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Knowledge Intensity and Product Cycles in Metropolitan Regions

Andersson, A.E. and Johansson, B.

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Åke. E. Andersson and Börje Johansson

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Contributions to the Metropolitan Study:8

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INTERNATIONAL INSTITUTE FOR APPLIED SYSTEMS ANALYSIS
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LIST OF CONTRIBUTIONS TO THE METROPOLITAN STUDY:

1. Anas, A., and L.S. Duann (1983) Dynamic Forecasting of Travel Demand. Collaborative Paper, CP-83-45, International Institute for Applied Systems Analysis (IIASA), Laxenburg, Austria.

2. Casti, J. (1983) Emergent Novelty and the Modeling of Spatial Processes. Research Report, RR-83-27, IIASA, Laxenburg, Austria.

3. Lesse, P.F. (1983) The Statistical Dynamics of Socio-Economic Systems. Collaborative Paper, CP-83-51, IIASA, Laxenburg, Austria.

4. Haag, G., and W. Weidlich (1983) An Evaluable Theory for a Class of Migration Problems. Collaborative Paper, CP-83-58, IIASA, Laxenburg, Austria.

5. Nijkamp, P., and U. Schubert (1983) Structural Change in Urban Systems. Collaborative Paper, CP-83-57, IIASA, Laxenburg, Austria.

6. Leonardi, G. (1983) Transient and Asymptotic Behavior of a Random-Utility Based Stochastic Search Process in Continuous Space and Time. Working Paper, WP-83-108, Laxenburg, Austria.

7. Fujita, M. (1984) The Spatial Growth of Tokyo Metropolitan Area. Collaborative Paper, CP-84-03, IIASA, Laxenburg, Austria.

8. Andersson, Å.E., and B. Johansson (1984) Knowledge Intensity and Product Cycles in Metropolitan Regions. Working Paper, WP-84-13, IIASA, Laxenburg, Austria.

FOREWORD

Contributions to the Metropolitan Study:8

The project "Nested Dynamics of Metropolitan Processes and Policies" started as a collaborative study in 1983. The series of contributions is a means of conveying information between the collaborators in the network of the project.

This paper by Andersson and Johansson is based on an earlier study of product cycle phenomena by the same authors (Andersson and Johansson 1984). It presents a theoretical framework which aims at understanding the role that metropolitan regions play in a global economic system in a dynamic context. This framework is used for analyzing how metropolitan regions may achieve, retain and lose their comparative advantages over time in a product cycle process. Certain hypotheses, derived from the product cycle analysis, are evaluated against empirical observations.

Åke E. Andersson
Leader
Regional Issues Project

February, 1984

CONTENTS

KNOWLEDGE INTENSITY AND PRODUCT CYCLES IN METROPOLITAN REGIONS

Åke E. Andersson and Börje Johansson

1. AN OUTLINE OF INDUSTRIAL DYNAMICS IN METROPOLITAN REGIONS

1.1 Product Cycles and Metropolitan Regions

Metropolitan regions may be viewed as large production systems. As a group they usually encompass a major share of the economic activity in a country. Their spatial interconnections also form the basic parts of the interregional trade and information network within nations and on a global scale.

The prototype metropolitan region is sometimes recognized as a system in which richness of ideas and activities provide an environment for creativity and novelty by combination. This image may be contrasted with an also common picture of an ageing metropolitan region which is characterized by large-scale production and a low frequency of innovations. A transition from the first to the second state represents a loss of long-term creativity and a gain of short-term productivity.

According to this perception, a metropolitan region potentially has a comparative advantage as a place for introducing new economic activities. However, this advantage can also be lost over time. Such a dynamic analysis of comparative advantages can be related to a more general analysis of product cycles. In order to outline a theoretical explanation of product cycles we will distinguish between three components of industrial dynamics and economic change:

(i) *Product change:* decline and disappearance of commodities as well as emergence of new or modified products.

(ii) *Process change:* decline and exit of old as well as entry and expansion of new production techniques.

(iii) *Market change:* establishment and deterioration of market channels as well as changes in prices of pertinent inputs and of products supplied.

For non-local products the described changes take place in an interregional and international context of factor supply and output demand. Two different paradigms can be used to understand patterns of activity location, the development of trade between regions, and the corresponding specialization of spatially defined economies. The two approaches are (i) the theory of comparative advantages, and (ii) the theory of product cycles. The latter attempts to capture the spatial dynamics of a change process, while the first usually is formulated in the form of comparative statics.

