Working Paper

INDUSTRIAL DYNAMICS, PRODUCT CYCLES, AND EMPLOYMENT STRUCTURE

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International Institute for Applied Systems Analysis
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FOREWORD AND ABSTRACT

The objective of the Forest Sector Project at IIASA is to study long-term development alternatives for the forest sector on a global basis. The emphasis in the project is on issues of major relevance to industrial and government policy makers in the diffeerent regions of the world, who are responsible for industrial and natural resource strategies and to related trade policies.

The key elements of structural change in the forest industry are related to the changing pattern of demand, supply capacity and trade. It is obvious that technological change, to a large extent triggered off by evolving Research and Development strategies, plays a major role in this process of structural change at the global level. Conclusions from this article are as follows:

- The forest sector is developing into an integrated systems industry in the same way as large parts of chemical and other process industries, with similar requirements on coordinative capacities and support from logistical infrastructure. This makes location to highly developed economies an advantage for the integrative parts of the sector.
- It is a low R & D industry, however measured, in a comparison with other manufacturing industries. This may cause problems for the sector in inter-industrial competition for labor and capital resources. For the non-integrative forest industry, like mechanical wood processing, it means a long-term process of relocation from the OECD region to less developed regions of the world.

- Within the OECD region the forest sector will continue to be located primarily in sparsely populated areas. Continued location outside the major densely populated knowledge centres of the world can accentuate the technological development problems of the sector, unless properly counteracted by new R & D strategies.

This paper, which is based on product cycle theory, has been written in collaboration between the Regional Issues Project and the Forest Sector Project at IIASA.

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INDUSTRIAL DYNAMICS, PRODUCT CYCLES, AND EMPLOYMENT STRUCTURE

by

Å.E. Andersson and B. Johansson

1. INTRODUCTION

1.1 Product Cycles and Labor Mobility

Policy formation, as regards industrial change, includes national and regional policies for research and development (R & D), investment patterns, education and retraining programs for the labor force. This process is, in a fundamental way, characterized by genuine uncertainty. Steady state growth ultimately means change without *development*, i.e., a change with constant industrial investment and employment shares. When development takes place in the environment of a country and a region, such an internal steady state becomes in fact undesirable. Changes in the environment comprise development of international markets for existing products and factors of production; it also includes the emergence of new products and production techniques as well as international and national institutional changes.

In this paper we shall relate the above types of changes to product cycles that can be observed on a global scale, and to changes in production and communication technologies, as well as to the development of new products. A fundamental part in this process of change is gradual spatial relocation of industrial activities within and among countries.

In order to be viable beyond the short term perspective, industrial change processes must include labor mobility in several dimensions. In particular, there must exist a net positive transition away from declining and obsolete industrial activities over to new activities which are emerging and expanding. Such a mobility combined with spatial mobility must generally also include changes in knowledge and skills of the labor force. The corresponding education effort constitute an investment process which is as vital as the investment in fixed capital (production techniques) and R & D. We can also identify a welfare problem associated with such labor mobility which is forced by external changes. Hence, industrial policy in general will also be associated with welfare policy.

In the subsequent sections we attempt to assess (i) structural impacts of observed product cycles in the world economy, (ii) labor market effects of transitions (in the industrialized economies) towards production with a high "knowledge content", and (iii) production rigidities and labor market inertia in the process of structural change. Finally, we illustrate how these aspects were considered in recent industrial scenarios for the Swedish economy.

1.2 Product Cycles and Spatial Relocations

In section 4 we provide some illustrative evidence of major product cycles on an aggregate level in the world economy. In section 2 and 3 basic assumptions about spatial industrial dynamics are introduced by incorporating comparative advantages in a dynamic framework. Figure 1.1 illustrate the time-space dynamics in the product cycle theory outlined in this paper. The probability that new products/processes are developed and initially introduced in a region is assumed to increase with the intensity and composition accuracy of knowledge in a region. As production scale increases and the production technique is gradually improved, routinized and simplified, the knowledge requirements decreases correspondingly. In this way other regions with different wage levels and factor prices provide more advantageous locations. As a consequence production processes are successively relocated in the world economy at a technology-specific speed.

The relocation process is a fundamental part of the competition in the world economy. Regions and countries, in which a specific type of production was introduced at an early stage, suffer from strutural change problems when new competitors emerge. Simultaneously new products and processes are gradually introduced and this also increases the tension on already existing industrial technologies in various regions.

When the international economy goes through such a process of structural change, industries in regions and nations have to react. When an established and mature segment of an industrial sector grows obsolete, its pattern of reaction to external distortions of its markets has

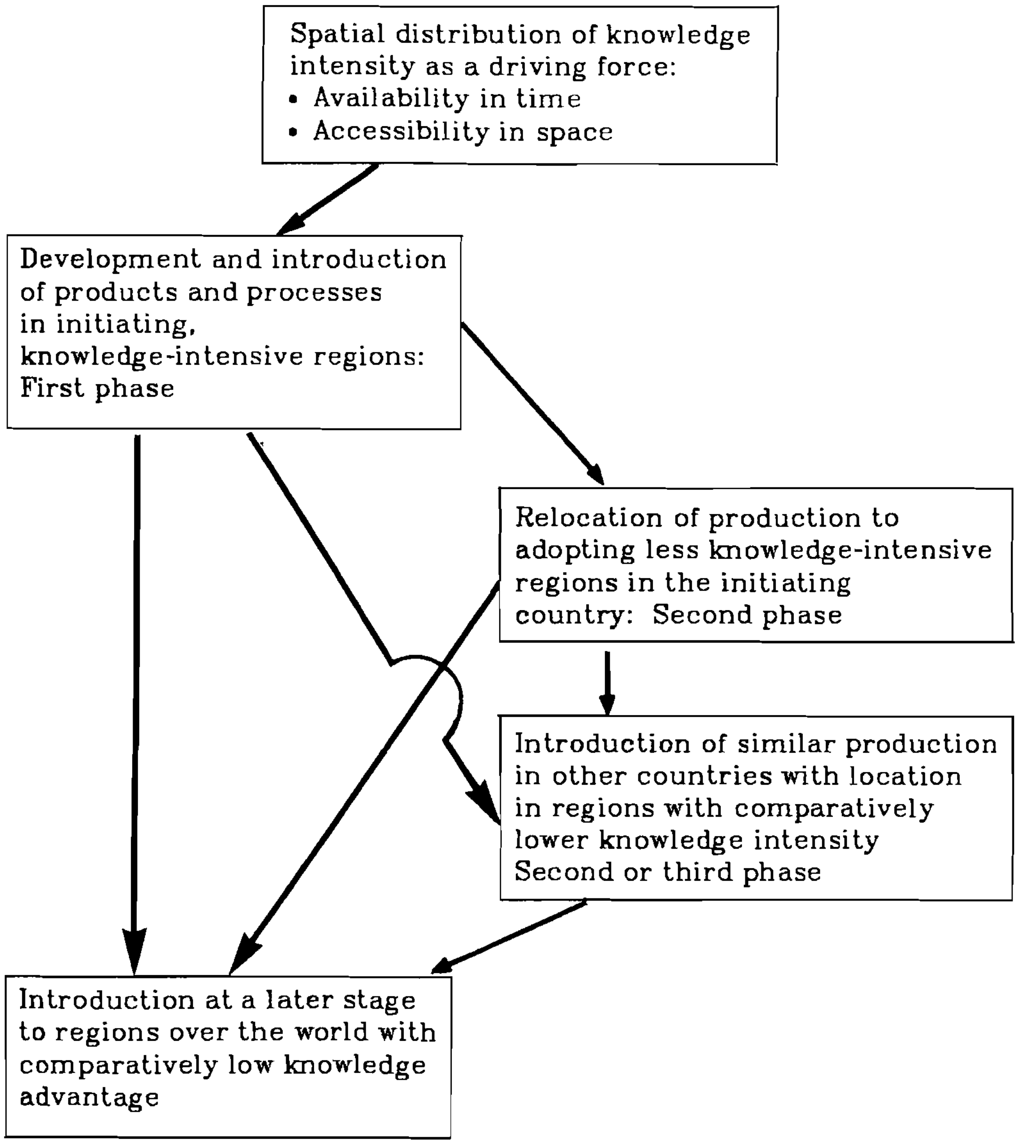


Figure 1.1. Illustration of product and technology transitions in space and time.

a conservative character. The responses frequently include (i) *intensive search for labor and factor saving changes in the production technique; (ii) increased scale of production and correspondingly improved logistics and marketing systems in an attempt to augment exports.* At the same time the policy system is often forced to protect the threatened production.

The pattern of reaction which we have stylized above, reinforces already strong rigidities which stem from the fact that production and distribution techniques are embodied in the fixed capital as well as the knowledge and skills of the persons employed in production units. Fixed capital, like buildings and equipment, are generally spatially immobile and often unadaptable to other uses. However, in many modern societies this feature is also shared by the labor force.

In summary, all these observations indicate that product cycles involve both development of new products and spatial relocation, as well as conservative resistance to change from already established industries which are growing absolete and have failed to renew their technology.

2. PRODUCT CYCLES AND TECHNOLOGY CHANGE IN A GLOBAL PERSPECTIVE

2.1 Products, Sectors and Jobs

Variables in models of economic dynamics are usually categorized by means of notions like sector, product and type of job (employment category). Although such variables are used as analytical concepts they do not refer to observables representing analytical variables, but to aggregate observations of the following type:

$$\text{(i)} \quad x_I(t) = \sum_{i \in I} x_i(t)$$

$$\text{(ii)} \quad P_I(t) = \sum p_i(t) x_i(t) / x_I(t) \qquad (2.1)$$

$$\text{(iii)} \quad P_I(t) x_I(t) = \sum_{i \in I} p_i(t) x_i(t)$$

where t denotes an observation period and I is an index set, referring to a product group, an aggregate sector or an aggregate category of jobs (employment category), and where x_i and x_I are accounting variables (representing volume or quantity) and p_i and p_I are price indices (including wages). Observations confined to types (ii) and (iii) can only be unambiguously related to analytical variables if $p_i(t)/p_I(t)$ and $x_i(t)/x_I(t)$ remain unchanged over time. The aggregate quantity $x_I(t)$ is obviously also a kind of index as long as the categories $i \in I$ are heterogenous. Once again, the aggregate observations remain unambiguous only if $x_i(t)/x_I(t)$ is fixed.

The conclusions drawn observations made above are, of course, discouraging if we recognize that the analysis of industrial dynamics should focus on the changes of $p_i(t)/p_I(t)$ and $x_i(t)/x_I(t)$. One may argue that if this is the case, then the observation process should be refined to the aggregation level indicated by index i instead of I. At the same time dynamic models easily become intractable when the dimensionality is increased in this way.

One obvious approach to managing this problem is to identify several levels of aggregation and characterize each level with a distribution over the relevant categories. If one follows this approach, the dynamics will be modeled as a process in which the pertinent distributions change.

In the subsequent analysis we are recognizing sectors as aggregates obtained by making a compromise between two classification principles: similarity with regard to the structure of (i) input, and (ii) output. This means that sectors must be considered heterogenous in both dimensions. In particular, we are applying the following conceptual model:

An economic sector is characterized by a multivariate distribution over its

(i) categories of inputs,

(ii) categories of jobs, and

(iii) types of commodities produced.

In concrete terms this may be perceived as a distribution of production techniques referring to a set of production units, each with input coefficients, a production capacity and a characteristic product mix which are fixed in the short-medium term. According to (2.2), intra-sectoral change will be described by changes of a multivariate distribution. This is in contra-distinction to intersectoral change which in our case refers to the development of aggregate measures of the relative importance of various sectors (sales value, number of persons employed, etc.).

2.2 Product Cycles in a Global Perspective

From the perspective outlined in the preceding section, industrial dynamics may schematically be decomposed into three basic dimensions: (i) process change comprising decline and exit of old as well as entry and expansion of new production techniques, (ii) product change incorporating decline and disappearance of commodities as well as emergence of new or modified products, (iii) market change referring to changing prices of inputs and of products supplied. For industrial products those changes take place in an international context of factor supply and output demand.

Two different paradigms can be used to understand the development of world trade, the international patterns of activity locations, and the corresponding specialization of economies. These two approaches to explaining international industrial interactions are (i) the theory of comparative advantages, and (ii) the theory of product cycles. The latter attempts to capture the dynamic aspects of change, while the first usually is formulated in the form of comparative statics.

The theory of comparative advantages claims that each region or country tends to specialize in the production and export of those commodities in which its cost level is seen as relatively most competitive vis á vis other regions.

A special version of this theory is the factor proportions theory (Ohlin, 1933). It predicts and prescribes a specialization in the production of goods which require inputs of factors of production which are relatively abundant in the country. Also in this case the relevant criterion is the relative or comparative position of the country. It became fairly clear in the 60's and the 70's that the usefulness of the factor proportions explanation of specialization patterns crucially depends on a proper delimitation of the types of input factors considered in the analysis. A classical subdivision of factors of production into capital, labor and land is not sufficient in this respect. Leontief's pioneering work (1953) made it evident that the concept of capital must be widened to include educational and other characteristics of the labor force in order to shed any light on the international division of labor. Also, it is necessary to identify how the requirements of labor force characteristics varies between the production of different commodities and associated production techniques. This essentially means that knowledge and its expansion through research and development becomes a fundamental factor in determining future international patterns of location and international market specialization.

The consequences of knowledge development on international patterns of location and specialization may be discussed qualitatively in the medium-term range (10-15 years). The theory of product cycles is designed to provide an understanding of these phenomena (Vernon, 1966). This theory essentially states that each product undergoes a development cycle in which each new commodity enters the most highly developed regions of the world after a phase of research, implementation development, and laboratory testing. The product is then primarily produced in the region with a comparative advantage in terms of a high R & D level. The product is exported from this region to other regions. When the product has matured in terms of process development (design of production techniques) and market penetration, the region of original introduction and specialization looses its comparative advantage and the production becomes regionally decentralized.

Figure 2.2 illustrates the product cycle patterns among the OECD-countries during the last 10-15 years. The upper left area in the diagram characterizes the commodities and the associated production in which OECD has a comparative advantage, and a corresponding high degree of specialization. This specialization is at the same time non-decreasing. The arrows in the figure show a transition process in which products over time move to stages of gradually reduced comparative advantages.

NEW PRODUCTS	THE SPECIALIZATION INCREASES OR REMAINS UNCHANGED IN THE OECD-REGION	THE SPECIALIZATION IS DECREASING IN THE OECD-REGION
HIGH DEGREE OF SPECIALIZATION IN THE OECD-REGION	o Systems oriented products and production processes o Capital and R&D intensive production o Products which are distance sensitive o Design dependent products o High income dependent products	High capital intensity combined with (i) low level of R&D, and (ii) low skill requirements
LOW DEGREE OF SPECIALIZATION IN OECD-REGION	Products in industries which are protected by the political system	o Labor intensive production combined with low capital and R&D requirements o Natural resources oriented production.

Figure 2.1. Characterization of products and associated production processes according to a product cycle description of OECD economies.

3. DYNAMICS OF KNOWLEDGE INTENSITY IN PRODUCTION PROCESSES

3.1 Dynamics of Market Shares, Costs and Technology

In this section we outline a conceptual framework which can serve to make more precise statements about the various phases in a product cycle development. This is done by considerating the introduction of a new product and the associated process (a combined product and a process innovation).

At its initial phase the process requires a high knowledge intensity, which we represent by an intensity variable $u = \kappa/(\kappa + L)$ where κ is the amount of labor with special skill and knowledge and L is the remaining part of the labor force. Hence, $0 \leq u \leq 1$.

The product cycle analysis requires a spatial dimension which we represent by demand regions $s \in R$ and supply regions $r \in R$. The growth of demand in region $s, d^s(p,t)$, is expressed by a logistic function

$$d^s(p,t) = N^s(p^s,t)\,[1+be^{-at}]^{-1} \tag{3.1}$$

where $N^s(p^s,t)$ denotes the potential demand level at time t, given the price level p^s, and where b and a are positive parameters. The delivery from region r to region s is expressed as

$$x^{rs}(t) = \beta^{rs}(t)d^s(p^s,t) \tag{3.2}$$

where $\beta^{rs}(t)$ is a time evolving share function. We observe that $\beta^{rs}(t) \geq 0$ and $N^s(p^s,t) \geq 0$ at all points in time. Also, if r is the region in which the innovation/introduction occurs at time $t = 0$, we have that $\beta^{rs}(0) = 1$. A fundamental aspect of product cycle phenomena is expressed by the time paths of the share coefficients β^{rs}. In section 4 the variable σ^s is used as an indicator of the specialization in region s, where

$$\sigma^s = \beta^{ss} = 1 - \sum_{r \neq s} \beta^{rs} \tag{3.3}$$

Consider now the case $\beta^{rs} > \beta^{ks} \geq 0$. How can we identify the reasons for such a difference and, in particular, how is a situation $\beta^{rs}>0$ and $\beta^{ks} = 0$ preserved and which factors can bring about a change in the situation? The following formula for determining the share coefficient can be derived from alternative theoretical models in spatial theory*:

$$\beta^{rs}(t) = \frac{q^{rs}(t)\exp\{\mu^r(p^s - \hat{c}^r - c^{rs})\}}{\sum_k q^{ks}(t)\exp\{\mu^k(p^k - \hat{c}^k - c^{rs})\}} \tag{3.4}$$

where $\hat{c}^r$ denotes production cost per unit supply in region r, and c^{rs} unit transportation cost on the link (r,s), and where $q^{rs}(t)$ represent the "memory effect" of past flows such that $q^{rs}(t)$ can be given a probability interpretation. In particular, $x^r(t) = 0$ implies $q^{rs}(t) = 0$.

