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CAUSALITY STRUCTURES IN MULTIREGIONAL ECONOMIC MODELS

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ABSTRACT

This paper contains the first results of a comparative study of multiregional models. It deals with the causality structure of multiregional models. We focus our attention on:

1. The relationship between national production and regional production ("top-down" versus "bottom-up")

2. The measure in which regional production is determined by variables from the demand side or from the supply side.

Their distinctions enables one to formulate a certain classification of multiregional models. The main part of the paper is devoted to a description and evaluation of an example of each model class. The following models are presented:

CANDIDE-R (Canada), REMA (Belgium), BALAMO (Japan) MORSE (Sweden), NRIES (U.S.A.) and a model built by Fukuchi (Japan).

CONTENTS

1. INTRODUCTION

This paper contains the first results of a comparative study concerning multiregional economic models, at present being carried out at IIASA, Laxenburg, and the Free University, Amsterdam. For a description of the aims of the study we refer to Nijkamp and Rietveld [1980]. The purpose of the present paper is to treat a limited number of classes of multiregional models to achieve a certain order in the multitude of models which have been developed thus far.

As indicated in Nijkamp and Rietveld [1980], multiregional models can be distinguished according to many features such as: the boundaries of a model, the elements described by a model, the relationships between the elements and modes of using a model. In this paper we will deal with the causal structure of the models. We will focus on two aspects of the causal structure:

1. The relationship between national variables and the corresponding regional variables. This relationship may have a "bottom-up", a "top-down" or a mixed character (especially in a dynamic model).

Table 1. Six types of multiregional models.

	Top-down approach	Bottom-up approach
supply orientation	Section 3 CANDIDE-R	Section 6 MORSE
demand orientation	Section 4 RENA	Section 7 NRIES
mixed orientation	Section 5 BALAMO	Section 8 FUKUCHI

2. The relationship between final demand, regional production, and the supply of production factors. In this respect models may exhibit a "supply orientation," a "demand orientation" or a mixed supply-demand orientation.

In Section 2 these terms will be provided with a precise meaning. It is important to note that these distinctions are not only relevant for the formal structure of the model but also for the type of policy which may be suggested by the model. For example, in a top-down structure where regional product is constrained by the regional supply of production factors, a national stimulation of final demand may give rise to inflationary pressure in regions with tight factor markets. Obviously, a policy aiming at regional growth should differentiate between the regions according to the tightness of the factor markets. According to the two aspects distinquished above we would arrive at a series of nine types of multiregional models. In the present paper we will focus on six of them (see Table 1). In a future paper more attention will be paid to the deleted column of mixed bottom-up/top-down models.

In Sections 3-8 we will present an example of the various types of models. In each cell of Table 1 the pertaining section and the name of the model (or the name of the model-builder) have been mentioned. The formal presentation of the causality structure of the six models can be found in the Appendix. Section 9 will be devoted to an evaluation of the models.

2. CLARIFICATION OF CONCEPTS

In this section the terms top-down approach, bottom-up approach, supply orientation, and demand orientation will be clarified by means of an analysis of the causal structure of models.

Consider the following linear model:

$$A_0\underline{y}_t + B\underline{y}_{t-\tau} + C\underline{z}_t = \underline{c}_t \tag{2.1}$$

where $\underline{y}_t$ is a vector with I endogenous variables, $\underline{y}_{t-\tau}$ is a vector with I lagged endogenous variables, and $\underline{z}$ is a vector with N exogenous variables. A_0, B, and C are matrices of order (I x I), (I x I_1), and (I x N), respectively. According to Simon [1953], the causal structure of this model is defined by the form of the matrix A_0 (see also Fox, Sengupta, and Thorbecke [1966]). The model is completely <u>recursive</u> when A_0 is strictly triangular matrix. In that case, the first endogenous variable can be determined by the first equation in (2.1). Given the value of the first endogenous variable, the second equation in (2.1) can be used to determine the value of the second endogenous variable, etc. In recursive models it is meaningful to say that the endogenous variable y_i is caused by the preceding endogenous variables (as well as by lagged endogenous and exogenous variables).

Strictly triangularity of the A_0 matrix is a strong assumption in may cases. Therefore, Simon [1953] also considers block triangularity.

$$A_0 y_t = \begin{pmatrix} A_{11} & 0 & 0 \\ A_{21} & A_{22} & 0 \\ A_{31} & A_{32} & A_{33} \end{pmatrix} \begin{pmatrix} \underline{y}_{1t} \\ \underline{y}_{2t} \\ \underline{y}_{3t} \end{pmatrix} \qquad (2.2)$$

where A_{11}, A_{22}, and A_{33} are square matrices. In this case the endogenous variables contained in $\underline{y}_{1t}$ can only be determined in a simultaneous way. The notion of causal ordering can be maintained, however, since for (2.2) it can be said that the elements of $\underline{y}_{2t}$ are caused by the elements of $\underline{y}_{1t}$, etc.

So far we have discussed only causal links in <u>linear</u> models. It appears to be easy to extend this analysis to nonlinear models. Consider the following series of equations:

$$\begin{cases} f_1(\underline{y}_t, \underline{y}_{t-\tau}, \underline{z}_t) = 0 \\ \vdots \\ f_I(\underline{y}_t, \underline{y}_{t-\tau}, \underline{z}_t) = 0 \end{cases} \qquad (2.3)$$

where the arguments of the I functions have the same meaning as in (2.1). Let $b_{ij} = 1$ when the variable y_{jt} plays a role in f_i and $b_{ij} = 0$ when this variable does not play a role in f_i. Then the b_{ij} form together an I x I matrix B_0. A model is a simultaneous equation model when B_0 cannot be partitioned in a block triangular matrix. When B_0 can be partitioned in that way:

$$B_0 = \begin{pmatrix} B_{11} & 0 & 0 \\ B_{21} & B_{22} & 0 \\ B_{31} & B_{32} & B_{33} \end{pmatrix}, \quad \underline{y}_t = \begin{pmatrix} \underline{y}_{1t} \\ \underline{y}_{2t} \\ \underline{y}_{3t} \end{pmatrix} \qquad (2.4)$$

it is meaningful to say that the elements of $\underline{y}_{2t}$ are caused by $\underline{y}_{1t}$, etc.

An important topic in multiregional modeling is whether a top-down approach or a bottom-up approach should be adopted. For arguments pro and contra we refer to Courbis [1980] and Nijkamp and Rietveld [1980].

In a top-down approach the regional variables x^r ($r = 1,\ldots R$) corresponding with the national variable x are determined by repartitioning the national variable which is assumed to be known[1]:

$$x^r = c^r(v_1,\ldots,v_M,\ w_1^r,\ldots,w_N^r,\ w_1^{r'},\ldots,w_N^{r'})x \qquad (2.5)$$

where c^r is a function depending on national variables v_m and variables pertaining to region r and other regions w_n^r, $w_n^{r'}$. In order to ensure consistency between national and regional variables, the functions c^r should satisfy[2]:

$$\sum_r c^r = 1 \qquad (2.6)$$

The function c^r may have many forms. A special case arises when the function is a constant. This would mean that the repartitioning is fixed and does not depend on the values of other national or regional variables (cf. d'Amours, Fortin, and Simard [1979]).

The causal ordering implied by a top-down approach can be represented as follows:

$$B_0 = \begin{pmatrix} 1 & 0\ldots\ldots0 \\ 1 & \\ \vdots & B_{22} \\ 1 & \end{pmatrix}, \quad \underline{y} = \begin{pmatrix} x \\ x^1 \\ \vdots \\ x^R \end{pmatrix} \qquad (2.7)$$

where B_{22} is possibly a diagonal matrix. In (2.7) the national variable x causes the regional variables x^r. Note that (2.7) does not describe the relationships between the complete set of endogenous variables. If that would be done it is not impossible that—via other endogenous variables—there is a feedback from the x^r on x. Obviously, such a feedback is absent when the model is a pure top-down model, which means that all regional variables are obtained by repartitioning national variables.

In a bottom-up approach the variables are first determined at the regional level:

$$x^r = g^r(v_1,\dots,v_M;\ w_1^r,\dots,w_N^r;\ w_1^{r'},\dots,w_N^{r'}) \qquad (2.8)$$

where v_m is a national variable[3] and w_n^r, $w_n^{r'}$ are variables pertaining to regions r and r', respectively. The corresponding national variable is found by adding up the regional values:

$$x = \sum_r x^r \qquad (2.9)$$

The causal ordering following from a bottom-up approach can be represented by:

$$B_0 = \begin{pmatrix} B_{11} & \begin{matrix} 0 \\ \vdots \\ 0 \end{matrix} \\ 1 \cdots\cdots 1 & 1 \end{pmatrix}, \quad \underline{y} = \begin{pmatrix} x^1 \\ \vdots \\ x^R \\ x \end{pmatrix} \qquad (2.10)$$

where B_{11} is an I x I matrix which may be a diagonal matrix but which may also attain more complex forms. Given (2.10) we may say that the national variable is caused by the regional ones.

