A STRUCTURAL CHANGE MODEL FOR REGIONAL ALLOCATION OF INVESTMENTS*

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PREFACE

This paper presents an approach which integrates the analysis of structural economic change on the national and regional levels of a country. It represents a collaboration between the Forest Sector Group and the Regional and Urban Development Group at IIASA. A first version of the paper was presented in 1980 at a conference related to IIASA's Forest Sector Study. The current version is a contribution to a special volume of TIMS Studies in Management Sciences on "Systems Analysis in Forestry and Forest Industries" which presents results obtained in the IIASA project on forestry and forest industries.

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ABSTRACT

The industrial establishments of the forest industry are often concentrated in distinct regions, in which they employ a significant part of the labor force. This paper presents a model which provides a means to analyze and evaluate investment patterns and programs in such regions. The model contains two integrated parts: one describes the obsolescence and renewal processes in the industry sectors of a region. This part of the model is formulated within the framework of a regionally specified multi-sectoral model. The other part is an optimization model which generates investment and production for regions, given national and regional constraints on production and employment levels.

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1. ANALYSIS OF THE FOREST INDUSTRY. A FRAMEWORK OF MODELS

1.1 Introduction

In Sweden the forest industry constitutes a sector which is extremely oriented towards the world market. At the same time this industry is characterized by a set of basic rigidities. First, the long run supply of inputs is determined by the slow growth process of forests in regionally concentrated areas. Second, the paper and pulp sector, here called "paper and paper products industry", has a high average capital coefficient and the capital equipment is characterized by extraordinarily long durability. Third, different sectors of the forest industry are highly concentrated in a distinct set of separated regions.

In small regions in which the forest industry is playing a dominant role, structural change may have severe effects on the employment situation. In this paper we suggest an approach to formulate investment policies for the industry in a region such that the structural change of the industry satisfies both certain profitability conditions and regional employment targets. Using a vintage type production model, we derive structural change requirements from international and national medium term scenarios. These scenarios are combined with regionally specified employment and production targets. We also suggest how this analysis may be extended to an interregional framework. To illustrate the method developed, we present a single-region application which focuses on the forest industry.

1.2 A three-level system of models

Figure 1 presents a framework to which the models presented in this paper belong. The top level in Figure 1 consists of world trade models. For a country in which a large share of the forest industry output is exported, world trade scenarios form a necessary basis for medium and long term analyses of the domestic development of the forest industry. A minimum requirement here is that a world trade scenario should specify the development of world market prices.

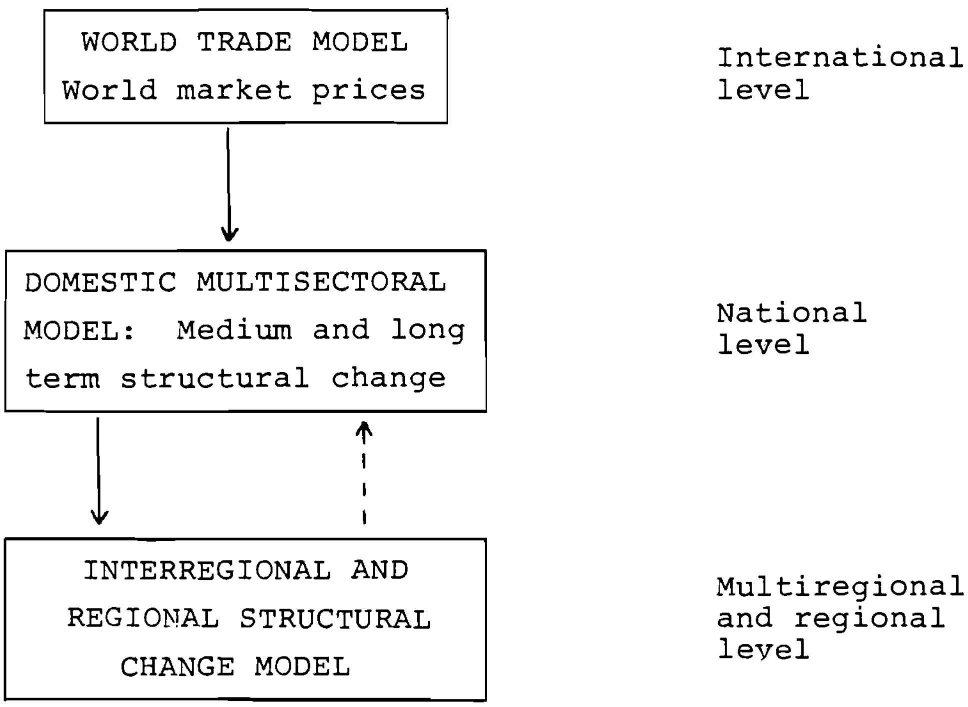

Figure 1. Medium and long-term models designed to analyze structural change of the forest industry.

The national level in the figure contains a multisectoral model which is designed to capture structural change between and within sectors of the economy. World market prices are obtained from the top level in the system, while domestic prices are determined endogenously by the national model. For each sector, this model [10] utilizes a specification of how production techniques are distributed over the production capacity of the sector. Structural change emerges as a change of the capacity associated with each production technique including new techniques. Capacity increase is obtained by investment in new capital equipment.

The regional level is depicted by the lower part of the system in Figure 1. Here the structural change process will have to satisfy certain employment and production targets which may affect the set of feasible changes on the national level. The national and regional models of the system [4], [5], [10] are formulated so as to reflect rigidities of the type described in models adhering to the vintage tradition, with early contributions by Houthakker [1], Johansen [2], [3] and Salter [11].