We may illustrate a threshold phenomenon in the product cycle development by considering the case in which the commodity is only produced in the introduction region r so that $\beta^{rs} = 1$ and $\beta^{ks} = 0$. Let the profit function per unit output of the plant(s) in region r be

$$\begin{aligned} \pi^r &= p^r - \hat{c}^r \\ \hat{c}^r &= c^r + l^r[w^r(1-u^r) + w_u^r u^r] \end{aligned} \tag{3.5}$$

where p^r is the price, c^r non-labor related costs, l^r average labor input

* We may relate this expression to (i) the Logit model (McFadden, 1975), (ii) random choice theory as outlined by Leonardi (1983), and (iii) entropy formulations (Lesse, 1983). See also Andersson, Persson (1982) and Johansson, Batten (1983) from which formula (3.4) has been collected and where it is based on a probabilistic argument combined with a learning process.

coefficient, w_u^r the unit costs related to knowledge intensive employment and w^r the unit costs related to the remaining part of the labor force. In general, $w_u^r > w^r$ and the ratio $w_u^r u^r / w^r (1-u^r)$ is a cost measure of the knowledge intensity. We may also say that w_u^r is the regional price associated with the knowledge intensity u^r. For a new product we may, in accordance with the product cycle theory, assume that $u^r = u^k = \bar{u}$ while $w_u^r < w_u^k$ if r is the initiating region.

An essential feature of the model sketched below is that $u^r(t)$ will be reduced over time as production is automated and routinized in combination with increased scale. Another important element of the change process is a reduction in c^r due to process innovations based on increased scale of production. A third component of the development cycle is the introduction of labor saving production techniques as the process "matures", and this is expressed by a falling labor input coefficient l^r.

In summary, we generate a product cycle dynamics on the basis of the following assumption in relation to (3.5):

> If region r has higher knowledge intensity than k and if the specific product is introduced in r and prevented from entry in k, then

(i) $l^r w_u^r < l^k w_u^k$

(ii) $l^r w^r > l^k w^k$ (3.6)

(iii) $\bar{u}$ falls as x^r grows

The formulation in (3.4) may be combined with various assumptions about how the market share coefficients change over time. One possible specification is the following:

$$
\begin{aligned}
q^{rs} &= \Phi^{rs} / \sum_r \sum_s \Phi^{rs} \\
\Phi^{rs} &= \int_{t_0}^{t} w(\tau)[q^{rs}(\tau) + \lambda^{rs} \delta^{r}(\tau)] d\tau, t > t_0 \\
\delta^{r}(\tau) &= \begin{cases} 1 - \bar{x}^{r}(\tau - \Delta) / \bar{x}^{r}(\tau) & \text{if } \bar{x}^{r}(\tau) > 0 \\ 0 \text{ otherwise} \end{cases}
\end{aligned}
\tag{3.7}
$$

where $\bar{x}^r$ denotes supply capacity, $w(\tau)$ weighting factors, and λ^{rs} *a priori* probabilities for the direction of export efforts related to new capacity. In particular λ^{rs} is needed to allow for changes from state $\bar{x}^k(t) = 0$ to $\bar{x}^k(t+\Delta)>0$, since such a sudden increase has to be distributed over potential markets. The dynamics related to (3.4) and (3.7) are described further in the Appendix.

3.2 Profit Criteria and Market Entry

Assume that price competition prevails in importing regions in the sense that exporters from region r receive the price $p^s - c^{rs}$ in region s. Then the condition for region k to enter the market by investing in new capacity $\bar{x}^k(t) > \bar{x}^k(t-\Delta) = 0$ may be expressed as follows

$$
\begin{aligned}
(p^k - \hat{c}^k) x^k &\geq \bar{\pi}^k \bar{x}^k \\
\bar{x}^k &\geq \sum_s \beta^{ks} d^s(p^s) = x^k \\
p^k x^k &\leq \sum_s (p^s - c^{ks}) \beta^{ks} d^s(p^s)
\end{aligned}
\tag{3.8}
$$

where $\bar{\pi}^k$ represents a threshold level below which the investment costs are not covered. Observe also that the investment decision in general should distinguish between expected sales x^k and new capacity $\bar{x}^k$. Further details are given in the Appendix.

The decision in region r to retain the capacity $\bar{x}^r$ only requires that

$$p^r - \hat{c}^r \geq 0$$
$$\hat{c}^r = c^r + l^r[w^r(1-u^r) + w_u^r u^r] \tag{3.9}$$

since in region r the investments represent sunk costs. Let $\bar{w}^i = w^i(1-u^i) + w_u^i u^i$. Then we may conclude that region r has a specific advantage from being first on the market:

> *PROPOSITION 1*: Let $p^r = p^k, c^r = c^k, \bar{x}^r > 0$ and $\bar{x}^k = 0$ and let the assumption in (3.6) hold. According to the conditions in (3.8) and (3.9) region k is prevented to entry also when $l^r\bar{w}^r \geq l^k\bar{w}^k$ as long as
>
> (i) $\bar{x}^r \geq \sum_s d^s(p^s,t)$, and
>
> (ii) $l^r\bar{w}^r < l^k\bar{w}^k + \bar{\pi}^k$.

The basic element in the proposition is that as long as $l^r\bar{w}^r < l^k\bar{w}^k + \bar{\pi}^k$ region r will always be capable of supplying the amount $\bar{x}^r$ at a lower price than region k. For demand larger than $\bar{x}^r$ new investments are necessary and then r will have a competitive advantage only if $l^r\bar{w}^r + \bar{\pi}^r < l^k\bar{w}^k + \bar{\pi}^k$.

Having introduced the price conditions in (3.7) it is essential to make the following observation:

> *REMARK 1*: Consider the third condition in (3.8). Firstly, as shown in the Appendix, a completely dispersed trade pattern ($\beta^{rs} > 0$ for all r and s) is only compatible with the weaker condition $(p^r - \varepsilon^r)\sum_s x^{rs} \leq \sum_s(p^s - c^{rs})x^{rs}, \varepsilon^r > 0$ if prices are non-

dispersed so that $p^r = p^s$ for all s. Secondly, as shown in the Appendix, this condition together with the information theory criterion applied in (3.4) implies that β^{rs} in (3.4) changes for

$$\beta^{rs} = \frac{q^{rs}\exp\{\mu^r(p^s - p^r - c^{rs} + \varepsilon^r)\}}{\sum_k q^{ks}\exp\{\mu^k(p^s - p^k - c^{ks} + \varepsilon^k)\}}$$

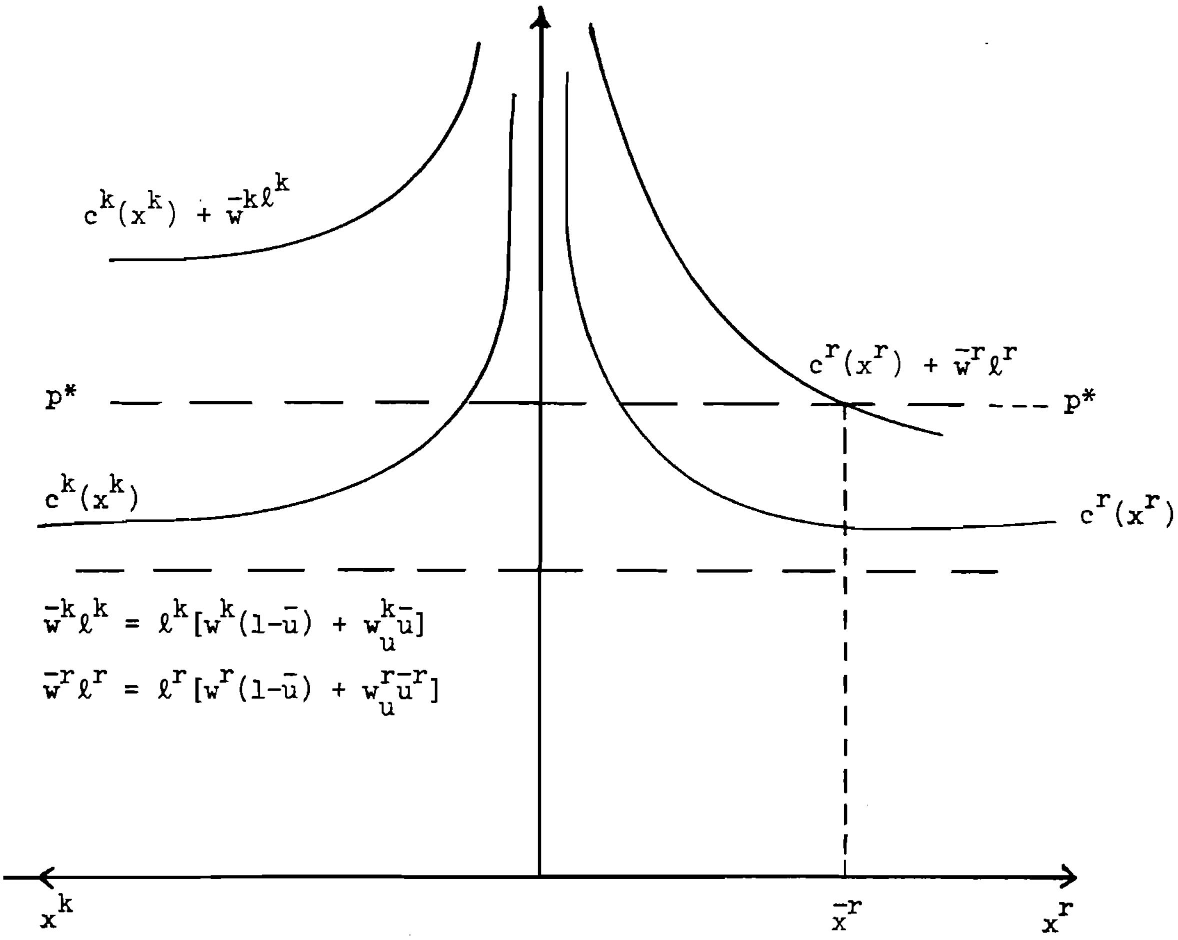


Figure 3.1: Cost levels and price level p^* in two regions r and k.

3.3 Production Scale and Dynamics of Knowledge Intensity

The situation outlined in Figure 3.1, which refers to *Proposition 1*, does not indicate how the relocation of production and changes in specialization may come about. In this section we sketch part of this process by analyzing the change in production scale and in requirements with regard to knowledge intensity.

Consider first the potential market $N^s(p^s, t)$ and its change, and let $p^s(t) = \hat{c}^r + c^{rs}$ for $t < t^o$. If $p^s(t)$ is too high, the market is inactive, and $N^s(p^s(t), t) = 0$. Assume that at time $t > t_0$ p^s has a value such that $N^s(p^s(t), t) > 0$ and $\dot{N}^s \geq 0$. This implies that $d^s(p^s(t), t)$ will grow, and the supplying region r will experience the following demand pull during the interval t and $t + \Delta t$

$$\sum_s \Delta x^{rs} = \sum_s [\Delta\beta^{rs} d^s + \Delta d^s \beta^{rs} + \Delta\beta^{rs} \Delta d^s]$$

where

$$\Delta x^{rs} = x^{rs}(t + \Delta t) - x^{rs}(t), \; \Delta\beta^{rs} = \beta^{rs}(t + \Delta t) - \beta^{rs}(t)$$

and

$$\Delta d^s = d^s(p^s(t + \Delta t) - d^s(p^s(t), t)$$

Since we have assumed that $\Delta d^s \geq 0$, the demand for delivery from r to s is growing if

$$\Delta d^s / (d^s + \Delta d^s) > -\Delta\beta^{rs} / \beta^{rs}$$

which can evidently be satisfied also for $\Delta\beta^{rs} < 0$ as long as Δd^s is large enough.

With growing delivery from r such that the demand is matched, the production is increasing, and the scale of production may also increase in a way which reduces cost of production, and this may finally lower the price p^r and thereby reinforce the demand growth in the different regions.

According to the assumption in (3.6), $\bar{u}$ is gradually reduced during this phase of the cycle. The decrease in $\bar{u}$ is assumed to be a result of the growth of the production. A gradual fall in $\bar{u}$ affects the profit criterion in (3.7). For region k the following situation may emerge

$$p^s - c^{ks} - c^k - \bar{w}^k l^k > \bar{\pi}$$

for certain market links (k,s). However, the change process $d\bar{u}/dt < 0$ takes place over the entire system, that is, it also occurs in region r. Hence, $w_u^k(t) > w_r^r(t)$ still may prevent region k from entering the market. There are essentially two factors which independently or jointly bring about the switch from $x^k(t) = 0$ to $x^k(t+\tau)>0$, given a reduction in $\bar{u}$ during t and $t+\tau$. Those factors are

(i) Region k has better accessibility than r to certain markets s, such that $c^{ks} < c^{rs}$

(ii) Region k has a lower cost level than r with regard to the cost factor $(1-\hat{u})$ so that $w^k l^k (1-\bar{u}) < w^r l^r (1-\hat{u})$.

Let

$$\pi^{is}(\bar{u}) = p^s - c^i - w_u^i \bar{u} l^i - w^i (1-\bar{u}) l^i,$$

denote profit in region i on deliveries to s, and recall that the assumption in (3.6) states that

$$l^r w_u^r < l^k w_u^k$$

and

$$l^r w^r > l^k w^k$$

We can summarize the arguments above in *Proposition 2* and *Remark 2*.

PROPOSITION 2: Let $c^k \equiv c^r$ and $c^{rs} \geq c^{ks}$, and let $\pi^{rs}(\bar{u})-\pi^{ks}(\bar{u}) = \mu>0$. Then given assumption (3.6) there is always a shift from $\bar{u}$ to $\bar{u}-\Delta\bar{u},\Delta\bar{u}>0$, such that $\pi^{rs}(\bar{u}-\Delta\bar{u})-\pi^{ks}(\bar{u}-\Delta\bar{u})<0$.

PROOF: Observe that (i) $(c^{ks}-c^{rs}) \leq 0$ and (ii) $[l^k w^k - l^r w^r] < 0$. Since

$$\pi^{rs}(\bar{u})-\pi^{ks}(\bar{u})=\mu=(c^{ks}-c^{rs})+(1-\bar{u})[l^k w^k-l^r w^r]+\bar{u}[l^k w_u^k-l^r w_u^r]$$

(i) and (ii) imply that

$$\mu < \bar{u}[l^k w_u^k - l^r w_u^r]$$

Evidently there is always a positive $\varepsilon < \bar{u}$ such that for $\Delta\bar{u} = \bar{u}-\varepsilon$ we have (iii)

$$\mu < \Delta\bar{u}[l^k w_u^k - l^r w_u^r]$$

Then we finally note that

$$\pi^{rs}(\bar{u}-\Delta\bar{u})-\pi^{ks}(\bar{u}-\Delta\bar{u}) = \mu+\Delta\bar{u}[l^k w^k-l^r w^r] - \Delta\bar{u}[l^k w_u^k-l^r w_u^r] < 0$$

as a consequence of (ii) and (iii). Q.E.D.

The trade-off between the cost components $l^r w^r(1-\bar{u})$ and $l^r w_u^r \bar{u}$ is regulated by the development of $\bar{u}(t)$. This cost composition is illustrated in Figure 3.2 in which a downward movement of the $\bar{u}/(1-\bar{u})$ line brings about the type of shift described in *Proposition 2*.