Some multiregional models are pure bottom-up or pure top-down models: they contain exclusively bottom-up or top-down relationships between variables, respectively. There are also models using a top-down approach for some variables and a bottom-up approach for other variables, however. These models are called: regional-national models (cf. Courbis [1980] and Nijkamp and Rietveld [1980]). In the present paper we will focus our attention on the relationship between regional production and national production. Consequently, one must be aware that when we speak of a top-down approach to regional production this does not mean to say that the pertaining model is a pure top-down model.

A mixed approach as a variable arises when on the one hand the national variable is determined by the regional variable while on the other hand the regional variable is determined by the national variable.

An example of this approach arises when (2.8) and 2.9) are written as a dynamic model:

$$x_t^r = g^r(x_{t-1}, v_{1t},\ldots,v_{mt}; w_{1t}^r,\ldots,w_{nt}^r; w_{1t}^{r'},\ldots,w_{nt}^{r'})$$
$$x_t = \sum_r x_t^r \qquad (2.11)$$

which implies that x_t^r is caused by x_{t-1}, while x_t is caused by x_t^r.

Another example arises when we interpret x^r as regional production which is the sum of the regional production in various economic sectors. For some sectors (e.g., national sectors) a top-down approach may be adopted:

$$x_i^r = c_i^r\ (v_1,\ldots,v_M; w_1^r,\ldots,w_N^r; w_1^{r'},\ldots w_N^{r'})x_i \qquad (2.12)$$

where x_i^r and x_i denote the regional and national production colume in sector i, respectively. For other sectors (e.g., regional sectors) a bottom-up approach may be more appropriate:

$$x_j^r = g_j^r(v_1,\ldots,v_M; x_i^r,w_1^r,\ldots,w_n^r; w_1^{r'},\ldots,w_N^{r'})$$
$$x_j = \sum_r x_j^r \qquad (2.13)$$

Hence we find that on the one hand x_i^r is caused by x_i, while on the other hand x_j is caused by x_j^r.

We turn now to the clarification of the terms related to the predominance of demand or supply in determining regional production. A model is demand oriented when the volume of production factors is determined by the volume of regional production.

A simple example of a demand oriented model is the following model:

$$\begin{cases} Y^r = C^r + I_0^r \\ C^r = cY^r \\ E^r = lY^r \end{cases} \tag{2.14}$$

where: Y^r = regional product
C^r = regional consumption
I_0^r = regional investment (exogenous)
E^r = regional employment.

The causal ordering implied by (2.13) can be represented as follows:

$$B_0 = \begin{bmatrix} 1 & 1 & 0 \\ 1 & 1 & 0 \\ 1 & 0 & 1 \end{bmatrix} , \quad \underline{y} = \begin{bmatrix} Y^r \\ C^r \\ E^r \end{bmatrix} \tag{2.15}$$

which indicates that the labor market variable E^r is caused by the endogenous product and demand variables Y^r and C^r without any feedback.

Supply orientation is defined as follows: A model is called supply oriented, when the volume of regional production is determined by the volumes of one or more of the production factors. A simple example of a supply oriented model where capital is the restrictive production factor is:

$$\begin{cases} K_t^r = K_{t-1}^r + I_{0,t-1}^r \\ Y^r = kK_t^r \\ Y^r = C^r + I_{0,t}^r \end{cases} \qquad (2.16)$$

where K_t^r is the capital stock in region r at the beginning of period t. As indicated by B_0 and $\underline{y}$:

$$B_0 = \begin{bmatrix} 1 & 0 & 0 \\ 1 & 1 & 0 \\ 0 & 1 & 1 \end{bmatrix} \qquad \underline{y} = \begin{bmatrix} K^r \\ Y^r \\ C^r \end{bmatrix} \qquad (2.17)$$

there is a causal ordering between K_t^r, Y^r, and C^r.

Note that supply oriented models also include the case of several production factors, not all of them being restrictive. In (2.18) we give a simple example of such a case where capital is the restrictive production factor and labor is the non-restrictive one:

$$\begin{cases} K^r = K_{t-1}^r + I_{0,t-1}^r \\ Y^r = kK_t^r \\ Y^r = C^r + I_{0,t}^r \\ E^r = lY^r \end{cases} \qquad (2.18)$$

A <u>mixed</u> supply/demand <u>orientation</u> arises when on the one hand regional production is determined by the supply of production factors while on the other hand the supply of production factors is determined by regional production. An example of such a model is:

$$\begin{cases} Y_t^r = f^r(E_t^r) \\ E_t^r = g^r(Y_{t-1}^r) \end{cases} \qquad (2.19)$$

In the following sections we will discuss examples of the model types arising from a confrontation of the two aspects of causual structure dealt with in this section (see Table 1). These model types should be conceived of as ideal types. It is not easy to find a multiregional model which completely fits the traits of the ideal type. When small departures from the ideal type do arise, it will be mentioned in the text.

3. A SUPPLY ORIENTED TOP-DOWN APPROACH TO REGIONAL PRODUCTION: CANDIDE-R

3.1 DESCRIPTION OF CANDIDE-R

CANDIDE-R is a regional-national model for the Canadian economy. CANDIDE stands for Canadian Disaggregated Interdepartmental Econometric model; R stands for regional. The model deals with five regions and has been inspired by the CANDIDE model, a macro-economic model for Canada. It is not a satellite model of CANDIDE, however. The aim of the CANDIDE-R model is an ex-ante and ex-post analysis of the economic development possibilities of the various sectors and regions on the medium term. The present description of the model is based on d'Amours, Simard, and Chabot-Plante [1975] and on d'Amours, Fortin, and Simard [1979]. It is noteworthy that the authors present a comparison of the outcomes of the CANDIDE and the CANDIDE-R model and conclude that for several variables the national-regional model gives rise to more accurate forecasts than the national model.

In the model, the volume of industrial production in region r is based on the following top-down approach[4]:

$$\frac{X_i^r}{X_i} = a_i^r + b_i^r \frac{T_i^r K_i^r}{T_i K_i} \qquad (3.1)$$

where: X_i = industrial production
T_i = rate of capacity utilization in the industrial sector
K_i = capital stock in the industrial sector.

The basic idea underlying (3.1) is that the regional distribution of industrial output is based on the regional distribution of capital which is a clear indication of the supply orientation in this model. The formulation actually used in the model is obtained by a partial adjustment version of (3.1):

$$\left(\frac{X_i^r}{X_i}\right)_t = c_i^r + d_i^r\left(\frac{X_i^r}{X_i}\right)_{t-1} + e_i^r\left(\frac{T_i^r K_i^r}{T_i K_i}\right)_t \tag{3.2}$$

From (3.2) we may conclude that the main variable determining the regional distribution of production is the regional capital stock. Also for this variable a top-down approach has been adopted. National investment I_i is repartitioned according to exogenous (not necessarily fixed) weights a_{it}^r:

$$I_{it}^r = a_{it}^r I_{it} \tag{3.3}$$

where the sum of the weights is equal to one. The authors mention that this exogenous repartitioning enables one to evaluate the differential consequences of alternative regional investment policies.

Regional industrial employment E_i^r is directly linked with regional industrial production:

$$E_{it}^r = \left[a_i^r\left(\frac{E_i^r}{X_i^r}\right)_{t-1} + b_i^r \Delta X_{i,t-1}^r\right] X_{it}^r \tag{3.4}$$

The term between brackets accounts for fluctuations in labor productivity. This formulation implies that for employment a bottom-up approach has been adopted.

