## A review of multiregional economic modeling

Nijkamp, P.; Rietveld, P.; Snickars, F.

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# A Review of Multiregional Economic Modeling

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Peter Nijkamp
Piet Rietveld
Folke Snickars

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Abstract

This paper presents results of a comparative study of operational multiregional economic models. No less than 50 models from 20 countries are included in the survey. Various aspects of model structure and model use are discussed. The possibilities to use these models for policy analysis receive special attention.

## 1. Regional Economic Modeling : a Retrospective View

Ever since its emergence in the 1950's, regional science has had a strong quantitative orientation, mainly as a consequence of the general tendency in social sciences to get more insight into the complexities of our world by means of statistical, econometric and modeling techniques.

Apart from partial regional economic models (e.g., gravity models), the first regional economic models were essentially based on a spatial input-output framework thanks to the pioneering work of Leontieff, Isard and others. Very soon also more elaborate models were developed, including labour market components, consumer and investment behaviour modules, and public policy aspects. Such regional economic models are being currently employed in planning practice in many countries. This first generation of regional economic models, developed in the sixties, may be regarded as a first search for a systematic and quantitative representation of spatial economic systems. During this stage much emphasis was placed on the definition and specification of the components and interactions in these systems.

A new development started at the end of the 1960's and at the beginning of the 1970's, when regional models were increasingly used as tools for planning and policy making in space and time; examples are land-use models and transportation models. In this period many - sometimes very elementary - programming models were designed to compute the most desirable state of a system according to <u>a priori</u> specified welfare criteria.
This development of models based on optimality concepts was paralleled by a strong trend towards econometrically specified regional economic models. In addition, the demand side mainly acted as a driving force in these models, although there had been an increasing awareness that integrated regional economic modeling required a structural framework for these models based on combined supply-demand characteristics. In consequence, the optimal factor input mix, the infrastructure endowment and the locational profile were also taken into consideration.

During the 1970's it turned out that the above mentioned models were based on fairly restrictive assumptions regarding available resources, so that limitations emerging from environmental constraints, energy availability, land use, quality of life and equity considerations were not taken into account. This awareness of limited resources has led to a new trend in regional economic model building in which the impacts of constraints and limits have played an especially major role. Examples are regional environmental and energy models (see, for instance, Muller, 1979, Lundqvist, 1980, Nijkamp, 1980).

From the middle of the 1970's onward, efforts have been made to design integrated (and sometimes comprehensive) spatial economic models that are suitable for an evaluation of actual regional trends by means of a whole spectrum of (sometimes conflicting) regional objectives and/or side-conditions (see, for instance, Snickars and Granholm, 1982, Nijkamp and Spronk, 1981, and Rietveld, 1980). Some of these models are multi-disciplinary or even interdisciplinary in nature, incorporating also demographic, environmental, energy and social variables.

During the 1970's single-region models were increasingly considered as unsatisfactory representations of a complex world made up of mutually interacting regions (see Bolton, 1980 and Glickman, 1982). From a theoretical viewpoint, single-region models ignored interregional links and did not guarantee consistency between separate regional models and a national model, while from the policy viewpoint single-region models did not meet the requirements of decision makers to assess the geographical equity aspects, the interregional spillover effects and other indirect spatial impacts of policy measures. Thus the current multiregional orientation may be seen as an important mile-stone in regional modelling efforts: it does justice to the more full-fledged regional economic theory and it is a response to emerging economic policy issues.

However, it should be added that several researchers and analysts have questioned this orientation and argued that comprehensive ME models also have limitations and pitfalls that outweigh their elegance. Hence, the underlying assumptions, theory and data while applying such a model to a specific problem should be carefully examined (see also Brewer, 1973 and Sayer, 1976). A careful judgement of the merits of integrated multi-regional models may therefore be a very meaningful endeavour at this development state.

## 2. Introduction to an International Review of Multiregional Economic Modelling

The history of regional science has been marked by a strong orientation towards models. In light of this tradition, the present paper aims at providing a review of regional modelling by summarizing the results of an international comparative study on operational multiregional economic (ME) models. This review has been undertaken as a joint project of scholars from the International Institute for Applied Systems Analysis (IIASA) at Laxenburg, Austria, and the Free University at Amsterdam. All details of the review can be found in an extensive publication in book form (see Issaev et al., 1982).

Thus the focus of this paper is on operational ME modeling. This choice has the following consequences for the models selected and examined:

- Models in a conceptual or theoretical stage are excluded; only models with an empirical content (or likely to be available in an empirical form in the near future) are taken into consideration.
- Single-region models are left out of consideration; only models with (direct or indirect) interregional linkages are relevant candidates.
- The regional demarcation of ME models is based on fairly closed regional labour markets (implying that commuting between regions is relatively insignificant), so that urban models are excluded; internationally linked models (via international trade relationships)are excluded as well.
- Only models containing a more or less complete economic system are selected, so that single-sector multiregional models are not examined; the same holds true for models with a major orientation to non-economic (e.g., demographic or environmental) aspects.
- The models selected should also provide an integrated mathematical presentation of a regional economic system, so that qualitative impact statements or descriptive multiregional input-output balance methods are omitted

Given the above mentioned requirements, this paper gives a comprehensive review and analysis of the current practice of ME modeling in North America, Western Europe, Eastern Europe, the Pacific Area and some developing countries This survey is based on 50 ME models and gives the state-of-the-art as felt in the year 1982. Information on these models was obtained by means of questionnaires, official documents, background material and personal communications. In Issaev et al. (1982) a systematic description of these 50 models - authorized by the successive model builders - can be found.

The anticipated result of the review is to facilitate the choice of proper model instruments for forecasting and /or policy purposes. This is also the reason for confining the review to operational models, purporting to have such a relevance.

Any model review runs the risk of being too much oriented towards searching for ideal models, by evaluating different models against one another in rankings of superiority. We have attempted to avoid this by concentrating on cross-comparisons of aspects common to large enough subsets of models. We wish to draw the attention to the range of model approaches currently available and refrain from poorly underpinned value judgements.

## 3. The Scope of Multiregional Economic Models

The list of ME models surveyed can be found in Appendix 1. For some models no acronym was available so that we had to invent one ourselves. The geographical distribution of the 50 models is represented in Table 1 : 20 from Western Europe, 6 from Scandinavia, 5 from Eastern Europe, 11 from North America, 6 from the Pacific and 2 from developing countries. It is clear that the list is not exhaustive and also that it is presumably not a representative subset of the complete set. For example, Eastern Europe and the developing countries seem to be underrepresented. Yet, it is our impression that the survey provides a reasonable coverage of the complete set and that it contains the large majority of the models at the frontiers of the ME modeling field.

| Country | number of models | Country | number of models |
|---|---|---|---|
| Federal Republic of Germany | 4 | Yugoslavia | 1 |
| The Netherlands | 4 | Czechoslovakia | 1 |
| Belgium | 5 | Poland | 1 |
| France | 1 | USSR | 2 |
| Italy | 2 | Canada | 2 |
| United Kingdom | 2 | USA | 9 |
| European Economic Community | 1 | Japan | 4 |
| Austria | 1 | Australia | 2 |
| Sweden | 5 | Korea | 1 |
| Norway | 1 | Kenya | 1 |

Table 1. Country of origin of models included in the survey.

