WORKING PAPER

TOWARDS A COMPARATIVE STUDY OF MULTIREGIONAL MODELS

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1. INTRODUCTION

This paper is the starting point of a comparative study concerning multiregional models. For many countries, multiregional model building is a rather recent experience. In most cases, multiregional model started only after the end of the sixties, although in certain countries among which the USA and the USSR, earlier efforts can be observed.

The common practice during the preceding period of building single-regional models was deemed unsatisfactory for several reasons (cf Bolton [1980] and Glickman [1980]).

From a theoretical point of view, the building of single-regional models was not completely satisfactory since:

- these models ignore links between the region studied and the other regions; the ensuing neglect of feed-backs can give rise to misleading results for the region at hand; and
- consistency between the outcomes of the single-regional models and a national model is not guaranteed[1)].

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Also, from a policy viewpoint, multiregional models appeared to be more suitable since many policy problems have clear multiregional dimensions. For example:

- economic decline calls for a framework to study the lagging and relatively prosperous regions simultaneously;
- large-scale infrastructure projects have interregional spill-over; and
- several countries aim at adopting decentralized development strategies (e.g. Belgium, Spain) and, consequently, need tools to appraise the consequences of such a policy framework.

At the moment, several multiregional models are being used in various countries although many of them are still in the phase of amendment and extension. Several comparative studies have been accomplished (c.f. Bolton [1980] and Hordijk and Nijkamp [1980]), but the comparisons have been limited to subsets of models: Bolton only considers American models and Hordijk and Nijkamp restrict themselves to some Western European models. Consequently, there is a good reason to start a more internationally oriented comparative study.

Another reason to start a survey stems from the general feeling that our capacity to develop theoretical models has outrun our capacity to implement them (cf. Miernyk [1976]). It is important, therefore, to consider which elements of theoretical models have proved to be applicable and to find out in which directions further research is most promising.

It is important to note that in related fields, modeling efforts have been heavily attacked. For example, D.B. Lee [1973] states with respect to urban models

> (1) the models were designed to replicate too complex a system in a single shot, and (2) they were expected to serve too many purposes at the same time. (pp.164).

A related critique has been produced by Sayer [1976]. He argues that standard urban modeling is based on very poor theory; identification errors occur in urban modeling and disequilibria are inadequately dealt with. Urban models legitimize the status quo and obscure the possibilities for radical change of the system structure.

Several of these criticisms may also be relevant for multiregional modeling but in this field a similar discussion has not (as yet) started. Therefore, a careful investigation of the features and performance of multiregional models is desirable.

The aims of the current project are:

1. The development of a framework describing relevant features of multiregional models.
2. The collection of information about a set of multiregional models from various types of countries.
3. A comparative study to trace the well-developed and underdeveloped aspects of the models and to find the common difficulties in developing and operating the models.
4. The formulation of suggestions for further activities to improving modeling and policy-making in a multiregional setting.

Obviously, these aims are completely in agreement with the idea that IIASA can perform a clearing house function with respect to modeling results in various fields. Accordingly, IIASA can play an important role in improving the transferability of multiregional models.

The present paper will be mainly devoted to the first phase of the project. In Section 2, we will give a short description of the range of models to be studied. Section 3 will be devoted to the presentation of features of multiregional models. In Section 4, some features of model-building and model-use will be discussed. In Section 5 we will focus on some important issues in (multi)regional modeling, while in Section 6, further thoughts will be presented for the remainder of the project.

2. THE RANGE OF MULTIREGIONAL MODELS

Multiregional models are devised to study phenomena at the regional scale in various regions simultaneously. In order to clarify the range of models to be discussed, we will pay attention to the following aspects:

1. the type of region;
2. the type of phenomena considered;
3. the relationships between regions; and
4. the aims for which models are developed.

ad 1. Concerning the type of regions to be considered, we will restrict our attention to regions which are so large that on the labor market commuting between regions is relatively insignificant. Thus, the regional labor markets considered are closed to a large extent. No delimitation will be imposed on the maximum size of the regions studied. For example, multiregional models may also pertain to international units such as the E.E.C., the member countries being the regions.

ad 2. Many phenomena can be studied on a regional scale. In our study, we will only pay attention to models dealing with at least a well-developed economic system. Important elements of such a system are: production, consumption, prices, investment, supply and demand for labor, etc. In addition to the economic system, other systems may also be dealt with, but that is not necessarily the case. Examples of related systems are: infrastructure, energy, water resources, and environmental systems.

ad 3. The functional relationships[2)], between spatial units in multiregional models can be approached from two viewpoints:

- mutual relationships between regions; and
- relationships between regions and the nation.