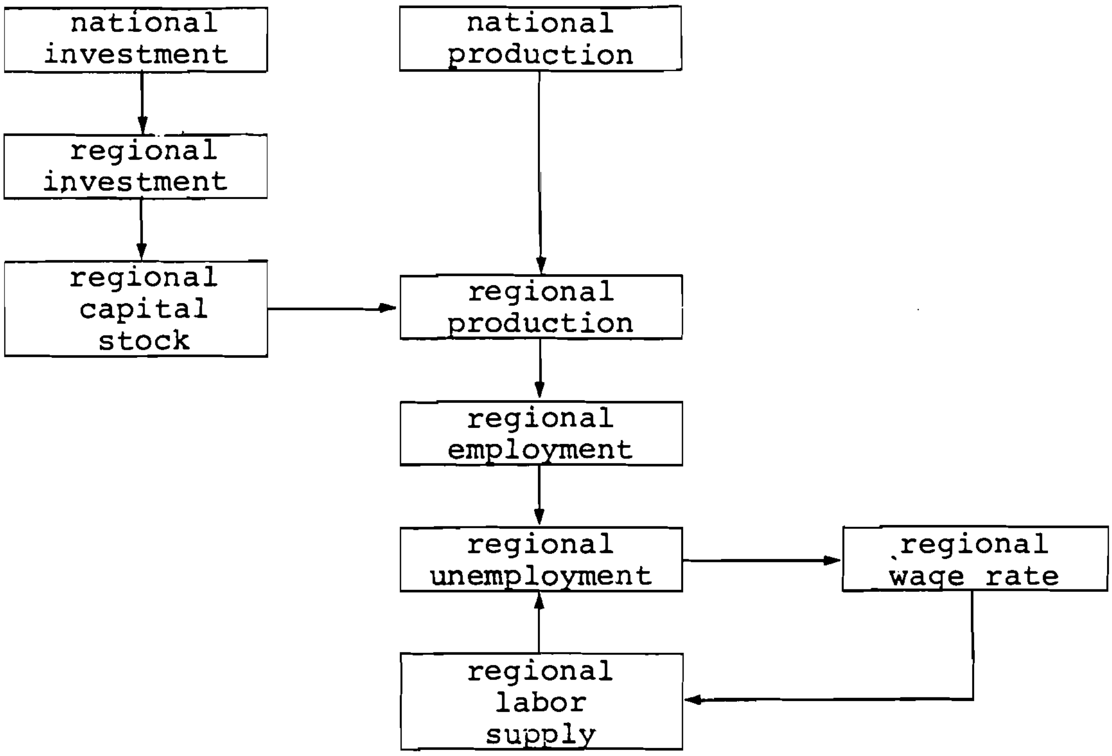


Figure 1. Causal structure of the industrial sector of CANDIDE-R.

Labor supply is determined in the model by applying participation rates to various age groups determined in a demographic submodel. One of the explanatory variables of the participation rates is the regional wage level. The regional wage level in its turn depends on regional employment and prices.

The causal structure of the relationships discussed has been represented in Figure 1. The figure clearly shows the top-down approach to regional production and investment and the role of regional capital as a restrictive production factor. The above-mentioned sources do not contain a complete description of the CANDIDE-R model. Therefore, it is not possible to find out whether there is a feedback from the regional labor markets on national production and, hence on regional production. Such a feedback could follow a trajectory such as: regional unemployment, regional wages, national wages, national production. The existence of such a feedback would mean that CANDIDE-R is not a pure supply oriented model.

3.2 EVALUATION OF CANDIDE-R

This model was one of the first operational regional- national models. Interesting are the top-down approach to investment and production and the bottom-up approach to employment.

The theoretical basis of the equations is not always strong. One should be aware, however, that the specification of the model is not only based on theory, but also on data availability. The specification of (3.1) and (3.2) is weak for at least two reasons. First, these specifications do not guarantee that the sum of the regional shares is equal to 1. Second, the inclusion of the capacity utilization rate T_i gives rise to strange results. When potential output in the industrial sector is equal to C_iK_i and actual output is X_i, then $T_i = X_i/c_iK_i$, so that $T_iK_i = X_i/c_i$. Substitution of this result in (3.2) yields:

$$\left(\frac{X_i^r}{X_i}\right)_t = c_i^r + d_i^r\left(\frac{X_i^r}{X_i}\right)_{t-1} + e_i^r \frac{c_i}{c_i^r}\left(\frac{X_i^r}{X_i}\right)_t \qquad (3.5)$$

which means that after all the regional share of production in period t is completely based on the share in period t - 1, while the capital stock does not exert any influence. Also the authors themselves suggest that it might be better to remove the T_i variables from (3.2) so that the regional production share is directly related to the regional capital share[5].

3.3 RELATED MODELS

The REM model, developed for the Netherlands (cf. Van Delft, Van Hamel, and Hetsen [1977] and Van Hamel and Van Delft [1978] and the model proposed by Crow [1979] are similar to the CANDIDE-R model. In both models the repartitioning of investment among regions is the main driving force behind the model. In contrast with the CANDIDE-R model, the repartitioning of investment is not based on exogenous weights but on variables indicating the comparative advantage of the regions. Investment subsidies are part of the comparative advantages. Consequently, in the REM and Crow models it is in principle possible to evaluate the effectiveness of various investment schemes.

4. A DEMAND ORIENTED TOP-DOWN APPROACH TO REGIONAL PRODUCTION: RENA

4.1 DESCRIPTION OF RENA

The RENA model has been developed for the preparation of the Belgian Economic Plan 1976—1980 (RENA stands for REgional-NAtional). Three regions have been distinguished in the model. A sectoral breakdown has not been introduced. The model includes a well-developed national block dealing with, among others, foreign trade, the government sector, a monetary sector, and income determination.

The regional block of RENA deals with the labor market and production. For production a top-down approach has been adopted whereas for wages, investment, and employment a bottom-up approach is used. The description of the model will be based on the following publications: de Falleur, et al. [1975] and Thys-Clement, van Rompuy, and de Corel [1979].

Regional production is obtained by the following repartitioning procedure. First regional production is determined by means of:

$$X^r = a^r + b^r V + c^r I^r \qquad (4.1)$$

where: X = production
V = final demand minus investment
I = investments

Thus, regional production depends on national final demand minus investment and on regional investment. There is no guarantee that $\Sigma X^r = X$ and hence in a second step X^r is computed as:

$$X^r = \frac{a^r + b^r V + c^r I^r}{\sum_r (a^r + b^r V + c^r I^r)} X \tag{4.2}$$

It follows from (4.2) that the growth or decline of national final demand may have differential effects on the growth or decline of the regions, especially when the coefficients a^r and b^r vary largely among the regions. The only final demand category which appears at the regional level in (4.2) is investment.[6]

The regional allocation of production factors is based on the following production function:

$$X^r = E^r \exp\left\{a^r + b^r \left(\frac{E^r}{K^r}\right)^2\right\} \tag{4.3}$$

which implies the possibility of substitution between labor E^r and capital K^r.

The factor demand functions are based more or less directly on (4.3) given the objective of profit maximization. For regional investment we find:

$$I_t^r = c^r \left(\frac{w^r}{s^r}\right)_{t-1}^{b^r} \Delta X_{t-1}^r + I_{0,t} \tag{4.4}$$

where: I = investment
w = wage level
s = user cost of capital
I_0 = exogenous part of investment (among others: government investment)

Thus, investment behavior is influenced by relative prices from the past. Via s^r the effects of investment and interest subsidies on policy variables can be studied.

The labor demand function reads:

$$\left(\frac{E^r}{K^r}\right)_t = d^r + e^r \ln w^r_{t-1} + f^r \left(\frac{X^r}{X^r_0}\right)_t \qquad (4.5)$$

In this relationship, X^r_0 is the maximum possible output given the capital stock. This variable can be derived from the production function (4.3). Thus, (4.5) means that the regional labor intensity depends on the lagged regional wage rate and the regional rate of capacity utilization.

Regional unemployment can be found as the difference between regional employment and regional labor supply. The regional wage rate is determined by the national price level and the regional volume of unemployment.

The causal structure of this model has been depicted in Figure 2 (an arrow with an * indicates a time-lag). According to this figure, RENA is a pure demand oriented model· it does not show any feedback from the regional wage rate on the regional production volume. One should be aware, however, that Figure 2 is only a stylized representation of the RENA model. In reality the RENA model does contain a feedback from the regional wage rate on the regional production level. This feedback follows the trajectory: regional wage rate → national wage rate → national price level → national final demand → regional production. Obviously, this feedback is indirect;

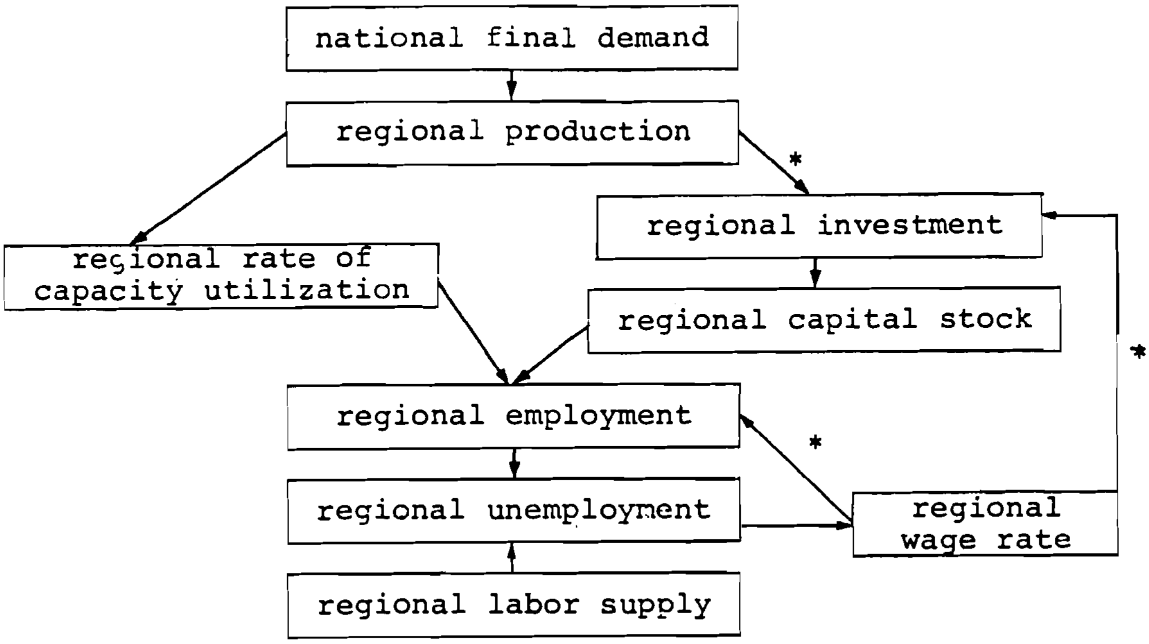


Figure 2. Causal structure of the RENA model.