The scope of a model can be indicated by the systems covered in the model. The economic system is covered by definition in all ME models, although the level of detail may differ significantly. Fig. 1 indicates [1)] that the models are also different in the extent to which non-economic systems are treated.

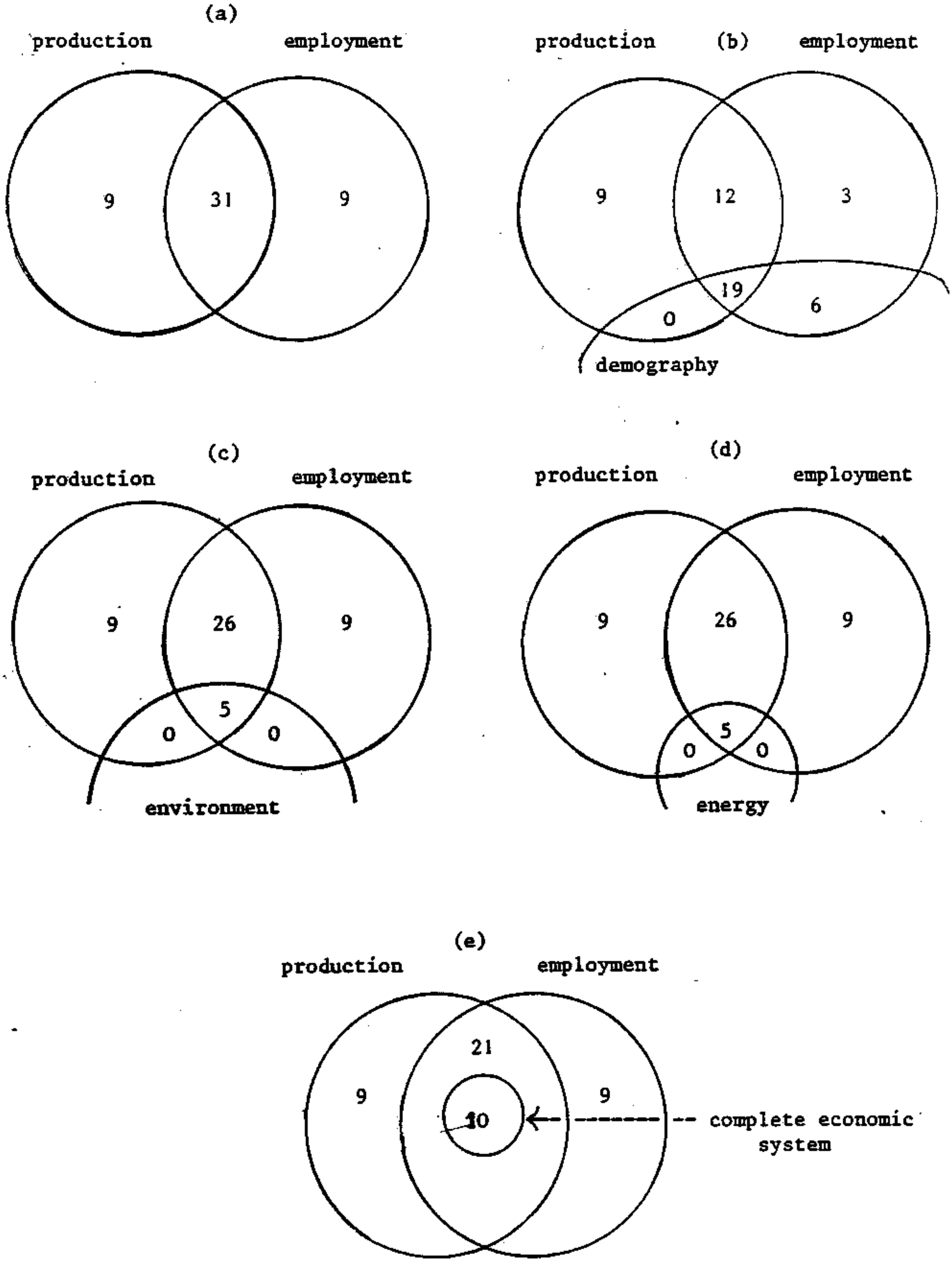


Fig. 1. The scope of multiregional economic models.

1) In Fig. 1. and also in some tables in the next sections, the total number of models is not 50 but slightly less, because of missing information.

Diagram (a) indicates that in 31 models both employment and production are endogenous. In 9 cases only production is endogenous, while employment is not included or exogenous. These models appear to be ordinary input-output models. In another 9 cases only employment is endogenous, while production is exogenous or absent: these are multiregional labour market models. We may conclude that a considerable part of the models is clearly partial. Obviously partial models are by definition useful for a smaller set of purposes than more comprenhensive models. In section 9, we find, however, that partial models are very well represented in the set of models with the broadest range users. Thus, there is no reason to look upon these partial models as less relevant than more comprehensive models.

In diagram (b) attention is paid to demographic elements in the models. It appears that in 25 cases the population size is endogenous. In most cases, the treatment of population is rather crude, however, : no detailed study of various age-sex classes, although there are some notable exceptions. Obviously, when demography is crudely treated or even missing in a model, such a model is less suitable for long-run analyses. Here we find a clear indication that most ME models are only useful for the short- and medium-run.

Diagram (c) shows that in five cases, environmental variables are endogenous. These models are: HESSEN, MEEEI, TLM, MREEED and RDM. Five models contain a detailed treatment of the energy sector (see Diagram (d)): MEEEI, TLM, MORSE, MAG and MREEED. One may conclude that in only a small part of the models the economic system has been linked with the energy or the environmental system.

Diagram (e) indicates that 10 of the models contain a 'complete' economic system. We call an economic system complete, when production, employment investments and prices/wages are endogenous. These models are : REM, RENA, SERENA, REGINA, BACHUE, MFM, MREEED, MEPA, ECESIS and NRPEM. We note that this number is relatively low, and that the distribution among the various countries seems to be rather regular.

## 4. Size Aspects of Multiregional Economic Models

In this section various size aspects of multiregional economic models will be discussed : number of regions, number of sectors and number of endogenous variables.
The number of regions distinguished in the models is represented in Table 2. Clearly, the variation is large. The largest share of the models describe only a relatively small number of regions. The median number of regions is equal to 9. There are some models with very large numbers of regions, however: MULTIREGION deals with 173 regions, while MRMI even contains a spatial disaggregation up till 3103 counties. In some models, one has the possibility to select the appropriate level of spatial detail. The above-mentioned MRMI model, for example, can be run for 3103, 435 or 51 regions.

| Number of regions | number of models |
|---|---|
| 2 - 8 | 21 |
| 9 - 20 | 13 |
| 21 - 100 | 13 |
| > 100 | 2 |

Table 2. Frequency distribution of the number of regions in multi-regional economic models.