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

We may now observe that the combination of factors which are essential for creating and introducing new products and processes often differ from the factors which allow a profitable (low cost) production when the production scale is growing and becomes routinized. Another observation relates to Leontief's pioneering work (1953) which indicates that factors of production must be widened to include a richer specification of the economic environment. Also, in a metropolitan region this environment is in all essence a created product which changes over time. The theory of product cycles can be designed to understand how these factors influence the location of birthplaces for new products and activities and the successive relocation of expanding production (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, laboratory testing, and implementation development. The product is then primarily produced in the region with a comparative advantage in terms of a high R & D level and access to employment categories with a required profile of competence. 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 loses its comparative advantage and the production becomes regionally decentralized.

It is important to observe that product cycles involve phenomena which make the theory of comparative advantages unsuitable for prediction of location patterns. One such phenomenon is increasing returns to scale. Figure 1.1 provides a pedagogical example.

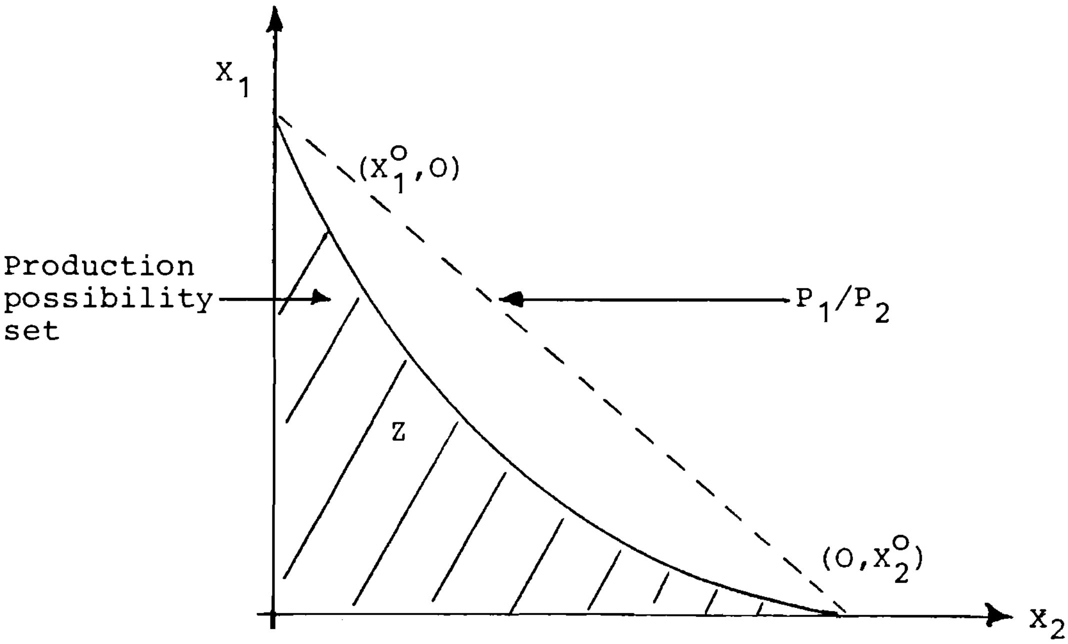


Figure 1.1. Indeterminacy with increasing returns to scale.

Consider now a single country or region which intends to select a mix of the two commodities X_1 and X_2 so as to maximize the revenue, given the constraint set Z. At the exogenously given price ratio P_1/P_2 any of the two extremal points $(X_1^o,0)$ and $(0,X_2^o)$ would do equally well.

Next, consider that several countries/regions with approximately the same production set Z deliberate on which mix of the two (new) products it should select. With the price ratio in the figure the locational pattern is evidently indeterminate. Deviations from this ratio will influence all regions involved to stampede towards the same complete specialization.

For new products on the market the above situation would represent the normal case. For new products with initially small markets and learning by doing effects, increasing returns to scale should be thought of as the rule and not the exception. Hence, with a static analysis of comparative advantages this problem remains indeterminate.

