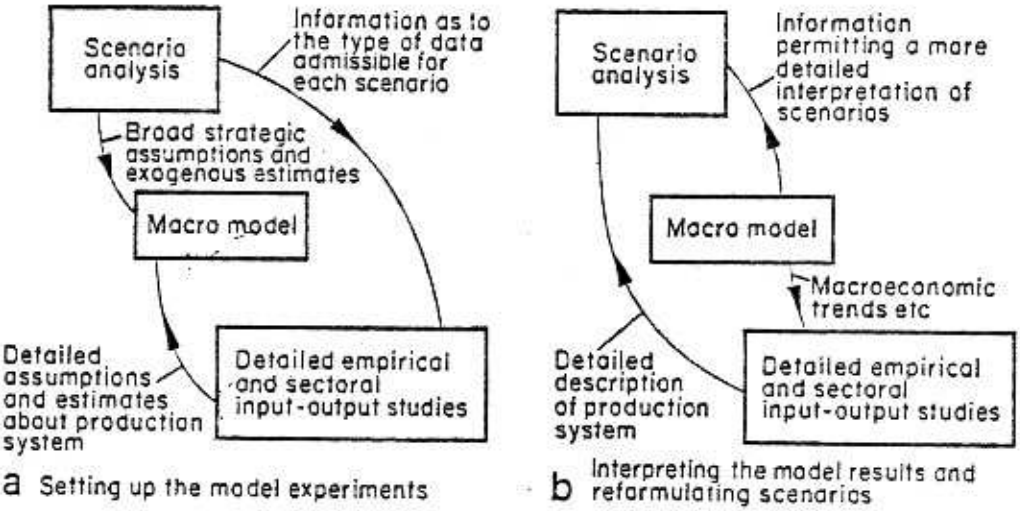


Figure 1. The relationship between different elements of the analysis.[5] The diagram shows the flows of information, in setting up the model (a), and in assisting the interpretation of model results and reformulating the scenarios (b). In principle, consistent analysis is obtained by systematically iterating steps (a) and (b)

## The meaning of "appropriate" technology

Theoretically there are many different answers to the question of what constitutes an appropriate form of development (and hence of technology). This depends in part, on competing views of the role of trade, specialisation of production, modernisation, the relative importance of growth and income distribution as well as many noneconomic factors. Two such competing views are, for instance, the neoclassical and dependency theories.

Whichever worldview one adopts, it is difficult to think of technology merely as a technique. Rather it is a combination of technical and social processes which affects the economic fabric of a society (and in turn is affected by it). This and the need to maintain a wide perspective while taking account of the discrete and local nature of technological choice therefore pose major analytical difficulties (see Figures 1 and 2).

Here an attempt is made to account for these different aspects of technology in a coherent manner, using several analytical techniques (principally scenario analysis) and aggregated macroeconomic modelling together with a combination of input–output and case-study analysis. A summary of the three principal elements of the approach and the relationships between them is given in Figure 1.[5]

## The macroeconomic model

The macroeconomic model constructed for the study is a highly aggregated dynamic model of North–South development, representing the interaction of different income groups and markets. It emphasises the importance of productivity and consumption in basic goods sectors (such as agricultural products) for production and distribution in the economy as a whole. In its present form

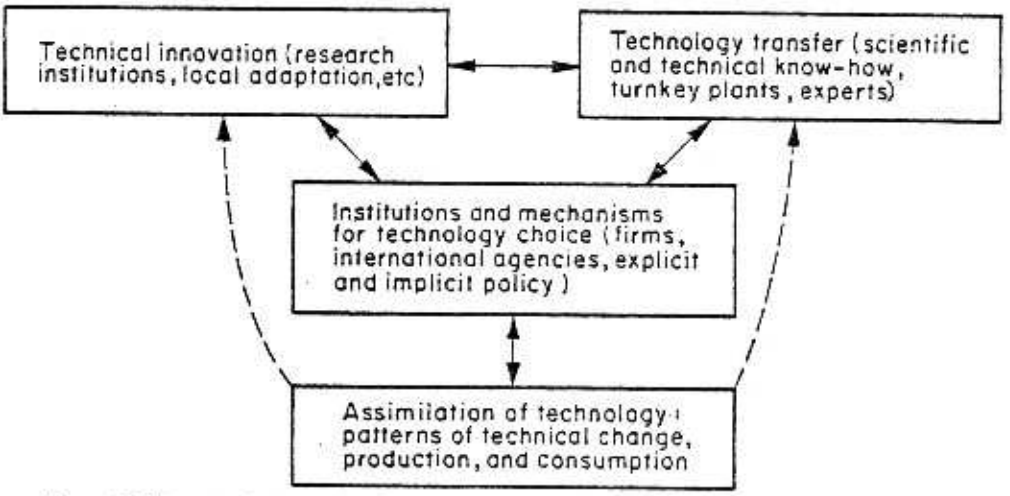


**Figure 2. The assimilation of technology. This figure is based on a suggestion by M. Bell**

(described here) the model is directed towards the central question of the role played by technology in the determination of income distribution within and between the countries of the North and the South. The choice of a high level of aggregation in the model fits in with much contemporary thinking about macroeconomic models.[6] Before discussing further the question of aggregation we will outline the content of the model and the reasons for the choice of variables. Figure 3 shows the main relationships in the model.[7]

*The model variables*

• Because technology and its effects on domestic economies strongly relate to the behaviour of international markets, international distribution of wealth, and use of resources, we model an international as well as a domestic economy. We consider two regions or groups of countries: the North and the South. These two regions do not necessarily represent the whole of the North economy or the whole of the South economy. For example, depending on the parameter values (and the detailed form of the functional relations), the two segments may be taken to represent a chosen "technology study" region corresponding to the archetypes indicated in Table 2 and their economic trading environment.