In Table 3, the frequency distribution of the number of sectors in the models is displayed. It may be noted that some models have no sectoral disaggregation at all. The median number of sectors is equal to 20. Models with a large number of sectors are: MRMI (108 sectors) and SCIIOM (200 sectors).

| Number of sectors | number of models |
|---|---|
| 1 - 10 | 17 |
| 11 - 20 | 9 |
| 21 - 40 | 11 |
| 41 - 100 | 10 |
| > 100 | 2 |

Table 3. Frequency distribution of the number of sectors in multi-regional economic models.

It is clear that the sectoral detail in the models is on average larger than the spatial detail. Table 4 presents the joint distribution of the number of regions and sectors. The distribution of the models among the classes in the table is certainly not uniform. There is a clear tendency that models with a large number of regions also describe a large number of sectors. The number of models in the North-East and South-West corner is relatively small. This means that model builders have a tendency to build models in which the sectoral and regional detail are in equilibrium. The number of models in which the sectoral detail is clearly above average and the regional detail is clearly below average (and vice versa), is relatively small.

Table 4. Contingency table of numbers of regions and sectors in multiregional economic models.

| | | Number of sectors 1 - 20 | ≥ 21 | Σ |
|---|---|---|---|---|
| Number of regions | ≥ 10 | 7 | 16 | 23 |
| | 2 - 9 | 19 | 7 | 26 |
| Σ | | 26 | 23 | 49 |

We will next pay attention to model size as measured by the number of endogenous variables (see Table 5). The median number of endogenous variables is equal to roughly 800. Model size is clearly above average in North America and somewhat below average in Western Europe. The largest models have been listed in Table 6.

Table 5. The number of endogenous variables in multiregional economic models.

| | Number of endogenous variables < 800 | ≥ 800 | Σ |
|---|---|---|---|
| Western Europe | 13 | 7 | 20 |
| Scandinavia | 3 | 3 | 6 |
| Eastern Europe | 3 | 2 | 5 |
| North America | 1 | 10 | 11 |
| Pacific | 4 | 2 | 6 |
| Developing countries | 1 | 1 | 2 |
| Σ | 25 | 25 | 50 |

Table 6. Models with a large number of endogenous variables.

| | | | |
|---|---|---|---|
| REGINA | France | 8,000 | variables |
| MULTIREGION | USA | 14,000 | " |
| NRIES | USA | 14,000 | " |
| MREEED | USA | ≥ 40,000 | " |
| MRMI | USA | ≥ 50,000 | " |
| SMOPP | USSR | ≥ 100,000 | " |

In most cases the large models have relatively large numbers of regions and sectors, but there are exceptions (e.g. REGINA). The exceptions indicate that model size is not only a function of the number of regions and sectors, but also of model scope and model completeness.

## 5. The Modeling of Supply and Demand

The purposes for which a model can be used depend on the structure of a model. For example, a model that is driven exclusively by demand variables is not very useful when one wants to study the effects of a reduction in the supply of production factors (e.g. energy). Indeed, the role of demand and supply is an important aspect of model structure . In this section we will examine to which extent the outcomes of ME models are determined by variables from the demand and/or supply side. We will make use of the following definitions[1]:

A model is demand oriented when the level of regional production is determined by final demand components without being influenced by supply variables.

A model is supply oriented when the level of regional production is determined by the supply of one or more production factors without being influenced by demand variables.

A model has a mixed supply-demand orientation when the level of regional production is determined by both supply and demand variables.

When these definitions are applied to the models in the survey we arrive at Table 7. It appears that the number of supply oriented models is much smaller than the number of demand oriented models. Yet is it is not warranted to say

1) When regional production is not endogenous (e.g. in labour market models) somewhat modified definitions have to be used.

| | |
|---|---|
| (mainly) demand oriented models | 17 |
| models with a mixed supply-demand orientation | 30 |
| (mainly) supply oriented models | 2 |

Table 7. Supply/demand orientation in ME models.

that there is in general a neglect of the supply side, given the large number of models with a mixed orientation.

In some models a mixed supply-demand orientation is achieved by treating basic and non-basic industries differently. Basic sectors such as manufacturing are assumed to be supply oriented: the regional production volumes in these sectors are determined after a distribution of investments among the regions. Location theory plays an important role in the explanation of this distribution. Next, the non-basic sectors are assumed to be demand oriented. The regional production volumes are determined given the production levels in the basic sectors and given regional final demand.

The rather general notion that models in which use is made of input-output analysis are characterized by a demand orientation is not confirmed for the models in the survey. It appears that the proportion of models in which use is made of input-output analysis is approximately equal for demand oriented models and models with a mixed supply-demand orientation. This is an indication that in a considerable number of cases input-output modules have been included in ME models with rather complex structures.

## 6. The Modeling of National-Regional Linkages

The interdependence between regions is a major feature of multiregional economic models. Two types of interdependence can be distinguished: direct and indirect. Direct interdependence occurs when one region is affected by other regions without an intermediary. This is the case in interregional models which will be dealt with in section 7.

Indirect interdependence occurs when one region is affected by other regions via an intermediary. In this section we will discuss the case when this intermediary is the nation (the sum of the regions). Thus we will examine how the linkages between nation and regions are modeled in ME models.

Usually three types of multiregional models are distinguished from the viewpoint of national-regional linkages : (1) top-down models, (2) bottom-up models and (3) regional-national models (see, for example, Courbis, 1980 and Glickman, 1981). These types can be defined as follows:

(1) in a top-down model, the levels of the national variables are first determined, then the levels of the regional variables are determined in accordance with the additivity condition, so that their sum (or average) is equal to the national aggregate;
(2) in a bottom-up model, the regional variables are first determined; the national variables follow as resultants of a sum (or an average) of the regional variables.

In regional-national models a mixture of top-down and bottom-up approaches is achieved. Such a mixture may give rise to a model in which regional and national variables are determined simultaneously, but that is not necessarily the case. Therefore regional-national models can be subdivided as follows:

(3a.) in an interactive regional-national (IRN) model the levels of the regional and national variables are determined simultaneously.

(3b.) in an non-interactive regional-national (NIRN) model a combination of BU and TD approaches is applied which does not give rise to national-regional interactions and hence not to a simultaneous determination of national and regional variables.

In fig. 2 the causality structures of these modeltypes are illustrated by means of simple arrow schemes.
In the figure, $x_1$ and $x_2$ refer to national variables and $x_1^r$ and $x_2^r$ refer to the corresponding regional variables.

The 50 models included in the survey can be classified as follows:

| | |
|---|---|
| Top-down models | 9 |
| Bottom-up models | 9 |
| Interactive regional-national models | 8 |
| Non-interactive regional-national models | 24 |

Table 8. Vertical structure of ME models.