We should finally emphasize that the high capital coefficients in the forest industry sectors means that structural change in these sectors may use up large proportions of the total "investment budget" in nations with a large forest industry sector. This fact makes it meaningful - perhaps necessary - to treat the investment process in a multisectoral framework.

2. A VINTAGE MODEL WITH REGIONAL AND INTERSECTORAL SPECIFICATION

The basic ideas in this section rely on the early contributions to vintage analysis by Johansen [2] and Salter [11]. We shall identify industrial establishments as production units. The design of an establishment is defined as the choice of a specific capital equipment with a given production capacity and an associated fixed relation between labor and other inputs. This means that ex post, i.e., after the investment in an establishment, its input coefficients and the production capacity remain unchanged. However, since an establishment generally consists of separate subsystems, we assume that as a result of renewal investments (i) new capacity may be added to the already existing capacity in the establishment, and (ii) parts of the old capacity may be removed simultaneously as new capacity is added.

2.1 Distribution of vintages over the input space

Let $x_{jr}^{\tau}(t)$ denote the total output in period t from the set of establishments, in sector j and region r, which are applying vintage (production technique) τ, where $\tau = 1,2,\ldots$. For this set of establishments we shall introduce the following notations

$$
\begin{aligned}
&\bar{x}_{jr}^{\tau}(t) = \text{production capacity in period } t \\
&a_{ij}^{\tau} = \text{input from sector } i \text{ per unit of output in sector } j\text{, given technique } \tau \\
&\ell_{j}^{\tau} = \text{labor input per unit of output in sector } j\text{, given technique } \tau
\end{aligned}
\qquad (1)
$$

We assume that $\bar{x}^{\tau}_{jr} \geq 0$, $\ell^{\tau}_{j} > 0$, $a^{\tau}_{ij} \geq 0$. The production technique specified in (1) represents the average technique belonging to vintage (technique) class τ. By α^{τ}_{j} we denote the average input vector $\alpha^{\tau}_{j} = \{a^{\tau}_{ij} \; ; \; \ell^{\tau}_{j}\}$ of this class.

For a single establishment, with capacity $\bar{x}$ and input coefficient vector α_j, we shall introduce the following assumption

$\bar{x}(t+1) = \bar{x}(t)$ if no capacity-increasing investments in the establishment occurs between t and t+1. (2)

$\alpha_j(t+1) = \alpha_j(t)$ if no investment in the establishment occurs between t and t+1.

Given the assumption in (2) it is natural to assume that the production capacity in a production unit can be increased, and that the vintage classification τ may be changed as a result of investment. From this assumption we may conclude that $\bar{x}^{\tau}_{jr}(t)$ and $\bar{x}^{\tau}_{jr}(t+1)$ may differ for three reasons: capacity increasing investments in existing establishments (indexed j,r,τ), exit from, and entry to the set of establishments with index j,r,τ. Exit may occur as the result of either shut down or investments changing the production technique from τ to τ^* for one or several existing establishments.

Entry occurs analogously: either completely new units are entering the economic sector or existing units are changing technique from τ' to τ.

Let $\bar{x}_j(t)$ and $\bar{x}_{jr}(t)$ denote the total production capacity in sector j in the whole economy and in region r, respectively. Then we have that

$$\bar{x}_{jr}(t) = \sum_{\tau} \bar{x}_{jr}^{\tau}(t)$$
$$\bar{x}_j(t) = \sum_{r} \bar{x}_{jr}(t) \tag{3}$$

Studies of industrial change should avoid relying on aggregates of the type desceibed in (3). The usefulness of such studies increases if they focus on the distributions of techniques and capacities forming the aggregates. For example, one may consider sequences like $(\bar{x}_{jr}^{1}, 1/\ell_j^{1}),\ldots,(\bar{x}_{jr}^{\tau}, 1/\ell_j^{\tau}),\ldots$ where $1/\ell_j^{\tau}$ represents the labor productivity of units belonging to class τ. In the very short run these distributions can change only if production units in a class are closed down. In a medium term perspective new establishments may enter and existing establishments may renew their technique through renewal investments. This study focuses on how distributions, of the type described above, change as the compound result of simultaneous shut down and investment.

2.2 Profits, exit and entry

In the type of framework which is presented here, it is tempting to introduce regionally specified prices and wages. Resisting this temptation, we shall assume that the price of product j (output from sector j), p_j, and the wage level in sector j, w_j, are economy-wide, i.e., equal in all regions. Using the notation in (1) we may then define the value added of a specific production unit as follows

$$[p_j(t) - \sum_i p_i(t) a_{ij}^{\tau}] \; x_{jr}^{\tau}(t) \tag{4}$$

The wage share of value added, θ_j^{τ}, is then determined as

$$\theta_j^{\tau}(t) = w_j(t) \ell_j^{\tau} / [p_j(t) - \Sigma p_i(t) a_{ij}^{\tau}] \tag{5}$$