The first viewpoint gives rise to a distinction between models which do contain interregional links and which do not.

The second viewpoint gives rise to four classes of multiregional models:

- no relationships are considered between nation and region;
- the regions are influenced by the nation, but not vice versa (top-down model);
- the nation is influenced by the region, but not vice versa (bottom-up model); and

- there is a mutual interrelationship between nation and regions (regional-national model).

The distinctions presented above give rise to eight classes of multiregional models (see Table 1).

The concepts top-down and bottom up will be more thoroughly discussed in Section 5. The models of type 5 - 8 will be coined interregional models. Models of type 1 will be excluded from the analysis since they are actually gatherings of single regional models.

ad 4. When we consider the purposes for which models can be devised, we arrive basically at three types (cf. C. Lee [1973]):

- descriptive/analytical purposes;
- predictive/forecasting purposes; and
- planning/policy purposes.

Models describing the structure of the (multi)regional system can be used for descriptive/analytical purposes. For example, such models can be used to answer the question why during a certain period, sector s in region r expanded, while on the national scale this sector showed a decline.

Models can also be used for predictive/forecasting purposes. It is important to note that, in general, forecasts are not only based on a model but also on predictions of exogenous variables. There are examples where undertainty about the exogenous variables seems to be of more importance than uncertainty about the (multi) regional structure (see Rietveld [1980]). In that case it seems advisable to direct the efforts towards an improvement of the

		links between regions:	
		no	yes
links between nation and regions:	no	1	5
	top-down	2	6
	bottom-up	3	7
	regional-national	4	8

Table 1. Types of multiregional models.

prediction of the exogenous variables instead of an improvement of the model structure. A constructive way to deal with this difficulty is the use of conditional predictions (these predictions have the form: if the exogenous variables are X, then Y will happen).

A third purpose for which models can be devised is planning and policy-making. In this case, the instruments and objectives of the various policy units have to be specified in the models. It is important to note that these models can be used in two policy contexts: policy generation and policy evaluation. In the first case the models are used to generate alternative feasible policies. In the second case the models are used to determine the ex-post effectiveness of the policies carried out. In general, policy units have little interest in ex-post evaluations which means that "learning from your mistakes" is not a generally accepted notion in regional policy-making.

Tinbergen [1956] provides a standard formulation for the use of models in the development of policies. Klaassen et al. [1979] indicate that this approach to policy-making is based on four hypotheses (p. 153).

1. There is a relatively simple system of equations that describes adequately the main features of economic development.
2. There is a definite and limited set of goal variables.
3. The government is free to use the available instruments and to introduce new instruments.
4. Subject to certain conditions, the desired value of the goal variables can be attained by the proper use of instrument variables.

In the field of regional policy-making and planning, however, these hypotheses give rise to difficulties:

ad 1. The introduction of the spatial element in regional planning gives rise to large and complex models[3]. Besides, the inclusion of other systems (social, infrastructure, environment) next to the economic system adds other dimensions to complexity.

ad 2. The number of objectives is commonly large in regional planning, given the number of policy fields to be integrated and the number of policy units.

ad 3. The scope of policies in regional planning is in general small, given the fact that regional policy units may impose restrictions on the national government. Besides, the influence of interest groups in regional planning may be substantial. On the other hand, there are certain policy fields (e.g. sector policy, housing and energy policy) which may have strong (unintended) effects on the performance of the various regions. From the viewpoint of regional policy-making, obviously the regional effects of these policies should be made explicit so that they can be integrated in a more comprehensive regional policy approach.

ad 4. In the light of the above statements, the last hypothesis is clearly problematic.

It is clear that many models have been designed to serve more than one of the modeling purposes mentioned above and therefore it may make little sense to classify a model as exclusively prediction- or policy-oriented (cf. Sharpe and Karlqvist[1980]). The importance of the distinction is that it points to the institutional context of modeling efforts (cf. Section 4). This context is relatively simple when analytical purposes dominate. When forecasting, and certainly when policy purposes prevail, the context is must more intricate, however, and consequently deserves profound attention when developing a framework for a comparison of models.