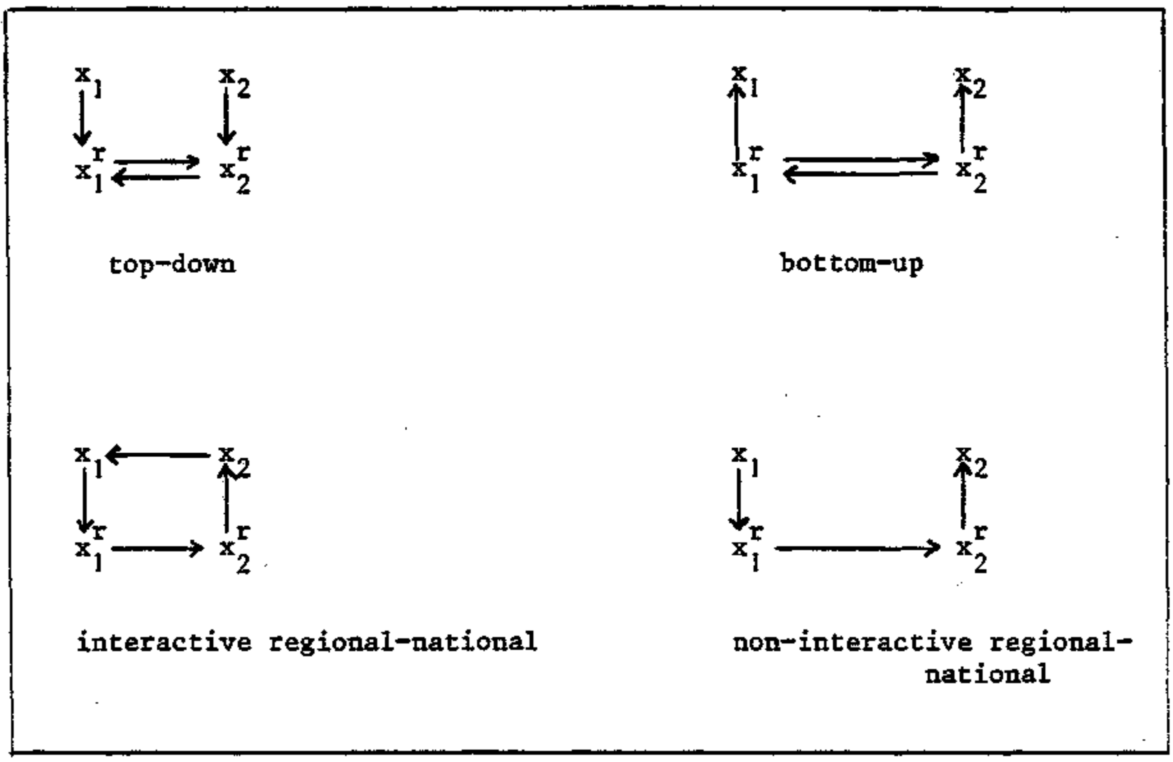


Fig. 2. Examples of TD, BU, IRN, and NIRN models.

The survey includes nine pure TD models (see Table 8).
An important proporty of TD models is that they can be fed with exogenous national variables generated by macroeconomic models. This is an attractive property when one has confidence in the ability of macroeconomic models to generate reliable outcomes. An obvious disadvantage is that in a TD model the national variables are not affected by the regional distribution of activities. Hence TD models cannot be used to study trade-offs between national efficiency and interregional equity. Most of the TD models in the survey are rather partial: the focus is on either the labour market, or the production system.but seldom on both.

A pure BU approach in multiregional economic models is only rarely found. One should be aware, for example, that when a model contains regionally invariant variables (e.g., prices, interest rates) as exogenous or endogenous variables, it cannot be classified as a BU model in a strict sense. Obviously, in such a case the appropriate national variable does not follow as a resultant from the corresponding regional variables. There appear to be 9 models in the survey that approach the BU type to a large extent. Most of these models are characterized by a relatively small number of regions that have been distinguished (2-10). Also the number of sectors in these models is smaller than average. One would expect that in BU models much attention would be paid to interregional linkages to compensate for the lack of national-regional linkage. A close inspection of these models shows that this does not hold for all BU models. In some of them interregional relationships receive indeed rather extensive attention, but there are also BU models in which interregional relationships are not specified at all. (see also Section 7).

Interactive regional-national models form an interdependent system of national and regional variables. The survey includes eight models of this type. These models differ considerably in size. Some are below average, others are among the largest. The scope of IRN models is clearly larger than that of the other models. The following key variables are endogenous in almost all models: production, employment, investments, and prices (wages). We may conclude therefore, that the level of integration in these models is not only high in view of regional-national linkages, but also in view of interrelationships between the main economic variables.

The share of ME models with a non-interactive regional-nataional structure is substantial. These models differ in the way in which TD and BU approaches are modelled. A rather common type includes a TD approach to production and a BU approach to factor demand. Thus, in a first step regional production levels are obtained by partitioning the exogenously given national production. In a second step, regional employment (or the use of other production factors) is determined. National employment can be found in a third step by adding the regional values.

In other NIRN models, TD and BU approaches may be used in the opposite way: a TD approach is applied to some production factors (e.g., investments) and a BU approach to production.

There is certainly reason to consider NIRN models as a welcome complement to a driving national model. NIRN models do not only generate a regional partitioning of the national variables, they may also generate national levels of variables for which a BU approach is more appropriate. The latter especially holds true for variables referring to markets operating at the regional level: housing, regional services, labour supply, unemployment, and (in some countries) wages.

The NIRN model type can be considered as a version derived from IRN by imposing a simplifying assumption, namely the absence of a feedback from $x_2$ on $x_1$ (see Figure 2). Thus the NIRN type is less general than IRN, which may be a disadvantage. The obvious advantage of NIRN models over IRN models is that their causality structure is more transparent since their basic structure is more in accordance with recursiveness than that of NIRN.

## 7. The modelling of interregional linkages

The study of the treatment of interregional linkages is a self-evident element of any effort to survey the current trends in multiregional economic (ME) modelling. A systematic analysis indicates that the interregional flows are often treated in the most elaborate way. In the following we will therefore focus on these aspects of our sample of 50 models and discuss their properties, mainly concerning ourselves with commodity and factor linkages between regions.

In relation to the classification given in Section 6, we wish to distinguish two types of ME models. The distinction between independency and interdependency is based on the presence of direct links between individual regions. For short- and medium-term models interdependency means that interregional trade of commodities is modelled with an explicit mention of origin and destination region. Models that distinguish between interregional and international trade but do not identify sender and receiver regions are thus classified as independent. The flows may also be commuting ones. This means that the scale of the individual region has an influence on the appropriateness of a particular way of modelling interregional interactions.

For medium- and long-term models the emphasis in the term interdependencies is shifted towards factor mobility considerations. Thus, even though a medium- or long-term model is of the limited-information input-output type, it is still warranted to call it interdependent if labour migration is treated in a region-to-region fashion. Here we need to make another remark on factor mobility. What we just said about migration is an example of a behavioural model of migration where it is tacitly assumed that labour mobility is not perfectly elastic, but that it responds to labour market disequilibrium by either increasing the disequilibrium conditions (which may be the case in those countries where labour migration is more influenced by social or environmental factors than economic factors) or decreasing them, but at a certain rate, as given by the response functions.