Consider now the sequence of techniques $\tau = 1,2,\ldots,$ each with its average input vector. Assume that techniques are arranged so that 1)

$$\theta_j^1(t) < \theta_j^2(t) < \ldots \tag{6}$$

Let A_j^o be an input set which becomes available at time t. Suppose next that the average input vector $\alpha_j^o \in A_j^o$ satisfies

$$\theta_j^o(t) < \theta_j^1(t) < \ldots \tag{7}$$

Suppose also that $1 - \theta_j^o(t)$ is greater than the capital cost per value added which obtains when the new technique is installed. Then establishments entering into this new class, $\tau = 0$, may through competition force the price in sector j to be lowered relative to $w_j(t)$ and other prices. According to (5), this implies that $\theta_j^{\tau}(t)$ has to increase for $\tau = 1,2,\ldots$ This process, characterized by growing

1) Observe that if the wage, w_j, is equal for all establishments, and if $\Sigma a_{ij}^1 \leq \Sigma a_{ij}^2, \ldots,$ then the ranking according to productivity, $1/\ell_j^1$, $1/\ell_j^2, \ldots,$ is necessarily equivalent to the ranking according to gross profit share, $(1-\theta_j^1),(1-\theta_j^2),\ldots$.

values of θ_j, reflects economic ageing of the existing establishments.

The ultimate effect of economic ageing is that θ_j approaches unity or becomes even greater. Suppose that $\theta_j^{\tau}(t) \geq 1$. If the objective is to retain the production capacity of an establishment in class τ, with non-positive gross profit, there are two options: the establishment can be shut down and replaced by a completely new production unit with an input vector $\alpha_j^{o} \in A_j^{o}$. The second option is partial renewal. In that case new equipment is added to the old, or parts of the old production equipment are replaced by new equipment. Of course, this also includes reorganization. Partial renewal should result in a change from technique τ to γ such that $\theta_j^{\gamma}(t) < 1 \leq \theta_j^{\tau}(t)$.

2.3 International, national and regional interfaces

In small countries many industry sectors are highly oriented towards the world market - both with regard to selling its output and buying its inputs. In Sweden, an extremely high proportion of the products from the forest industry is exported. Inputs are primarily domestic.

In the previous section economic ageing was related to the introduction of new and competitive techniques. For industries interacting with the world market we may add changes in world market prices as an important cause of economic ageing. In this case, we may argue as follows: if the world market price of the output from sector j is falling relative to other prices on the world market, the domestic price of sector j will also be reduced in relative terms.[1] From (5) it follows that this change in relative prices will cause economic ageing, i.e., the wage share will increase in the sector experiencing a reduced relative price. In this situation establishments in sector j will have to search for new techniques and renew their old techniques, if possible.

Referring to Figure 1, we may introduce a domestic multisectoral model of the following kind

$$x(t) = A(t)x(t) + B(t)c(t) + f(t) , \tag{8}$$

where all variables refer to the last year of period t (e.g. five years), and where $x(t) = \{x_i(t)\}$ is a vector of sector outputs, $A(t) = \{a_{ij}(t)\}$ is a matrix of average input-output coefficients, $B(t) = \{b_{ij}(t)\}$ is a matrix in which an element b_{ij} denotes investment deliveries from sector i per unit of new capacity (equipment) in sector j, $c(t) = \{c_i(t)\}$ is a vector of annual capacity increments in sector j during the period, and where $f(t) = \{f_i(t)\}$ is a vector summarizing export, import and net final demand.

Different ways of solving a system of the kind described in (8) are presented in [7], [9] and [10]. In order to establish a link between the domestic and the world economy, f(t) may be specified as a vector function of domestic income and prices, and of the relation between domestic and world market prices.

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1) If this is not the case, there is no regular interaction between the domestic and the world market.

In addition, we may embed a structural change model in the multisectoral framework. With the features specified in the previous section, such a model will react to changes in prices, wages and demand. Those reactions include removal of existing capacities and construction of new capacities embodying new techniques. As described in [10], the reactions in such a structural change model will also affect the formation of domestic prices. In this way each sector may simultaneously satisfy total demand and counteract economic ageing.

A solution to the system in (8), together with its interacting model components, consists of a set of equilibrium prices and wages together with an associated balanced structure of outputs, investments, etc.

The system in (8) could be regionalized in several ways. For the moment we just note that according to (2) the aggregates of the system in (8) consist of regionally specified quantities x^{τ}_{jr}. A similar observation can be made with regard to the average input-output coefficients of the matrix A. Such an element is determined as follows

$$a_{ij} = \sum_{\tau} \sum_{r} a^{\tau}_{ij} \bar{x}^{\tau}_{jr} / \bar{x}_j \qquad (9)$$

Entry of new production units applying technique $\tau = 0$ and renewal of existing units will change the distribution of capacities $\bar{x}^{\tau}_{jr}$ between time t-1 and t. The same is of course true for regionally specified (average) coefficients a_{ijr} such that

$$a_{ijr} = \sum_{\tau} a_{ij}^{\tau} \bar{x}_{jr}^{\tau} / \sum_{\tau} \bar{x}_{jr}^{\tau} \qquad (10)$$

3. STRUCTURAL CHANGE MODELS

This section presents different ways of modeling structural change within sectors on the national level. In a first step structural change is analyzed without considering renewal of existing establishments. Thereafter renewal or restoration is considered explicitly. It is shown how these two approaches may be integrated. The structural change model which includes renewal is utilized in the regional models of sections 4 and 5.