We end this discussion with a short note on scenarios. Scenarios are often used for forecasting and planning purposes. In forecasting activities, scenarios can be generated to find how alternative assumptions concerning exogenous variables give rise to alternative developments in the regions. Thus scenarios can be used to deal with uncertainties concerning the external environment in a coherent way. Another type of scenarios can be found in the development of policy alternatives. In that case, scenarios can be used to deal with uncertainties concerning priorities among various objectives. Thus, various alternatives--called scenarios--can be developed reflecting different weights

attached to the objectives. As these scenarios are based on models, they should not be conceived of as results of wishful thinking, but rather as the results of a consistent confrontation of desirabilities and possibilities.

3. FEATURES OF MULTIREGIONAL MODELS

In this section, which is partly based on Hordijk and Nijkamp [1980], we will present a list of features of multiregional models to be employed for the classification of the models. Some of the features will be discussed more thoroughly in Section 5.

We will respectively deal with (1) the boundaries, (2) the elements, and (3) the relationships between the elements of the system represented by the multiregional model.

1. By indicating the boundaries of a system, the scope of the system is determined. For multiregional models the boundaries can be drawn in at least three ways:
   a) spatial boundaries, indicating the larges spatial unit of the system (e.g. a national economy);
   b) temporal boundaries, indicating the time horizon of the system; and
   c) structural boundaries, indicating which phenomena are taken into consideration and which are not. For example, next to the economic system, other systems may be included in the model.
2. Concerning the elements of multiregional systems, the following distinctions are relevant:
   a) regions and sub-regions can be distinguished according to size and type (nodal, homogeneous, administrative);
   b) the time unit can be distinguished according to length;
   c) actors: entrepreneurs, households, national and regional governments, interest groups, etc. Further refinements can be obtained for example by distinguishing between entrepreneurs from various economic sectors or households with various income levels;

d) objectives and instruments of actors: maximization of profits, quality of services; investment subsidies, etc.;
e) activities: production, consumption, investment, pollution abatement, etc.;
f) stocks of resources: natural resources, labor force, etc.;
g) inputs and outputs of activities: stocks per time unit, goods per time unit;
h) prices of inputs, outputs stocks;
i) interregional flows of inputs, outputs and stocks; and
j) various types of measurement of the above elements can be distinguished: nominal, ordinal, cardinal.

3. In multiregional models the elements mentioned above can be related to each other in numerous ways. We propose to focus on:

a) interdependencies between elements in various regions. There are various ways to link regional systems or to formulate the relationships between national and regional variables;
b) interdependencies between different subsystems. For example, a linkage between an economic and demographic subsystem can be formulated in several ways;
c) the interplay of demand and supply at the various markets (is equilibrium assumed? If so, how is it achieved?);
d) conflicts between actors;
e) relationships between instruments and objectives of actors (direct/indirect);
f) the theories and behavioral assumptions underlying the formulated relationships. For example, the relationships between economic sectors can be specified in accordance with economic base theory, input-output analysis or by means of neo-classical production theory;

g) the occurence of dynamic relationships involving variables measured at different time period;
h) the specification of the relationships (linear, loglinear, etc.); and
i) the occurence of uncertainties in the relationships (e.g. because of stochastic responses).

4. FEATURES OF THE PROCESS OF MODEL BUILDING AND MODEL USE

Were we to stop the construction of the list of features of multiregional models at this point, we would miss several important aspects of these models. The features listed thus far only concern the models as a final product, irrespective of the way in which or the actor by whom they have been developed The importance of these features for a meaningful use of multiregional models should not be underestimated. For example, Friedman and Abonyi [1976] call attention for the relationship between the model-builder and the policy unit going to use the model. They survey various institutional settings for co-operation between the two (e.g., a market and a bureaucratic setting and indicate that each setting may give rise to special problems in the co-operation between the actors.

Some of the co-operation problems to be expected are studied by Fisch [1980] in the field of regional environmental models. He focusses on the transferability of models developed by university institutes which are to be used by policy units. After an analysis of the features of 18 models and the desirable properties of models as expressed by several policy units, he concludes that no model is available which comes to meet to a reasonable extent the policy units' desires. He also notes that another aspect of transferability is clearly problematic: for almost all models, a satisfactory documentation is lacking. See House and McLeod [1977] for an indication of a satisfactory documentation of large-scale models.

The following activities are in general carried out in model-building (cf. Klein and Glickman [1977]):

1. model specification;
2. data preparation;

3. parameter estimation;
4. simulation and validation; and
5. application.