• The populations of the North and South are treated as comprising two income groups. These are defined according to their relative income, endowment of skilled and unskilled labour and of basic and non-basic capital (including land). The demand functions of each group reflect observed and postulated consumption patterns. The lower income groups tend to consume proportionally more basic goods than the higher income groups. Alternative elasticities of demand (for basic, luxury, and investment goods) are incorporated at different levels of development. Although the economies of each region are segregated into income groups for the study of their internal markets, the trade takes place between the whole economies of the North and South.

• Because of our concern with the problem of satisfaction of basic needs, the output produced for consumption is aggregated into two types of goods, basic

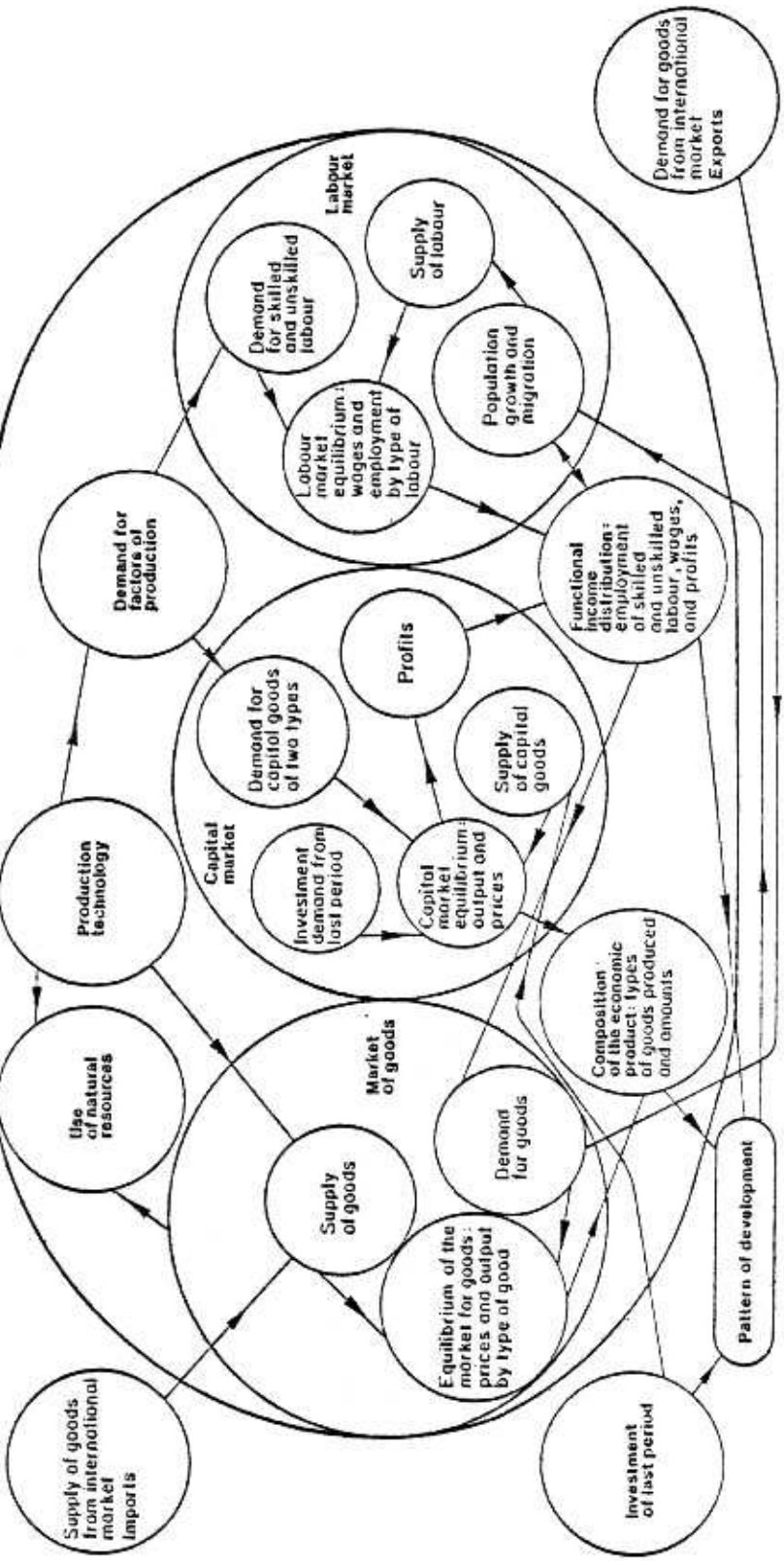


Figure 3. Diagram of the short-run equilibrium model of the domestic economy of one region

and non-basic (or luxury) goods. For some purposes these are defined differently in the North and the South. For instance, basic goods are essentially those comprising the bulk of the "consumption basket" of the lower income groups. Lower income groups in the North have a different "consumption basket" from those in the South.

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• In order to explore alternative modes of investment and production two types of capital goods are considered (basic and non-basic), which relate to different employment, wages, and profit structures. Shifts in the allocation of capital and of labour of different types are constrained. For instance, a certain capital stock allocated to one sector cannot be moved much for reallocation into a different sector at a later date. Related constraints apply to skilled labour.

• Production functions are used to simulate the aggregate use of labour (skilled and unskilled) and capital (basic and non-basic) in the productive sectors of the economy. This macroeconomic description of the production system is augmented by the microeconomic analysis and input–output analysis discussed below.