3.1 Structural change without renewal

Consider a medium term period. Let the prices and wages during this period be given. By using formula (5) we may then calculate the wage share θ_j^{τ} for each class τ. Let ε_j be a function describing the frequency of capacity removed during the period for each value of θ_j^{τ}. The total capacity removed, e_j, will then be

$$e_j = \sum_{\tau} \varepsilon_j(\theta_j^{\tau}) \bar{x}_j^{\tau} \qquad (11)$$

The function ε_j will reflect the obsolescence policy of sector j. For medium term periods empirical observations show (see [4], [10]) that in general, the obsolescence policy is delayed so that the following three conditions are satisfied for each τ: (i) $\varepsilon_j(\theta_j^{\tau}) \geq 0$, (ii) $\partial\varepsilon_j/\partial\theta_j^{\tau} > 0$, and (iii) $\varepsilon_j(\theta_j^{\tau}) < 1$ for $\theta_j^{\tau} > 1$. In a strict version of vintage theory [3], [11] we should have that (i) $\varepsilon_j(\theta_j^{\tau}) = 0$

if and only if $\theta_j^\tau < 1$, and (ii) $\varepsilon_j(\theta_j^\tau) = 1$ if and only if $\theta_j^\tau \geq 1$.

Having established the form of ε_j, we can calculate the value of e_j as shown in (11). One may then determine the new capacity, $c_j(t)$, which must be created in order to reach the capacity level $\bar{x}_j(t)$ at the end of the period

$$c_j(t) = \bar{x}_j(t) + e_j(t) - \bar{x}_j(t-1) \tag{12}$$

For every vector of given prices, the investment costs per unit capacity in sector j are determined as $\Sigma_i p_i b_{ij}$. We shall compare these costs with the associated profits. By $\{a_{ij}^o, \ell_j^o\}$ we denote the input coefficients which obtain from the new technique embodied in the new capacity. The associated profits are

$$\begin{aligned} \pi_j^o &= p_j - \sum_i p_{ij} a_{ij}^o - w_j \ell_j^o \\ \pi_j &= \pi_j^o c_j(t) + \sum_\tau \pi_j^\tau [\bar{x}_j^\tau(t-1) - \varepsilon_j(\theta_j^\tau)] \end{aligned} \tag{13}$$

where π_j^o denote profits per unit output in the new technique, and π_j total sector profits after removal of old capacities. For every wage level the first function is exclusively determined by the price structure. With each of the functions one may associate an investment criterion such that the investment process is reflected in the determination of equilibrium prices of the multisector model. In Persson and Johansson [10] an average return criterion is used such that $\Sigma p_i b_{ij} c_j \leq r_j \pi_j$, where r_j is an estimated coefficient. With a standard rate of return coefficient β_j the requirement $\beta_j \geq \bar{\beta}_j$ yields

$$\bar{\beta}_j \leq \pi_j^o / \sum_i p_i b_{ij} \ , \ j = 1, \ldots, n \tag{14}$$

Since $\theta_j^o = w_j \ell_j^o / [\pi_j^o + w_j \ell_j^o]$ and $1 - \theta_j^o = \pi_j^o / [\pi_j^o + w_j \ell_j^o]$ a similar criterion may be expressed in terms of θ_j^o or $1 - \theta_j^o$.

Remark 1: For given wages the n prices $p_1, \ldots, p_n$ are directly determined by (14) if an equality sign is used. This remark may be related to the empirical observation that for each sector the medium term average of θ_j^o is approximately constant over time. When θ_j^o is falling as time goes by we observe contracting sectors.[1)]

In this subsection we have described structural change without renewal. It is possible to embed this change process in the national model related to (8). In a second step one may apply to the regional level a change process which includes renewal. By requiring mutual consistency between the two levels, the two approaches may be integrated. The renewal or restoration type of process is presented in the subsequent section.

3.2 Structural change with restoration

In this section we are introducing a way of distributing the new capacity, $c_j(t)$, over the set of old and entirely new establishments, where units belonging to

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1) This may for example be caused by external competition from countries which are increasing their production and which have lower wages and other input costs (raw materials, etc.).

the same class are treated as a group. We shall do this by focusing on the following property of observed behavior [4]. Over time a high proportion of production units are renewing their techniques as if their objective was to keep the gross profit share, $1 - \theta_j$, approximately constant. We shall call this type of renewal a restoration policy.

Consider establishments in technique class τ, and imagine a change of prices and wages such that $\theta_j^{\tau}(t-1) < \theta_j^{\tau}(t)$. Let γ be a technique such that $\theta_j^{\gamma}(t) = \theta_j^{\tau}(t-1)$ and let $\mu_j^{\tau\gamma}$ be defined by

$$\mu_j^{\tau\gamma} = \theta_j^{\gamma}(t)/\theta_j^{\tau}(t) \tag{15}$$

We may now define restoration as an investment policy by which production units shift from technique τ to γ so as to satisfy the condition $\theta_j^{\gamma}(t) = \theta_j^{\tau}(t-1)$.

Let $\bar{x}_j^{\tau\gamma}$ be the capacity in class γ which obtains as a result of a restoration shift from τ to γ. Assuming that restored units are retaining their initial labor force we may add the constraint

$$\bar{x}_j^{\tau\gamma}(t) \leq S_j^{\tau\gamma}(t-1)/\ell_j^{\gamma} \tag{16}$$

where $S_j^{\tau\gamma}(t-1)$ denotes the number of persons employed during period t-1 in units shifting from τ to γ, and ℓ_j^{γ} is the labor input coefficient of class γ. The restoration is called universal if either $S_j^{\tau\gamma}(t) = S_j^{\tau}(t-1)$ or $\varepsilon_j(\theta_j^{\tau}(t)) = 1$. The new capacity (in the form of new equipment) in class $\gamma, c_j^{\tau\gamma}$, is approximated by

$$c_j^{\tau\gamma} = (1-\mu_j^{\tau\gamma})\bar{x}_j^{\tau\gamma} \tag{17}$$

Remark 2: The exact value of $c_j^{\tau\gamma}$ is $[1-\mu_j^{\tau\gamma}(F_j^{\gamma}/F_j^{\tau})]\bar{x}_j^{\tau}$, where $F_j^{\delta} = [p_j-\Sigma p_i a_{ij}^{\delta}]$. Formula (17) obtains for $F_j^{\gamma}\approx F_j^{\tau}$.