it proceeds along variables at the national level. We conclude, therefore, that although the RENA model does not show a pure top-down demand oriented approach to regional production, it certainly provides a good illustration of the main features of such an approach[7].

4.2 EVALUATION OF RENA

The factor demand functions of the RENA model are based on regional production functions and have a firm theoretical foundation. The specifications allow for substitution between capital and labor induced by changes in relative prices. Consequently, the RENA model can be used to study the differential effects of price policies (e.g., investment subsidies) on the regional allocation of production factors.

The theoretical justification of the repartitioning procedure (4.1) and (4.2) is weak. Also, from the viewpoint of estimation, the repartitioning procedure is questionable. The problem is that although (4.2) guarantees a consistency between national and regional data, this consistency requirement has not been imposed with the estimation of the coefficients in (4.1). Accordingly, the quality of the estimates of the coefficients is questionable.

5. A TOP-DOWN APPROACH TO REGIONAL PRODUCTION WITH A MIXED SUPPLY DEMAND ORIENTATION: BALAMO

In the preceding sections we have dealt with multiregional models showing main features of either the demand or supply oriented type. However, in many models there is a clear interaction of demand and supply variables in determining the regional production volume. These models cannot be classified as being exclusively demand or supply oriented. Therefore, we introduce as a third type: models with a mixed supply-demand orientation. In this section we present as an example the BALAMO model.

5.1 DESCRIPTION OF BALAMO

BALAMO is a model for the Japanese economy. It contains a combination of a multiregional, BALanced input-output model and an ordinary Adjustment MOdel in the sphere of production and labor supply (hence the name BALAMO). The model deals with space at three levels: nation, regions, and localities. The number of localities is 46. There have been distinguished eight economic sectors (three for national goods, two for regional goods, and three for local goods).

The model has been used to study the effects of government investments in road infrastructure on the economic development of the localities. The following description is based on Kawashima [1977].

The model assumes as given

— a national input-output table
— national final demand for national goods
— regional final demand for regional goods
— local final demand for local goods
— distribution coefficients to allocate the output shares of regional goods to localities.

By means of these data the regional and local production volumes can be computed for the eight sectors. These volumes are interpreted as production pressure levels and will be denoted as $X^{*r}_{i,t}$.

Labor supply is assumed to react in the following way on the production pressure:

$$E^r_{i,t} = E^r_{i,t-1} + a_i\left(X^{*r}_{i,t} - X^r_{i,t-1}\right) + b_i \qquad (5.1)$$

Symbols: E_i = employment in sector i
X^*_i = production pressure in sector i
X_i = realized production level in sector i

In this section r refers to localities.

The other production factor is the local road stock S^r. The road stock is determined by exogenous variables: road stock investment (a policy variable) and road stock replacement, the latter being related to the intensity of use in the previous period.

The potential supply $Q^r_{i,t}$ in sector i of locality r during period t is:

$$Q^r_{i,t} = c_i E^r_{i,t} + d_i S^r_t \qquad (5.2)$$

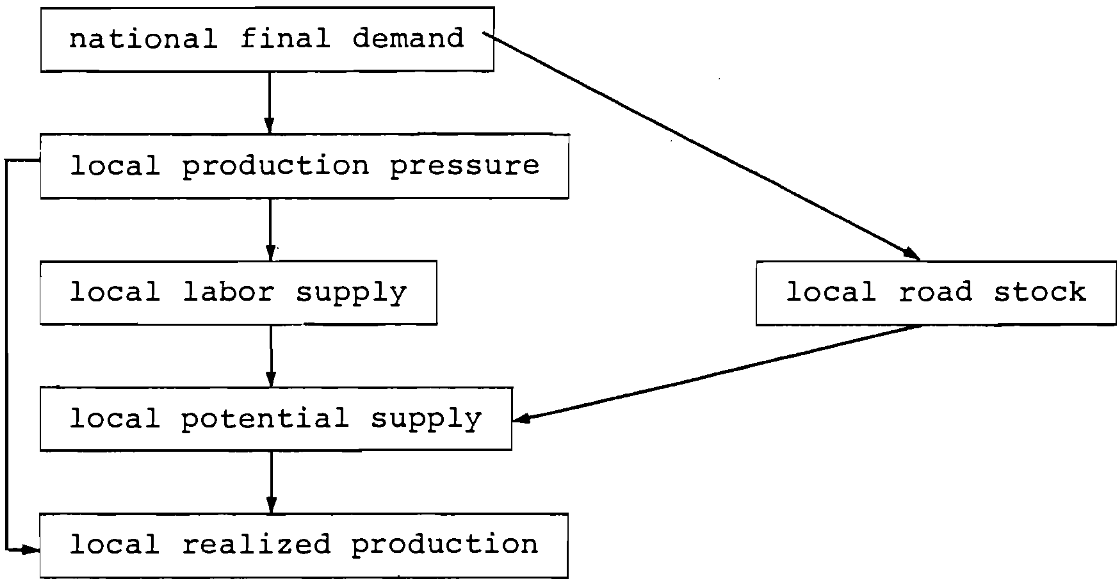


Figure 3. Causal structure of sector i in the BALAMO model.

Note that in (5.2) S_t^r has the character of a public good: it can be used by all sectors i in the locality. Congestion is not dealt with in this formula; it does play a role in the intensity of use of the road stock mentioned above.

The realized production level is based on the following adjustment process:

$$X_{i,t}^r = Q_{i,t}^r + e_i\left(X_{i,t}^{*r} - X_{i,t-1}^r\right) \qquad (5.3)$$

This expression indicates that the constraints on the production level arising from the demand and supply side are to a certain extent soft. Kornai [1980] indicates that such soft constraints can give rise to many types of adaptive behavior.

The causal structure of the BALAMO model has been represented in Figure 3. The top-down character of the model is obvious. Also the supply-demand interactions appear clearly: the realized production volume is the result of the interplay of demand (production pressure) and potential supply.

5.2 EVALUATION OF BALAMO

It is an attractive property of the BALAMO model that it combines an input-output model with an econometric model. Thus it is possible to combine detailed information about intersectoral links with theoretically well-developed behavioral equations concerning factor supply and production decisions. In this way, the BALAMO model enables one to deal explicitly with disequilibrium phenomena at the markets of final products.

We have the following critical comments:

1. The distribution method is as such an interesting device to avoid the necessity to construct regional and interregional input-output tables. A problem may be that the national input-output coefficients are applied to spatial units of a smaller scale. Another problem is mentioned by the author: the distribution method may give rise to inconsistencies in the sense that the local outputs in a sector do not necessarily add up to the national output in that sector.
2. Changes in the labor supply in sector i of locality r may, among others, reflect changes in the participation rate, migration from one region to another region and the change of occupation from one sector to another sector. In (5.1) the explanatory variable for these phenomena is the discrepancy between production pressure and realized production in the previous period in the pertaining locality and sector. Assuming that activities such as migration or change of occupation are based on a comparison of alternatives, it seems better to adopt relative discrepancies as the explanatory variables.

3. The model does not contain a link between the realized production and the final demand. The latter is simply exogenous. For example, final demand for local goods is not related to variables such as local income or local population. This means that the BALAMO model is actually a <u>partial</u> model.

5.3 RELATED MODELS

A related model has been developed for the U.S.A. by Treyz [1980]. In this model the focus is on the determination of the share of employment in sector i of region r compared with national employment in sector i. Treyz bases these shares on interregional trade relationships. In these trade relationships a key role is played by relative prices (including transportation costs) which are used in a very sophisticated way. This is an important departure from the BALAMO model where prices are not dealt with in a explicit way. Another difference is that in the model of Treyz, unemployment is taken into consideration, while in the BALAMO model it is not.