Proposition 2 represents a direct continuation of Proposition 1 and is obtained by adding the effect of a falling $\bar{u}$ to the latter. In the following remark we also observe that the structural change in profitability can be related to transportation cost differentials

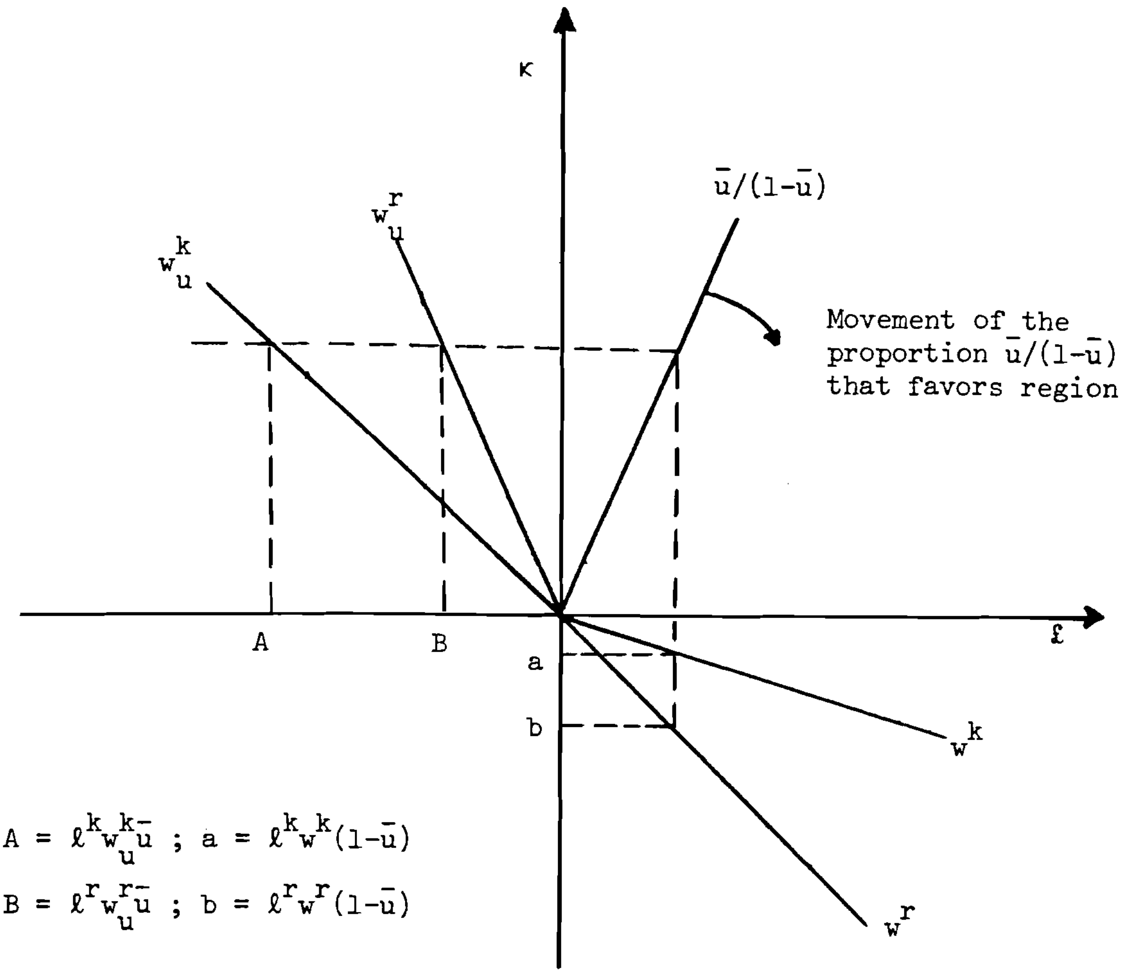
> *REMARK 2*: Let all assumptions in proposition 2 be true with the following exception $c^{rs} > c^{ks}$ and $l^r w^r \geq l^k w^k$ Then the statement in the *Proposition* obviously remains unchanged.

The phenomenon in *Proposition 2* implies that region r is losing markets over time. When this phenomenon involves a growing part of region r's markets, then its industry is growing obsolete.

> *REMARK 3*: Consider a situation such that $\pi^{ks} = \pi^{rs}$, $w_u^r < w_u^k$ and $w^r > w^k$. Suppose that $\bar{u}(t)$ continues to decrease. If production techniques remain fixed except for the fall in $\bar{u}(t)$, region r will gradually be forced out from market s; the only remaining measures for region r to safeguard the established market share with an unchanged product is either protection by means of subsidies and/or introduction of new techniques which reduce c^r and l^r.

The frequently observed bias towards investments in techniques which reduce l^r is usually explained by a change process in which the ratio w^r/w^k is growing. This means that $\bar{w}^r/\bar{w}^k$ also grows.

With imitative behavior between competing regions, a process innovation which reduces c^r and l^r will only have temporary effects. However, a successive change in the product(s) in terms of attributes and quality can bring about new product cycles which make use of the fact that $w_u^r < w_u^k$. This is discussed in the subsequent section.



$A = \ell^k w_u^k \bar{u}$; $a = \ell^k w^k (1-\bar{u})$

$B = \ell^r w_u^r \bar{u}$; $b = \ell^r w^r (1-\bar{u})$

Average labor cost in regions r and k is B+b and A+a, respectively.

Figure 3.2 Knowledge intensity and average labor-related costs.

3.4 Product Development and Knowledge Intensity

In sections 1 and 2 we have emphasized that a product class (or commodity class) is generally not homogeneous, but constitutes a group of heterogenous commodities which are clustered together because of certain fundamental similarities with regard to attributes (or characteristics) of the commodities. Following Lancaster (1971) we shall consider an n-dimensional characteristics space such that the properties of each commodity in a specific commodity group can be described by a point in a characteristics space. Commodity i is then described by a vector $(b_{i1},...,b_{in})$ where $b_{ij} \geq 0$ and at least one $b_{ik} > 0$. We assume that a canonical classification of products is obtained by identifying zeros and non-zeros in the vectors $(b_{i1}, \cdots, b_{in})$.

Assuming that characteristics are measurable we can form functions of the following kind

$$z_j^i(p_i) = b_{ij} / p_i \tag{3.10}$$

where p_i is the price of commodity i and $z_j^i(p_i)$ equals the amount, z_j, of characteristic j obtained by purchasing one unit of commodity i. In order to simplify our analysis we will introduce an *attribute index*, $\hat{z}$, which is obtained with the help of a transformation from vectors $(z_1, \ldots, z_n)$ to a real number $\hat{z}$. The following is an example of such a transformation:

$$z = A\prod_j \omega_j (\alpha_j + z_j)^{\beta j}; \omega_j, \alpha_j, \beta_j > 0 \tag{3.11a}$$

With regard to commodity i the index value becomes

$$\hat{z}(i) = A\prod_j \omega_j (\alpha_j + b_{ij} / p_i)^{\beta j} \tag{3.11b}$$

Consider now a reference index $\hat{z}(*)$ that represents the product class. Let $p(*) = F(x(*))$ be the associated demand relation, where $p(*)$ is the market price of the reference commodity when the sales volume is $x(*)$. We shall assume that customers are willing to pay a higher price than $p(*)$ for commodity i if $\hat{z}(i) > \hat{z}(*)$. We can make such an evaluation by keeping

$$x(*) = \sum_{i \in I} x_i \tag{3.12}$$

where I is the index set for all commodities in the class of which $\hat{z}(*)$ is a reference index. Given this we construct a function f such that

$$p_i = f(\hat{z}(i)F(x(*))$$

denotes the price of i, given that (3.12) is satisfied. With this construction $p_i/p(*) = f(\hat{z}(i))$, and we can interpret $f(\hat{z})$ as the bid-price of attribute-level (or quality level) $\hat{z}$. Such a bid-price function is described in Figure 3.3 which also depicts a cost function showing how production costs, $c(\hat{z})$, are increasing as $\hat{z}$ is augmented.

> *REMARK 4*: An attribute index of the type described in (3.11a) can be interpreted as a preference function defined on characteristics.

In Figure 3.4 we illustrate how the required knowledge intensity, u, increases with the attribute level $\hat{z}$, and how the labor and associated costs, $h(u)$, increases as the required u-level grows. In Figure 3.5, we show how $c(\hat{z})$ is derived from $h(u(\hat{z}))$.

Figure 3.5 illustrates how attribute level and knowledge intensity may be combined, given that we have "neutralized" for other types of

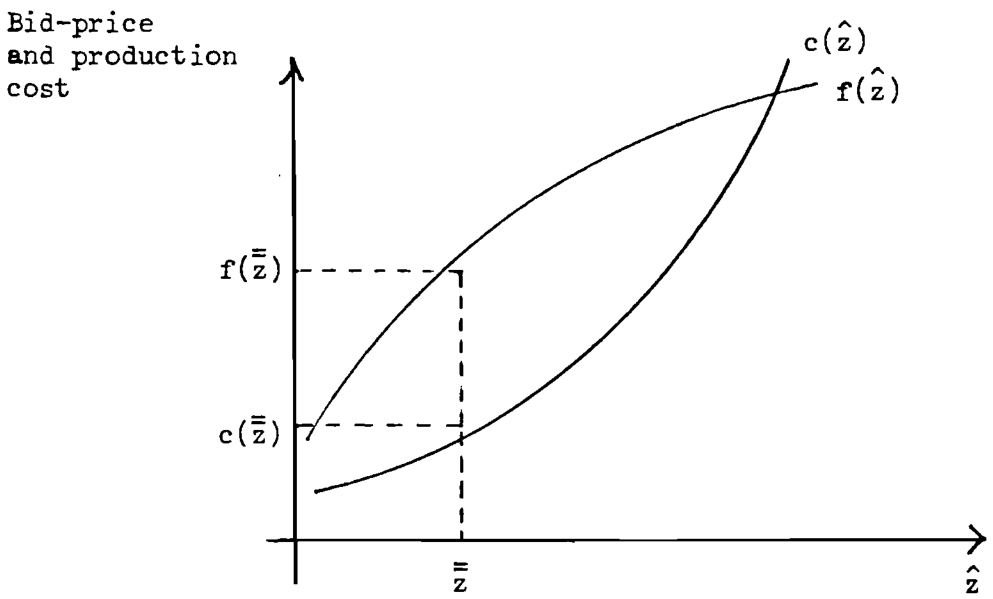


Figure 3.3. Price and costs for alternative attribute levels.

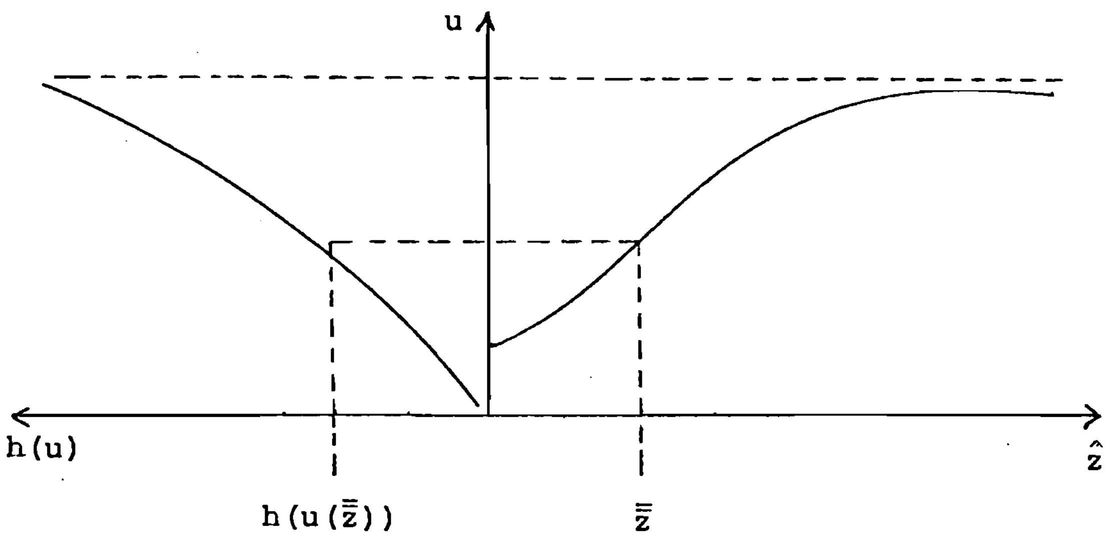


Figure 3.4. Attribute level, knowledge intensity and costs of increasing the knowledge intensity.

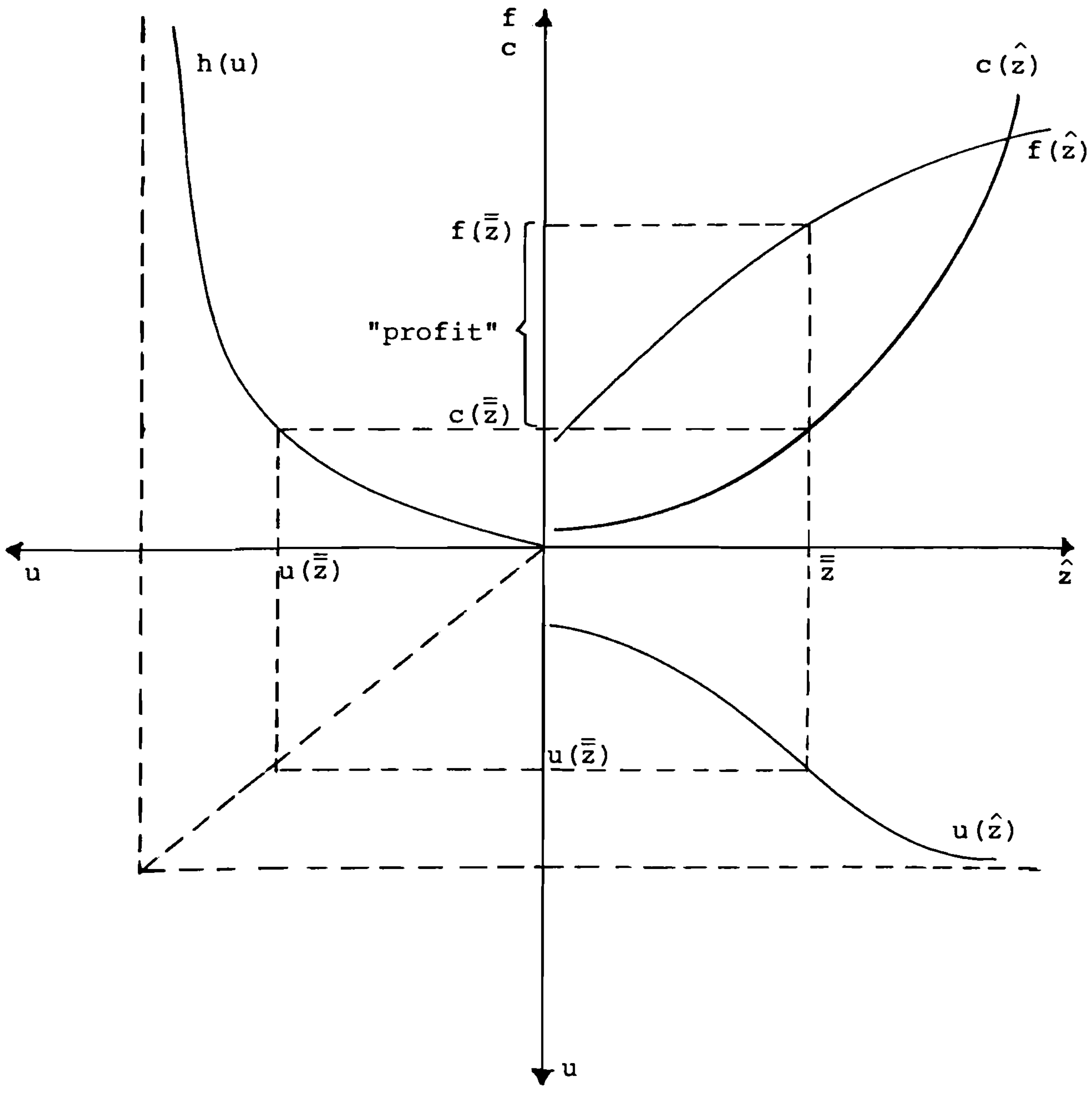


Figure 3.5. Optimal (profit maximizing) combination of attribute level and knowledge intensity.

costs. It also indicates a way of further enriching the analyses in sections 3.1 - 3.3. On the production side regional differences in terms of advantages/disadvantages are represented by differences as regards the $h(u)$- and $u(\hat{z})$- functions. In the product cycle analysis we add that such differences are evolving over time.

Differences between markets are represented by variations in the bid-price function $f(\hat{z})$ between regions. When the whole vector of characteristics is utilized in the analysis, it will also allow an examination of product differentiation which for a given attribute level may divide a market into subsegments related to specific customer groups.

Cost-reducing shifts in $u(\hat{z})$ and $h(u)$ should be related to research and development in combination with a matching education and training of pertinent employment categories.

4. THE SPATIAL ELEMENT IN INDUSTRIAL STRUCTURAL CHANGE PROCESSES

4.1 Empirical Observations on Product Cycles and Patterns of Location

Proper testing of the model proposed is of course not possible at the global level. Some of the trade statistics available do, however, lend themselves to consistency tests of some macro propositions formulated. The most important propositions are:

1) High knowledge intensity in production is an important predictor of specialization in favor of highly developed regions.

2) Change in locational patterns will occur, when the sectoral production technology becomes increasingly well-known.

3) Protection increases both by government controls and increased market organization investments when a sector is maturing technologically.

These hypotheses can be partially tested at the global level on macro sectoral data. Finer tests have to be performed on national, interregional data.

4.2 Product Cycle Phenomena in the OECD-Region

In this section we use the overall description provided by Table 4.1. In accordance with (3.3) we shall use the following indicator, σ_i, as a proxy for specialization in the OECD-region with regard to product group i

$$\sigma_i = m_i / M_i \tag{4.1}$$

where m_i denotes intraregional trade (i.e. import into OECD-countries from other OECD-countries), and where M_i denotes the total import into the countries of the OECD-region. Change in specialization between year t and $t + \tau$ is simply calculated as $\sigma_i(t + \tau) - \sigma_i(t)$. The results in Table 4.1 were obtained with this way of measuring specialization and its change during the period 1971-1977.