The remark follows from (15) where $\mu_j^{\tau\gamma}w_j\ell_j^{\tau}/F_j^{\tau}=w_j\ell_j^{\gamma}/F_j^{\gamma}$. For $F_j^{\tau} = F_j^{\gamma}$ this yields $\mu_j^{\tau\gamma} = \ell_j^{\gamma}/\ell_j^{\tau} = \bar{y}_j^{\tau}/\bar{x}_j^{\tau\gamma}$, where $\bar{y}_j^{\tau} = S_j^{\tau\gamma}/\ell_j^{\tau}$ and $\bar{x}_j^{\tau\gamma} = S_j^{\tau\gamma}/\ell_j^{\gamma}$. This implies that $(1-\mu_j^{\tau\gamma})\bar{x}_j^{\tau\gamma} = \bar{x}_j^{\tau\gamma} - \bar{y}_j^{\tau} = c_j^{\tau\gamma}$.

By setting $\tau=\gamma=0$ and $\mu_j^{00}=0$ for completely new units, these are included in (17). Consistency between the multisectoral model and universal restoration requires that the following additivity condition is satisfied

$$\sum_{\tau} c_j^{\tau\gamma} = c_j(t) \text{ , and } \sum_{\tau} x_j^{\tau\gamma} = \bar{x}_j(t) \tag{18}$$

Similar conditions may be formulated for structural change with partial or non-universal restoration.

The investment costs corresponding to (17) may be expressed as $I_j^{\tau\gamma} = \Sigma_i p_i b_{ij} c_j^{\tau\gamma}$. From this one may determine an investment coefficient, $k_j^{\tau\gamma}$, which relates to value added. This yields $k_j^{\tau\gamma} = \Sigma_i p_i b_{ij}/[p_j-\Sigma_i p_i a_{ij}^{\gamma}]$ and we may write

$$I_j^{\tau\gamma} = k_j^{\tau\gamma}(1-\mu_j^{\tau\gamma})\bar{x}_j^{\tau\gamma}[p_j-\Sigma_i p_i a_{ij}^{\gamma}] \tag{19}$$

4. REGIONALLY SPECIFIED STRUCTURAL CHANGE

In this section we start by specifying regional and interregional constraints which may be derived from a national multisectoral model. This is illustrated in Figure 2 where production and employment targets and an economic ageing scenario for a region or a system of regions are derived from a multisectoral model on the national level.

With this as a background we focus on a single region and present two optimization models which generate structural change solutions for the region. If the approach presented is applied to the complete set of regions simultaneously, it provides a means to examine the feasibility of the national multisector model when regional rigidities and employment policies are taken into account. Formulating an interactive scheme between the national and multiregional structural change model, removal and investment in the national model may be adjusted so as to reflect the rigidities on the regional level.

4.1 Interregional interdependencies and constraints

A structural change model may either focus on one single region or it may, for example, be formulated as a multiregional programming model utilizing an interregional input-output system as in Lundqvist [8]. In the latter case the national and regional levels of structural change merge into one multiregional level. In both cases we have to consider balance constraints such that regional

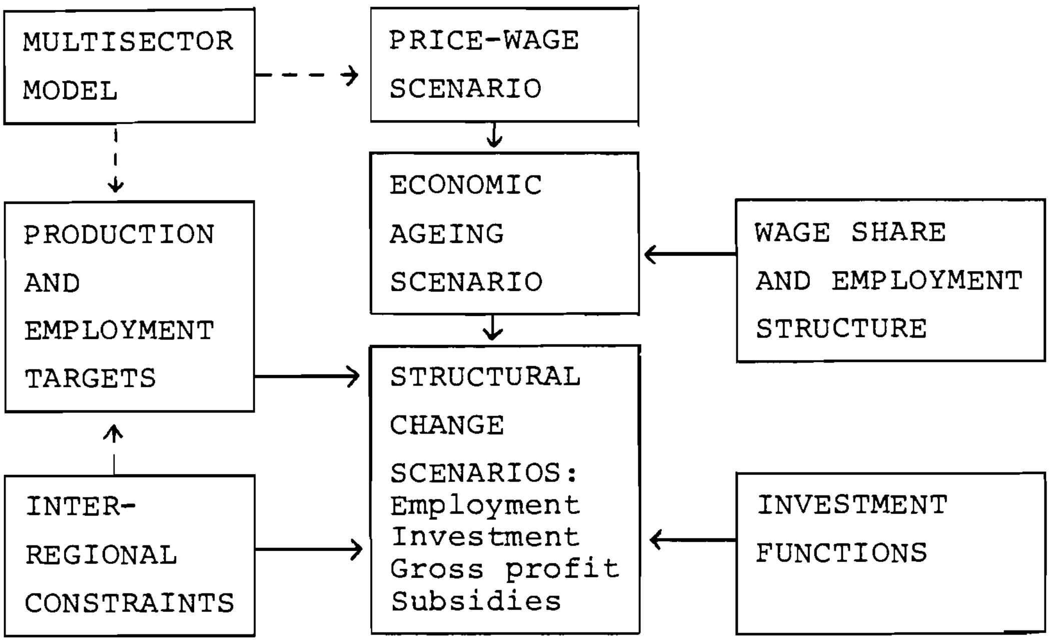

Figure 2. Basic components of a structural change model.