We may conclude that the sequence in time of the location decisions plays a fundamental role for the above type of problem. However, dynamics is not enough, since disequilibrium forces are also present. At the core of product cycle phenomena one is confronted with pure dynamics working in combination with increasing returns to scale. Both phenomena are alien to standard comparative advantage theory to the same extent as Schumpeterian development theory is alien to general equilibrium theory.

In the two following subsections we combine the two paradigms discussed here to develop a conceptual model for analyzing dynamic comparative advantages and product cycles. With the help of this framework we attempt to make precise the role of metropolitan regions in the global process of spatial industrial dynamics. In subsequent sections hypotheses are formulated and assessed against empirical observations.

1.2 Product Cycles and Spatial Relocation

The most intricate part of a dynamic analysis of comparative advantages and product cycles is the determination of which social environments are most likely to generate the creation and initiation of new products and processes. Once the initial introduction has taken place, the product cycle theory predicts a time-space dynamics of the kind illustrated by Figure 1:2. The probability that the initiation takes place and is adopted in other regions is assumed to follow a hierarchical time-space path. In the beginning of the cycle the gradual introduction in other regions is assumed to depend on the existing competence and knowledge intensity in the region. As the production scale increases and production is gradually improved, routinized and simplified, the knowledge requirements decrease correspondingly. When this happens it also becomes easier to transfer the production knowledge, and to initiate the already existing solutions in other regions. In this way, other regions with different wage levels and factor prices successively provide more advantageous locations. Altogether this describes a time-space hierarchy of comparative advantages for a given technological solution. What is an advantage in an initial phase later becomes a disadvantage, while initially less favorable locations become more competitive as alternatives for location as the production matures.

One should also recognize that a technology matures as a result of a repeated introduction of new technical and commercial solutions. This means that when transfer and diffusion of a given solution occurs, firms which entered the production at an early stage may be renewing their production processes. This may, of course, involve both product and process development. However, a basic hypothesis is that as the production matures and competition is intensified, the probability of having conservative process innovations increases. Such responses to competition include (i) a direct search for labor and factor saving changes in the production technique, (ii) increased scale of production and correspondingly improved logistics and distribution systems in an attempt to augment exports. At the same time the policy system is often forced to protect the threatened production.