During the period 1977-1980 the overall σ-value decreased from 66 to 64 percent. As indicated in table 4.2 a significant restructuring also occurred in this period: (i) *the protection was increased for mining and the production of textiles, and released for clay, glass and other buildings materials as well as for shipbuilding, and other manufacturing*, (ii) *specialization in transport equipment decreased and iron & steel entered*

Table 4.1. Product cycles and specialization in the OECD- region 1971-1977.

	Unchanged or increased Specialization 1971-1977	Decreased Specialization 1971-1977
HIGH SPECIALIZATION	o Paper products o Transport equipment o Machinery o Pulp o Printing o Beverages o Chemical $\bar{\sigma}$(1977) = 0.95 R & D intensity = 6	o Rubber products o Plastic products o Metal products o Iron & steel o Instruments $\bar{\sigma}$(1977) = 0.93 R & D intensity = 5
LOW SPECIALIZATION	o Shipbuilding o Clay & stone o Food products o Other manufacturing o Wood products o Wood o Non-ferrous metals $\bar{\sigma}$(1977) = 0.74 R & D intensity = 2	o Electric products o Textiles o Clothing o Mining o Crude rubber o Telecommunication o Petrol $\bar{\sigma}$(1977) = 0.56 R & D intensity = 3

Remark: R & D intensity = R & D expenditures/value added in Sweden 1980.
Sources: OECD Trade statistics, 1971-1980; SIND, 1982:16.

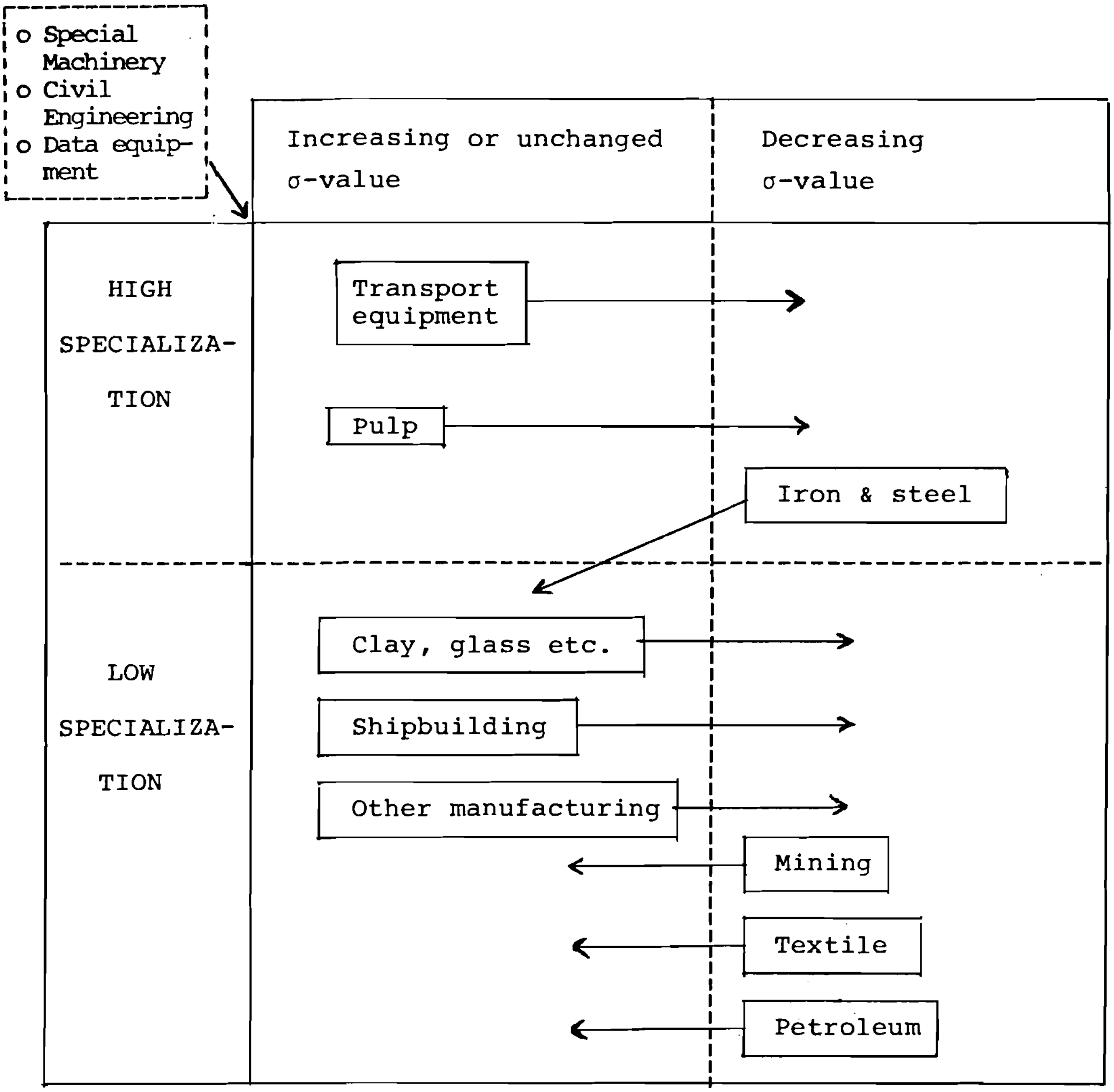
the group of protected sectors.

Other marked changes during the second half of the 70's are:

Rapid increase in the σ-value for special machinery, civil engineering equipment, and data equipment.

We may summarize certain aspects of the time pattern of product cycles with the time profile of Figure 4.1. The first part of the profile describes a standard logistic introduction or market growth curve. Its

Table 4.2. Product Categories with Changing Specialization Classification between 1977 and 1980.



first phase of decline is slowed down by means of political protection measures, and in a second decline phase military defense motivated protection may prevent the production in the country to fall below a politically safeguarded level. Observe also that this whole pattern may be distorted in statistical records when new products enter under an old classification. One may for example contemplate such a revitalization of the commodity group "telecommunication" (see Table 4.1). It is clear from the tables that sectors with a large self-sufficiency is markedly higher in sectors where the knowledge intensity is expanding as measured by the Swedish R & D statistics.

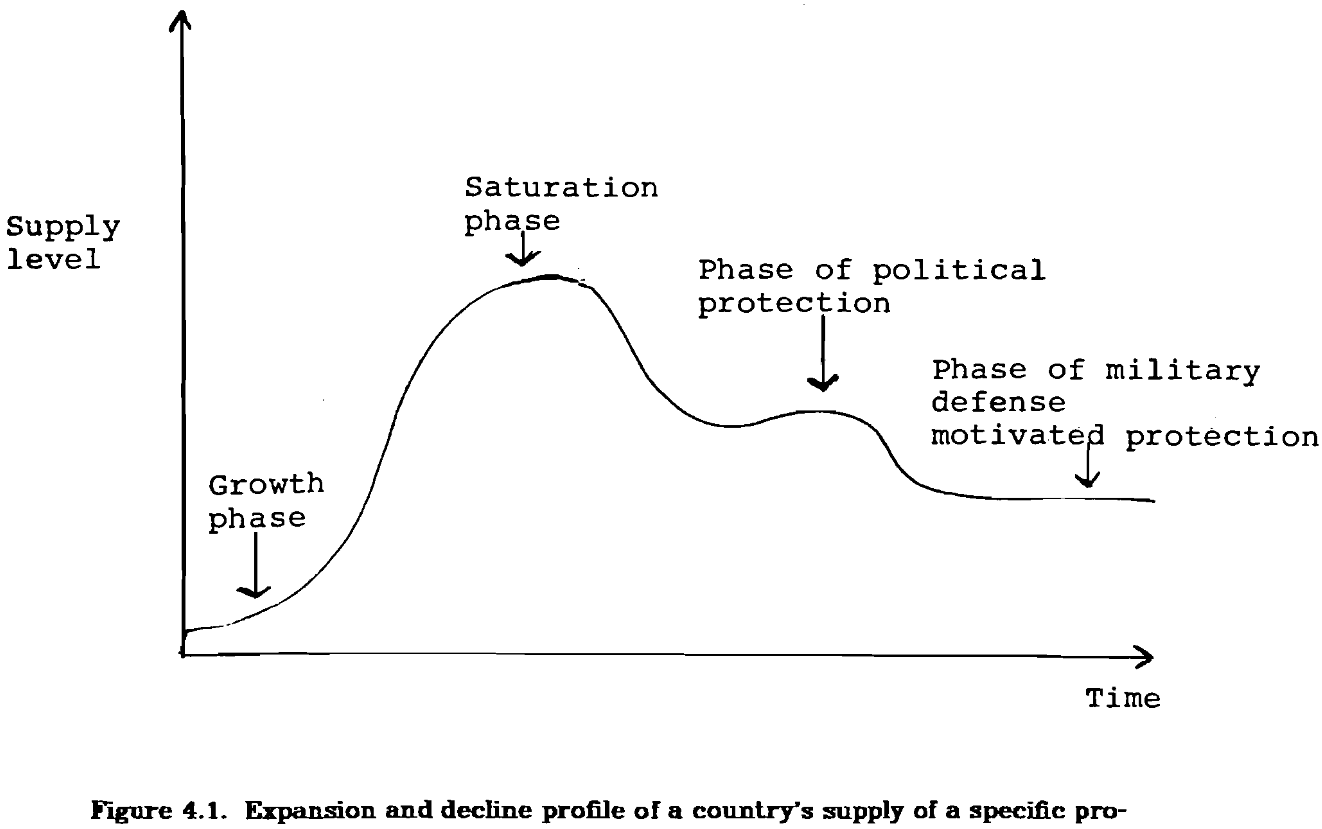


Figure 4.1. Expansion and decline profile of a country's supply of a specific product group.

There is a rather great difference in table 4.2 between the R & D intensity (R & D expenditure in relation to value added) of the OECD high and low specialization sectors of industry.

The tendency to favor market investments in situations of maturing can be tested. The average ratio between market and R & D investment in Sweden was approximately 2 for the OECD high specialization industries, while it was considerably higher, about 4, for the OECD low specialization sectors. This lends some support to the hypothesis that technologicaly maturing change these efforts into investment in new market organization and promotion.

Table 4.3. Maturity of sectors as measured by the ratio of marketing to R & D expenditures.

Sector	Maturity index
Wood products	7
Food	6
Beverages	4
Textiles and apparels	4
Printing products	3
Rubber	3
Plastics	3
Minerals	2
Pulp and paper	2
Metal products	1.5
Mining	1
Iron and steel	1
Chemicals	1
Machinery	1
Electronics	1
Instruments	1
Transport equipment	0.5

Source: SIND 1982:16 (Swedish Industrial Board)

4.3 Accessibility, Land Values, and Birthplaces for New Production

During the last two centuries, there has been a lot of effort devoted to the explanation of patterns of specialization in space. The dynamic theory of comparative advantages -- the theory of product cycles -- is a convenient vehicle for understanding and predicting macro-regional division of labor. However, product development, knowledge intensity and knowledge production (R & D) are all unevenly distributed also within a country and a region. As a consequence, we can observe how new product cycles are initiated with a higher frequency in certain locations than in others. In order to understand the role of local economic environments we must also recognize that at lower levels of spatial resolution, other factors, primarily related to accessibility and availability of land tend to be of greater importance. How this competition in space works can be illustrated by Figure 4.2.

In this figure it is assumed that there is a unique point with a maximum potential accessibility on all the transportation and communication networks. Close to this center of maximum accessibility, economic activities will cluster only if they have a limited need of land per unit of output combined with a large use of transportation and communication services per unit of output. This combination of characteristics is typical of a few human activities such as lecturing, dramatic performances, etc. Very often the advantage of a central location is a reinforced by a low relative scale of demand such that potential customers only add up to a small share of the population (like with the avant-garde forms of performing art). Other human activities like forestry and agriculture are much less dependent upon a good accessibility and relatively much more

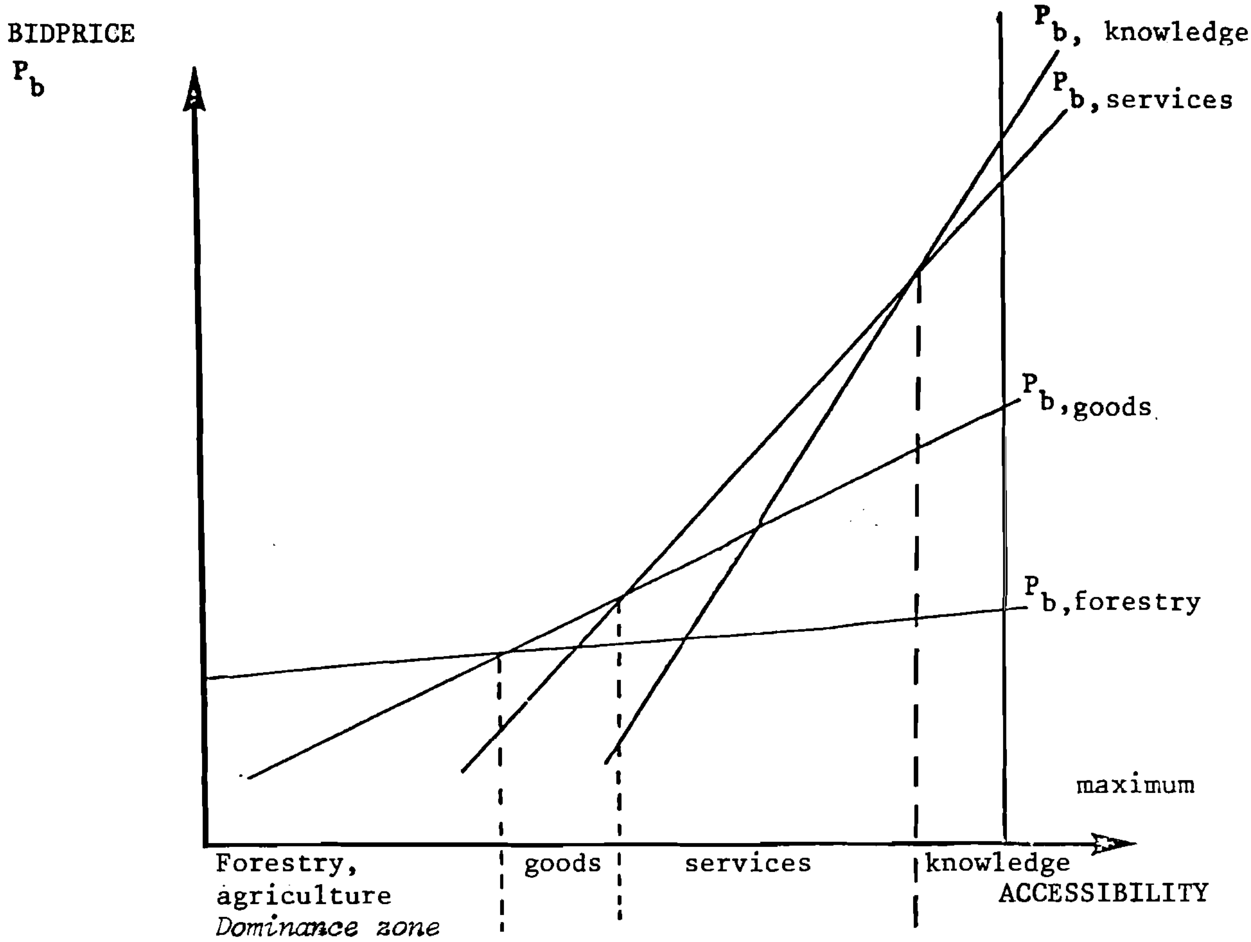


Figure 4.2. The competition for space according to knowledge intensity of production and accessibility in space.

dependent upon land as an input in the production process.

Our discussion of the product cycle as a factor determining specialization and location can also be closely related to the intra-national location patterns. When new products are introduced on the market, it is normally at a very limited scale of the market. It automatically means that the initial marketing of the product can only be successful in the centers of accessibility (with a maximum market coverage). Centers of accessibility are also centers of communication, and often have a rich variety of knowledge-intensive labor supply. Such locations are therefore preferred in the stage of early product development.

Finally, new production must normally be organized in non-routinized and small-scale ways, which prevents the use of production lines and other land consuming technological solutions.

With the diffusion of market demand and as a consequence growth of the total demand level, the parallel diffusion of technology and the development of larger-scale production, the commodities become less dependent on accessibility to a national or international market and more dependent upon large-scale operations outside the centers of communications and information. At this stage the bid price for land becomes less steep, since the accessibility needs are reduced and land intensity is increased. Hence, the competition process will tend to diminish the profit level towards zero in locations with high land values, and the production is decentralized within the country farther and farther away from the its original birthplace, the center of maximal accessibility.

4.4 The Nature of Comparative Knowledge Advantage at the Micro-Regional Scale

We have argued at some length that the introduction of new products requires a high level of accessibility, especially in terms of personal transportation. In order to see this, it might be necessary to introduce a few concepts closely related to technological change and communication.

These concepts are *Information, Knowledge, Competence, and Creativity.* The ordering of these concepts is not random, but represents a ranking.