solutions are consistent on the national level and in an interregional perspective. One constraint of this type concerns the breakdown of $\bar{x}_j(t)$ to a regionally specified vector $\{\bar{x}_{jr}(t)\}$ such that

$$\bar{x}_j(t) = \sum_r \bar{x}_{jr}(t) \tag{20}$$

In order to capture all regional interdependencies we should need a complete multiregional input-output system. Information from such a system may be added as constraints to the more simple scheme presented here which basically utilizes (10) together with employment constraints as restrictions. In this context we shall sketch an optimization model which is able to generate consistent scenarios of multiregional structural change.

First, assume that we can determine an employment target, $S_r(t)$, denoting the desired number of persons employed in the industry sectors in region r. Observe then the following relationships based on (1)

$$\begin{aligned} S^{\gamma}_{jr} &= \ell^{\gamma}_{j}\bar{x}^{\gamma}_{jr} \\ S_{jr} &= \sum_{\tau} S^{\gamma}_{jr} \\ S_r &= \sum_{j} S_{jr} \end{aligned} \tag{21}$$

In the sequel we assume universal restoration so that there are unique pairs (τ,γ) for which $S^{\tau\gamma}_{jr}(t-1)=S^{\gamma}_{jr}(t)$, and S^{γ}_{jr} denotes $S^{\gamma}_{jr}(t)$.

We shall formulate a restoration policy, as specified in section 3.2, for region r with the following objective function which implies universal restoration

$$L_0^r = \sum_{\gamma}\sum_{j}\rho_j h_j^{\tau\gamma} s_{jr}^{\gamma} - \sum_{\gamma}\sum_{j}\delta_j^{\tau\gamma} s_{jr}^{\gamma} \tag{22}$$

where ρ_j denotes an interest rate (discount factor), where $\delta_j^{\tau\gamma}$ denotes the gross profit per person employed in all establishments which are changing technique from τ in period t-1 to γ in period t so that[1)]

$$\delta_j^{\tau\gamma} = (1-\theta_j^{\gamma})[p_j - \Sigma_i p_i a_{ij}^{\gamma}]\bar{x}_{jr}^{\gamma}/s_{jr}^{\gamma} \tag{23}$$

and where $h_j^{\tau\gamma}$ denotes the investment cost per person employed in establishments changing technique from τ to γ during period t. From (19) we have that[1)]

$$h_j^{\tau\gamma} = k_j^{\tau\gamma}(1-\mu^{\tau\gamma})[p_j - \sum_i p_i a_{ij}^{\gamma}]\bar{x}_{jr}^{\gamma}/s_{jr}^{\gamma} \tag{24}$$

Using (22) we introduce the following multiregional objective

$$\text{Min} \sum_r L_0^r ,$$

subject to

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1) Observe that for new establishments, $\gamma=0$, we write δ_j^{oo} and h_j^{oo}. These coefficients are calculated separately, according to the specification of technique $\gamma=0$.

$$\text{(i)} \qquad S^{o}_{jr}(t) \leq \bar{S}^{o}_{jr} \text{ for all } j \qquad (25)$$

$$S^{\gamma}_{jr}(t) \leq S^{\tau}_{jr}(t-1) \text{ for all } r, j, \text{ and } (\tau,\gamma)$$

$$\text{(ii)} \quad \sum_{\gamma}\sum_{j} S^{\gamma}_{jr}(t) = \hat{S}_{r} \text{ for all } r,$$

$$\text{(iii)} \quad \sum_{\gamma}\sum_{r} S^{\gamma}_{jr}(t)/\ell^{\gamma}_{j} = \bar{x}_{j}(t) \text{ for all } j$$

where (i) restrains the introduction of the new technique and states that transition from τ to γ does not increase the labor force in the establishments, (ii) states that the regional employment target for the industry must be satisfied, and (iii) states that the national production target as specified in (20) must be satisfied. Observe that (i) is an indirect capacity constraint and that (iii) is the solution to the national multisectoral model. Observe finally that the interregional objective in (25) is equivalent to a maximization of the difference between annual gross profits and annual costs associated with investment in the new technique $\tau=0$ and with the restoration investments. Ultimately the gross profit determined by the solution to (25) must be consistent with the income formation in the national multisectoral model. In particular, one may introduce a consistency criterion for regional profits, formulated in a similar way as the additivity condition in (18).