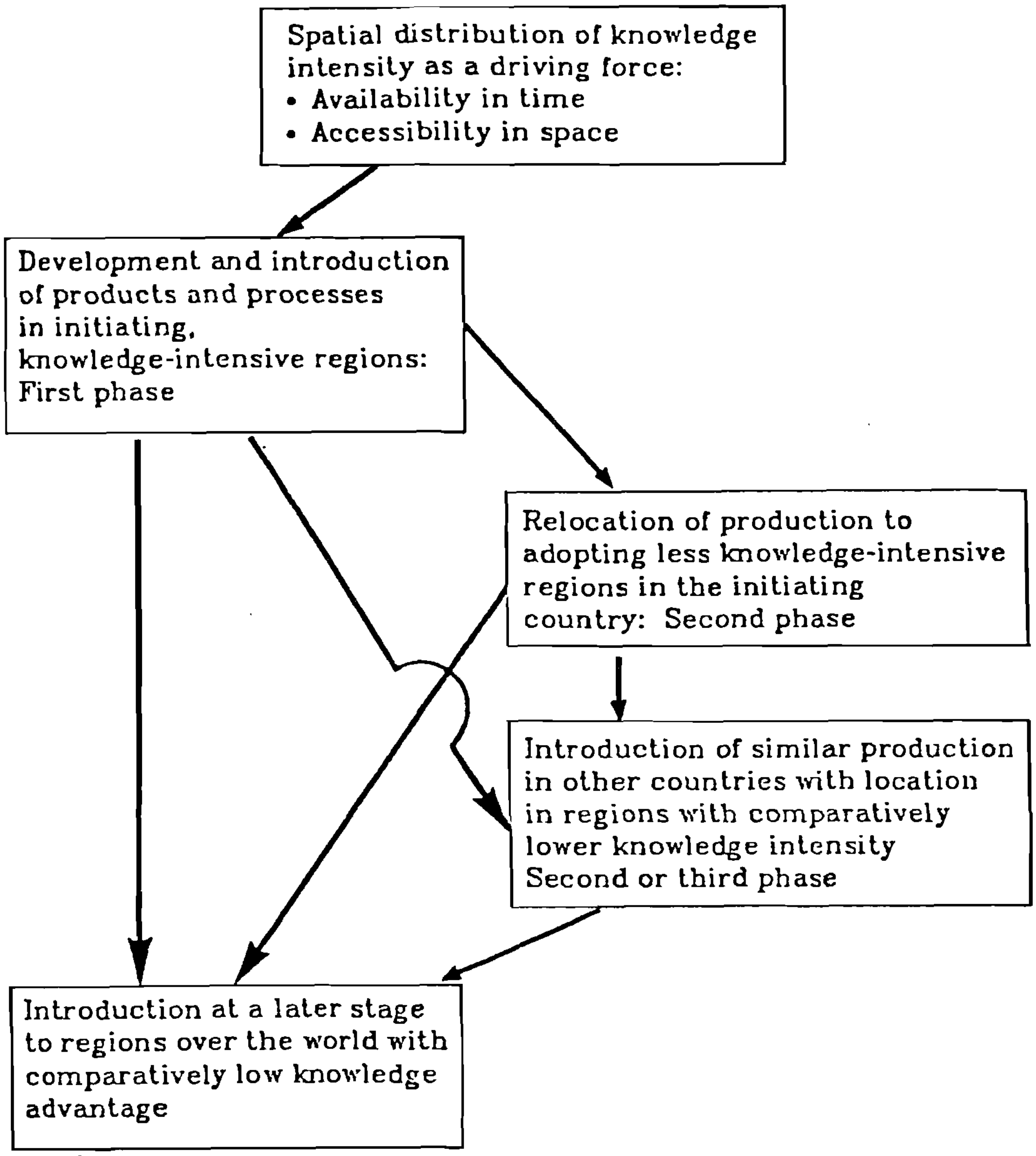


Figure 1:2. Illustration of product and technology transitions in space and time.

1.3 Birthplaces for New Production

As will be illustrated in section 3 it is possible to observe product cycle phenomena at different levels as regards the aggregation of (i) products into product classes and industrial sectors, and (ii) space into groups of countries, nations, and subnational regions like metropolitan areas.

With a fine subdivision of space one can observe that new product cycles are initiated with a higher frequency in certain locations than in others. At such lower levels of spatial resolution, factors related to accessibility and availability of land tend to be of greater importance. Since various activities compete for land, the pattern of comparative advantages will also be reflected in the distribution of land values and the interplay between accessibility and the bid price for land. How this competition in space works can be illustrated by Figure 1:3.

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 economic activities will cluster only if they have a limited need of land per unit output combined with a large use of transportation and communication services per unit output. This combination of characteristics is typical of a few human activities such as lecturing, dramatic performances, etc. Very often the advantage