The first activity has already been dealt with in Section 3. Relevant features of the other activities are:

a) the type of data used for the estimation (e.g. cross-sections and/or time series);
b) the kind of estimation procedure;
c) the quality of the validation results;
d) the type of method used to reach numerical outcomes. For example, in non-linear simultaneous models various methods can be used to find solutions of the model. In policy models various methods can be used to generate alternatives (for example, multiobjective decision methods);
e) the purpose(s) for shich the model has been devised (analysis, forecasting, policy evaluation). This distinction can be further refined, for example by distinguishing between various types of policy problems;
f) the type of actors involved (research institutes, policymakers);
g) the documentation of the model;
h) the phase of development of the model; and
i) the transferability of the model. Various types of transfer can be distinguished:
   - from model-builder 1 to model-builder 2;
   - from model builder to model user;
   - from problem x at time t to problem x at time t + 1; and
   - from country y to country z.

5. ELABORATION OF SOME FEATURES OF MULTIREGIONAL MODELS

In this section, we will give a more detailed discussion of some elements mentioned in the preceding sections. These elements provide more insight into the problems currently faced in multiregional modeling and the solutions proposed for them by some authors. We will deal with:

1. the scale of regions (Section 3-2a);
2. regional-national modeling (Section 3-3e);
3. links between subsystems (Section 3-3b);
4. equilibrium assumptions (Section 3-3c); and
5. the co-operation between model-builder and policy-maker (Section 4-i).

1. The determination of the appropriate scale of regions depends on the aim for which a multiregional model is built. For example when the impacts of national policies on urban problems are studied, a smaller regional scale is needed than when the focus is on interregional trade. Obviously, difficulties may be expected when a model is used for various aims simultaneously. This occurs especially when a model is used for an integrated analysis of various subsystems (for example: economics and ecology). The scale of a region on which it is meaningful to draw inferences in ecology is very small compared to economics. In economics on the other hand, small regions are difficult to model since they are usually very open (see Arntzen and Braat [1980]).

A possible way out of this dilemma may be a multilevel approach. In the above example, it would mean that economic variables are determined on a high spatial level (say regions). The consequences for the ecological variables can then be determined on a lower spatial level (say zones). An example of a multilevel approach is contained in Wegener [1980]. A problem with multilevel approaches is how possible feedbacks from the zones to the region have to be modeled. This problem is related to the subject of the second item.

There is an important link between this discussion about the scale of regions and the transferability of models from one country to another. Transferability can be hampered when

different countries are partitioned in regions of clearly different scales. For example, when in a model dealing with relatively small regions the distinction between basic and non-basic sectors is used, such a distinction may be useless when the model would be applied to a system with large regions.

2. An important item in the discussion about the relationships between the national and regional systems is whether a top-down or a bottom-up approach has to be adopted (cf. Courbis [1980]). In a top-down approach the regional variables are determined given the national values, without the possibility of feed-back from the regional to the national level. This approach is relatively simple; it requires that existence of a national model and is actually a distribution model of exogenously given macro-variables. In a bottom-up approach on the other hand, the national variables are the results of an aggregation of regional variables. An important advantage of the bottom-up approach compared with the top-down approach is that on the former the impacts of the changes in the regional-distribution of investments on the national economy can be analyzed which is not the case with the latter. On the other hand, top-down models are easier to construct than bottom-up models since for most countries a national economic model already exists.

Several models developed during the last years are a mixture of top-down and bottom-up approaches. Courbis [1980] proposes to adopt a bottom-up approach for variables which are determined on a regional market or which are the results of a decision-making process of regional agents. He mentions as examples: labor supply, production processes, household consumption, residential investment and the investment of local public authorities. A top-down approach would be more appropriate for variables on the national market. This way of analysis--formulating the conditions on which a top-down or bottom approach is most appropriate--is a promising subject for further research in this field.

The discussion about the desirability of a top-down versus a bottom-up approach in multiregional modeling bears a certain resemblance with the same discussion in multilevel programming. This programming approach deals with the co-ordination of

several components (e.g. regions) by a central unit. The dilemma whether a bottom-up or a top-down approach should be adopted loses much of its relevance when multilevel programming is carried out in dynamic setting so that the messages produced at a certain level at moment t can be used as inputs at the other level during the subsequent period and so on.