From (25) we may specify the following Lagrange function for distinct (τ,γ)-pairs

$$L = \sum_r L_o^r - \sum_j \lambda_j [\bar{x}_j(t) - \sum_{\gamma r}\sum S_{jr}^{\gamma}(t)/\ell_j^{\gamma}]$$

$$- \sum_r \lambda_r [\hat{S}_r - \sum_{\gamma j}\sum S_{jr}^{\gamma}(t)] \tag{26}$$

$$- \sum_{\gamma j}\sum \lambda_{jr}^{\gamma} [S_{jr}^{\tau}(t-1) - S_{jr}^{\gamma}(t)]$$ 1)

The optimum conditions may be described as follows

$$S_{jr}^{\gamma}[\partial L/S_{jr}] = 0 \Rightarrow \begin{cases} S_{jr}^{\gamma} = 0 \text{ or} \\ \delta_{jr}^{\gamma} = \rho_j h_j^{\tau\gamma} + \lambda_r + \lambda_j/\ell_j^{\gamma} + \lambda_{jr}^{\gamma} \end{cases} \tag{27}$$

For this solution we may interpret λ_r as a regional policy parameter and $\lambda_j/\ell_j^{\gamma}$ a sectoral policy parameter specified with respect to technique class γ, where policy parameter means "subsidy" of "tax". Finally, λ_{jr}^{γ} represents the additional profit that obtains if the capacity constraint is binding.

4.2 Structural change in one region

In section 5 the structural change analysis is illustrated by an application to a single region. There we utilize two different "mini-versions" of the optimization model in (25). In both versions we minimize the objective function L_o^r in (22). The first version utilizes constraints (i) and (ii) in (25), which means that it allows free allocation between sectors up to the limits set by the constraints. This version should only

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1) In this formulation $\bar{S}_{jr}^{o}$ is denoted by $S_{jr}^{o}(t-1)$, in order to simplify notation. Observe that technique $\tau=0$ did not exist in period t-1, by definition.

be applied to a small region, since it has no mechanism which relates it to the sector balance on the national level in (20). The Lagrangian becomes for (τ,γ)-pairs

$$L_I = L_o^r - \lambda_r[\hat{S}_r - \sum_{j\gamma}\sum S_{jr}^{\gamma}] - \sum_{j\gamma}\sum \lambda_{jr}^{\gamma}[S_{jr}^{\tau}(t-1) - S_{jr}^{\gamma}(t)] \quad (28)$$

The second version differs from version I in only one respect. The target $\hat{S}_r$ is taken away and replaced by sector-specific targets, $\hat{S}_{jr}$. Then the following Lagrangian applies for distinct (τ,γ)-pairs

$$L_{II} = L_o^r - \sum_j \lambda_{jr}[\hat{S}_{jr} - \sum_{\gamma} S_{jr}^{\gamma}(t)] - \sum_{j\gamma}\sum \lambda_{jr}^{\gamma}[S_{jr}^{\tau}(t-1) - S_{jr}^{\gamma}(t)] \quad (29)$$

Observe finally that the price-wage scenario affects L_o^r through $h_j^{\tau\gamma}$ and $\delta_j^{\tau\gamma}$ in (22). For each such scenario, (28) and (29) generate associated structural change scenarios. In the following section we provide a comparison between scenarios generated by (28) and (29).

5. ILLUSTRATION OF STRUCTURAL CHANGE SCENARIOS WITH SINGLE-REGION ALLOCATION

In this section we shall illustrate an application of the models associated with (28) and (29). We call them Program I and II, respectively. The programs have been applied to a Swedish region, Värmland, for the period 1978-1985. In table 1, the initial employment structure (1978) is described. The techniques are aggregated to 5 technique classes, of which $\tau=0$ represents the new technique. The restoration profile for the period 1978-1985 is illustrated by Figure 3, which shows that the period has been divided into 2+5 years.

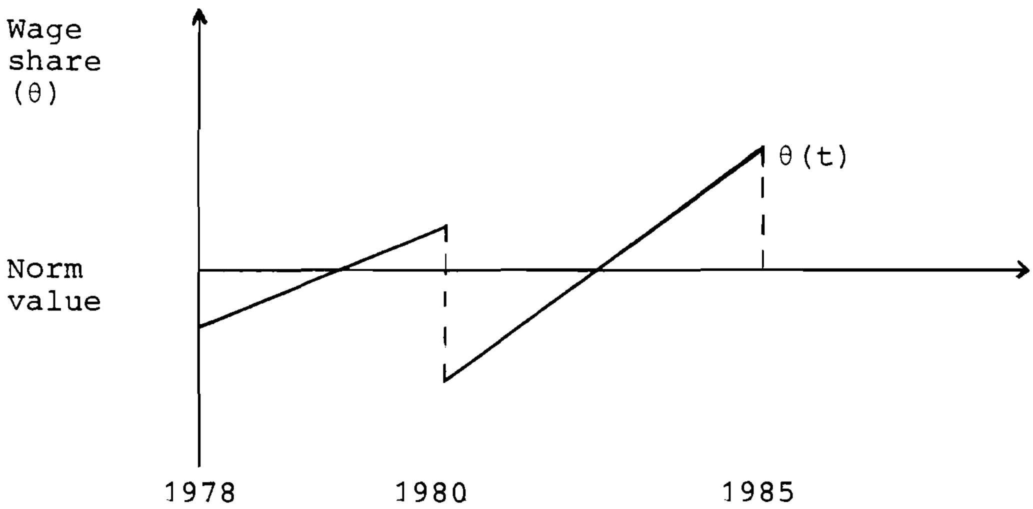

Figure 3. The change of the wage share in a specific sector and profit share class with a restoration program.

5.1 Two structural change scenarios

Table 2 summarizes two structural change scenarios with associated investment allocations. The two scenarios are based on the same price-wage scenario. The scenarios utilize Program I and II, respectively.