6. A SUPPLY ORIENTED BOTTOM-UP APPROACH TO REGIONAL PRODUCTION: MORSE

6.1 DESCRIPTION OF MORSE

MORSE is a MOdel for the analysis of Regional development, Scarse resources and Employment and has been developed for Sweden. It deals with 8 regions and 9 economic sectors and is based on interregional input-output analysis. The scarse resources distinguished in the model are labour, capital and several energy sources. MORSE has been formulated as a programming model with three objectives which are related to consumption, energy use and employment in several periods. The model has been used among others to study the sensitivity of the regional consumption and investment pattern with respect to increased oil prices and the abolishment of nuclear power. The following description of MORSE is based on Lundqvist [1980].

The decision variables in MORSE are:

X_{it}^{r} : production level in sector i, region r, time t

C_{t}^{r} : consumption level in region r, time t

I_{it}^{r} : investment level in sector i, region r, time t

EX_{t} : national export level.

The set of feasible solutions of the model is defined by three types of constraints:

- supply constraints
- commodity balances
- constraints based on political preferences.

The supply constraints relate to labour, capital and/or are related to energy, respectively. The labour constraint has been formulated for each region and period separately:

$$\sum_i l_{it}^{r} \, X_{it}^{t} \leq \bar{\bar{L}}_t^r \tag{6.1}$$

where l_{it}^r is the labour coefficient in sector i, region r, period t, and $\bar{\bar{L}}_t^r$ is the supply of labour which is exogenous in the model.

The capital constraint has been formulated for each sector, region and period:

$$c_{it}^r X_{it}^r \leq (1-\delta_i)^t K_{io}^r + (1-\delta_i)^{t-1} I_{i1}^r + \dots\dots\dots + I_{it}^r \tag{6.2}$$

In the inequality, c_{it}^r, δ_i and K_{io}^r denote the capital coefficient, the rate of depreciation and the initial capital stock, respectively. Energy constraints are imposed for 4 types of energy (k=1,..,4) at the national level:

$$\sum_r \left[\sum_i e_{ikt}^r X_{it}^r + ec_{kt}^r C_t^r \right] \leq \bar{\bar{E}}_{kt} \tag{6.3}$$

where $\bar{\bar{E}}_{kt}$, e_{ikt}^r and ec_{kt}^r denote the supply of energy and the energy coefficients for sector i and for consumption, respectively.

The commodity balances in MORSE imply that the regional supply (including imports) in each region, sector and time period should be larger than or equal to the demand from the own region, from other regions and from international exports[9]. The following demand components have been distinguished: intermediary deliveries, consumption and investment. The constraints have been formulated as follows:

$$X^r_{it} + m^r_{it}X^r_{it} \geq \beta^r_i \sum_j a^r_{ij}X^r_{jt} + \gamma^r_i \left\{ ac^r_{it}C^r_t + \sum_j ai_{ij}I^r_{jt} \right\}$$
$$+ \sum_s \omega^{rs}_i \left[\left(1-\beta^s_i\right) \sum_j a^s_{ij}X^s_{jt} + \left(1-\gamma^s_i\right) \left\{ ac^s_{it}C^s_t + \sum_j ai_{ij}I^s_{jt} \right\} \right] + ex^r_{it}EX_t \qquad (6.4)$$

Symbols: m = import coefficient
β = regional self-sufficiency in provision of intermediary goods
γ = regional self-sufficiency in provision of consumption and investment goods
a = input-output coefficient
ac = consumption coefficient
ai = consumption of investment goods
ω^{rs}_i = proportion of regional imports of sector i in region s coming from region r
ex = export coefficient

The political constraints have been imposed to ensure that certain socio-economic goals are satisfied in each period:

1. a lower bound on regional consumption
2. a lower bound for the balance of payments
3. an upper bound on regional unemployment
4. a lower bound on the national capital stock

MORSE has been implemented for three consecutive five-year periods (1975-1990). In this application, MORSE comprised 417 decision variables and 498 constraints. In order to analyze the causal structure of MORSE, we first rewrite the inequalities in terms of equalities by means of slack variables $\underline{s}$. Thus, when the constraints defining the set of feasible solutions in MORSE are represented by

$$\begin{aligned} D\,\underline{x} &\leq \underline{c} \\ \underline{x} &\geq \underline{o} \end{aligned} \qquad (6.5)$$

where $\underline{x}$ is the vector of decision variables, these inequalities are rewritten as:

$$\begin{cases} (D \,\vdots\, I) \begin{pmatrix} \underline{x} \\ \underline{s} \end{pmatrix} = \underline{c} \\ \underline{x},\ \underline{s} \geq \underline{o} \end{cases} \qquad (6.6)$$

In the present case this is a system consisting of 915 variables and 498 equalities. Once the objective function is known, one can determine which element of (6.6) is the optimal solution (assuming that (6.6) has a feasible solution). When the objective function is linear, it is a standard result of linear programming that the optimal solution can be written as:

$$(\bar{D} \,\vdots\, \bar{I}) \begin{pmatrix} \bar{\underline{x}} \\ \bar{\underline{s}} \end{pmatrix} = \underline{c} \qquad (6.7)$$

where $\bar{\underline{x}}$ and $\bar{\underline{s}}$ consist of the basic elements of the optimal solution and where $\bar{D}$ and $\bar{I}$ consist of the columns corresponding to $\bar{\underline{x}}$ and $\bar{\underline{s}}$. In the case of MORSE, (6.7) is a system of 498 equations and 498 variables. The 417 variables which are not represented in $\bar{\underline{x}}$ and $\bar{\underline{s}}$ are zero.

Expression (6.7) enables one to analyze the causal structure of MORSE along the lines of Section 2. The exogenous variables represented in the vector $\underline{c}$ are: the supply of labour, the initial capital stock, the supply of energy and lower or upper levels for socio-economic variables. We conclude that the model is supply oriented when (some of) the slack variables related to the supply constraints are non-zero. Given the fact that approximately half of the constraints is of the supply type we may say that it is very improbable that none of the supply constraints is active. Hence, we may conclude that MORSE is almost certainly a supply oriented model (see Fig. 4).

It is important to pay attention to the role of the objective function in the discussion of the causal structure of a model. It is not difficult to see that the answer to the question whether a constraint is active, does in general not only depend on the values of $\underline{c}$ and D, but also on the coefficients of the objective function. This is obviously a property of programming models which is not shared by analytical or predictive models.

Finally, we note that MORSE is a model in the bottom-up mode. Once a solution of the model has been found, the national production volume can be determined by adding the regional volumes.

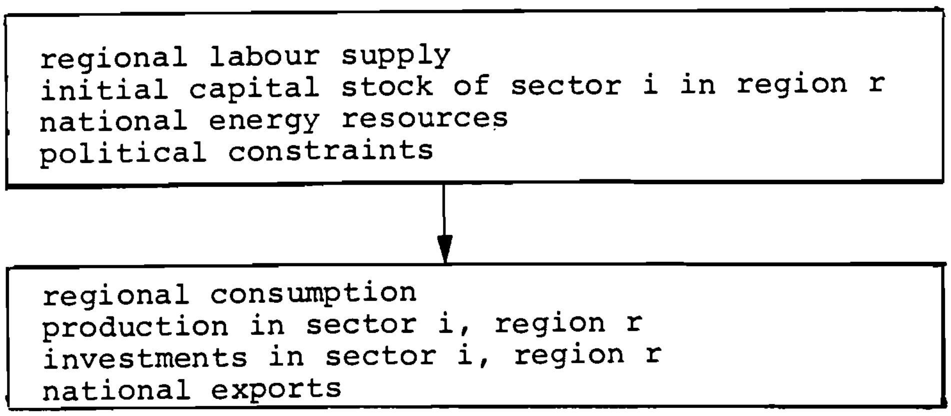


Figure 4. Causal structure of MORSE.

6.2 EVALUATION OF MORSE.

MORSE has several attractive properties. It gives a rather detailed account of the energy sector in the economy. Further, explicit attention is paid to capital accumulation so that the model can be used for multiperiod analyses. An interesting aspect of the interregional trade relationships described in MORSE is that the rates of selfsufficiency for intermediary goods (β_i^r) and final demands (γ_i^r) are not necessarily equal.

An obvious drawback of MORSE is that prices do not play a role in it. Consequently, substitution processes induced by price changes cannot be analyzed in this model.

Another problem with MORSE is related to the status of the decisionvariables (X_i^r, C^r, I_i^r, EX). No attention is paid to the question whether next to the central planning authority also other actors (e.g., firms or households) influence these variables. Thus it seems to be tacitly assumed that the central planning authority can realize any feasible solution. Obviously, this assumption is questionable in a country such as Sweden.