• Because of the critical relationship of technology to supply as well as to demand, the short-run model of the domestic and international economy is of the general equilibrium type.[8] Markets for goods, labour, and capital either clear or attempt to clear until a constraint is reached, explaining in the process imports, exports, and prices. The constrained temporary equilibrium of each region affects employment, output, prices, wages, and profits at each point in time; it is determined up to investment demand.

• Investment demand links successive short-run equilibria through time. Other variables (eg population) are simultaneously adjusted either exogenously or endogenously. Government intervention (eg policy adjustment of the rate of investment, taxes, exchange rates, and tariffs) is simulated through the variation of appropriate equation parameters in the model.

*The level of aggregation*

The level of aggregation selected for the model is high, and was guided by several considerations: the lack of availability of data and theoretical justification of particular relationships, and past experience of the use of different models.[9] The experience of attempts to construct large multisectoral economic models for planning and research tends to support the choice of a high level of aggregation.

While the model is crude in terms of detail, it is relatively sophisticated in terms of its theoretical content.[10] It is this theoretical sophistication which is important to the qualitative behaviour we wish to demonstrate. Since we are

primarily concerned to understand certain basic relationships between technology, trade, production, and consumption, within the context of alternative paths of global development, we take a level of aggregation and an accompanying set of actors and variables that help our quantitative understanding while not hindering or obscuring our qualitative understanding. The model is used not so much to give quantified estimates, in the first instance, but to look for tendencies in variables under different sets of assumptions and to guide the analysis of detailed issues.

The calibration of the basic "reference" model is therefore bound to be approximate. At best the model is intended to capture the basic character of each economy rather than to look for a highly significant estimation. In the pilot study we are interested in development at the regional level; for the results to have relevance for any specific country (see, for example, Table 2) the model and data would clearly have to be refined at the local level.

An important *caveat* has to be made here. Although it is true that the general character of an economy may be captured (ie qualitatively similar results should be obtained whether the ratio of high to low incomes is assumed to be, say, 20 : 1 or 10 : 1) the results may be *very sensitive* to certain parameter values in some situations. For example, levels of trade predicted by the model used in this study are very sensitive to changes in the technical coefficients used in the production functions.[11]

Although the model is highly aggregated by comparison with many other current global or development models, the choice of aggregation is such that the main qualitative results obtained should not differ if greater detail was added and, furthermore, many of the more detailed phenomena explored by less aggregated models may be deduced from an "enlightened interpretation" of the results of the aggregated model.

This is illustrated by the following examples: with the present calibration of the model (based on Brazil and UK data), highly skilled workers and owners of capital in the South form a single high-income group. Low-income unskilled workers are also grouped together. Nevertheless, it is clear that if, in a given experiment with the model, the income from wages of the high-income groups is seen to rise more rapidly than its income from profits, it is evident that a more detailed treatment of income classes would indicate (all other things being equal) that skilled workers are improving their position relative to the owners of capital.

A major criticism of large multisectoral models is that insufficient sensitivity testing is carried out.[12] Since any socioeconomic model inevitably contains somewhat arbitrary assumptions it is important to show how the results depend on the assumed structure of the model and the relative magnitudes and details of the relationships. Apart from questions of clarity, therefore, the advantage of retaining a simple model is that a relatively large number of scenarios and alternative assumptions may be tested.

The basic structure of the model is sufficiently simple to allow alternative theories to be used. For instance one can simulate different hypothesis about the generation of savings and investment from different income groups, or how market and nonmarket factors operate, eg how unionisation and urban migration may affect labour supply, employment, and wages. Such differing hypo-

theses will produce different policy recommendations, possibly based on different goals. Therefore the macromodel is used to explore both the internal consistency and the possible consequences of the economic implications of the scenarios (including policies) based on differing world views.

## Analysis of the production system

In this study we are principally concerned with the broad qualitative effects of different medium-term and long-term development strategies. Within these broad development strategies more detailed policies have to be determined at a sectoral or local level.

Attempts to link directly, usually through input–output tables, the two distinct approaches for considering the economic implications of technology—macroeconomic approaches such as that adopted in the model described above, and largely empirical microeconomic approaches—have only been modestly successful.[13] Lack of understanding of the complex relationships between macro and micro behaviour, as well as lack of data, hamper this problem being solved at the present time. Nevertheless, for the purposes of our study, the qualitative implications of empirical studies can be simulated.

*The characteristics and effects of technologies*

In the macroeconomic model, production functions are used to estimate output for each sector from inputs of labour and capital of both types. However, as indicated in the introduction, this does not imply that we are concerned only with capital and labour output ratios. In the model, technology is to be identified by, in addition to factors of production (unskilled, skilled labour and capital), ownership (foreign or domestic income groups), import content (integrated vertically), vintage of stock, resource inputs (energy and raw materials), and returns to scale (economies and diseconomies), and by its impacts on model variables such as income distribution, employment, and profitability.

The form of production function currently used in the calibrated macroeconomic model is of the Leontief fixed-coefficient type, which fixes the relative use of factors to each given set of techniques.[14] As different techniques are tried, these coefficients change. This has the advantage that estimates of the coefficients in the "reference matrices"—on the basis of which the models are initially calibrated—can be obtained more or less directly from national input–output tables or from the more recent social accounting matrices. The macro model considers only final consumption and capital goods sectors. Input–output analysis based on a social accounting matrix framework is used to provide a more detailed breakdown of the raw-material and intermediate goods flows within and between sectors. It is used, for example, to determine intermediate import content and the use of domestic or imported resources, consistent with the aggregated macroeconomic trends indicated by the equilibrium model. It is also used to determine the aggregate coefficients in the macroeconomic description of the production system (see Figure 1).