In table 2 we have not described the distribution of techniques. This is illustrated in table 3. Program I generates the same total employment as Program II. It does so by requiring a greater total investment effort. At the same time it generates a higher net surplus which is the difference between the annual gross profits and the annual costs associated with the investment allocation. One should then observe that Program I, which refers to (28), allows free allocation between sectors, while Program II operates with one employment target per sector. The outcome of the two programs is specified in percent of a base alternative which is also presented in table 2.

In table 3 we illustrate Program I and II in more detail for the two subsectors of the forest industry. The similarity between the two outcomes makes it easy to grasp the structure of the solutions. One should observe that every class τ includes at least three establishments, since this is a confidentiality criterion in the industrial statistics of Sweden. If we regard Program II and focus on the wood products sector, the parameter value $\lambda_i = 16.4$ indicates the taxation per employee on a marginal unit in class $\gamma = 3$ that would force the reduction of this class to 89 percent of full capacity utilization. For further details, we may refer to Johansson and Strömquist [4] and Johansson [5].

Table 1. Initial Employment Structure and Capacity Constraints. Värmland 1978.

	Paper Products	Wood Products	Summation over remaining 16 industry sectors
Employment target	6 250	2 911	24 850
Capacity constraints in terms of persons employed in class:			
$\tau = 0$	620	300	2 520
1	2 750	730	4 580
2	2 560	1 490	11 040
3	750	440	6 410
4	190	260	2 850
Total capacity constraint	6 870	3 220	27 400

Source: Johansson [5]

Table 2. Structural change scenarios with Program I and II.

		Wood products	Paper products	All 18 sectors	Annual net surplus per person
Annual growth of economic age =		1,0	2,3	2,5	
BASE ALTERNATIVE	Employment 1978	2 911	6 250	34 011	35 400
	Investment 1972-78 per year (1.000 Swkr)	48 500	197 200	604 100	
PROGRAM I	Employment percent	102	107	99	50 554
	Investment percent	45	100	104	
PROGRAM II	Employment percent	100	100	99	49 155
	Investment percent	45	53	85	

Net surplus = Gross profits minus costs associated with the investment (1.000 Swkr).

Remark: Annual growth of economic age refers to the difference $\alpha - \beta$, where α, in percent, is the annual growth of the wage level and β is the annual growth of the value added price index, in percent.

Table 3. Illustration of Program I and II for the forest industry.

	Index class τ	Capacity utilization in percent	Gross profit $\delta_i^{\tau\gamma}$	Inv. costs $\rho_i h_i^{\tau\gamma}$	Regional shadow prices λ_i^{γ}	λ_i	Wage share, per cent
PROGRAM I Wood products	0	100	106.1	59.2	46.9	--	39
	1	100	106.1	10.4	95.7	--	39
	2	100	47.1	2.8	44.3	--	59
	3	100	16.9	0.5	16.4	--	80
	4	0	- 10.3	--	--	--	118
PROGRAM II Wood products	0	100	106.1	59.2	30.5	16.4	39
	1	100	106.1	10.4	79.3	16.4	39
	2	100	47.1	2.8	27.9	16.4	59
	3	89	16.9	0.5	0	16.4	80
	4	0	- 10.3	--	--	--	118
PROGRAM I Paper products	0	100	172.1	172.1	0	--	30
	1	100	149.8	0	149.8	--	33
	2	100	51.3	17.9	33.4	--	59
	3	100	18.4	6.0	12.4	--	80
	4	0	- 21.1	--	--	--	140
PROGRAM II Paper products	0	31	172.1	172.1	0	0	30
	1	100	149.8	0	149.8	0	33
	2	100	51.3	17.9	33.4	0	59
	3	100	18.4	6.0	12.4	0	80
	4	0	- 21.1	--	--	--	140

REFERENCES

[1] Houthakker, H.S., The Pareto distribution and the Cobb-Douglas production function in activity analysis, Rev. of Econ. Studies 23 (1955).

[2] Johansen, L., Substitution versus fixed production coefficients in the theory of economic growth: a synthesis, Econometrica 27 No 2 (1959).

[3] Johansen, L., Production Functions (North-Holland, Amsterdam, 1972).

[4] Johansson, B., and U. Strömquist, Vinster och Sysselsättning i Svensk Industri (SIND 1980:2, Statens Industriverk, Stockholm 1980).

[5] Johansson, B., Förutsättningar för Industriell Utveckling; Värmland under 1980-talet (Värmlands lans landsting, Karlstad 1981).

[6] Johansson, B., Structural change in the forest industry - a framework of models, IIASA CP-81-3, Int. Inst. for Applied Systems Analysis, Laxenburg Austria,(1981).

[7] Johansson, B., and H. Persson, Dynamics of Capital Formation, capacity constraints and trade patterns in a multisectoral model, IIASA WP-83-3, Int. Inst. for Applied Systems Analysis, Laxenburg, Austria (1983).

[8] Lundqvist, L., A Dynamic multiregional input-output model for analyzing regional development, employment and energy use, TRITA-MAT 1980:20, Royal Inst. of Techn., Stockholm (1980).

[9] Persson, H., On extensions of a medium-term input-output model, Working Paper, Dept. of Mathm., Royal Inst. of Techn., Stockholm (1980).

[10] Persson, H., and B. Johansson, A dynamic multisector model with endogenous formation of capacities and equilibrium prices: an application to the Swedish economy, IIASA PP-82-8, Int. Inst. for Applied Systems Analysis, Laxenburg, Austria (1982).

[11] Salter, W.E.G., Productivity and Technical Change (Cambridge Univ. Press, London 1960).