— *Information (or data)* is the most elementary concept. It has a very limited structure and can consequently be disaggregated and aggregated without losses of understanding. It is the smallest element in the other concepts.

— *Knowledge* is structurally ordered information. As a parable, one can see information as variables, while knowledge is a set of equations containing these variables.

— *Competence* can be seen as knowledge embodied in instruments, social interaction patterns and other social and physical objects. This means that competence is knowledge regulated by the human body in its relations to other human beings, machines and the environment. This implies that competence can be subdivided into at least three specific types:

  - instrument-oriented
  - sector-specific
  - regional specific competence

— *Creativity* is the concept of the highest order. Creativity presumes a capacity to order and re-order information with the aid of a knowledge system. We assume that the creative process is synergetic and this implies that information, knowledge, and competence are brought into an intensive *interaction* with each other in order to shape new knowledge, i.e. new products, new processes, and even new scientific fields.

It is obvious that the communication and computer revolution has meant a very large increase in the efficiency of information collection, processing, and information communication. It is however doubtful if it has had any deep influence on the development of knowledge, competence, and creative processes. It could rather be argued that the further down in this hierarchy of concepts, the less important has telecommunication turned out to be. The social dimension of knowledge and competence communication seems to be extremely strong and gives a very large relative efficiency of face to face communication.

Summing up, it can be assumed that the transportation and telecommunication revolution has primarily had a decentralization effect for *those occupations involved in producing and transporting goods and information, in the sense defined above.* According to this hypothesis, we should expect that persons involved in knowledge, and competence transfers, and in creative activities should have a very strong tendency to cluster in the metropolitan areas and other centers of extremely good accessibility, while information handling, (especially when it is used to control goods processing and transportation activities), should be squeezed out of these areas to regions of lower density and lower short-distance accessibility.

In order to assess the effect of short-distance and long-distance accessibility on the location of different occupations, a simple regression model has been used to illustrate how each employment category's share of total employment is correlated with two proxies of accessibility: (i) accessibility on long distances to all the national markets, denoted by a,

(ii) accessibility on short distances within a region, denoted by b.

$$a_i = \sum_j e^{-\beta d_{ij}} [S_j / \sum_j S_j]$$

b_i = total employment within commuting distance (average distance 45 km) in region i

where

d_{ij} = distance from region i to j

S_{jk} = total employment in region j in occupation k

Employment in occupation k is then regressed against these accessibility measures in an equation

$$S_{ik} = \gamma_0 a_i^{\gamma 1} b_i^{\gamma 2}$$

The following table summarizes the effect of local accessibility (population size within the community region) and national accessibility. The table clearly indicates the clustering intensity of knowledge creation and transmission activity in the large regions, possessing a good intraregional accessibility. It is possible to relate the occupational characteristics to the spatial pattern of division of labor. This is done in the next table which is a summary table based on table 4.4.

The table 4.5 shows a very well-structured pattern. The knowledge creation and transmission occupations are primarily clustered in the group with parameter values indicating a dominance of intraregional access orientation. The services are also accessibility-oriented but to a large extent towards *interregional accessibility*. Goods manufacturing which is space consuming or embodying already matured knowledge is oriented to disperse location with a low population pressure on the land market.

Table 4.4. The effect of intraregional and interregional accessibility on location of occupational categories in Sweden 1975.

Occupational category (type of work)	% share of subcategories with region size elasticity larger than 1	Average size elasticity	% share of subcategories with national accessibility elasticity larger than 0
I			
(s) Military	100	2.09	0
( ) Unidentified	100	1.20	0
(k) Medical	100	1.22	0
(s) Health	90	1.11	0
(k) Technical, scientific (other)	89	1.39	11
(k) Literary and artistic	88	1.37	0
(s) Civil protection	83	1.15	0
(k) Pedagogical	80	1.07	0
(g) Chemical	80	1.18	0
(k) Technical (scientific)	78	1.18	22
(g) Food processing	78	1.18	22
(k) Chemistry and physics	75	1.33	0
(g) Printing	75	1.37	50
(s) Administrative	75	1.17	50
(g) Instrument production	75	1.13	0
II			
(s) Financial and office	73	1.22	45
(s) Transportation and communication	71	1.10	45
(s) Household services	67	1.02	11
(g) Electrical comp. prod.	60	1.13	0
(s) Commercial	58	1.00	33
(g) Textiles, shoe prod.	50	1.00	42
(g) construction	43	0.97	14
(k) Biological	40	0.88	0
(g) Other manufacturing	36	0.88	36
(g) ceramics, glass, etc.	33	0.96	50
(s) Machinery prod.	30	0.87	43
(s) Religious	33	0.77	0
III			
(g) Machinists	14	0.81	0
(g) Painters	0	0.96	100
(s) Housing supervision	0	0.88	0
(g) Misc. blue collar	0	0.86	0
(g) Agriculture, forestry, etc.	21	0.40	26
(g) Mining	0	0.40	0
(g) Iron and metal prod.	0	0.83	75

s = service; k = knowledge creation or transmission; g = manufacturing of goods. *Source*: Regression based on computer tapes of the Swedish censuses 1975.

Table 4.5. Location and occupational characteristics.

Orientation \ Sectors	Knowledge	Services	Goods Manufacturing	
I (Intraregional access oriented	6	4	4	14
II (Interregional access oriented)	1	5	6	12
III (Dispersed and land oriented)	0	1	7	8
	7	10	17	34

$\chi^2 = 11$

It is clear from the preceding analysis that the development of new ideas and the transmission of knowledge has a connection with the early stages of the product cycle. It is also clear that the development of new knowledge and its transmission is primarily concentrated in centers of good intraregional accessibility. These centers, of which Stanford, Princeton, Ann Arbor and similar cities are prime examples, do not necessarily have to be centers of interregional accessibility. Some good manufacturing, in our case food processing, printing, instrument production and chemical processing, are clustered also in their manufacturing parts onto the knowledge centers. This is completely in accordance with our general analysis of the product cycle in space.

4.5. On the Importance of Regional Specialization and the Availability of Knowledge for the Locational Pattern.

Our general conclusion from the first study of the effect of accessibility on the location of economic activities, it was considered necessary to also study if R & D activity concentration has specific effect on the location of knowledge intensive activities. The estimated relationship involves the following variables.

Z_i^r = employment of type i in region r as a share of total employment of type i in the country

X_i^r = employment of type i in region r as a share of total employment in region r. Hence, $\sum_i X_i^r = 1$

A^r = measure of regional and national accessibility

B^r = dummy variable indicating the existence of university level R & D activities above a certain minimum level.

For each employment category i, the following equation was estimated

$$y_i^r = \log\,(Z_i^r / (1 - Z_i^r)) = A^r + \gamma X_i^r + \beta B^r \tag{4.2}$$

Introducing the standard deviation measures σ_i^y of y, σ_i^x of X_i and σ^b of B, the following kinds of μ_i- coefficients were calculated

$$\begin{aligned} \mu_i^x &= \gamma \sigma_i^x / \sigma_i^y \\ \mu_i^b &= \beta \sigma^b / \sigma_i^y \end{aligned} \tag{4.3}$$

It is obvious from the table that those knowledge-oriented sectors which are most strongly clustered onto the university towns also tend to be in specialized regions. Thus chemistry and physics science occupations tend to be strongly associated with centers of research and development as well as having a tendency to cluster in some of these universities regions. On the other hand, the table also indicates that regional specialization of knowledge intensive activities can act as a substitute for location to the R & D centers, i.e., to the universities towns.

Table 4.6. Employment with high specialization and R & D Dependency.

	Specialization Effect: μ^x-coefficient	R & D-effect μ^b-coefficient
Aggregate occupation categories:		
Special technical and natural science occup.	0.73	0.11
Literature, art	0.70	0.0
Administration	0.69	0.27
Juridical professions	0.67	0.0
Accounting, etc.	0.66	0.30
Biological science occup.	0.64	0.29
Technical science occup.	0.58	0.43
Commercial science occup.	0.57	0.36
Chemistry and physics science occup.	0.51	0.35
Religious occup.	0.47	0.46
Medical science occup.	0.46	0.44
Education	0.26	0.55

Source: FOB 1970 and 1975, SCB. Remark: The μ-coefficients in this table represent median values of the subcategory coefficients for aggregate categories. Those coefficients are usually significant at the 0.05 level.

5. DYNAMICS OF PRODUCTION UNITS AND LABOR PRODUCTIVITY

5.1 Productivity Distributions and Time Invariances with Illustrations from the Forest Sector in Sweden

In Section 5 we recognize that sectors are non-homogenous and present an approach to understanding industrial dynamics at the level of production units or establishments. The change process will be described as a gradual change of the distribution of production capacity and employment over production techniques. Since the focus is on employment problems we shall pay special attention to the distribution of labor productivity of the labor force in a sector.

We start by observing that production techniques in a broad sense are more or less rigidly embodied in durable resources and variables such as:

(i) Buildings and constructions

(ii) Machinery equipment

(iii) Production and marketing knowledge and skills of the labor force

(iv) Quality of output and product mix

(v) Distribution techniques and established market channels

With a few exceptions, durables of this kind have a fixed location and they change over time by means of investment and removal (scrapping, shut-down, etc.). Since investment in existing and new production units is a slow process, many characteristics of a sector consisting of such units is changing at a low pace. This is in particular true for the labor productivity distribution in a sector. First let μ denote labor productivity (value added at fixed prices per persons employed in an establishment). Then we define

$$\rho_i = \rho_i(\bar{\mu},t)$$
$$0 \le \rho_i \le 1 \tag{5.1}$$

as the share of total employment in sector i which works in units with a productivity $\mu \ge \bar{\mu}$. For a very fine classification of the Swedish industry into sectors it has been possible to approximate this distribution with a function of the following logistic form:

$$\rho_i(\bar{\mu},t) = [1+ \exp\{-A(\bar{\mu},t)\}]^{-1}$$
$$A(\bar{\mu},t) = a_0+a_1\bar{\mu}+a_2 t \tag{5.2}$$

where t denotes time, where $a_0>0$, $a_1<0$, and where $a_2>0$ when the average productivity is growing over time. Figure 5.1 describes the direct observations that correspond to $\rho_1(\bar{\mu},t)$ for two different sectors in two distinct years 1968 and 1978. It is easy to see that the structure of the productivity adhering to each sector is largely time invariant. This may also be verified by statistical analysis. The function in (5.2) represents a combined time series and cross section estimate. A good statistical fit is reported in Johansson & Marksjö (1983) which indicates a strong structural invariance over time.

The productivity curves illustrate the heterogeneity of sectors. The productivity differs because of variations in production technique, type of commodities produced, etc. The slope of the curve indicates the speed of introducing new products and techniques, and of removing obsolete production. The difference in level between the two curves in Figure 5.2 reflect that the wood products industry has a low capital coefficient while

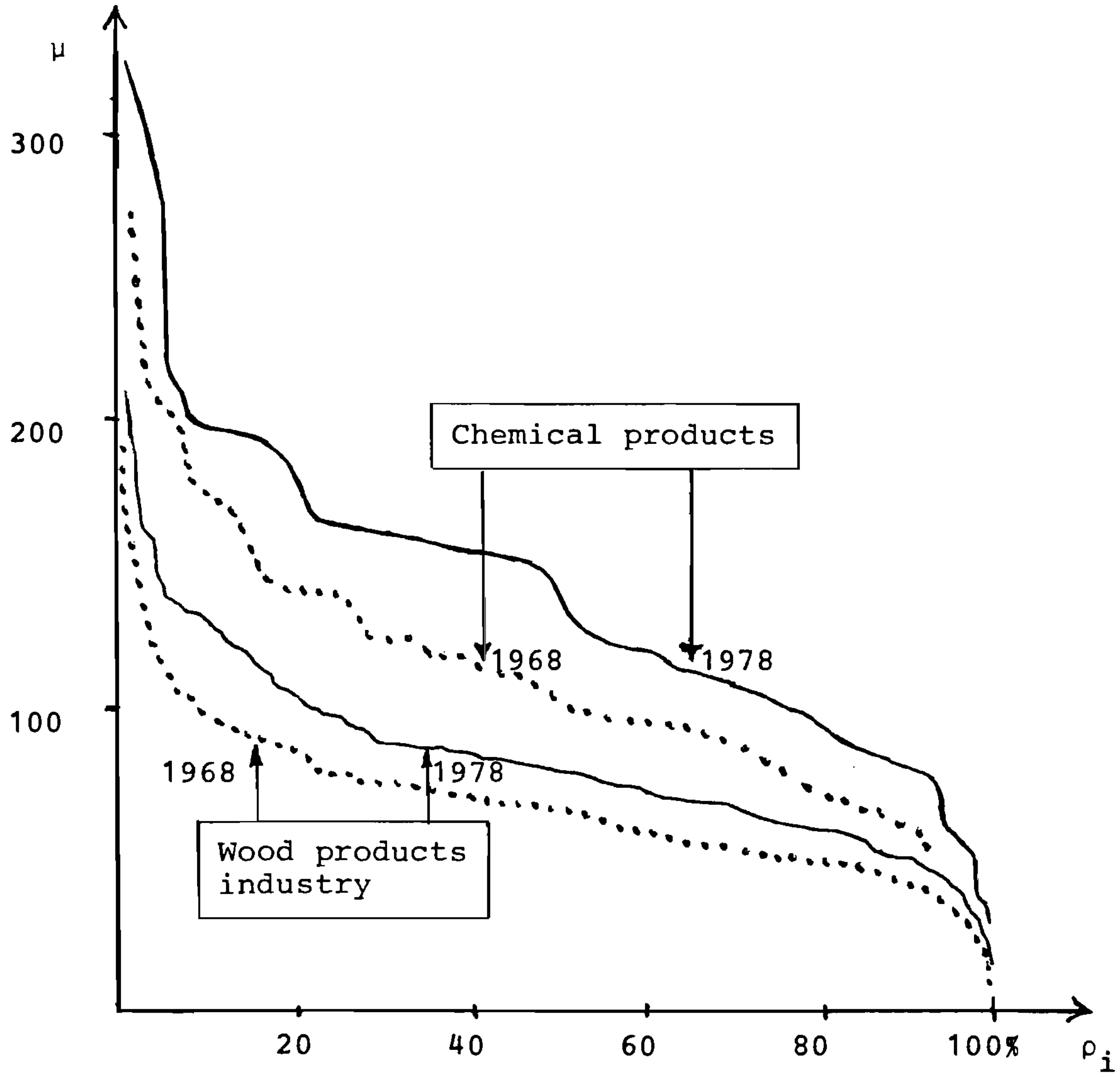


Figure 5.1. Labor productivity curves in Sweden's wood products and chemical products industries 1968 and 1978.

the paper and pulp sector has a high one.