Another interesting approach to this subject is aggregation theory, not so much since it can be expected that in some cases a perfect aggregation of regional relationships can be reached (cf. Theil [1954]) but because it may help to investigate how serious the inconsistencies due to aggregation are (cf. Van Daal ([1980]). In this respect, it is important to note that recently in the field of mathematical programming, some results have been obtained concerning the effects of aggregation on the objective function (cf. Geoffrion [1977] and Huberman [1979]). This is a promising way to analyze the "costs of aggregation".

3. When a model consists of several subsystems of different types (e.g. economic, environmental) the problem arises how these models have to be linked. The linkage of such subsystems is, however, often one of the most difficult activities in model-building. Christov and Panov [1980] indicate that sometimes in regional modeling it is impossible to reach a linkage such that the output of one subsystem is the input of the other subsystem. In that case, the evaluation of experts is necessary to reach a linkage. It is important to learn more about the reason of these linkage problems: Are they due to deficient data, under-developed theories or defective agreements among researchers in the different subsystems? The inclusion of evaluations of experts in models means that a kind of man-machine interaction will be reached.

4. An important aspect of modeling market mechanisms is the equilibrium assumption. In several models, the equilibrium assumption used is very simple: many input-output or economic base models in western countries assume that supply is flexible so that it can always be made equal to demand (cf. Sayer [1976]). Obviously, this means that a situation of overcapacity is present,

which may be a reasonable assumption for the short term, but certainly not for the longer term. In models being used in the socialist countries, on the other hand, it is often assumed that supply is restricted and demand is flexible. Also, this assumption may give rise to difficulties when it is used in longer term studies.

It is important to note that during the last years there has been some progress im modeling markets for disequilibrium situations (cf. Siebrand [1979]). The main features of disequilibrium models are that ex-ante supply and demand are distinguished from ex-post demand and supply, and that ex-ante supply and ex-ante demand are not necessarily equal. There are various ways to relate the ex-post values to the ex-ante values. For example, Muellbauer [1978] states:

$$\text{ex-post supply} = \text{ex-post demand} = \min(\text{ex-ante supply}, \text{ex-ante demand}) \quad .$$

This means that the realized quantity exchanged in the market is equal to the minimum value of ex-ante demand and ex-ante supply. When several regional markets are aggregated, while some of them show an excess demand and others an excess supply situation, the result is that on the national market the realized value exchanged is smaller than both national demand and national supply. For the labor market this means the co-existence of vacancies and unemployment.

5. An essential element in the transfer of planning models is the possibility to achieve a communication between policy-maker and model-builder. For example, in the phase of model building it often appears difficult to let the policy-maker state his ideas about the scope and potential use of the model. Also, once a model has been built, the communication is in general vulnerable, since the models are complex so that it is not easy for the model-builder to make them transparent to the policy-maker. On the other hand, it may be difficult for the policy-maker to state his priorities among the policy objectives in an explicit manner so that the model-builder can generate alternatives in agreement with these priorities.

Multiobjective decision methods are a tool to improve the communication between the two actors. These methods provide a framework for a step-wise information exchange. In each step, the model-builder provides information about some feasible alternatives implied by the model and about the structure of conflicts between the various objectives. This information is used by the policy-maker to express his opinion about the direction in which a satisfactory alternative has to be looked for. Given certain conditions, this communication process is convergent. For further details we refer to Rietveld [1980].

6. PROSPECTS

A frame of reference for a comparative study of multiregional models is presented in this paper. Before carrying out the actual comparison it seems worthwhile to deal with comparative studies on related types of models (e.g. macro-economic models or urban models). The next step in this project will be the study of published material on multiregional models. We expect that additional information has to be collected by means of questionnaires or interviews. An important element of our ultimate aim is to compare the properties of multiregional models by means of some well-defined and generally applicable numerical exercises or simulations.

NOTES

1) Obviously, from the viewpoint of regional modeling, it is only meaningful to aim at consistency between models and a national model when there are good reasons to have confidence in the national model. When this confidence is absent, it may be better to revise the national model in the light of the regional models. We refer to Section 5 for more details about this approach.
2) The term "functional relationship" is used on purpose in this sentence, since ideally, interregional links shall not be based on spatial proximity as such (as is the case with the "nearest neighbor" concept), but on functional relationships between spatial entities.
3) One dimension of the complexity due to the introduction of spatial elements is that influences between regions may go in two directions (e.g., $r \rightarrow r' \rightarrow r'' \rightarrow r$). In temporal models, the direction of influences is only one-way (e.g., $t \rightarrow t + 1 \rightarrow t + 2$).