Perfect mobility between regions will be looked upon here as an interdependent treatment of interrelations between regions. This is because there is no explicit perfect representation of the direct links between individual subregions. Assumptions of perfect mobility of this type are generally introduced by equations aggregating supply and demand of production and its factors.

Table 9 shows that only ten of the 50 models in the sample can be classified as independent models. Almost half of the models are interdependent through trade flows only. Among the models that are not interdependent through trade but through factor mobility several are partial models, for instance focusing on the migration of labour or commuting between regions. The HESSEN model, which contains a pollution submodel, and the MACEDOINE model, which treats unemployment influences, are exceptions in this respect.

Among the models containing both trade and factor mobility the FLEUR model is the most difficult to classify because of its leaning towards analysis of location factors. In a way the FLEUR model of the EC is reminiscent of the American MRMI model although the latter does not contain explicit accessibility measures to factor markets. The sample contains only two models that might be termed complete in the sense that they contain both trade and factor flows, and also are built around closed models, in the sense we have defined here, for the national and regional levels, i.e., the French REGINA model and the SMOPP model used in territorial planning in the USSR.

We also see from Table 9 that the majority of the models in the sample have been classified as NIRN models. One-third of all the models in the survey are NIRN and interdependent through trade. This means that they do not contain a complete description of the economic system at the national level, although they do purport to model regional-national links.

Table 9: Classification of models along linkage dimensions.

| Indirect Linkages between regions | Type of linkages between individual subregions | | | | |
|---|---|---|---|---|---|
| | Interde-dendent | Interde-pendent (trade) | Interde-pendent (factors) | Interde-pendent (trade & factors) | Total |
| Bottom-up | 2 | 2 | 2 | 3 | 9 |
| Top-down | 2 | 3 | 4 | 0 | 9 |
| Regional-national (non-interactive) | 6 | 16 | 1 | 1 | 24 |
| Regional-national (interactive) | 0 | 2 | 4 | 2 | 8 |
| Total | 10 | 20 | 11 | 6 | 50 |

The models we are reviewing are normally not used as illustrations of theoretical arguments but are instead directed towards applications. These applications range from ex-ante policy analysis to economic forecasting. Therefore, the presentations of the models often refer to practical considerations when adopting a certain modelling approach than to alternative economic theories. However, we can basically find the following theoretical variants of trade modelling in current practice:

a) general equilibrium models, including discussions of comparative advantages;
b) linear programming models;
c) interregional input-output models (economic-base, Chenery-Moses, Isard, balanced Leontief);
d) gravity and entropy models, including transport network considerations;
e) econometric models, using accessibility and potential concepts.

In the general equilibrium oriented models reference is made to the Heckscher-Ohlin theories of the effectiveness of international and interregional trade. The multiregional models strictly adopting this framework treat only surplus interregional trade (and such factor movements as migration). One reason for this is that the theory excludes so-called cross-hauling of products. Thus, the equilibrium theory presupposes a perfect functioning of the trade market. Among other things, this would imply that any change in comparative advantages immediately gives rise to a chain of changes in the trade patterns, i.e., no trade inertia can exist. Among current models adopting this framework fairly strictly for interregional trade we may classify any model that treats trade in the independent fashion.

Linear programming may either be used as a means of producing a transport equilibrium or to yield cost-optimal shipment patterns. It is surprising to see that this method of treating interregional trade is used in the two largest models available, i.e., the US model MRMI and the USSR model SMOPP. In the MRMI model the resulting trade flows are not used per se. Instead, the shadow prices of production and consumption are taken as proxies for the influence of transport costs on total regional production costs. The USSR models works with a specially designed commodity classification to optimize the costs for transporting bulky and heavy input materials and goods through a coarse national transport network.

Whereas the general equilibrium models are closely related to nonlinear production theory, the interregional input-output models are prime examples of linear activity analysis. The linearity and fixed-coefficient assumptions are extended in space by various simplifying techniques. This approach leads to a rigidity in the spatial interdependencies that is quite opposite to the comparative cost concepts employed in general equilibrium oriented models. Strict input-output models disregard supply shortages. This assumption is even stronger at the regional level,

because of the uneven geographical distribution of production capacities in the majority of current production systems. The models employ the classical Leontief treatment of interregional and intersectoral dependencés. A few models however, in fact attempt to extend regional trade relationships towards combined trade-location equilibria by introducing nonlinear functional forms and price information.
The gravity and entropy models are not particularly unlike the interregional input-output models discussed above. We might make the distinction that gravity models are still fixed-coefficient models in which trade patterns have been explicitly related to transport costs: see the well-known US MRIO model and the West German MIO model. Recent developments in entropy modelling include a more detailed treatment of the transport market. In the FRET model and the recent treatment of Boyce and Hewings (1980) the results from urban transport modelling of zone-network interactions are brought to bear on interregional shipment flows via transport mode.

There are very few models in which an attempt is actually made to trace the direct interregional linkages in econometric techniques. As we will see below, this is not quite the case for migration flows. However, most so-called bottom-up models make use of econometric techniques to estimate net or gross total product flows from one region to the rest of the country or to the world market. In the regression relation between the region and its input and output markets. Examples of this procedure are provided by the NRIES, FLEUR, and RDM models. In the MREEED model these types of accessibility measures are used as determinant factors for the interregional distribution of investments.

The treatment of factor mobility depends on the regional and time perspectives used. The labour commuting is of course more important for a small urbanized and economically integrated country than for a large one. However, short-term factor mobility need not be concerned solely with commuting but may also be connected to other submarket variables such as occupational groups. The MRIO, MEPA, and SMOPP models are examples of approaches where occupational and sectoral disaggregation are treated simultaneously. Any ME model where the assumption of a skill- and occupation-homogeneous labour supply is used implicitly assumes perfect occupational mobility to act as the primary intraregional equilibrating force. It is only when this process has ended that geographical mobility is considered. Thus the theories of segmented and dual labour markets recently put forward in other branches of economics have not yet been brought to bear in ME models.

A number of models treat capital formation exogenously. Therefore these models have placed capital mobility at a higher level in the model hierarchy; this perhaps may be derived from a national model. There are also theoretical problems related to an endogenous determination of capital development in input-output models. The class of programming models is less affected by such problems. Therefore the HESSEN, DREAM, and MORSE models, as well as the public sector oriented REGAL model, are quite elaborate as concerns capital formation and capital mobility.

As mentioned earlier, migration of labour is the factor movement most often treated by current multiregional models. The applications-oriented ones (LPFM, REGAM) basically analyze net migration. A set of econometrically oriented models set out to explain labour migration by differences in labour demand and supply. The RNEM model developed for Italy contains one of the most elaborate econometric migration submodels. Several models that have a demoeconomic orientation treat migration in a more detailed demographical, but less economic, way. Examples are provided by the Norwegian REGION model, which actually contains a large-scale migration submodel, and the REMO and IRUD models, which also treat rural-urban migration.