If we integrate over the domain of non-negative productivities we obtain the value added V_i, in the sector

$$V_i = S_i \int_0^{\infty} \mu \rho_i'(\mu) d\mu; \quad \rho_i'(\mu) = d\rho_i / d\mu \tag{5.3}$$

where S_i is the total number of persons employed in the sector. Moreover, observing that there is a wage level $\omega_i(\rho_i)$ for each point $\rho_i \in [0,1]$,

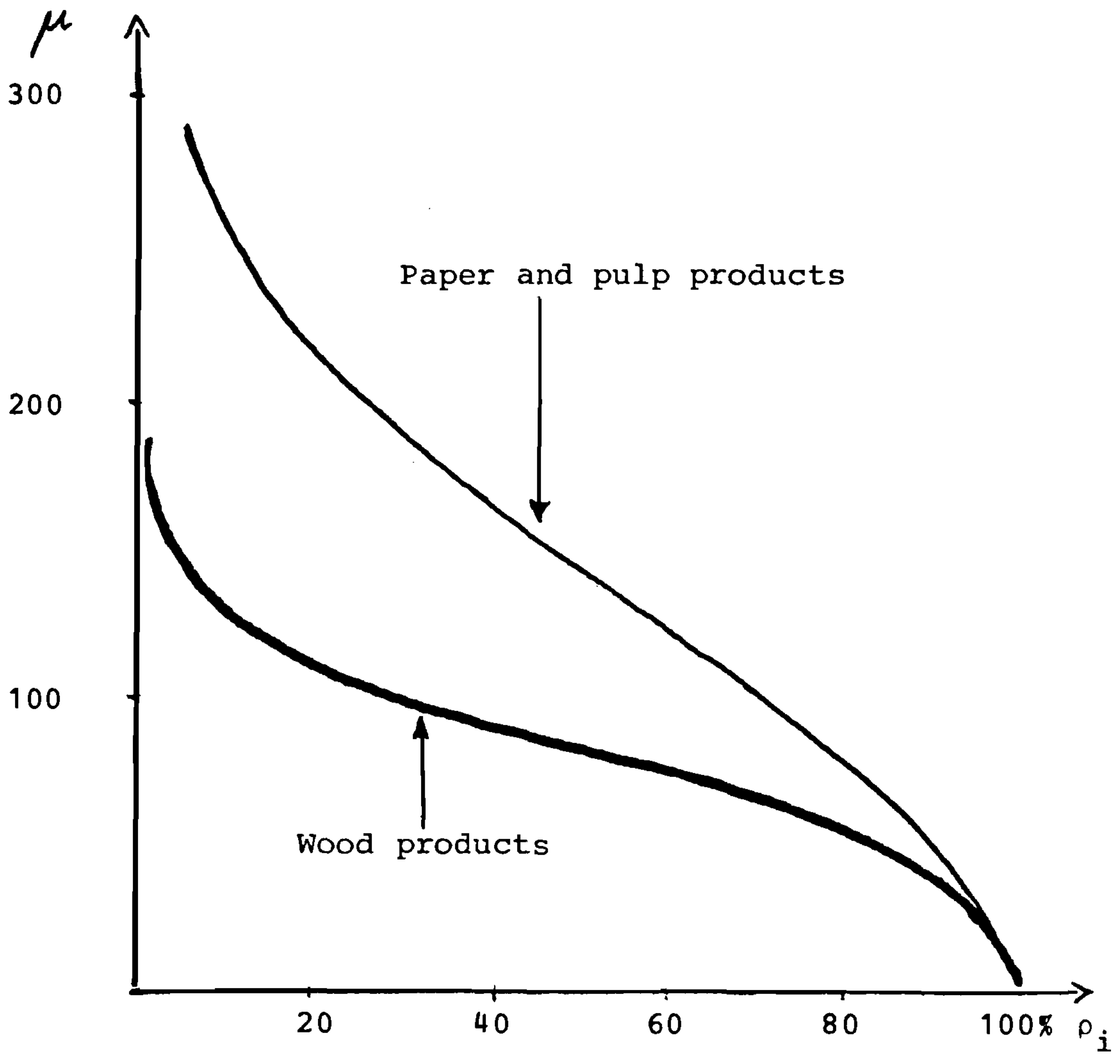


Figure 5.2. Continuous productivity curves. Sweden 1978.

and that $\rho_i = \rho_i(\mu)$, we can determine the wage level (labor costs) $\omega_i = \omega_i(\mu)$ that is associated with each μ- value. This gives the gross profit P_i in the sector

$$P_i = S_i \int_0^{\infty} (\mu - \omega_i(u))\rho_i'(\mu) d\mu \qquad (5.4)$$

With our earlier distinction between knowledge-intensive and normal employment we can for each productivity segment M_i also calculate for

w_{iu} and w_i constant over μ,

$$P_i(\mu) = S_i \int_{u \in M_i} u(\mu)[\mu - w_{iu}]\rho_i'(\mu)d\mu$$

$$P_i(1-u) = S_i \int_{\mu \in M_i} [1-u(\mu)][\mu - w_i]\rho_i'(\mu)d\mu \qquad (5.5)$$

5.2 Dynamics of Exit, Entry and Productivity

From equation (5.2), we may derive the change in the productivity distribution over time as*

$$\dot{\rho} = -\frac{\rho(t)a_2(\mu)G(\mu,t)}{1+G(\mu,t)} \qquad (5.6)$$

where $G(\mu,t) = \exp\{-a_0 - a_1\mu - a_2(\mu)t\}$, and where the coefficient $a_2(\mu)$ is defined as a function of the productivity level itself. For a process where all investment is directed towards best practice techniques with high productivity and where shutdown occurs in low productivity units the coefficient $a_2(\mu)$ will be increasing in μ.

Formula (5.6) gives a compressed version of the changing distribution. More concretely, the productivity structure changes because of two fundamental processes: (i) the exit of production capacities, and (ii) the entry of new production capacity. Entry has two forms: (i) new capacity may be installed in existing units, and (ii) new units may be created. Exit occurs in a similar way: (i) old or obsolete capacity is removed from existing units (eventually replaced by new), and (ii) certain units are closed down.

* Observe that $a_2(\mu) < 0$.

We can now make use of the fact that the productivity distribution changes slowly over time, which means that we can study the process over a sequence of discrete time intervals. First we divide the interval [0,1] into subintervals $\rho^1, \ldots, \rho^k, \ldots,$ such that

$$\sum_k \rho^k = 1$$
$$S_i^k(t) = \rho^k S_i(t) \tag{5.7}$$

where $S_i^k(t)$ is the employment in the group of production units which have the average productivity μ_i^k such that

$$\mu_i^k = \int_{\mu \in M_k(t)} \mu \rho'(\mu) d\mu \tag{5.8}$$

where $M_k(t)$ is the productivity interval corresponding to ρ^k. Now let $\bar{x}_i^k(t)$ be the production capacity for the group k. Then the value added in class k can be calculated as

$$\mu_i^k(t) S_i^k(t) = v_i^k(t) \bar{x}_i^k(t) = V_i^k(t) \tag{5.9}$$

where $v_i^k(t)$ is a value added price index.

Consider now a time interval $\Delta \geq 0$ with a length such that during Δ the productivity distribution changes only slightly. Let $\Psi_i^k(t)$ be the rate of gross capacity increase and let $\xi_i^k(t)$ be the rate of capacity removal. Then we can define

$$[\tilde{\Psi}_i^k(t) - \tilde{\xi}_i^k(t)] \bar{x}^k(t) = \int_t^{t+\Delta} [\Psi_i^k(\tau) - \xi_i^k(\tau)] \bar{x}_i^k(\tau) d\tau \tag{5.10}$$

which gives $\Delta \bar{\bar{x}}^k(t+\Delta) = \tilde{\Psi}_i^k(t) \; \bar{x}^k(t)$ as the gross capacity change and $\Delta \bar{\bar{x}}_i^k(t+\Delta) - \tilde{\xi}_i^k(t) \bar{x}_i^k(t) = \Delta \bar{x}_i^k(t+\Delta)$ as the net capacity change during the interval Δ.

Assume now that a productivity level $\mu_i^*(t)$ is associated with any gross capacity increase (investment). Then we can calculate the new employment level $S_i^k(t+\Delta)$ in production group k as follows:

$$S_i^k(t+\Delta) = \frac{\Delta\bar{\bar{x}}_i^k(t+\Delta)v_i^k(t+\Delta)}{\mu_i^*(t)} + \frac{\bar{x}_i^k(t)(1-\tilde{\xi}_i^k(t))v_i^k(t+\Delta)}{\mu_i^k(t)} \qquad (5.11)$$

The following statement follows directly from (5.11)

PROPOSITION 3: The number of persons employed in group k will remain unchanged or increase if and only if

$$\Delta\bar{\bar{x}}_i^k(t+\Delta) \geq \tilde{\xi}_i^k(t)\bar{x}_i^k(t)(\mu_i^*(t)/\mu_i^k(t))$$

To see this we can write

$$S_i^k(t+\Delta) = \mu^*\Delta\bar{\bar{x}}^k(t+\Delta)+\mu^k(t)\bar{x}^k(t)(1-\tilde{\xi}_i^k(t))$$

and

$$S_i^k(t) = \mu^k(t)\bar{x}^k(t)$$

which yields

$$S_i^k(t+\Delta)-S_i^k(t) = \mu^*\Delta\bar{\bar{x}}^k(t+\Delta)-\mu^k(t)\bar{x}^k(t)\tilde{\xi}_i^k$$

The conclusion follows directly from this. Hence, when available new techniques are associated with a ratio $\mu_i^*(t)/\mu_i^k(t)$ which is large, the gross capacity increase must also be large. It is not sufficient that there is a net growth in capacity.

A basic element in the product cycle dynamics outlined in earlier sections is the economic obsolescence of production units or capacities in establishments which have been introduced at an earlier stage of the development and apply a production technique that is inferior to more recent ones. The removal of such capacities is represented by the exit factor ξ_i^k. A frequent assumption is that exit occurs when the profit ceases to be positive, i.e., when $\pi_i^k < 0$.

Observations of individual industrial establishments show that the exit process is more smooth. Also at positive profits there is a small probability of exit which increases as the profit is reduced. For the Swedish industry the following type of exit function has been estimated

$$\xi_i(\mu,\omega_i) = \alpha_i \exp\{\beta_i \omega_i / \mu\} \tag{5.12}$$

where $\omega_i / \mu_i^k = \omega_i S_i^k / v_i^k x_i^k$ denotes the wage share. When ω_i / μ_i is low the likelihood of exit is low and increases exponentially as ω_i / μ_i becomes larger, i.e., when the profit share π_i / v_i is reduced and becomes negative. Profits and wage share have the following obvious relation

$$\pi_i^k = v_i^k - \omega_i S_i^k / x_i^k$$
$$\pi_i^k / v_i^k = 1 - \omega_i S_i^k / v_i^k x_i^k = 1 - \omega_i / \mu_i^k$$

According to (5.10) the total entry of new gross capacity is $\Delta\bar{\bar{x}}_i(t+\Delta) = \sum\tilde{\Psi}_i^k(t)\bar{x}^k(t)$. The distribution of new capacities over various classes, is represented by the value of each $\tilde{\Psi}_i^k(t)$- factor. Introducing an investment criterion which compares the expected present value of profits of an investment with the investment costs will make $\tilde{\Psi}_i^k(t)$ a function of expected prices and demand level. In general, too rapid growth of investment (increase of supply capacity) will reduce both current and expected prices which will increase the rate of exit and decrease the subsequent rate of entry. This self-regulating mechanisms (which should work reciprocally when investments are two low) has two components: (i) reduced current prices augments the exit rate, (ii) reduced expected priced lowers the expected present value of future profits.

5.3 Average and Best Practice Productivity Change

Consider the general information for change in the distribution $\rho_i(\mu)$ as expressed by (5.6). Focusing on the introduction of new technology we are interested in whether there is a significant difference between $d\mu(\rho)/dt$ for small and large ρ's, where small ρ's are associated with high productivity levels. This problem may be illustrated by studying the first segment of $\rho_i(\mu)=\rho_i^1=0.25$. This corresponds to the best practice segment in Figure 5.3. We may then compare $d\mu(\rho^1)/dt$ with the average change $d\bar{\mu}/dt=-a_2/a_1$ from (5.2), since that formula yields

$$ln(\rho_i(\mu)/(1-\rho_i(\mu)) = a_0+a_1\mu+a_2t \qquad (5.13)$$

Table 5.1 gives a comparison of the annual increase in best practice and average productivity. In general we would expect a situation with a stagnating demand together with a labor saving policy to yield a lower ratio between the best practice change $\Delta\mu^1$ and the average change $\Delta\bar{\mu}$ than in other cases. During the 1970's in Sweden this ratio was especially low for rubber products, the chemical industry, food industry, mining, and iron and steel industry. Except chemistry, these industries either have a low specialization or have a falling specialization in OECD. However, we shall also observe that a rapid shutdown of obsolete production units gives rise to a fast increase in productivity on the right-hand side of the productivity curve. This type of change quickly translates higher levels of the curve towards the right.

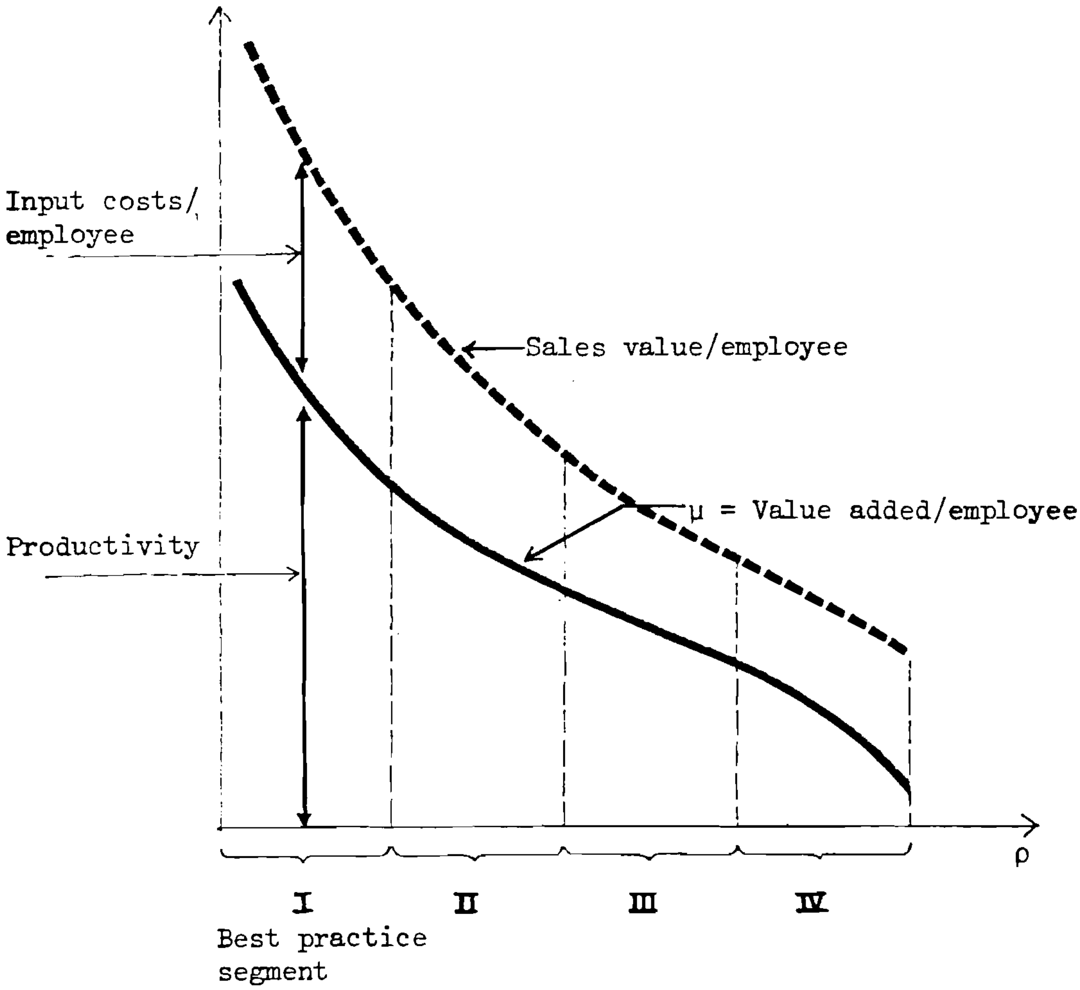


Figure 5.3 Productivity.

As a further exercise we shall compare $\Delta\mu^1/\mu^1$ in the metropolitan region of Stockholm with the same change in Sweden as a whole. This comparison is made in Table 5.2.

From Table 5.3 we can also see that the average the reduction of employment has been larger in sectors with a low OECD specialization than in other sectors. At the same time there has been a strong tendency in Stockholm to increase the best practice productivity at a fast rate in sectors with a low degree of specialization in the OECD region.

Table 5.1 Average and best practice productivity change per year. Sweden 1968-1978.

	Average annual productivity change in productivity in percent		
	Best practice segment (%)	Average for the industry (%)	Index for average productivity level %
Transport equipment	4.9	2.2	128
Textile and clothing	4.3	3.1	70
Wood products	3.9	1.1	87
Paper and pulp	3.4	0.0	155
Other manufacturing	3.3	0.5	75
Electrical products	3.2	3.4	104
Printing and publishing	2.6	1.4	114
Food industry	2.1	3.0	110
Plastic products	2.1	1.6	102
Machinery equipment	2.0	1.2	92
Metal products	1.6	0.9	92
Rubber products	0.2	3.4	87
Instruments	0.1	-0.1	88
Chemistry	0.0	1.4	155
Mining	-1.8	0.3	122
Iron and steel	-2.4	-1.4	91

Remark: Average productivity level in the whole manufacturing industry is set to 100.

Source: The SIND-information system (Swedish National Board for Industry).

Table 5.2 Best practice productivity change in Stockholm metropolitan region 1968-1978.

	Annual value in percent of $\Delta\mu^1/\mu^1$ in Stockholm, Sweden		Average productivity in Stockholm divided by average productivity in Sweden.
	Stockholm	Sweden	Percent
Clay and stone	21.1	2.4	130
Printing & publishing	3.1	2.6	122
Machinery	5.2	2.0	119
Metal products	- 3.9	1.6	114
Instruments	1.3	0.0	111
Plastic products	- 1.3	2.1	109
Electrical products	10.0	3.2	107
Other manufacturing	- 5.6	3.3	94
Wood products	- 1.5	3.9	89
Food products	6.5	2.1	86
Rubber products	4.6	0.2	85
Chemical products	0.7	0.0	79
Textile and clothing	6.0	4.3	76
Iron and steel	8.7	-2.4	47

Source: B. Johansson (1982).

Table 5.3 Employment change 1975-1980 and best practice productivity change 1968-1978 in the Stockholm region.

HIGH SPECIALIZATION IN THE OECD REGION 1980	$\frac{\Delta S}{S}$ %	$\frac{\Delta \mu^1}{\mu^1}$ %	LOW SPECIALIZATION IN THE OECD REGION 1980	$\frac{\Delta S}{S}$ %	$\frac{\Delta \mu^1}{\mu}$ %
Rubber & plastic	-30	-	Iron & steel	-45	+ 8.7
Metal products	-26	-3.9	Wood products	-39	- 1.5
Paper and pulp	-17	-	Textil & clothing	-30	+ 6.0
Instruments	-15	+1.3	Mining	-30	-
Machinery	-12	+5.2	Clay and stone	-22	+21.1
Transport equipm.	- 3	-	Electric	-18	+10.0
Printing & publish.	+ 4	+3.1	Food & beverages	- 7	+ 6.5
Chemical	+ 8	+0.7			

Source: B. Johansson (1982).