Another problem with MORSE is related to the commodity balances. According to (6.4) it is possible that in a certain period there is an overproduction of X_{it}^r. There is no indication what happens with this surplus. The model does not deal with the formation of inventories.

6.3 RELATED MODELS

A similar bottom-up supply oriented model can be found in Carlberg [1979]. In Carlberg's models I and II, developed for the Federal Republic of Germany, the restrictive production factor is labour supply. Given the regional supply of labour the regional production volumes are determined. An input-output model and an interregional trade model based on the gravity concept are used to determine inter-industry and inter-regional deliveries. Capital does not play a role as a restrictive factor in these models.

7. A DEMAND ORIENTED BOTTOM-UP APPROACH TO REGIONAL PRODUCTION: NRIES

7.1 DESCRIPTION OF NRIES

NRIES (National Regional Impact Evaluation System) is a short to medium term model which has been developed for the U.S.A. at the Department of Commerce. It deals with 12 economic sectors and 51 regions (states). It has been used for several types of impact analyses such as the external spill-overs of new production activities in a state or the distributional effects of federal grants. This description is based on Ballard and Wendling [1980] and Ballard, Gustely, and Wendling [1980].

The distinguishing feature of NRIES is that the production levels in the export sectors of a region depend on the total production levels in all regions, all being endogenous. For example, the demand function of the manufacturing sector for durable goods (say sector j) reads as follows:

$$X_j^r = a_j^r + b_j^r X^r + c_j^r IX^r + d_j^r \frac{w_j^r}{w_j} \tag{7.1}$$

Symbols: X_j^r = production in sector j of region r
X^r = total production in region r
IX^r = interactional production of region r
w_j^r = wage rate in sector j of region r
w_j = average national wage rate in sector j

The interactional production IX^r has been introduced in (7.1) to account for the impact of the other regions. It is defined as:

$$IX^r = \sum_{\substack{r' = 1 \\ r' \neq 1}}^{51} \left(\frac{1}{d^{rr'}}\right)^{\alpha} \cdot X^{r'} \tag{7.2}$$

where $d^{rr'}$ is the distance between regions r and r' and where α has been assigned the value 1 on a priori grounds. Thus IX^r indicates the weighted sum of the production of all regions outside r, the weights being the inverse distances from region r. The last explanatory variable in (7.1) indicates the price elasticity of demand. A relatively high wage level in a region gives rise to high prices and, hence, to a reduction in the demand in sector j of that region.

In the non-export sectors, the main explanatory variables are regional income Y^r and regional population.

The general form of the labor demand function is:

$$\begin{aligned} E_{i,t}^r = {} & a_i^r + b_i^r X_{i,t}^r + c_i^r \left(\sum_{m=1}^{s} X_{i,t-m}^r / E_{i,t-m}^r \right) \\ & + d_i^r E_{i,t-1}^r + e_i^r \frac{E_{i,t}}{X_{i,t}} + f_i^r \frac{w_{i,t-1}^r}{w_{t-1}^r} \end{aligned} \tag{7.3}$$

In this function the third explanatory variable accounts for regional trends in labor use, the fifth explanatory variable is an indicator of technological development, the sixth variable accounts for substitution effects between industries in region r.

Labor supply is not modeled directly in NRIES. It can be obtained by means of the following roundabout way. NRIES contains a demographic submodel dealing with births, deaths, and net migration. As a result of the submodel we find that the main economic determinants of the regional working age population size are: regional income and regional employment, both relative to the national level.

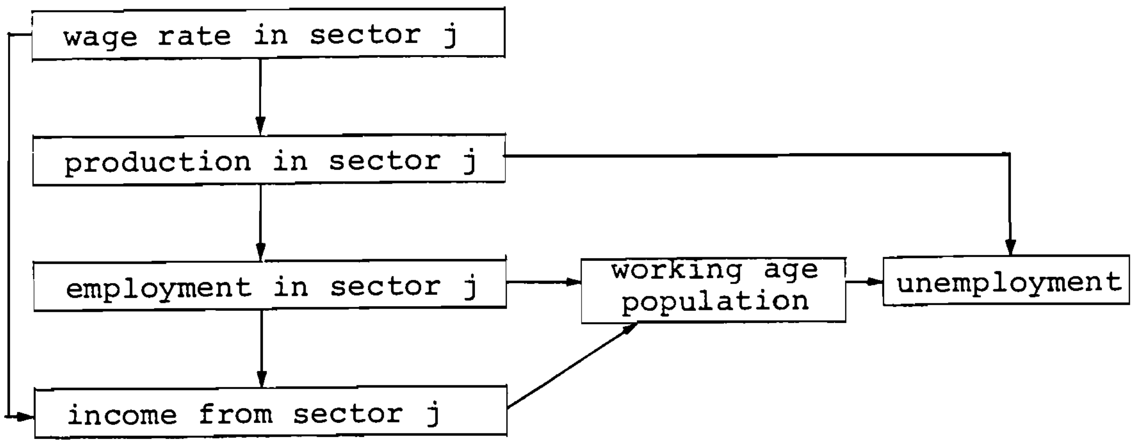
Regional unemployment cannot be obtained as the difference between regional labor supply and regional employment since the former is not known. Therefore, regional unemployment is determined by means of regional working age population and regional employment in the following way:

$$u_t^r = a + b^r \left(\frac{\Delta P_t^r}{P_t^r} \right) + c^r \left(\frac{\Delta X_t^r}{X_t^r} - d \right) \div e^r u_{t-1}^r \qquad (7.4)$$

Symbols: u = unemployment rate
P = working age population

Once regional employment and the regional unemployment rate are known, the determination of the regional labor supply is straightforward.

A sketch of the causal structure of NRIES can be found in Figure 5. The bottom-up structure is evident: national variables do not play a role in this scheme; they result by aggregating regional variables. Concerning the demand orientation of the model we note that capital does not play any restrictive role in the model. The role of the production factor labor is somewhat more intricate. Labor supply as such is not part of the model. However, the working age population functions as a substitute for it. Therefore, we have to find out in which measure a tight labor market influences the volume of regional production. One possibility is a Phillips curve relationship between regional unemployment and the regional wage rate in sector j. It appears that such a relationship does not exist for sector j. The pertaining wage rate only depends on price variables, so at most a rather



All variables pertain to a particular region.

Figure 5. Causal structure for the manufacturing sector of durable goods (sector j) in NRIES.

indirect link may exist (depending on the measure in which prices are influenced by wage rates).

For some other sectors Phillips curve relationships have been estimated but for these sectors no direct link exists between wage rate and production as is the case with sector j. In that case an other feedback from the labour market on regional production is possible, however, proceeding along the following chain: $U^r \rightarrow w_i^r \rightarrow Y_i^r \rightarrow Y^r \rightarrow X_i^r$. We conclude, therefore, that although the demand side plays an important role in NRIES, it is not a pure demand oriented model.

7.2 EVALUATION OF NRIES

NRIES is a large model; for each of the 51 regions a model of 268 equations has been formed, of which 68 are behavioral. Thus, NRIES enables one to carry out rather detailed analyses. NRIES can be used without an accompanying national model: it does not assume any major national variable as given.

Considerable attention is paid in NRIES to interactions between regions for the export sectors. The present specification of interactional demand is capable of improvement by using transport costs instead of distances and by allowing the gravity parameter α to assume other values than 1.

The supply of production factors has been modeled, in a rather superficial way, probably due to data problems. For example, capital and investments have not been specified at all in NRIES. The treatment of unemployment and labor supply is not completely convincing. For example, the model does not give an explicit explanation of the participation rate in the labor market.

8. A BOTTOM-UP APPROACH TO REGIONAL PRODUCTION WITH A MIXED SUPPLY-DEMAND ORIENTATION: FUKUCHI'S MODEL.

8.1 DESCRIPTION OF FUKUCHI'S MODEL

The model of Fukuchi [1978] has been built for Japan; it deals with nine regiOns and three sectors. The aim of the model is the forecasting of economic growth on the medium term. In connection with the model, a political sub-model has been developed, dealing with the influence of economic conditions on the elections of members of parliament.

The regional employment level is modeled as follows:

$$\log E^r_{i,t} = a^r_i + b_i \log X^r_{i,t-1} + c_i \log N^r_{i,t} + d_i \log w^r_{i,t-1} \qquad (8.1)$$

symbols: E_i = employment in sector i
X_i = production in sector i
N = population
w_i = wage rate in sector i

Note that only the constant term varies among regions. Actually the constant term has been modeled as a dummy variable. The values of d_i appear to be negative (they are approximately equal to -.15). This means that the employment level decreases when the pertaining wage rate increases.