*The choice of technologies*

The problem, therefore, is to assess what assumptions about the production

system (in terms of the type of inputs required and the nature of the goods produced) it would be reasonable to include in the macroeconomic model in the light of microeconomic and macroeconomic empirical evidence or speculation and hence what adjustments to make to the reference model in exploring different scenarios.

By examining in detail the alternative techniques at each stage in the process of production of a *given* consumption good the possibilities consistent with a chosen development path may be considered. By generalising such results some estimate of the appropriate magnitude of parameters in the model describing the production system may be chosen.[15,16] Because of data limitations a more pragmatic approach is initially adopted. This is to ask the question, in exploring different paths of development, which trends in the nature of the production system (in terms of the parameters of the macroeconomic model describing it) appear most likely to further the objectives of that strategy. The possibility of such directions and varying magnitudes in technological trends may then be considered with reference to specific suitable examples.

The case studies here are selected to give particular insights into the relationship between the economic and sociopolitical aspects of technology.[17] A case study of the international fruit industry, for example, illustrates the importance of management techniques and the problems of transferring control from transnational firms to local or government enterprises and its implications for profitability, wages, and income distribution. Studies of metal extraction and fabrication (eg tin and copper) explore different evaluations of the opportunities for cartelisation of supplies, nationalisation, long-term trends in material intensity of use, and the difficulties of developing economies very dependent on relatively few export goods. Studies of textiles raise questions of transfer of labour-intensive manufacturing to developing countries and back to industrial countries as new labour-displacing automative technologies are introduced.

In particular, studies of basic goods industries (eg housing and certain foodstuffs) take account of the possibility of alternative modes of production relevant to specific localities or social groups. From these and other studies of technologies (eg automative and robotive technologies), institutions (transnational enterprises) and social phenomena (authoritarianism, social effects of unemployment), a case may be built up for assumptions as to, for example, the generalisability and time scales for widespread application of particular types of technology and hence to adjustments to parameters in the model. Nevertheless there will always be anomalous cases to account for.

How one takes account of such data depends (in part) on personal predisposition. What the scenario framework described below provides is at least some check on the consistency of information included in the model. It is clear that this procedure has many failings. On the other hand it is less arbitrary than merely assuming technological performance to be a linear function of per capita income, as is done in some of the models listed in Table 1. Even if this assumption is a starting point for analysis, there are many other factors to be accounted for.

The framework indicated in Table 3 which is based on one theoretical interpretation, offers some guidance to the choice criteria (local and regional) used for one scenario to identify appropriate technology, and takes account of

TABLE 3. SOME CRITERIA FOR IDENTIFYING APPROPRIATE TECHNOLOGIES

| Criterion of appropriateness | Local | National | Short term | Long term |
|---|---|---|---|---|
| *Output* | | | | |
| Quality of product | Satisfies basic needs | Export quality | Improves present standard | Can be upgraded |
| Scale of activity | Size of local markets | Surplus production | Overcapacity | Economies of scale |
| Redistributive effects | Uniform quality | National distribution | Immediate impact | Mass-produced |
| Price | Cheap—consistent with local income | Competitive | Response to market buildup | Response to changes in market |
| *Inputs* | | | | |
| Capital | Local capital paid in kind | Imported goods, balance of payments | Low capital requirement | Generates surplus, accelerator effects |
| Labour | Local skills, seasonal unemployment | Special imported skills | Generates or displaces other jobs, multiplier effects | Provides training for other skills |
| Raw materials | Local materials, otherwise wasted | Imported materials | Traditional materials | Alternative inputs possible |
| Environment | Minimal damage | Surface water or air pollution | Immediate amenity considerations (eg visual) | No irreparable damage |
| *Institutional and other considerations* | | | | |
| Control | Local know-how | External advice needed | Dependence on central government, etc | Resistance to take-over |
| Investment risk | Lack of confidence | Viewed as "unconventional" by banks, etc | Differential interest rates for social groups | Rate of return on capital |

nonquantified factors and others not explicit to the model. It operates as a "filter" on empirical findings to be considered. It also offers some guidance as to the way in which technologies employed in one locale might be expected to operate in another. Using such a table as a checklist it is possible to hypothesise firstly about the likely performance of specific techniques in the context of given social, economic, and political conditions, and second, and even more tentatively, to speculate as to the likely impact of adopting appropriate technologies in a more general manner in the input–output analysis and hence on the macroeconomic variables.

In principle, different development strategies cannot be satisfactorily explored simply by changing individual parameters in the model. For internal consistency one should carry out a fairly detailed exploration of all the changes likely to be associated with a given policy and adjust as many parameters in the model as seems necessary. Table 4 indicates, for consideration of certain "policy variables", some of the parameters in the model which may need to be adjusted in the model in order to simulate a desired change.

## Scenario analysis

The approach to scenario analysis used in the study has been described in detail elsewhere.[18] We therefore concentrate here on the relationship between the scenario analysis and other parts of the study indicated in Figure 1.