Remark: $\Delta S/S$ = Total change in employment between 1975 and 1980 in percent

$\Delta\mu^1/\mu^1$ = Annual best practice productivity change between 1968 and 1978 in percent.

6. INDUSTRIAL SCENARIOS AND THE PRODUCT CYCLES

6.1 From World Trade to Regional Labor Markets

Section 6 illustrates how the framework outlined in previous sections was utilized to generate scenarios for the Swedish industry in the '80s.* A fundamental input to these scenarios was a multiregional data base containing distributions of the type described in (5.1) as regads wage levels, value added and sales value per person employed in establishments ordered as described in Figure 5.1 Among other things the study was used to assess for each scenario regional labor market policies compatible with the scenario.

Figure 6.1 illustrates the systems analytical framework which was used to evaluate feasible combinations of national sectoral growth, capital formation and labor market conditions. The steps in the analysis may be classified in the following top-down, hierarchical order. A national multisectoral growth model is used to generate alternative economic development paths contingent on a separate analysis of export and import conditions. The outputs from the national model comprise production and employment levels in sectors and investment levels for individual sectors and for the economy as a whole. This constitutes information for a multiregional, multitechnology programming model which generates regional sectoral productivity, employment and investment development. Such solutions put requirements on employment restructuring, which we can interpret as interregional, intersectoral and intra

* This scenario analysis is described in detail by Karlqvist & Strömqvist (1982).

industry employment mobility. As depicted in the figure, feasibility is obtained iteratively by adjusting labor market policies so as to allow for a feasible multiregional allocation which is compatible with national scenarios. In concrete terms such labor market policies consist of job training to make intra- and intersectoral transitions possible and financial support to facilitate labor force migration. They may also refer to employment subsidies directed towards specific regions and sectors.

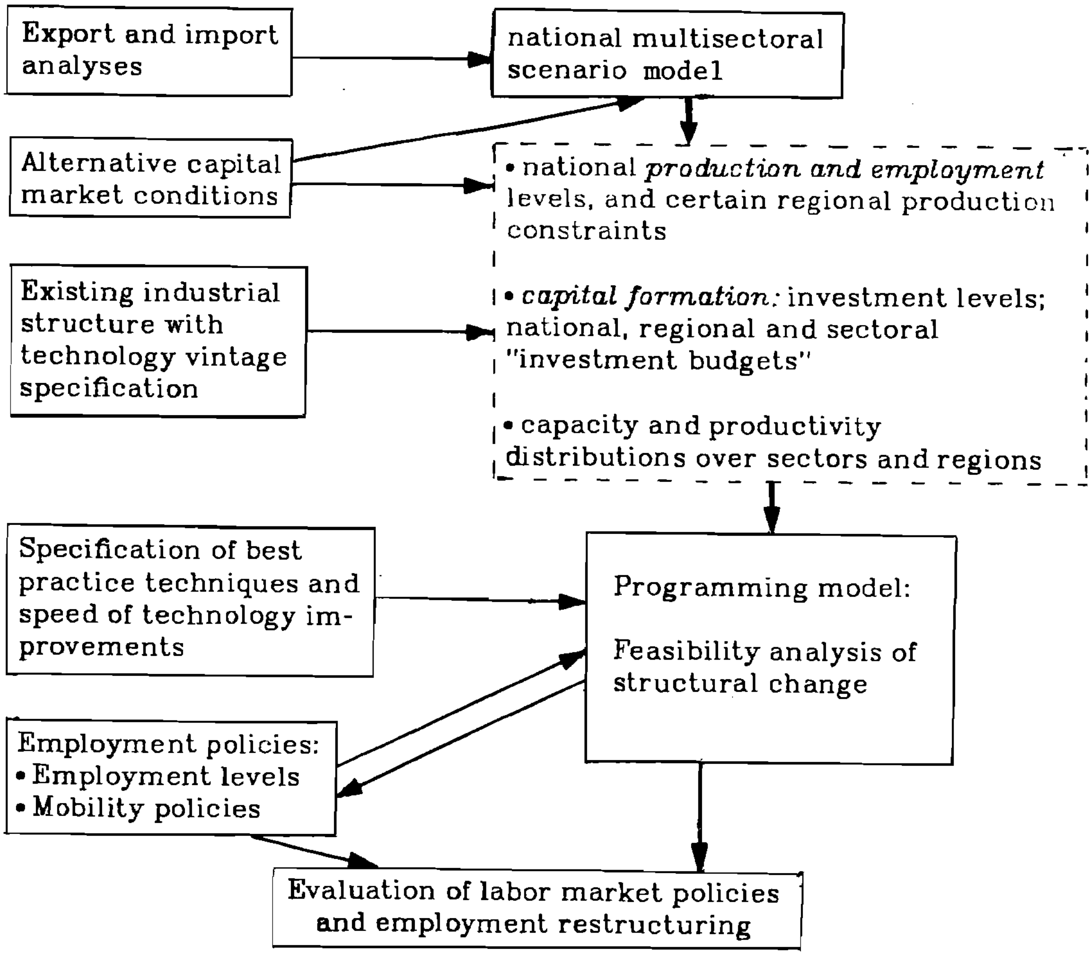


Figure 6.1 Systems analysis of industrial scenarios and labor market policies.

An important element in the model system is information for each region about sectoral distributions of the type described in (5.1) - (5.4) with regard to value added, gross output, profit and wages. This information has a discrete form as described in 5.7. Hence, in every region each sector is divided into technique or vintage classes k, each with an employment number S^k and a specification of productivity μ^k, gross output $x^k = \mu^k S^k / v^k$, wage level w^k and profit level π^k.

Another source of information is estimated trends describing how the productivity distribution changes in various segments as specified in (5.6) and illustrated in Figure 5.3. With this information one may calculate the productivity of best practice techniques introduced by means of capacity investments.

6.2 Outline of the Programming Model

Let k, j and r denote technique (vintage) class, sector and region, respectively. The new best practice technique class is denoted by $k=0$. Technical parameters are denoted as follows

$$\begin{aligned}
\mu_{jr}^k &= \text{productivity (value added per man years)} \\
k_{jr} &= \text{investment per unit labor in new capacity} \qquad (6.1) \\
q_{jr}^k &= \text{gross output per unit labor; } q_{jr}^k = p_j x_{jr}^k \text{ where } p_j \text{ is sector price} \\
\bar{S}_{jr}^k &= \text{employment corresponding to full capacity}
\end{aligned}$$

Some of the policy variables are generate as outputs from the national model. The policy variables are denoted as follows:

S^*, S_j^*, S_r^* = employment targets on national, sectoral and regional level

I^*, I_j^*, I_r^* = investment budgets available (6.2)

Q^*, Q_j^*, Q_r^* = gross output targets

S_{jr}^o = constraint on employment in new capacity by sector and region

The model solves for employment distributions $\{S_{jr}^k\}$ and generates simultaneously price information (shadow prices). The results presented in subsequent sections were obtained by the following version of the programming model which generates an allocation in a future time period:*

$$\text{maximize} \sum_j \sum_r \sum_k \mu_{jr}^k S_{jr}^k \tag{6.3}$$

subject to

$$\begin{aligned} \underline{S}^* &\le \textstyle\sum_j \sum_r \sum_k S_{jr}^k \le \bar{S}^* \\ \underline{S}^* &\le \textstyle\sum_r \sum_k S_{jr}^k \le \bar{S}_j^* \\ \underline{S}_r^* &\le \textstyle\sum_j \sum_k S_{jr}^k \le \bar{S}_r^* \end{aligned} \tag{6.4}$$

$$\begin{aligned} \textstyle\sum_j \sum_r k_{jr} S_{jr}^o &\le I^* \\ \textstyle\sum_r k_{jr} S_{jr}^o &\le I_j^* \\ \textstyle\sum_j k_{jr} S_{jr}^o &\le I_r^* \end{aligned} \tag{6.5}$$

$$\begin{aligned} \underline{Q}^* &\le \textstyle\sum_j \sum_r \sum_k q_{jr}^k S_{jr}^k \le \bar{Q}^* \\ \underline{Q}_j^* &\le \sum_r \textstyle\sum_k q_{jr} spk S_{jr}^k \le \bar{Q}^* \\ \underline{Q}_r^* &\le \textstyle\sum_j \sum_k q_{jr}^k S_{jr}^k \le \bar{Q}_r^* \end{aligned} \tag{6.6}$$

$$S_{jr}^k \le \bar{S}_{jr}^k \tag{6.7}$$

* Top bar denotes upper and bottom bar lower target levels of policy variables.

The shadow prices associated with (6.4) and (6.6) may change sign as a solution switches from an upper to a lower binding constraint. The various shadow prices adhering to the employment constraints may be used to assess wage differentials describing how tight each labor market is, and to examine employment subsidies which may be necessary to ensure given employment targets. We should observe that the shadow price information has a distinct economic interpretation. This means that from (6.3) to (6.7), one determines endogenously wage levels, investment costs, profits, rate of return on investment etc., together with additional policy subsidies.

Changes in best practice technology during the time period of the model (10 years) is described as an increase in μ_{jr}^{o} between base year and terminal year. Two alternatives is used in the exercises to represent "best practice":

- "Advanced best practice" is represented by the production technique of the industrial units which corresponds to the average for the 10 percent of the productivity curve with the highest productivity.
- "Average best practice" is in a similar way represented by the average for the 25 percent of the productivity curve with the highest productivity.

Two versions of technology change are used. In one set of scenarios the technological change is referred to as capital embodied. In this case the productivity can only change when (i) new capacities embodying the best practice are introduced through investment, and (ii) old capacities with low productivity are removed.

In another set of scenarios the technological change is referred to as combined embodied and disembodied. In this case the productivity changes also when no investment takes place; the disembodied part of the technological change is an autonomous process that increase the productivity as a function of time. Obviously, the investment requirements are higher when technological change is assumed to be embodied than when it is a combination of embodied and disembodied change. The exit and entry of capacities during the scenario period is entirely determined by the solution to the optimization problem outlined in (6.3) - (6.7).

6.3 Scenarios Assessed at the National Level for the Industry as a Whole

Figure 6.2 summarizes 6 scenarios combined in three groups such that each group has approximately the same effect on wages, productivity and rate of return on investments. The three groups are characterized in Table 6.2.

Alternative Ia and Ib have the same total reduction in employment. However, Ib has a considerably higher investment level and a superior best practice level than case Ia. This is compensated for in the latter case by a high labor mobility between regions. The labor market conditions which make the six scenarios feasible are described in aggregate terms below:

(Ia) *High mobility and reduced employment*; any regional labor market is allowed to expand within the limits of the national labor market. No employment reduction is allowed in Mid-

Table 6.2. Aggregate characteristics of three groups of scenarios.

Scenarios	Ratio between wage level 1990 and 1979 (fixed prices) in percent	Annual productivity growth in percent	Minimal level for rate of return on investments
Ia and Ib	154-159	4.0-4.2	11
IIa and IIb	137-138	3.9-4.0	12
IIIa and IIIb	97-98	2.5-2.7	16

Change in employment level (1980-1990)	Investment level during the period compared with the average for the 1970's		
	+16%	25%	+38%
-3%	Ia Average best practice with fast change Combined technological change		Ib Advanced best practice with fast change Combined technological change
±0		IIa Advanced best practice with fast change Combined technological change	IIb Average best practice with fast change Combined technological change
+8%	IIIa Advanced best practice with fast change. Embodied technological change	IIIb Advanced best practice with slow change Embodied technological change	

Figure 6.2. Some Aggregate Characteristics of the Six Main Scenarios.

Sweden and North Sweden. Maximum reduction in any other region is 20 percent.

(Ib) *Reduced total employment and national control of regional labor markets*; the employment is held constant in Mid-Sweden and North Sweden. In all other regions the industrial employment is reduced by at least 4 percent but not by more than 20 percent.

(IIa + IIb) *Constant total employment and regional stabilization policy*; total employment is not allowed to increase in any region, and no reduction is allowed in Mid-Sweden and North Sweden. Maximum reduction in other regions is constrained to be less than 25 percent.

(IIIa + IIIb) *Expanding total employment and high mobility*; all regions have the same expansion possibilities within the limits set by national expansion of industrial employment. No region is allowed to loose more than 20 percent of its industrial labor force.

We may observe that IIIa, IIIb and Ib give rise to an annual increase in production around 4 percent; in the other case the growth rate varies around 3.5 percent. In particular, case IIIa and IIIb generate high profitability, low productivity growth and reduction in real wages.

6.4 Regional Consequences of the Scenarios

We shall illustrate the regional consequences of the various scenarios by comparing the outcome for the following three regions:

- Sweden as a whole
- Mid-Sweden which has a high proportion of heavy industry and production with a low level of OECD-specialization; for large fractions of the industry in this region the capital coefficients are high and large shares of the industrial labor force works (1980) in production units with a high exit probability (low or negative profits).
- East-Sweden which includes the Stockholm region. In this case the industry is dominated by sectors with a comparatively low capital coefficient and by production with a high OECD-specialization.

Table 6.3 describes the intensity of two change processes in each region. The intensity of the exit process is measured by the share of industrial labor force that are loosing their work places due to closure of obsolete production capacities. The more intensive this process is the higher is the pressure on the entire labor market in the region. Table 6.2 also describes an entry process in which persons get new work places as new industrial units are created through investments. The intensity of this process is measured as the ratio between new jobs and the size of the initial labor force in each sector of the region's industry. This renewal share indicates the requirements put on retraining measures for the regional labor market.

The intensity of the restructuring process as a whole is monitored by the sum of entry and exit rates per ten year period. This intraregional labor mobility with regard to industrial sectors is considerable in

Table 6.3. Total mobility of the industrial labor force 1980-1990 in percent.

Market labor policy:	Sweden Ex+Ent	Sweden Tot	Mid-sweden Ex+Ent	Mid-sweden Tot	East Sweden Ex+Ent	East Sweden Tot
Reduced employm.						
Ia (mobility)	26+29	55	30+30	60	19+19	38
Ib (control)	31+33	64	35+35	70	21+25	46
Constant employm.						
IIa (stabilization)	22+22	44	25+25	50	11+11	22
IIb (stabilization)	26+26	52	37+37	74	15+15	30
Increase employm.						
IIIa (mobility)	20+13	33	27+15	42	10+4	14
IIIb (mobility)	24+14	38	26+22	48	15+6	21

Remark: Ex = exit rate per ten year period; Ent = entry rate per ten year period.

several of the scenarios This is in particular true for Mid-Sweden in which the sum of removed and new work places in scenario IIb amounts to 3/4 of the entire employment in the industry. This reflects the fact that this region has a production profile which is unfavorable according to the product cycle model developed earlier. In Mid-Sweden, the proportion of mining, iron and steel, wood products and pulp is considerably higher than the average in Sweden, which is high in itself. In East Sweden, the situation is the opposite. This part of Sweden includes the Stockholm region. In the latter more than 70 percent of the manufacturing industry is concentrated in production areas with a high OECD-specialization. As a consequence the required labor mobility is less dramatic in Mid-Sweden than in East Sweden and in Sweden as a whole.

6.5 The OECD-Product Cycle and Sectoral Restructuring in the Programming Scenarios

The sectoral consequences in the six scenarios we have presented reflect a change pattern that corresponds to the product cycle analysis put forward in this paper. Table 6.4 illustrates for each sector the maximal employment reduction that the sector has in any scenario; it also shows in a similar way the maximum employment expansion. Some products with low OECD-specialization are characterized by a relatively seen low maximum employment reduction. Three of them belong to the group of protected production (Iron and Steel, Wood and Food products). The electric products sector in Sweden deviates significantly from the change of other products with low OECD-specialization; we have earlier emphasized that in Sweden the development of this sector has been strongly influenced by specific innovations accompanied by increased export.

Table 6.4. National Consequences of the Six Scenarios.

	Maximal reduction of employment in any scenario %	Maximal expansion of employment in any scenario %
Sectors with a high OECD-specialization (similar max-values for all sectors, nationally)	-7	+2
Sectors with a low OECD-specialization	-10	-2

Another illustration of sectoral change is provided in Table 6.5 which illustrates the labor mobility for sectors in the Stockholm region. This table is based on an analysis of how the East Sweden scenarios with constant employment affect the Stockholm region and the rest of East Sweden. In this case the price sensitivity of the solutions has been examined by varying the price changes during the period. Also at this local level the product cycle patterns can be recognized with high requirements on labor mobility in the textile, wood products and electric product industries.

Table 6.5. Labor Mobility in Industries of the Stockholm Region during 1980-1990.

Share of employment in removed plus introduced new industrial units during the period in			
Sectors with high OECD-specialization	%	Sectors with low OECD-specialization	%
Metal products	25	Textiles	44
* Instruments	22-45	Wood products	39
Machinery	17	Electric products	39
* Chemistry	12-29	Food products	21
Printing	12	• Clay & Stone	12-39
Transport equipment	12		
Plastic	12		

* The three sectors instruments, chemistry and clay & stone reveal a high sensitivity in the labor mobility of variations in the assumptions about changes in market prices including world market. The other sectors do not show any price sensitivity at all for modest price variations.