Very few of the current ME Models contain direct interregional trade, factor, or related links other than the examples we have given above. Atmospheric pollution is a prime candidate for treatment by the direct method; however, in the current survey only the HESSEN model treats environmental pollution. In some cases, such as interregional income transfers which are collected and distributed by the public sector and are not related to commuting or service trips, an indirect treatment of interregional links is of course the natural way of modelling. It is evidently not warranted to go into the field of data-demanding modelling of direct linkages between individual regions without strong theoretical or practical reasons.

A synthesis of the above arguments clearly reveals that the current frontier of applied ME models is extremely diversified. There are a large number of variants of trade (and final demand and income distribution) models built around the core of the original linear Leontief model for intersectoral technical couplings. One current trend is that the external trade linkages are more often modelled endogenously than by fixed-coefficient methods. At the same time, there is a shift away from the full-scale international input-output models specified by Isard 30 years ago. There is even a tendency to build ME models around a core of reduced-form input-output relationships, where production or changes in production are related to different sets of demand variables. In these ways trade and transportation are separated more clearly from production technology than in earlier generations of ME models.

Many current ME models treat labour migration in a quite ambitious way. The costs and benefits of other types of factor mobility are not modelled in the same elaborate way. The question might be raised of whether this emphasis is motivated by data availability, theoretical motivation, or a search for policy relevance.

## 8. Policy Analysis by means of Multiregional Economic Models

In recent years, policy analysis has increasingly focused its attention on the assessment of impacts of public policies (see, e.g. Pleeter, 1980). This development can also be observed in regional planning practice. As regional policies deal with problems of interregional equity, efficiency and unintended or undesirable side-effects of spatial developments, ME models are a potentially useful tool in preparing these policies. In this respect, the notion of effectiveness of policy instruments is of crucial importance. Effectiveness refers to the impacts of policy instruments or policy objectives (see also Kirschen et al., 1964, and Tinbergen, 1956). This of course, requires a comprehensive representation of an ME system based on objectives, other endogenous variables, instruments and predetermined variables.

In the context of the present paper, 3 aspects of policy analysis in ME models will successively be discussed, viz. the choice of objectives, the choice of intruments and the measurement of effectiveness. For a treatment of these subjects the responses of the 50 model builders of the questionnaire have been used.

One of these questions was: "Which policy goals/objectives are endogenous in the model (at the regional and/or national level)?" In 35 cases the response contained useful information. In several other models policy instruments and/or objectives were not dealt with in an identifiable way, so that they had to be left out of consideration. The frequency distribution of these responses has been represented in Table 10.

Table 10. Frequency distribution of objectives in 35 ME models

| | |
|---|---|
| *Socioeconomic objectives* | |
| Income, production, consumption | 25 |
| Employment | 21 |
| Unemployment | 9 |
| Prices, inflation | 7 |
| Balance of payment | 2 |
| Income Distribution | 3 |
| *Budgetary objectives* | |
| Tax revenues, investment costs, budget deficit | 4 |
| *Facilities* | |
| Infrastructure, utilities | 4 |
| *Energy and environment* | |
| Energy consumption | 4 |
| Pollution | 3 |
| *Physical planning objectives* | |
| Land use | 1 |
| Population | 4 |
| Land prices | 1 |
| Trip distribution | 1 |

We conclude that the most important socioeconomic objectives are present in the table, although the frequencies of economic growth and labour market variables are clearly higher than those of the other socioeconomic objectives. Policy objectives from related fields are only present to a moderate extent. We may therefore conclude that in a strict sense ME models can only be used to a very limited extent to analyze the effects of policy instruments on energy, environmental or physical planning objectives. Only when these models are linked with other models (e.g., environmental models), is an analysis of effectiveness, in this sense, feasible in general.

With respect to the instruments, the following question has been posed: "For which policy instruments of policy measures can the effects on the policy objectives be determined (at the regional and/or national level)?" In 29 cases the response contained useful information. The frequency distribution has been represented in Table 11.

The main instruments in multiregional models can be found in the fields of government consumption expenditures, public investments, and subsidies of private investments. Other instruments receiving some attention are taxes and employment investments. Other instruments receiving some attention are taxes and employment in government services. Relatively little attention

Table 11. Frequency distribution of instruments in 29 ME models

| | |
|---|---|
| *Government revenues and expenditures* | |
| Consumption expenditures | 11 |
| Employment in government services | 3 |
| Public investments | 17 |
| Flows between national and regional governments | 3 |
| Social security payments | 1 |
| Taxes | 7 |
| *Prices* | |
| Subsidies of private investments | 10 |
| Wage subsidies | 1 |
| Average or minimum wage | 2 |
| Interest rate | 2 |
| Public prices | 1 |
| Transportation costs | 1 |
| Fuel prices | 1 |
| *Physical planning* | |
| Housing | 2 |
| *Environment* | |
| Pollution standards | 4 |
| *Other instruments* | |
| Limits on productive age | 1 |
| Agriculture policies | 1 |
| National immigration policies | 2 |

is paid to price policies (apart from investment subsidies) and to instruments from related policy fields such as physical and environmental planning.

It should also be noted that no distinction has been made between national and regional objectives and/or instruments, although this can formally be taken into account (see Issaev et al., 1982).

The measurement of the effectiveness of instruments can evidently be related to specific instruments and objectives. In the context of the present international study, a selection of specific policy areas has been made, viz. government revenues and expenditures, stimulation of private investments and investments in infrastructure. For these three policy areas, we have restricted ourselves to 14 models, since only with them well documented policy analyses and simulations have been carried out.

Some brief conclusions regarding the effectiveness analyses for the abovementioned three policy areas will be presented here:

a) public revenues and expenditures

- some models allow one to study the effects of an interregional redistribution of income or government expenditures on national efficiency. The common idea that there is a trade-off between national efficiency and interregional equity is not confirmed by these models. These models give rise to the conclusion that - given the present situation - it is possible to increase both national efficiency and interregional equity.

- uniform national policies may have substantially different effects for the regions.

b) stimulation of private investments

- effects of investment subsidies are in several cases fairly modest compared to autonomous effects or changes in general economic conditions.

- all models take for granted that investments resulting from simulation measures are qualitatively equal to other instruments, so that the risks of inframarginal new investments are neglected. (leading to a potential overestimation of the long-term effectiveness of investment subsidies).

- the frequently mentioned and often observed uncertainty in investment behaviour has unfortunately not been taken into account in the simulation experiments of ME models.

c) investments in infrastructure

- a distinction should be made between the short-run (demand oriented) effected and the long-run (supply oriented) effects of investments in infrastructure. Only in a minority of the cases, ME models allow one to study these effects simultaneously. Experiments with these models indicate that the short-run effects may be completely different from the longer run effects.

A final observation regarding all effectiveness analyses in ME models is that insufficient attention is paid to uncertainties concerning instrumental effectiveness caused *inter alia* by the stochastic nature of parameters, specification errors, uncertainties about future developments of exogenous variables, etc.).

## 9. The Use of Multiregional Economic Models

Information on model use is often one of the weaker points of models. Therefore, we pay special attention to it in this section. We start with a description of the linkages between model users and model builders. The extent to which models are used appears to depend considerably on the type of institution where the model has been developed. We distinguish four types of institutions :

A : academic institutions (universities, academies of sciences);

C : consultancy agencies;

$G_N$ : national governmental agencies;

$G_R$ : regional governmental agencies.