TABLE 4. THE RELATION OF EXPERIMENTAL VARIABLES TO EQUATIONS[a]

| Variable | Equations describing the variables[b] | Issues explored[c] |
|---|---|---|
| *Regional model* | | |
| Consumption | Demand/supply functions | Consumption patterns, including demonstration effects and sectoral composition |
| Prices | Price equations | Pricing policies, indirect taxes |
| Saving | Budget equations/investment demand | Direct taxation on incomes or investment |
| Profits | Rate of profit equation and output | Investment policy and incentives to technical change |
| Investment good output | Budget equations, production equation | Basic "capital", capital accumulation and concentration of economic power |
| Wages | Cost equations | Wages policy, high unemployment |
| Production and technology | Production function, utility function | Technology transfer, changes in productivity, import dependence, returns to scale, energy and raw material requirements |
| Labour and employment | Labour supply and demand, production function | "Backward-bending" supply curve, rural–urban migration |
| *Trade sector* | | |
| Trade | International price equations, imports and exports | Tariffs, quotas, fixed and floating exchange rates |
| Investment | Investment equations by region | Domestic versus foreign investment and capital flows |
| Technology transfer | Production functions, import and export components in accounting matrix | Uniform or diverse paths of technical change, balance-of-payments implications |
| *Dynamic* | | |
| Investment | Budget equations, investment function | Short-term versus long-term trade-offs in different sectors and income groups |
| Population and labour | Population, labour supply equations | Sensitivity to demographic factors including age structure and migration |
| Technical change | Production functions, utility functions | Range of "basic needs" and self-reliance strategies; trends in capital and labour intensity |
| *Other* | | |
| Time horizon | Rates of change in dynamic relations | Time to reach social and economic goals |
| Scale of economy | Capital stock, population, and labour supply | Collective self-reliant and joint action strategies, transnational enterprises |

*Notes:* [a] This table is indicative only; [b] ie equations which in principle may be adjusted in simulating a change in the variable; [c] this does not necessarily include general equilibrium effects.

In the earlier scenario studies, a mathematical model was not used. In this study both the macroeconomic model and the more detailed microanalysis are employed in an attempt to provide greater internal quantified consistency. The structured approach to scenario analysis used facilitates its integration with the macro and micro studies.

The scenario analysis has several functions.[19] First it provides a broad conceptual framework within which the alternative development paths to be explored using the model (or its variants) may be considered. Thus we employ a set of assumptions which are consistent with a given socioeconomic theory (as in the Sussex and Fundacion Bariloche projects—see Table 1). Here the sociopolitical theory provides an explanation (or a critique) of the alternative sets of assumptions used in the model, for example, with regard to technological

change, investment behaviour or population growth. The theory underlying the sociopolitical analysis in the scenarios provides the historical and empirical rationale for the assumptions made and also provide a qualitative and more detailed account relevant to a particular country or group of countries (eg Table 2).

This sociopolitical analysis may be conducted from several world views. In the introduction we mentioned two types of argument underlying different scenarios of development. The first argument was that of neoclassical theorists, the latter that of the *dependencia* theorists like Furtado and Sunkel.

We use these world views as a starting point—it does not imply we believe both to have equal merit. It permits an internally consistent study of the implications of the associated assumptions and prescriptions.

The scenarios provide the framework for discussion of social, political and institutional factors which may be associated with or required for given economic developments. Thus a rural development programme in developing countries may involve changes in land tenure, educational programmes, collectivisation, or deurbanisation, in addition to the introduction of new agricultural and manufacturing techniques. Similarly the introduction of labour displacing automative or robotive technologies in industrial countries may lead to strong trade union or popular reaction. The extent to which one believes (or assumes) these factors to operate, and the corresponding consequences, depends on the worldview adopted.

In principle, the scenario analysis helps to ensure that the assumptions made are internally consistent. This consistency is important for the setting up of the alternative versions of the model, the choice of data to be used, and the experiments to be conducted. For example, a given policy for redistribution in a given context may necessarily be associated with other domestic and international policies. Income redistribution may lead to migration of skilled or professional groups or to a change in the demand for domestic and imported goods unless adequate compensatory incentives or tariff adjustments are made. The assumption of the availability of foreign investment on satisfactory terms or of advanced technology may be inconsistent with proposals for nationalisation. Policies which may be politically acceptable at a national level may thus lead to shifts in international political or economic relations that may be inconsistent with the initial assumptions.

## The scenarios and the model

The scenario analysis also provides the context for detailed discussion of specific technological and social innovations and hence the possible variation in parameters to be explored with the model. For example, if the resistance by workers fearing loss of employment to automation in particular industrial countries is high, resulting in overmanning, the resultant labour/output coefficients to be used in the model would be correspondingly higher. In considering technological transfer between North and South or the use of "village-scale" techniques, the fact that the technical coefficients used in the production sectors of the model are socially as well as technologically determined is especially important. For the former, overmanning, for example, may be part of a deliberate training programme. For the latter only certain techniques may be viable as

part of, for example, a rural redistribution programme; technologies which exhibit economies of scale may in certain cases lead to worsening income distribution since they may be appropriated by higher income groups.

The key to the linking of the model to the scenario analysis is the theoretical framework chosen to construct the scenarios. If we take a given worldview and use it to generate a development strategy, implicit in that are certain tradeoffs. For example, there may be tradeoffs between investment and short-term consumption, between high production and low unemployment.[20] Alternatively, one may choose to evaluate a given development strategy in the light of different worldviews or by making different assumptions about specific elements of the strategy. For example, although proposals to nationalise foreign companies may lead (at least in the short term) to a lowered productivity because of a lack of indigenous managerial skills, proponents of different worldviews would dispute the circumstances in which this is likely to be the case.[21]

Similarly, a given scenario of international economic relations may be linked with particular patterns of consumption and technology. A given strategy (eg import substitution or exporting) narrowly specifies products and hence the range of techniques. Conversely, because technology affects the output as well as the inputs to the production system, consumption patterns may change in response to technological changes. Indeed, advocates of increased trade argue that postwar increases in productivity and consumption are a direct result of specialisation and trade leading to increasing returns from scale. *Dependencia* theorists, on the other hand, argue that an important aspect of developing countries achieving self-reliant growth is to break the demonstration effect of consumption patterns in developed countries on their own elite groups. They would also argue that attempts to achieve self-reliance could be met with the withholding of technological know-how; and, more likely, restrictive conditions under which technology becomes available could be imposed by advanced countries, requiring the indigenous development, adaptation and diffusion of modes of production.[22]

These factors are incorporated in the model by specifying demand functions, productivity parameters, and trade flows (although for each theory the specification will be different).