7. SUMMARY AND CONCLUSIONS

This paper is concerned with the interindustrial and spatial consequences of technological development. One of the basic driving forces behind the rapidly changing international and interregional division of labor is the increasing Research and Development potential of the highly developed industrial nations. With the exception of the USA, all developed market economies have in the last two decades shown stable or increasing shares of their GNPs going to investments. Furthermore, relative shares of the labor force working with creation, development and transmission of knowledge are steadily increasing in most industrialized nations. These changes together with computerization and increasing telecommunication capacity will have a large impact on the international location of industries and employment. Analyses of these changes are now urgently needed.

The theory of product cycles is designed to provide such an analytical framework for studies of industrial division of labor between regions under conditions of technological development. As a contrast the *theory of comparative advantages* focuses on understanding the division of labor between regions when the technology, resource constraint and demand patterns are given. The latter is the theoretical fundament of most numerical global trade models, including the forest sector global trade model of IIASA. The theory gives unique equilibrium solutions in prices and traded quantities when there are constant or decreasing returns to scale. However, for new products there are by definition *never* constant returns to scale. The markets are, at the initial stages of production, too small. The consequences of this has been formulated by

Ethier* in the following way:

- *Increasing returns to scale furnish a basis for trade, independently of comparative advantage.*
- *The pattern of trade tends to be indeterminate if the cause of trade is increasing returns to scale, and finally*
- *Trade is likely to be characterized by complete specialization if it is due to increasing returns to scale.*

Until the theory of comparative advantages has been unified with the product cycle concepts, the two approaches should be regarded as complements to each other. Both theoretical fundaments are needed to provide a full insight into the changing international and interregional pattern of industrial specialization and trade.

According to our formulation of the product cycle theory, *product R & D* is a primary driving force behind changes in the division of labor between regions. New products are primarily created and innovated in the densely populated knowledge centres like the Boston region, the American West Coast, and the Shinkansen region, and thereafter diffused to other regions of the industrialized world. Only after the technological maturing of a product, when the R & D intensity has declined, will the diffusion process reach the developing world. One sign of technological maturing is an increase in market investments relative to R & D investments. Another sign is the concentration of R & D investments on more efficient processes rather than new products.

* Ethier, W., Modern International Economics, New York, 1983.

The analysis has been confronted with data on the changes of the international pattern of industrial location during the 1970s. A set of industries are currently stabilized in the developed market economies, namely:

- *Paper and paper products*
- *Transport equipment*
- *Machinery*
- *Printing and publishing products*
- *Chemicals*
- *Beverages*

These product groups are either characterized by an ongoing high rate of R & D or by being outputs of industries characterized by systems orientation of the products or production processes; e.g., chemicals and integrated paper production.

From the point of view of the Forest Sector Project, three major observations can be made:

- *The paper and paper products integrated industries are currently stable in their location to the developed world region.*
- *The pulp industry is now facing the same relocation tendencies as the steel industry in the 1970s. It thus seems probable that the pulp industry -- unless integrated into industrial complexes -- will be relocated away from the developed market economies.*
- *Wood and wood product manufacturing has long since, to a large extent, been located to areas outside the OECD. There is a*

very probable further shift in the location of these activities away from OECD when the international business cycle turns upwards.

Statistics from one of the major countries of wood processing -- Sweden -- indicate that the sector is indeed maturing. The wood product industries have the highest market R & D investment ratio of all industries. This is not the case with the paper and paper product industry which has quite a balanced relation between market and R & D investments although the paper and paper products industry does not devote a large share of resources into R & D. In the US, the average share was approximately 1.2 percent of sales value in 1982. This should be compared with an average for US manufacturing of approximately 2.5 percent. The relations were similar in Sweden and Norway. The forest industries are also comparatively weak on product R & D (Appendix B). This could cause a long run development similar to the recent history of the steel industry.

The patterns of location *within* developed national economies is also analyzed in the paper. It is shown that the quickly expanding occupations associated with creation, innovation and transmission of knowledge will be the strongest future competitors for metropolitan land. Some technology intensive manufacturing like the chemical industry and the advanced transportation equipment and electronic system industries will also be part of this locational tendency.

The forest industry will also in the future be driven towards *the other extreme* of the regional hierarchy, locating close to the natural resources. There are two factors generating this result. The first is related to the theory of industrial location, which shows that only locations close to markets or to the basic resources can be optimal. The other is our product cycle analysis which indicates that a sector with a relatively low knowledge intensity in its labor force must seek a location outside national and regional centres of accessibility, i.e., in sparsely populated areas.

There is only one risk for the industry in such a locational pattern. The forest sector will remain outside the main centres of general product development and thus lose opportunities of synergisms and consumer market contacts. "Prematuring" can of course be counteracted by increased investments in product R & D and separate location of marketing and R & D divisions in metropolitan and other information rich environments.

APPENDIX A

A.1 Determination of Trade Shares

Let $Q = \{q^{rs}\}$ be the mobility distribution introduced in (3.4) such that $\sum_r \sum_s q^{rs} = 1$, $q^{rs} \geq 0$. Assuming that flows are based on elementary trade contracts each with equal probability, the probability $P(x^{rs})$ of a specific flow pattern becomes

$$P(x^{rs}) = H^{rs} \prod_{r,s} [q^{rs}]^{x^{rs}} / \prod x^{rs}, \tag{a.1}$$

where H^{rs} is a parameter reflecting the number of elementary contracts and regional combinations. Using Stirling's approximation, (a.1) is transformed to

$$P(x^{rs}) \approx - \sum_r \sum_s x^{rs} \log x^{rs} / q^{rs} \tag{a.2}$$

Assume now that at each time regional prices p^s are adjusted such that (i) demand is satisfied, i.e.,

$$\sum_r x^{rs} = d^s(p^s) \tag{a.3}$$

and (ii) such that in each region r the net price at least exceeds $p^r - \varepsilon^r$, where $\varepsilon^r \geq 0$ represents the minimum average reduction from the domestic price in region r accepted by exporters in region r, i.e.,

$$(p^r - \varepsilon^r)\sum_s x^{rs} \leq \sum_s (p^s - c^{rs})x^{rs} \tag{a.4}$$

Consistency also requires that the supply capacity $\bar{x}^r$ exceeds demand, i.e.,

$$\bar{x}^r \geq \sum_s x^{rs} \tag{a.5}$$

Writing $x^{rs} = \beta^{rs} d^s(p^s)$ and using multiplier μ^r for (a.4), the highest $P(x^{rs})$-value that can be obtained given (a.3)-(a.4) is given by

$$\beta^{rs} = \frac{q^{rs}\exp\{\mu^r(p^s - c^{rs} - p^r + \varepsilon^r)\}}{\sum_k q^{ks}\exp\{\mu^k(p^s - c^{rs} - p^k + \varepsilon^k)\}} \tag{a.6}$$

Prices in (a.6) should adjust so that (a.5) is satisfied. If, in addition, we set $\hat{c}^r = p^r - \varepsilon^r$ we obtain formula (3.4).

With regard to the statement in *Remark 1* about the expressions in (a.4) and (a.6) we may observe the following

> *REMARK*: Suppose that (i) prices are non-dispersed so that $p^r = p^s$ for all s, (ii) $c^{rs} > 0$ for all r and s. Then if $\varepsilon^r = 0$ for all r we cannot have $\beta^{rs} > 0$ for all r and s.

To see this we may sum over r in (a.4) which yields

$$\sum_r p^r \sum_s x^{rs} \leq \sum_r \sum_s p^s x^{rs} + \sum_r \varepsilon^r \sum x^{rs} - \sum\sum c^{rs} x^{rs}$$

However, non-dispersed prices imply that

$$\sum p^{r} \quad x^{rs} = \sum\sum p^{s} x^{rs}$$

which gives the desired result.

A.2 Observationson on Trade Share Dynamics

Formula (a.6) above describes how the β^{rs}-terms adjust instantaneously given the actual values of the q^{rs}-terms. This formula incorporates (3.4) as a special case. Those instantaneous adaptions to price patterns are fed back into the slow process of change given by (3.7), from which follows that

$$\Delta q^{rs} > 0 \text{ if } [\Phi^{rs} + \Delta\Phi^{rs}]\sum\sum\Phi^{ks} > \Phi^{rs}\sum\sum(\Phi^{ks} + \Delta\Phi^{ks}) \qquad \text{(a.8)}$$

When no new capacity is introduced $(\bar{x}^{r}(t-1) = \bar{x}^{r}(t))$, the Φ^{rs}-term changes if

$$\int_{t_0}^{t} \omega(\tau) q^{rs}(\tau) d\tau$$

changes. From this we can see that with constant prices and $\int \omega(\tau) d\tau = 1$, the Φ^{rs}-term will converge to a constant.

According to (3.8) and Proposition 2, new capacity will be introduced when the following condition is satisfied

$$\sum_{s} (p^{s} - \hat{c}^{r} - c^{rs}) \Delta d^{rs} \geq \bar{\pi}^{r} \sum \Delta d^{rs} \qquad \text{(a.9)}$$

where $\bar{\pi}^{r}$ may be a function of the size of $\sum \Delta d^{rs}$ and where

$$\Delta d^{rs} = \Delta\beta^{rs} d^{s} + \Delta d^{s} \beta rs + \Delta\beta^{rs} \Delta d^{s} \qquad \text{(a.10)}$$

The threshold level $\bar{\pi}^{r}$ in (a.9) and (3.8) can be based on a standard investment criterion. To see this, let $\Delta\bar{x}^{r} = \sum d^{rs}$ be the additional new capacity, $d^{rs} = \beta^{rs} x^{rs}$ the corresponding delivery pattern and $I(\Delta \bar{x}^r)$ the associated investment costs. Moreover, let

$$Y^{rs} = (p^s - c^{rs} - \hat{c}^r) d^{rs} / \sum d^{rs}$$

and let expected path for Y^{rs} be denoted by $\tilde{Y}^{rs}(t+\tau)$ if t is the time of capacity entry. Then with a time horizon T and a discount rate r

$$\bar{\pi}^r(t) \geq \sum_s \int_t^{t+T} \tilde{Y}^{rs}(\tau) e^{-r\tau} d\tau$$

The whole dynamic process is outlined in the main text by describing and characterizing the different component equations. However, the whole system is not assembled and compressed into a reduced from which is analytically tractable. The following figure cannot compensate for this but provides an overview of the principle relations with

(i) The instantaneous market mechanisms in (Ia) and (Ib)

(ii) The processes of capacity and trade probability (q^{rs}-terms) change

(iii) The slow logistic evolution of potential demand in (Ia). We may observe that capacities change with discrete jumps which in turn affect the change in trade pattern probabilities. Note also that the relations in (Ia) - (Ib) reflect instantaneous adjustments or "embedded statics" (compare Luenberger, 1979).

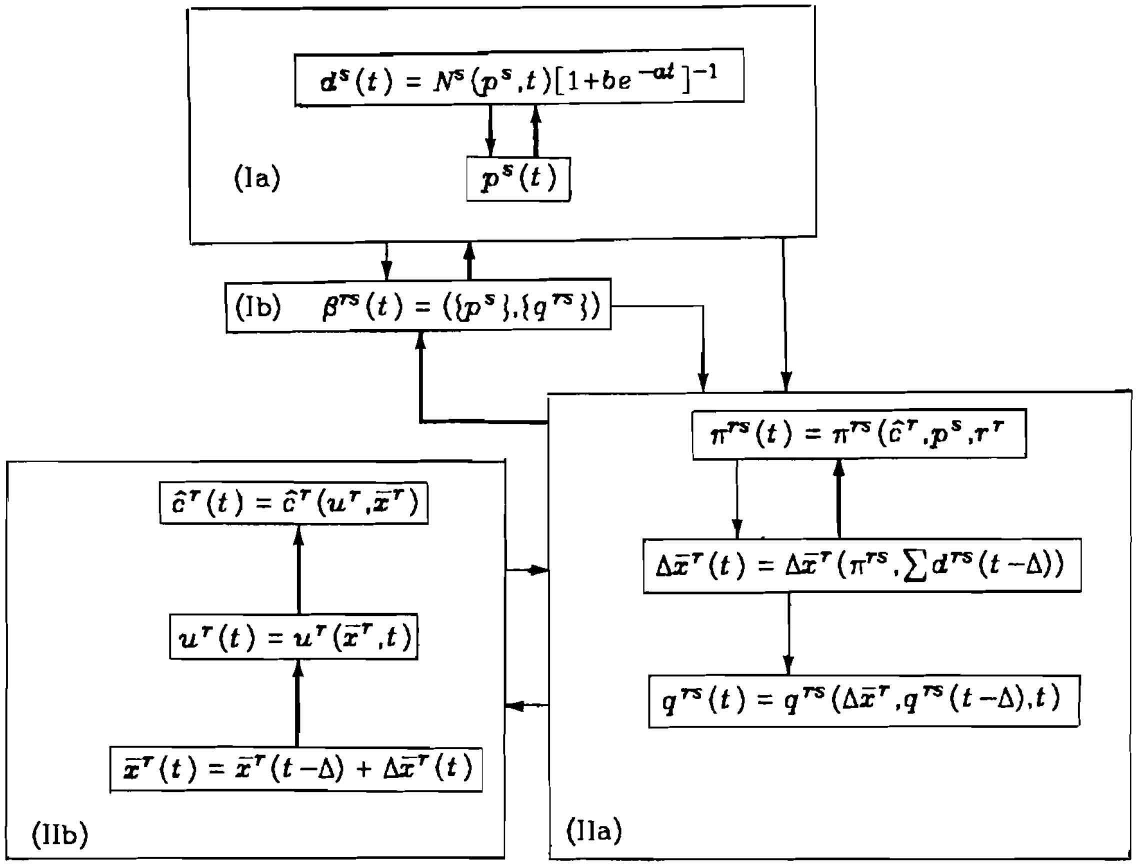


Figure A.1. An overview of the time evolving system.

APPENDIX B

Table B1. R & D as a percentage of profits and sales in US manufacturing, 1982.

		Percent of sales	Percent of profits
	Semi conductors	7.8	282
	Information processing	6.4	111
	Drugs	6.0	60
	Instruments	5.2	122
	Aerospace	5.1	168
	Automotive	4.0	negative
	Electronics	3.8	86
	Chemicals	2.9	82
	Electrical	2.8	45
	Tyres & rubber	2.3	132
F			
O	Masonite	1.7	negative
R	Sorg paper	1.6	230
E	Mead	1.6	negative
S	Kimberly clark	1.6	24
T			
S	Rexham	1.4	30
E	Scott paper	1.3	40
C	Union camp	1.3	17
T	Westwaco	1.3	30
O	Weyerhaeuser	1.2	35
R	Consolidated Papers	1.2	16
	Crown Zellerbach	0.5	-
C	St. Regis	0.5	28
O	Fort Howard Paper	0.4	2
R	Hammermill	0.3	15
P	Boise Cascade	0.2	62
	Telecommunication	1.3	13
	Metals & mining	1.2	-34
	Food	0.7	18

Source: International Business Weekly supplied by Shell Oil Co.

Table B2. R & D costs in relation to value added in Swedish industries 1975 and 1977.

Industry	R & D as % share of value added 1975	1977
Electrical products	8.7	14.2
Instrument products	6.1	3.4
Chemical products	6.6	6.1
Machinery	4.9	6.8
Transportation equipment	5.7	14.0
Other industrial products	2.6	1.7
Plastic products	2.3	1.9
Metal products	2.3	2.9
Metals	3.7	2.6
Rubber products	1.5	1.9
Minerals	1.5	2.6
Pulp, paper and paper products	1.1	2.2
Petroleum products	3.3	2.6
Food	1.1	1.6
Textile products	0.2	0.8
Wood products	0.1	0.3
Printing products	1.3	0.1
Wood furniture	0.1	-
All industry	3.3	5.4

Sources: SM nr 1 1976:8 Industristatistik 1975 (preliminära uppgifter), SMU 1979:25.

Table B3. Process development cost as percent share of total R & D costs in Swedish industry, 1980.

Industrial branch	Process development
Iron & Steel	36
Food	36
Paper & pulp	35
Other industries	30
Machinery	19
Chemicals	19
Metal products	18
Electronics	15
Instruments	9
Drugs	7
Transportation	0
All branches	15

Source: See Table B2.

Table B4. R & D in industry in Norway, 1981.

Industry branch	R & D costs/value added %
Machines for metal and chemical/ mechanical wood processing	21.7
Computer equipment	20.1
Drugs	15.2
Refineries	8.9
Electrical products	5.6
Instruments	4.7
Machines (other)	4.6
Chemicals (other)	4.4
Metals	3.7
Paper and pulp	2.3
Forestry	2.1
Forestry logistics	1.5
Mechanical wood processing	0.8
Other industries	4.4

Source: Specially prepared statistics from the Norwegian Forestry and Forest Industries Research Council.

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