In Table 12 the numbers of models developed in these institutions have been represented. We have confined our attention here to models which are operational for a long enough time to allow them to be applied.

Table 12. Builders and users of models.

| Model builders | number of models | mean number of users per model |
|---|---|---|
| academic institutions | 25 | 1.2 |
| consultants | 4 | 2.2 |
| national governmental agencies | 9 | 1.6 |
| regional governmental agencies | - | - |

The majority of the models has been built in academic institutions. The number of models built by consultancy agencies and governmental agencies is considerably smaller.

In the questionnaire the model builders have been asked in which of the types of institutions mentioned above, results of their models have been used. Thus, the maximum possible number of users per model is equal to 4. The mean number of users per model appears to be 1.4. The distribution among the types of model builders has been represented in the last column of Table 12. The (not very surprising) conclusion is that the number of users is on average largest for consultancy agencies and smallest for academic institutions. Generally, model builders can also be considered as the users of their own models. This kind of use has been excluded in the figures of Table 12.

The extent of model use appears to vary considerably from country to country. For example, the mean number of users in North America is clearly above average : 2.7.

We will next go into a closer inspection of the models with the widest range of users, as defined above. One should conjecture, for example, that the more comprehensive a model is, the larger the range of potential users will be. In Table 13 the models are listed which have been used in three or four different types of institutions. The above conjecture is not confirmed by this list: most of the included models are clearly partial. For example, the first three models exclusively deal with labor markets. Models 4 to 6 are models in which the focus

Table 13. Models with a wide range of users.

| | | |
|---|---|---|
| 1. | WREM | United Kingdom |
| 2. | LPFM | Sweden |
| 3. | MULTIREGION | U.S.A. |
| 4. | SCIIOM | Canada |
| 5. | MRIO | U.S.A. |
| 6. | IDIOM | U.S.A. |
| 7. | MRMI | U.S.A. |

is predominantly or exclusively on input-output relationships. The only exception is MRMI, which gives a rather complete description of the economic system and related systems.

Another feature of the listed models is that they provide a large regional and sectoral detail. The median number of regions and sectors in these models are 51 and 79, respectively. The median values for the whole set of models have been reported in Section 2 : they are 9 and 20, respectively. This is a quite substantial difference.

One of the problems in modeling is that the communication between users and builders usually does not proceed smoothly. The complaints about model builders who produce irrelevant results or about users who do not recognize the importance of results or who misuse results are common. Part of these problems can be explained by the large distance between model users and model builders. In Table 14 three ways of communication between model builder and model user have been distinguished. In 7 cases there is a short distance between model (builder) and model user : the user directly takes care of the runs of the model. In 21 cases the model builder has access to users by means of oral presentation of model results. In 17 cases the distance between model results are only presented in written form; there is no room for a discussion between the two parties.

We now turn to the question whether outcomes in multiregional economic models have had impacts on (regional) policymaking. It is not easy to answer this question since model outcomes may influence policies

Table 14. Modes of communication in multiregional economic models.

| Mode of communication between model builder and model user | Frequency of use of communication modes | |
|---|---|---|
| A. Model builder runs model, presents results in written form | Only A | 17 |
| B. Model builder runs model, presents results in a briefing to model user | Both A and B, not C | 14 |
| C. User agency directly runs model and analyzes results | Both A, B and C | 7 |

in several direct and indirect ways. For example, they may give governmental agencies a better understanding of the problems they face, but they may also provide pressure groups with arguments against certain proposed policies. Table 15 contains a summary of the answers of the model builders to the above question. It appears that in approximately

Table 15. Impacts of model outcomes on regional policymaking.

| Impact of model outcomes on regional policy-making | academic institutions | consultants | national governmental agencies | Σ |
|---|---|---|---|---|
| 1. direct impact (e.g. model forecasts served as a basis for five-year plan) | 9 | - | 6 | 15 |
| 2. indirect impact (e.g. model outcomes lead to improved understanding of problems) | 5 | 4 | 1 | 10 |
| 3. no impact; too early to say | 11 | - | 2 | 13 |
| Σ | 25 | 4 | 9 | 38 |

one-third of the operational models, a clearly positive answer is given. The table also shows that model builders in national governmental agencies are clearly more confident that their models had an impact than the model builders.

Obviously there are several reasons why the results of Table 15 have to be interpreted carefully. One may expect a tendency that model builders are over-optimistic about the impacts of their models. In some cases models may be built and used to enable politicians to postpone difficult decisions. Sometimes models seem to be used exclusively as a justification for certain policies. It is not impossible therefore, that less positive outcomes would have been obtained when the question had been asked to the model users (see also Fromm et al., 1975).

## 10. Prospects

It is a notable conclusion that useful ME models are not necessarily complex or large-scale models, though a large scale model as such is not problematic as long as the modular design is clear. Hence, an examination of the structure and main driving forces of a model is always desirable.

The awareness of and insight into the main driving forces in a model provides also many ways to facilitate its use on a computer, to validate its assumptions, to exclude redundant variables, and to increase its accessibility and transferability. This observation holds true for modelling efforts in many disciplines.

A discussion of future prospects of ME modelling is a difficult task due to the great diversity of models and model aims. It may be meaningful to address this issue by employing Figure 3 which represents the process of model building as a series of steps from the observation of a complex reality towards the actual scope of the model.

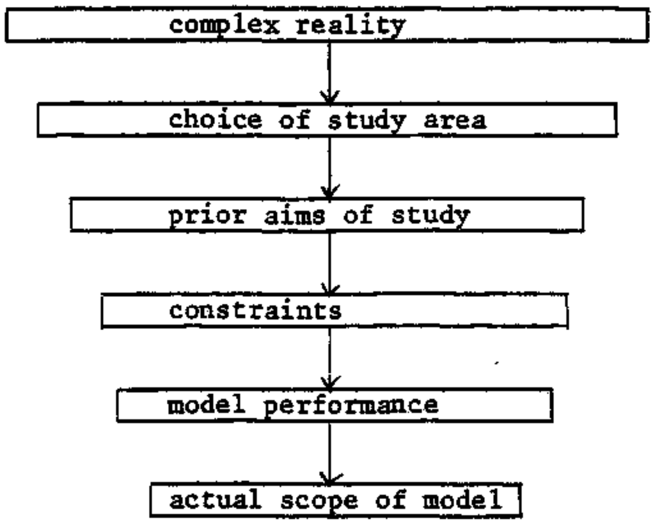


Figure 3. The process of model building

Especially the existence of the block of constraints often hampers a fruitful application of ME models. Several constraints will now briefly be discussed:

- data availability: a weak data base may lead to a less satisfactory performance of ME models, but it should also be mentioned that in various cases, the pretenses of models are too high; in this respect, it may also be useful to call attention to analytical techniques developed for data with a low measurement level (e.g., Lisrel, partial least squares, categorical data analysis, fuzzy set methods, soft econometrics). In conclusion, a more appropriate organization of information systems and a better use of available techniques is needed.