As explained above, the extent to which these factors are believed to operate will usually depend on (ideologically-based) judgements. However, the consequences of the assumptions can be traced with the use of the model and, to a certain extent, contrasted with data.

The important thing is to have consistency throughout the model in the way value judgements and theory are applied. Exploring alternative growth scenarios or theories or policies using a model does not entail merely changing one or two policy variables. An underlying value system pervades the model and, in principle, affects all the relations and variables it contains.[23] Thus, a given mathematical model (together with the practical modifications of it) can only be relevant to a limited range of socioeconomic theories and scenarios.

## Structuring the scenario analysis

One reason why sociopolitical analysis and quantitative analysis are difficult to combine is because the former is usually presented in "essay" form and consists

of a wide range of variables and subtle relationships which are difficult to quantify—while the latter is highly structured and treats a restricted set of variables in a very simplified way.

In part this was considered in the above example of the one to one relationships between scenario events and the model equations. However, one methodological problem remains: how to structure the *overall* qualitative analysis in a form compatible with the model. Because models are relatively inflexible, we have to structure the whole of the scenario analysis so that the evolution of the scenario events can be related to the economic model without oversimplification.

Fortunately most scenario analysis (and the parallel modelling) can be broken down into approximately three stages:

first, a *diagnostic* stage, which is a demonstration of the hazards posed by present trends (calibration and extrapolation);
second, a *transition* stage in which the detailed tradeoffs within a viable range of *solutions* are considered (sensitivity and policy analysis); and
third, a prognosis of the likely success of the strategy proposed in relation to specific goals (eg normative projection).

The diagnostic stage provides the basic justification for the worldview employed in the analysis (as was discussed earlier). The transition stage takes up competing arguments about solutions: such as the Kuznets' curve hypothesis that a short-run worsening of income distribution in developing economies is to

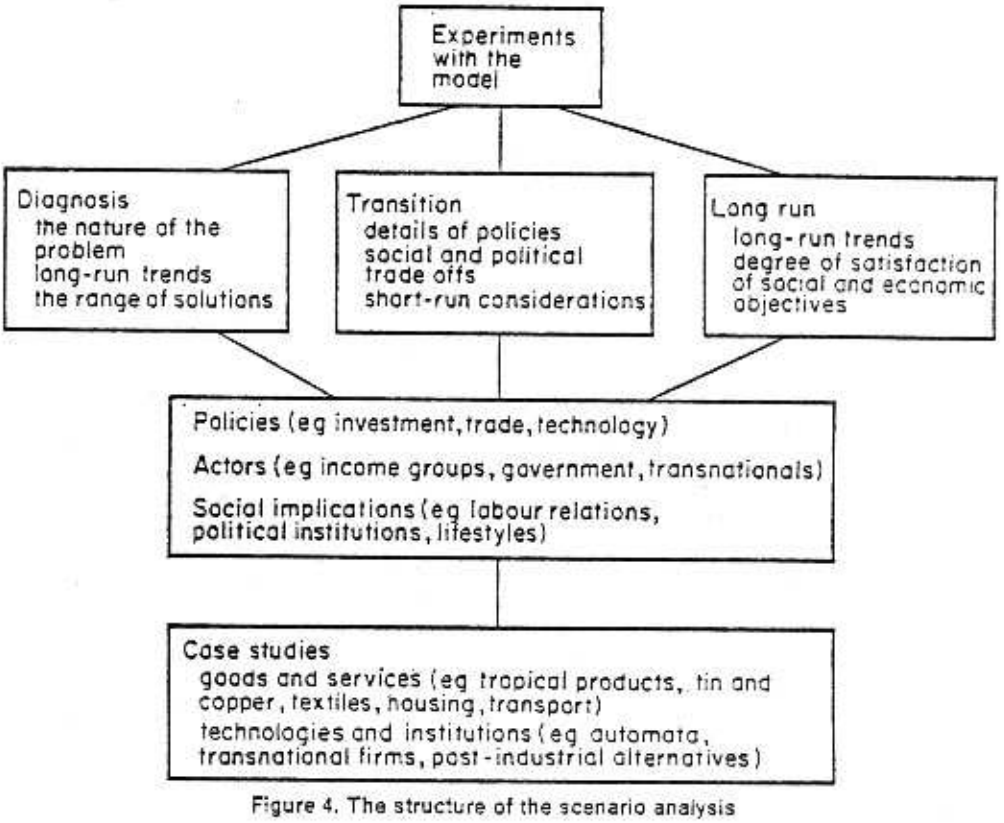


Figure 4. The structure of the scenario analysis

be expected as part of successful overall long-term development, the possible need for authoritarian regimes to carry through the transition, or possible calculated economic opposition (eg withholding of technological know-how), or military threats faced by developing nations seeking greater autonomy suggested by some *dependencia* theorists. By describing the scenarios as a series of processes and "snapshots" of events, in each stage the roles played by different actors, the different steps in policy, and the social and economic implications may be highlighted. For each stage, this consists of constructing "images" of the activities within different domains (eg social and political institutions, the technology regime, urbanisation, work and leisure, eduation, and family life). Figure 4 elaborates this structure of the scenario analysis in relation to the case studies and the model which was outlined earlier in Figure 1. In this way, we hope to achieve a satisfactory correspondence between the scenario analysis and the model results.

## Uncertainties in policy modelling

We have explained the need to have an interdisciplinary approach, sociopolitical as well as economic, for the study of technology as an element of policy. Since policies in underdeveloped countries can seldom be divorced from the interplay of domestic economic variables with those of industrialised countries, we are studying these policies in the context of a North–South model of the world economy.