REFERENCES

Arntzen, J.W., and L.C. Braat. 1980. An integrated environmental model for regional policy analysis. In: P. Nijkamp (ed.) A Survey of Dutch Integrated Energy-Environmental-Economic Policy Models. Research Memorandum 1980-10. Amsterdam: Free University (Department of Economics).

Bolton, R. 1980. Multiregional models: introduction to a symposium. Journal of Regional Science 20:131-142.

Christov, E., and O. Panov. Strategic planning for the development of a regional system. In: Proceedings of a Joint Task Force Meeting on Development Planning for the Notec (Poland) and Silistra (Bulgaria) Regions, M. Albegov, R. Kulikowski and O. Panov, eds. CP-80-9, pp.29-48. Laxenburg, Austria: International Institute for Applied Systems Analysis.

Courbis, R. 1980. Multiregional modeling - A general appraisal. Paper presented at the conference on Theoretical and Practical Aspects of Regional Development Modeling (March 18-21, 1980) at IIASA. Laxenburg, Austria: International Institute for Applied Systems Analysis (forthcoming).

Daal, J. van. 1980. On Aggregation of Economic Relationships. (Mimeographed). Rotterdam: Erasmus University (Econometric Institute).

Fisch, O. 1980. Technological Transfer of Regional Environmental Models. Paper presented at the conference on Theoretical and Practical Aspects of Regional Development Modeling (March 18-21, 1980) at IIASA. Laxenburg, Austria: International Institute for Applied Systems Analysis.

Friedmann, J., and G. Abonyi. 1976. Social learning: a model for policy research. Environment and Planning 8:927-940.

Geoffrion, A.M. 1977. Aggregation Theory and its Application to Modeling in Mathematical Programming. Working Paper 278. Los Angeles: University of California, Western Management Science Institute.

Glickman, N.J. 1980. Using empirical models for regional policy analysis. Paper presented at the conference on Theoretical and Practical Aspects of Regional Development Modeling (March 18-21, 1980) at IIASA. Laxenburg, Austria: International Institute for Applied Systems Analysis.

Hordijk, L., and P. Nijkamp. 1980. Integrated Approaches to Regional Development Models. Research Memorandum 1980-4. Amsterdam: Free University (Department of Economics).

House, P.W., and J. McLeod. 1977. Large-Scale Models for Policy Evaluation. New York: Wiley and Sons.

Huberman, G. 1979. Variable Aggregation in Convex Programming. (Mimeographed). New Haven, Connecticut: Yale School of Organization and Management.

Klaassen, L.H., J.H.P. Paelinck, and S. Wagenaar. 1979. Spatial Systems. Westmead, U.K.: Saxon House.

Klein, L.R., and N.J. Glickman. 1977. Econometric model-building at the regional level. Regional Science and Urban Economics 7:3-23.

Lee, C. 1973. Models in Planning. Oxford: Pergamon Press.

Lee, D.B. 1973. Requiem for large-scale models. Journal of the American Institute of Planners 39:163-178.

Miernyk, W.H. 1976. Comments on recent developments in regional input-output analysis. International Regional Science Review 1:47-55.

Muellbauer, J. 1978. Macrotheory vs. macroecononometrics: the treatment of 'disequilibrium' in macromodels. Paper presented at the European Meeting of the Econometric Society, Geneva.

Rietveld, P. 1980. Multi Objective Decision Methods and Regional Planning. Amsterdam: North-Holland Publishing Company.

Sayer, R.A. 1976. A critique of urban modelling. Progress in Planning 6, no. 3:187-254.

Sharpe, R., and A. Karlqvist. 1980. Towards a unifying theory for modelling urban systems. Regional Science and Urban Economics 10:241-257.

Siebrand, J. 1979. Towards Operational Disequilibrium Macro Economics. The Hague: Nijhoff.

Theil, H. 1964. Linear Aggregation of Economic Relations. Amsterdam: North-Holland Publishing Company.

Tinbergen, J. 1956. Economic Policy, Principles and Design. Amsterdam: North-Holland Publishing Company.

Wegener, M. 1980. A multilevel economic-demographic model for the Dortmund region. Paper presented at the Workshop on Urban Systems Modelling, Moscow.