- techniques: in many ME models, the potential of available econometric and statistical methods has not been used; especially in the area of nonlinear dynamics and factor substitutability (including energy and materials) much progress may still be made.

- scale: the scale and aggregation level of ME models should be in agreement with the prior aims of the models; interregional flows (commodities, people) should make up an essential component of ME models; linkage methods such as multilevel systems analysis, graph theory and path analysis may be useful tools.

- time dimensions: especially dynamic models evoke the problem of spatio-temporal stability of ME models; long waves and innovation have to be incorporated in long-term models designed for next decades in order to take into account the basic driving forces in a period of structural economic changes.

- comprehensiveness and integration: aspects to be taken into consideration are: urban, international, environmental, energy, demographic, social and technological elements.

- policy relevance: both impact analyses and decision-making procedures are to be included in policy analyses, taking into account the specific socio-economic systems at hand, the specific planning structure and the existence of socio-economic policy conflicts; in this respect, ME models may serve as an important communication instrument in policy-making and planning.

In conclusion, even with the existing body of knowledge and the existing information systems, an improvement of ME modelling is certainly possible. It is clear that an ideal model will never be attained. But, given the limitations imposed by data, theory, techniques and policy considerations, an optimal use of ingredients for model building has to be made. This is illustrated in Figure 4, where the boxes indicate a quantitative representation of the abovementioned six items.

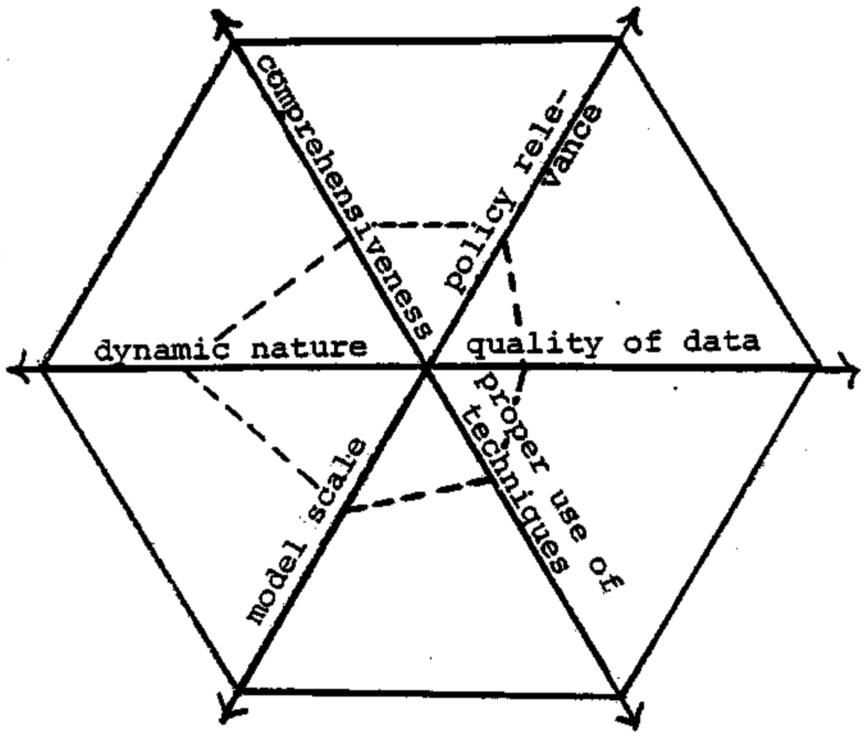


Figure 4. Characteristics of items of a model.

Given the ex-ante aims of the model at hand, one might expect an ideal characterization of the model in the vicinity of the envelope; the envelope representing an optimal treatment of presence of the 6 aspects concerned in the model. In reality however, the actual scope of the model is much more restricted so that the actual characterization of these items implies a position more nearby the centre of the figure (see the dashed line).

The major challenge in multiregional economic modelling will evidently now be: to improve the quality of these models by driving the dashed line towards the envelope curve of this figure. This would imply that the constraints discussed above in greater detail are to be relaxed so as to attain a situation where the ex-ante aim of the model does not differ too much from the ex-post scope.

Appendix : Multiregional Economic Models included in the survey.

| | |
|---|---|
| **F.R.G.** | |
| H. Birg | IMPE |
| R. Thoss et al. | HESSEN |
| C. Schöneback | NRWF |
| M. Carlberg | MIO |
| **Netherlands** | |
| B.A. van Hamel et al. | REM |
| W. Suyker and A. van Delft | REGAM |
| F. Muller and P.J.J. Lesuis | MEEEI |
| W.A. Hafkamp | TLM |
| **Belgium** | |
| F. Thijs-Clement et al. | RENA |
| G. d'Alcantara et al. | SERENA |
| M. Despontin and H. Glejser | MACEDOINE II |
| W.K. Brauers et al. | BREIN |
| W.K. Brauers et al. | KIM |
| **France** | |
| R. Courbis | REGINA |
| **Italy** | |
| S. Arora et al. | RNEM |
| D. Martellato | NORD-SUD |
| **U.K.** | |
| I. Gordon | IIOM |
| P. Elias et al. | WREM |
| **E.E.C.** | |
| W. Molle et al. | FLEUR |
| **Austria** | |
| U. Schubert et al. | REMO |
| **Sweden** | |
| P.-O. Engelbrecht and O. Martensson | LPFM |
| F. Snickars et al. | LURE |
| L. Lundqvist | MORSE |
| A. Granholm et al. | REGAL |
| Å.E. Andersson et al. | GISSIR |

| | |
|---|---|
| **Norway** | |
| O. Bjerkholt and T. Skoglund | REGION |
| **Yugoslavia** | |
| M. Macura and B. Popović | BACHUE |
| **Czechoslovakia** | |
| S. Mizera | MFM |
| **Poland** | |
| R. Kulikowski and L. Krus | IRUD |
| **U.S.S.R.** | |
| E.F. Baranov and I.S. Matlin | SMOPP |
| A. Granberg | SIREN-OPT |
| **Canada** | |
| C. Lardinois | FRET |
| R. Hoffman et al. | SCIIOM |
| **U.S.A.** | |
| K.R. Polenske | MRIO |
| D.J. Bjornstad et al. | MULTIREGION |
| N.J. Glickman et al. | MAG |
| S.P. Dresch et al. | IDIOM |
| K. Ballard et al. | NRIES |
| T.R. Lakshmanan | MREEED |
| C.C. Harris, Jr. and M. Nadji | MRMI |
| G.I. Treyz et al. | MEPA-III |
| A. Isserman et al. | ECESIS |
| **Japan** | |
| N. Suzuki et al. | RDM-II |
| T. Kawashima et al. | BALAMO |
| T. Fukuchi et al. | NRPEM |
| T. Fukuchi et al. | EPAM |
| **Australia** | |
| D.F. Batten | INTEREG |
| R. Sharpe et al. | DREAM |
| **Korea** | |
| T.J. Kim | OTSIS |
| **Kenya** | |
| A. Bigsten | IIOSMK |

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