Preliminary results with the model used in the present study which explore the effects of technology at the macro level (and of the elasticity of supply of factors of production) on terms of trade indicate also the possible incompatibility of certain combinations of trade and income-distribution policies, given prevailing techniques of production in developing and industrial countries.[24]

Because technology policy, explicit and implicit, usually takes place at the sectoral or project level, we have also attempted to take account of empirical data emerging from studies at that level, and to provide a framework within which such specific policies can be discussed. The economic and sociopolitical analyses are being linked through an iterative use of scenario analysis and macroeconomic modelling.

The balance of methodologies used is designed to recognise limitations in numerical data on variables central to the theories used, the need to take account of soft variables and the very incomplete data on alternative production methods. The aim is to provide a context for analysis of particular technology policy choices and to explore the consequences of more general technological trends. The approach can be seen as a formalisation (or simulation) of the implicit real-world procedures. For example, politicians and other policymakers do extrapolate from experiences gained from isolated projects or from other countries with different social and economic environments. This study aims to obtain a better understanding of the uncertainty inherent in such forecasting exercises, and it may make the social and economic tradeoffs implicit in different technological options somewhat clearer.

## Notes and references

1. See for example D. Meadows *et al.*, *The Limits to Growth* (New York, Universe,

1972); M. Mesarovic and E. Pestel, *Mankind at the Turning Point* (New York, Readers Digest/Dutton, 1974); A. Carter *et al*, *The Future of the World Economy* (Oxford, Oxford University Press, 1977); A. Herrera *et al*, *Catastrophe or New Society?* (Ottowa, IDRC, 1976). In fact, only Herrera's Bariloche study assumes a model structure based on the experience of developing rather than developed countries and recognises, for example, the importance of employment as a redistributive mechanism to reduce poverty—which is, after all, an explicit goal of all global modelling studies. The basic assumption regarding technology in other models is that eventually developing (and other) countries will adopt technologies with the economic characteristics of those used in the USA. It is worth giving an example of this, since in part by illustrating the deficiencies of one of the more "data-conscious" studies, the United Nations Input–Output model, we excuse similar deficiencies in our own. For the 15-region, 48-sector UN input–output model, technical parameters are estimated and projected in the following way. A "reference" matrix is constructed for the USA for 1970 by aggregating and adjusting a 1967 table. Future changes in the technical coefficients are based on extrapolation. Differences in the coefficients for other regions as a function of capita income are then obtained using a "by eye" regression based on eight countries, for different years (of which only India [1960] and Columbia [1969] are developing countries). However, no substitution between capital and labour is permitted, so that technologies are fixed by the input–output coefficients. For many coefficients serious errors and inconsistencies could arise. This is by no means the least satisfactory method to be found in global modelling exercises. It is clear there is plenty of room for improvement.

2. See J. Quinn, *Scientific and Technical Strategy at the National and Major Enterprise Level* (Paris, Office of Economic Analysis, UNESCO, 1968); C. Cooper, ed, *Science, Technology and Development: The Political Economy of Technical Advance in Developing Countries* (London, Cass, 1977); International Development Research Centre (IDRC), *Science and Technology Implementation in Less Developed Countries*, IDRC-067e (Ottawa, IDRC, 1976).
3. See, for example, reviews by D. Morawetz, "Employment implications of industrialisation in developing countries: a survey", *The Economic Journal*, September 1974; G. Jenkins, *Non-agricultural Choice of Technique: An Annotated Bibliography of Empirical Studies* (Oxford, Institute of Commonwealth Studies, 1975); M. Carr, *Economically Appropriate Technologies for Developing Countries* (London, Intermediate Technology Publications, 1976).
4. For example, J. Tinbergen, *Reshaping the International Order: A Report to the Club of Rome* (New York, Dutton, 1976) and C. Freeman and M. Jahoda, eds, *World Futures: The Great Debate* (London, Martin Robertson, 1978).
5. *The macroeconomic model* is a highly aggregated description of the main economic relations used as a framework for the study of the processes and the issues considered above. The model describes production and consumption of basic and luxury consumption goods and capital goods by high and low income groups in countries of the North and South, and the interrelation between these, in a dynamic general equilibrium framework, and the model is matched to data from appropriate countries and regions. Several variations of the model may be considered.

   Detailed analysis of *socio-technical systems* has resulted in much empirical evidence on both the macroeconomic and microeconomic, and social, consequences of technology often in the form of "case studies". To the extent that macroeconomic trends can be broken down (through, for example, input–output analysis of microprocesses), or the performance of different production processes and

techniques in different social and economic contexts can be generalised, these results are incorporated into the study. This will be done by taking a range of hypotheses as to the implications of alternative technology strategies.

*Scenario analysis* provides a theoretical and conceptual framework for experiments to be explored using the model. Scenario analysis also provides the link between the macroeconomic and microeconomic analyses and is used to "flesh-out" the the economic trends suggested by the macroeconomic model.