For the capital stock we find:

$$\log K^r_{i,t} = a^r_i + b_i \log X^r_{i,t-1} + c_i \log \left(\frac{K_i}{E_i}\right)_{t-1} + d_i \log R_{t-1} \tag{8.2}$$

new symbols: K_i = capital stock in sector i
R = interest rate

In this equation the values of d_i are close to -1, which means that the size of the capital stock is very sensitive to the interest rate.

The production volume per sector i and region r depends on the corresponding values of E and K, and on the volume of infrastructure G, provided by the government:

$$\log X^r_{i,t} = a^r_i + b_i \log E^r_{i,t} + c_i \log K^r_{i,t} + d_i \log G^r_t \tag{8.3}$$

The model contains feedbacks from the production level on the supply of production factors via the population size and the wage rate. The economic variables influencing regional population size are the regional per capita social capital and the regional levels of production, employment, and prices relative to the national level:

$$\log N_t^r = a + b^r \log N_{t-1}^r + c \log (H^r/N^r)_{t-1} + d \log\left(\frac{X^r}{X} \cdot \frac{E}{E^r} \cdot \frac{p}{p^r}\right)_{t-1} \tag{8.4}$$

New symbols: H = social capital stock
p = index of consumption prices

The other feedback is based on a bidding up process of wages by employers. The variables influencing the wage levels are: production, population size, and prices:

$$\log w_{i,t}^r = a_i^r + b \log X_{i,t-1}^r + c \log N_t^r + d \log p_{t-1}^r \tag{8.5}$$

The causal structure implied by the above equations can be found in Figure 6. Lagged relationships have been indicated with an *. The figure clearly displays the mixed supply-demand orientation of the model. The employment level, for example, is caused by the production level in the previous period but is also a cause of the production level in the same period. The bottom-up structure appears from the fact that national variables do not play a role in the figure. They are not imposed on the model, but are the outcome of it.

8.2 EVALUATION OF FUKUCHI'S MODEL

Fukuchi's model represents an interesting attempt to build a pure bottom-up model. No exogenous information about national variables is needed to operate the model. Because of the many lagged endogenous variables, the model is recursive, which means that it is easy to operate.

Concerning the specification of the model, the following remarks can be made. The character of (8.1) and (8.2) describing the realized levels of the production factors is rather obscure.

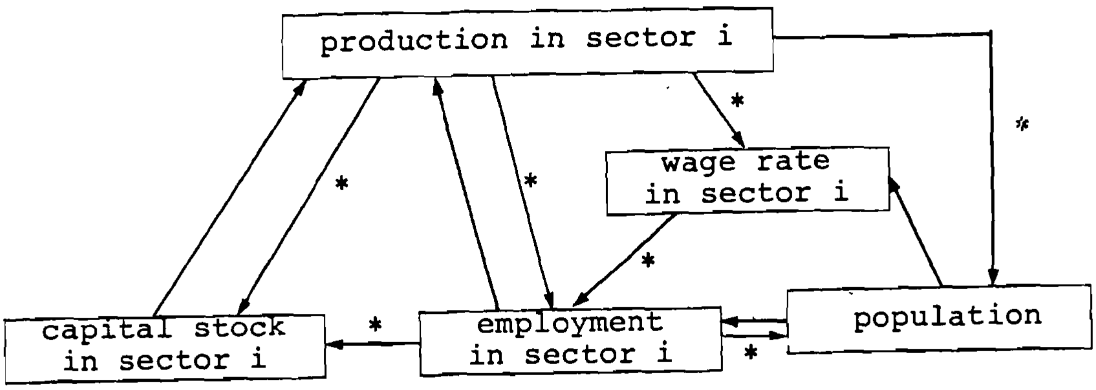


Figure 6. Causal structure of sector i in Fukuchi's model.

They could be interpreted as demand or supply functions or as functions occurring in the reduced form of the model. Conse quently it is not impossible that identification problems arise with the estimation of these functions. Another problem with (8.2) is that it is formulated in terms of the capital stock instead of investment flows. Consequently, it does not recognize that the capital stock in period t depends heavily on the stock in the previous period.

In (8.4) the regional population size is determined without considering births, deaths, and net migration separately. The population size of the previous period is used to deal with births and deaths. Since no age groups have been distinguished, this is only a rough approximation. For net migration the following explanatory variables are used: regional per capita social capital and the regional values of production, employment, and prices relative to the national values. It might be argued that also for social capital a regional value relative to the national level would be desirable. Since the level of net migration is not determined separately from the other demographic processes, it is not possible to check whether the national net migration is equal to zero.

9. EVALUATION

We draw to the following provisional conclusions after this concise survey of multiregional models.

1. Pure forms of top-down or bottom-up models do exist. Most models are of a mixed nature, however, with a top-down approach used in one part of the model and a bottom-up approach used in another part.
2. Pure forms of demand-oriented or supply oriented models do exist. The models discussed are mostly approximations of the ideal types, however. Although there may be a tendency that demand variables play a more important role than supply variables in most models, it is not warranted to say that there is a general neglect of the supply side in multiregional economic models.
3. Little attention has been paid in the abovementioned models to the linking of multiregional economic models with other models, especially environmental models. Fukuchi's model is linked with a multiregional model dealing with political preferences of voters; for NRIES the model builders mention that efforts are made to achieve a linkage with a multiregional energy model.

4. Most of the multiregional models are only suitable for the short and (maybe) medium term. A model should satisfy at least the following requirements to be suitable for the long-term (say longer than 15 years). The model should describe the regional distribution of capital and of population. Further, the model should not be based on the constancy of certain coefficients which may be expected to change in future. The model should not be a partial model; i.e., no important element of the economic system should be exogenous. Given these requirements we conclude that of the five models considered, RENA, NRIES, and BALAMO are mainly short term models. CANDIDE-R, MORSE and the model of Fukuchi are mainly long term models. Thus, among the six there is not typical long term model.
5. Consistency problems arise in several models, mainly arising from the fact that the specifications of the relationships do not explicitly account for the fact that regional shares should add up to 1. Also in other respects certain relationships appear to be specified in an unsatisfactory way, for example, because of faulty use of economic theories. These problems will be partly due to the data bases for multiregional models, which are in general rather poor. Yet, it is reasonable to conclude that there is certainly scope for an improvement of specifications in multiregional models.
6. The models vary largely according to the degree in which coefficients are uniform for all regions. For example, Fukuchi assumes uniform coefficients for all regions (except for the constant term). The same holds true for BALAMO. On the other hand, CANDIDE-R, MORSE, RENA, and NRIES estimate all relations for each region separately. Obviously, this difference has to do with the availability of sufficient time series data. For impact analysis the uniformity assumption implies that the outcomes of the analysis are of little value

when one is interested in the differential regional effects of national measures. It is illuminating to note the link between this topic and aggregation theory: a sufficient condition for perfect aggregation in the linear case is the equality of the coefficients (except for the constant term) for all regions.

7. Models vary largely in sectoral detail. For example, RENA deals with 1 sector, NRIES with 12 sectors, and the model of Treyz with 25 sectors. Obviously, the value of impact analysis increases when the economic sectors are less heterogenous.
8. The number of regions is relatively small (not larger than 10) in most models, except for NRIES, dealing with 51 regions. It follows that the regions will be rather heterogeneous. In general they do not allow a distinction between urban and rural regions. Since the urban-rural relationships are of large interest in many countries, this is obviously a disadvantage (cf. Gordon [1977]). Note, for example, that spatial economic models for developing countries are not so much focused on interregional links in general, but more specifically on urban-rural relationships. To solve this problem, in BALAMO a third spatial level is introduced: the locality. This approach is also adopted in REGINA, a multiregional model for the French economy (cf. Courbis [1979]).
9. There are some examples of models in which an input-output model is combined with econometric relationships, i.e., BALAMO and the models of Treyz and Carlberg. In many models these input-output relationships are neglected, however. One should be aware that when these models are used to compute multiplier effects, unreliable results may be obtained.
10. In many cases, in multiregional models little attention is paid to interregional relationships.

Often the interregional links are modeled in an indirect way: they proceed via the national le-level. For example, in CANDIDE-R a wage increase in region 1 does not directly influence the wages in region 2, but does so only via the national wage level, which is one of the determinants of the wage level in region 2. A field where one would expect bilateral links is migration. A closer look at the models reveals that only in CANDIDE-R has an analysis been made of migration from a certain region to each of the other regions. The other models either neglect migration or only deal with it from one region to the other regions in an aggregate way. Of the models mentioned thus far, only MORSE and the ones of Treyz and Carlberg explicitly deal with interregional trade. NRIES contains a first step in this direction because of the introduction of so-called interactional variables.

We conclude that not all multiregional models are suitable to study spatial spill-over effects from one region to another.