6. See S. Cole, "The Latin American World Model as a tool of analysis and intergrated planning at a national and regional level in developing countries", a paper prepared for a UNESCO meeting of experts on the applicability of global modelling techniques to integrated planning in developing countries, Sussex, UK, 1977 (mimeo). The choice of a general equilibrium framework or the use of production functions is more controversial (and is considered in G. Chichilnisky and S. Cole, "A model of North–South development", *Tech. Forecasting & Soc. Change*, forthcoming 1978); in this respect the model takes a different approach from the Fundacion Bariloche model which as a planning model did not deal with market mechanisms. Since most countries in fact operate mixed economies and since there is a world market in most commodities it is necessary to model the market element as a prelude to a discussion of planning alternatives.
7. Further details of the equations are given in Chichilnisky and Cole, *op cit*; some preliminary experiments are described in G. Chichilnisky, J. Clark and S. Cole, "A model of technology and North–South development", mimeo proceedings of a UNESCO meeting of experts on global models as a tool of integrated planning, Institute of Development Studies, Sussex University, UK, 1977.
8. As modified to account for imperfections introduced by the separate income groups.
9. Data relevant to the central variables and relationships in the model are comparatively poor, especially for developing countries, particularly those concerning the consumption and production of basic goods, the ownership of capital, and foreign investment. In particular, empirical studies do not separate consumption and production into basic and non-basic components, although this situation is changing. For example, recent work on social accounting matrices (G. Pyatt and E. Round, "Social account matrices—an evaluation" (mimeo), Warwick University 1977—to be completed) has provided data for a number of developing countries in a form relevant to the model described here. However, within reason, it is better to include variables or their effects (if they are demonstrated to be vital to a theory through sensitivity analysis) than to exclude them altogether.
10. The level of detail in the aggregated long-term model used in our study is not significantly less than many models currently used in policy. For instance, many development plans have been based on very simple "two-gaps", Harrod/Domar or Marxist growth models (see S. Cole, reference 6).
11. See Chichilnisky and Cole (1978).
12. S. Cole, *Global Models and the International Economic Order*, a paper for the UNITAR Project on the Future (New York and Oxford, Pergamon Press, 1977).
13. For example, Tokman ("Distribucion del ingreso, technologia y empleo en el sector industrial de Venezuela", I-620 72-S, OEA-ILPES, Santiago, 1972, mimeo) has attempted to assess the effect on overall employment in Venezuela of using labour-intensive techniques wherever possible. His approach was to carry out a process-by-process study of available techniques. J. Saxton and R. Ayres, in *The Materials Process Product Model: Theory and Applications in Mineral Materials*

*Modelling* (New York, Johns Hopkins Press for Resources for the Future, 1975), have attempted to construct a very detailed input–output matrix of the US economy through which the effect of changing specific techniques in one industry on the rest of the economy may be explored in detail. B. Winter and R. Nelson, in "Neoclassical versus evolutionary theories of economic growth: critique and prospectus", *Economic Journal, LXXIV,* December 1974, have developed an alternative formulation of production functions which simulates the causal processes underlying the choice of technology, using a Markov-chain approach which may be particularly suitable for analysis of the data generated by the methods considered in this paper. Chenery and Radulet (1971) have explored the implications of using more labour-intensive methods by using "guessed" data in macroeconomic production functions.

14. Alternative types of production function (eg the Cobb-Douglas and Constant Elasticity of Substitution functions) could be tried. However, if we are concerned largely with medium- and long-term effects due to technical change, we may, arguably, concentrate on the fixed-coefficient form.
15. In some cases, and for some goods, this is not such a bad approximation as it sounds. For example, for some Latin American countries, fruits (eg bananas from Ecuador, Panama, and Puerto Rico) or metal ores (eg copper from Chile or tin from Bolivia) make up a major proportion of foreign income, and changes in technology may have a major impact on import requirements and export prices.
16. See C. Vaitsos, "Power, knowledge and development policy: relations between transnational enterprises and developing countries", The 1974 Dag Hammarskjold Seminar on Third world and international economic change, Uppsala, Sweden, 1975 (mimeo).
17. But in addition the studies proposed for the pilot study are based on the experience of personnel associated with the project. As with the scenario analysis, as far as possible, the study makes use of previous and ongoing studies, such as those carried out for *World Futures: The Great Debate* (see reference 4).
18. Freeman and Jahoda, see reference 4, and S. Cole, I. Miles, and J. Gershuny, "Scenarios of world development", *Futures*, February 1978, *10* (1), pages 3–20.
19. Different elements of the work to some extent relate to different time spans. Typically, we expect the detailed analysis only to have quantitative value for the short term (although we use it to make inferences for the medium-term and long-term), the macroeconomic model explores the medium term, while the scenario analysis is used to explore the longer term, in addition to providing a context and consistency for the shorter-term analysis.
20. See Vaitsos, reference 17.
21. This is simulated by specifying the corresponding savings-investment equations in the macro-model.
22. Lower productivity is simulated by changes of the coefficients of the appropriate production functions.
23. For example, assumed changes in the preferences of people with regard to their lifestyles affect not only the parameters used in the utility functions describing consumption habits, but also those representing investment, labour supply, income distribution and also the technical coefficients themselves. For example, reductions in working hours may be reflected in changes in labour productivity. Different theories affect the definition of variables and also the structure of the model. For example, "basic needs" may be defined in very many different ways. It can be thought of essentially as a welfare concept to be translated into a minimum income target (as in the ILO study—M. Hopkins *et al*, "Basic needs, growth and redistribution: a quantitative approach", ILO, Geneva, 1975

(mimeo)—or Streeten's World Bank Study—P. Streeten and S. Burki, "Basic needs: an issues paper", Policy Planning and Program Review Department, World Bank, 1977) or it may be thought of as the level of nutrition, shelter, health, and education necessary to provide complete and active incorporation of all people into their culture (as in the Bariloche World Model) and leading to further development, or as in Marxist economic theory it may be replaced by the concept of "mass consumption goods" (to be contrasted with luxury goods purchased in the main out of income from capital). Each of these interpretations requires a different model structure or at the very least redefinition of sectors of production and income groups.

24. G. Chichilnisky, "Terms of trade and domestic distribution: export-led growth with abundant labour supply", Harvard Institute for International Development, USA, 1978.