11. Prices play a role in four of the six models discussed. The exceptions are BALAMO and MORSE. Fukuchi's model allows for a regional differentiation of prices. The other models only contain national prices.
12. Wages are absent in BALAMO, and MORSE but function in the other models. They are regionalized in all cases. Obviously in multiregional models more attention is paid to regional variations in wages than in prices.
13. Industrial investment figures are not always easy to obtain on the regional level. For example, in NRIES and BALAMO these investments do not play a role. This state of affairs is an obstacle for the development of long term models, as indicated in the fourth conclusion.

14. Infrastructure is a variable which is often absent in economic models although it may play an important role in economic stimulation policies. In the six multiregional economic models considered, infrastructure plays a role in no less than two models. In BALAMO road infrastructure is a determinant of industrial productivity. In Fukuchi's model, infrastructure plays a role both in the industrial production functions and in the functions describing net population migration. Further efforts to introduce infrastructure variables in multregional models are desirable.

15. Multiregional models can be used for policy analysis when they describe the impacts of policy instruments on indicators of regional economic performance such as regional production or regional employment. The main policy instruments described in the six models discussed in this paper can be classified as follows:

a. instruments effecting regional industrial investments:

CANDIDE-R:	direct regional distribution	(3.3)
RENA:	regional investment subsidies	(4.4)
	public industrial investment	(4.4)
Fukuchi's model:	interest rate	(8.2)

b. investments in social capital:

RENA:	general	(4.4)
Fukuchi's model:	infrastructure for firms	(8.3)
	infrastructure for families	(8.4)
BALAMO:	road infrastructure	(5.2)
MORSE:	nuclear power	(6.3)

c. social security, state finance:

RENA: social security revenues and expenditures
tax measures, public consumption

NRIES: national grants to regional authorities.

For RENA, NRIES, MORSE and BALAMO, the cited references contain detailed results of various policy analyses.

10. FURTHER RESEARCH

This paper contains a partial analysis of some multiregional models. The analysis was partial in the sense that we focused on the causal structure around regional production. Little attention has been paid for example to the government sector in the models. The number of models considered was small and not completely representative.

We plan to carry out a more comprehensive comparative study of multiregional models in the future. We also plan to pay special attention to the policy aspects of models: the policy objectives and instruments described, the scenario's developed, the conclusions concerning the effectiveness of instruments and last but not least: the actual use of models in regional policies and planning.

APPENDIX: FORMAL PRESENTATION OF CAUSALITY STRUCTURES OF SIX MULTIREGIONAL MODELS

The formal structure of the models dealt with in this paper will be discussed by means of the matrix B_o and vector $\underline{y}$ defined in Section 2. The meaning of most of the variables in $\underline{y}$ can be found in the pertaining sections. New symbols are:

- P: population
- L: labour supply
- V: final demand

<u>CANDIDE-R (Section 3)</u>

$$\underline{y} = \left(I_i \; I_i^r \; K_i^r \; X_i \; X_i^r \; E_i^r \; U_i^r \; w_i^r \; L_i^r\right)'$$

$$B_o = \begin{pmatrix} 1 & & & & & & & & \\ 1 & 1 & & & & & & & \\ & 1 & 1 & & & & & & \\ & & & 1 & & & & & \\ & & 1 & 1 & 1 & & & & \\ & & & & 1 & 1 & & & \\ & & & & & 1 & 1 & & 1 \\ & & & & & & 1 & 1 & \\ & & & & & & & 1 & 1 \end{pmatrix}$$

Evaluation: X_i causes X_i^r : top-down mode
K_i^r causes X_i^r : supply orientation

RENA (Section 4)

$$\underline{y} = \left(X \; X^r \; \frac{X^r}{X^r_o} \; I^r \; K^r \; E^r \; L^r \; U^r \; w^r\right)$$

$$B_o = \begin{pmatrix}
1 & & & & & & & & \\
1 & 1 & & & & & & & \\
 & 1 & 1 & & & & & & \\
 & & & 1 & & & & & \\
 & & & 1 & 1 & & & & \\
 & & 1 & & 1 & 1 & & & \\
 & & & & & & 1 & & \\
 & & & & & 1 & 1 & 1 & \\
 & & & & & & & 1 & 1
\end{pmatrix}$$

Evaluation: X causes X^r : top-down mode
X^r causes E^r : demand orientation

BALAMO (Section 5)

$$\underline{y} = \left(X^r_{i,t-1} \; V_{it} \; X^{*r}_{it} \; E^r_{it} \; S^r_t \; Q^r_{it} \; X^r_{it}\right)$$

$$B_o = \begin{pmatrix}
1 & & & & & & \\
 & 1 & & & & & \\
 & 1 & 1 & & & & \\
1 & & 1 & 1 & & & \\
 & 1 & & & 1 & & \\
 & & & 1 & 1 & 1 & \\
1 & & 1 & & & 1 & 1
\end{pmatrix}$$

Evaluation: V_{it} causes X^r_{it} : top-down mode

$\left\{\begin{array}{l} X^r_{i,t-1} \text{ causes } E^r_{it} \\ E^r_{it} \text{ causes } X^r_{it} \end{array}\right.$: mixed supply-demand orientation

MORSE (Section 6)

$$\underline{y} = \left(K^r_{io} \; \bar{\bar{L}}^r \; \bar{\bar{E}} \; C^r \; X^r_i \; I^r_i \; EX \; X_i\right)$$

$$B_o = \begin{pmatrix}
1 & & & & & & & \\
 & 1 & & & & & & \\
 & & 1 & & & & & \\
 & & & 1 & 1 & 1 & 1 & \\
 & & & 1 & 1 & 1 & 1 & \\
 & & & 1 & 1 & 1 & 1 & \\
 & & & 1 & 1 & 1 & 1 & \\
 & & & & 1 & & & 1
\end{pmatrix}$$

Evaluation: X^r_i causes X_i : bottom-up mode
K^r_{io}, $\bar{\bar{L}}^r$, $\bar{\bar{E}}$ cause X^r_i : supply orientation

<u>NRIES (Section 7)</u>

$$\underline{y} = \left(w_j^r \; X_j^r \; E_j^r \; Y_j^r \; P^r \; u^r \; X_j\right)'$$

$$B_o = \begin{pmatrix} 1 & & & & & & \\ 1 & 1 & & & & & \\ & 1 & 1 & & & & \\ 1 & & 1 & 1 & & & \\ & & 1 & & 1 & & \\ & 1 & & & 1 & 1 & \\ & 1 & & & & & 1 \end{pmatrix}$$

Evaluation: X_j^r causes X_j : bottom-up mode

X_j^r causes E_j^r : demand orientation

<u>Fukuchi's Model (Section 8)</u>

$$\underline{y} = \left(X_{i,t-1}^r \; K_{it}^r \; P_t^r \; E_{it}^r \; X_{it}^r \; w_{it}^r \; X_{it}\right)'$$

$$B_o = \begin{pmatrix} 1 & & & & & & \\ 1 & 1 & & & & & \\ 1 & & 1 & & & & \\ 1 & & 1 & 1 & & & \\ & 1 & & 1 & 1 & & \\ & & 1 & & & 1 & \\ & & & & 1 & & 1 \end{pmatrix}$$

Evaluation: X_{it}^r causes X_{it}

$X_{i,t-1}^r$ causes K_{it}^r and E_{it}^r } : mixed supply-demand orientation

K_{it}^r and E_{it}^r cause X_{it}^r }

NOTES

1. The time subscript will be deleted where it will not give rise to confusion.

2. Formulation (2.4) assumes that the national variable x is the <u>sum</u> of the regional variables x^r. In some cases x may also be the <u>average</u> of the x^r (e.g., when x is a price variable). In that case, (2.4) should be replaced by $\sum_r w^r c^r = 1$, where w^r denotes the weight of region r.

3. The national variable x is not an element of $v_1, \ldots, v_m$.

4. We adopt the following notational conventions. The error terms in the stochastic equations will be deleted. The indices r, i, and t refer to a particular region, industry, and time period, respectively. They will be deleted when no confusion will arise.

5. Cf. d'Amours, Simard, and Chabot-Plante [1975], p. 623.

6. We interpret the role of I^r in (4.2) as a final demand component and not as an indicator of production capacity. In the latter case, it would not be reasonable to coin the RENA model as a demand model. We discard this interpretation of I^r as an indicator of production capacity

since it gives rise to a questionable specification of (4.2). We note in passing that Thys-Clement, et al. [1979] ignore the role of I^r in their diagrammatic representation of the RENA model (p. 105).

7. Note that even if RENA does not contain a pure demand oriented approach to regional production volumes, it does contain one to regional production shares.

8. For certain sectors a logarithmic version of (5.1) has been used. The same holds true for (5.2) and (5.3).

9. For sectors with a pattern of location determined by the geographical distribution of resources another approach has been adopted. For these sectors exogenously specified spatial distributions are introduced.

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