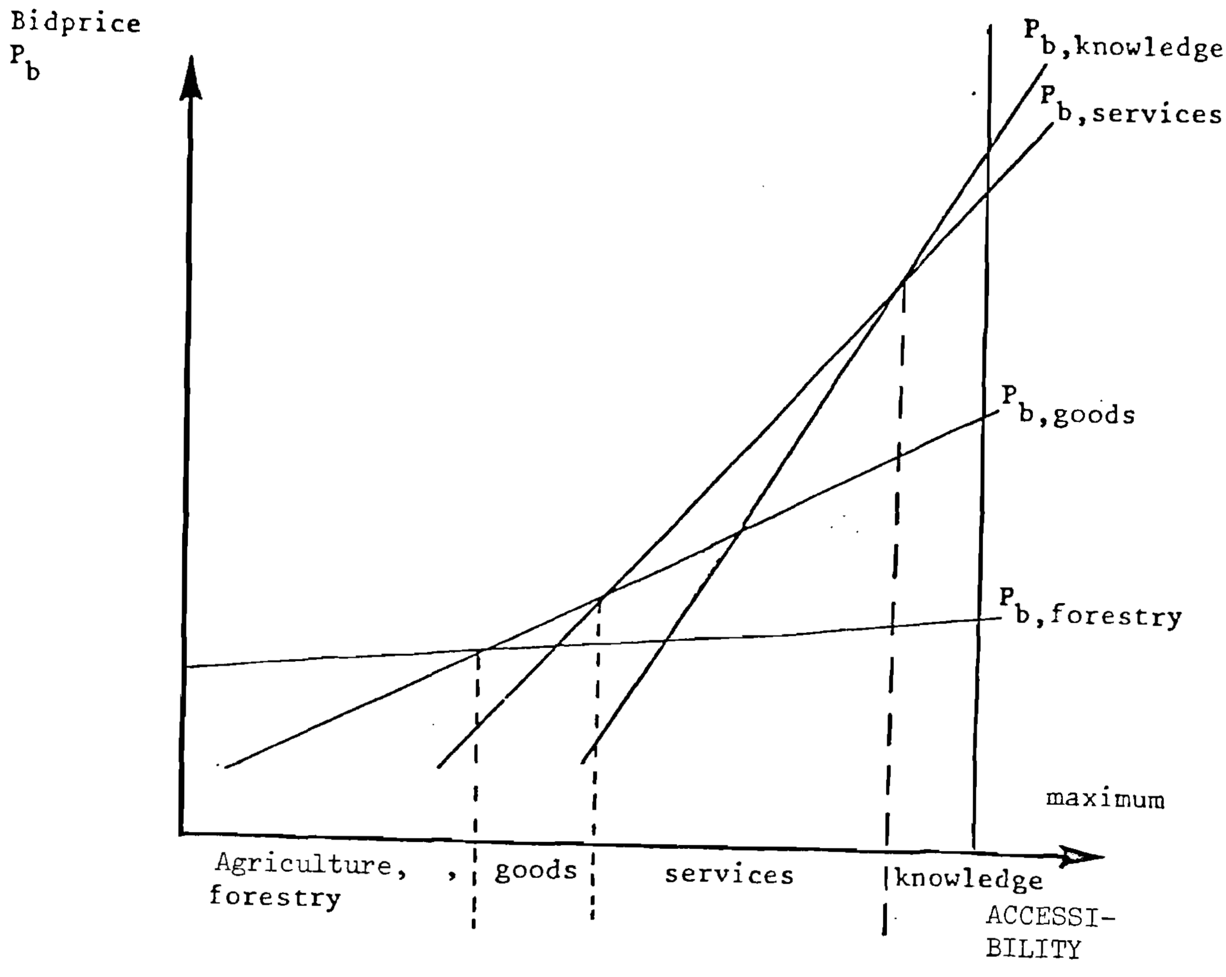


Figure 1:3 Bid price for land and demand for accessibility[1]

1) A structure of the type illustrated in Figure 1:3 may be related to the work by von Thünen (1966).

of a location with great accessibility is reinforced by a low density of demand such that potential customers only add up to a small share of the population--which means that the demand has to be "densified" by high accessibility.

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 in which the market coverage is large enough. Such centers often also have a good accessibility to R & D organizations, a rich variety of knowledge-intensive labor supply and have thus an advantage in the stage of early product development.

When successful introductions are operated on a larger scale, land consuming production techniques have to be used, and then the accessibility centers with high land values become less attractive. As a consequence the incentives for relocating the production to locations with a less steep bid price for land become larger. The driving force of this process is the diffusion of market demand.

1.4 The Succession Order of Comparative Advantages

We have argued that the introduction of new production 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, and can be disaggregated, aggregated and transmitted more easily than knowledge and competence.
- *Knowledge* is structurally ordered information. As a parable one can see information as variables, while knowledge is a set of equations containing these variables. Compared with competence, knowledge is more general and less instrumental.
- *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.

- *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.

Given the outlined characterization, it is natural to assume that transfer and transmission costs are relatively low as regards information, and become increasingly higher for knowledge, competence and creativity.

Therefore, especially creativity and competence should primarily be treated as localized factors which characterize a local economic environment. This means that an interregional transfer of systems with high competence and/or creativity usually implies prohibitively high transfer and set up costs.

A main hypothesis in our framework is that as a specific type of production matures it gradually uses less of competence-dependent production inputs and more of standardized inputs which are available at lower costs in locations with relatively lower knowledge intensity and competence. From this viewpoint our approach cannot be classified as merely a dynamization of the comparative advantage theory.

Figure 1:4 illustrates an application of our analysis to product cycle patterns in 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 correspondingly high and non-decreasing specialization. The arrows in the figure show a transition process in which products over time move to stages of gradually reduced, comparative advantages. The figure illustrates that product cycles may also be identified at rather aggregate levels.

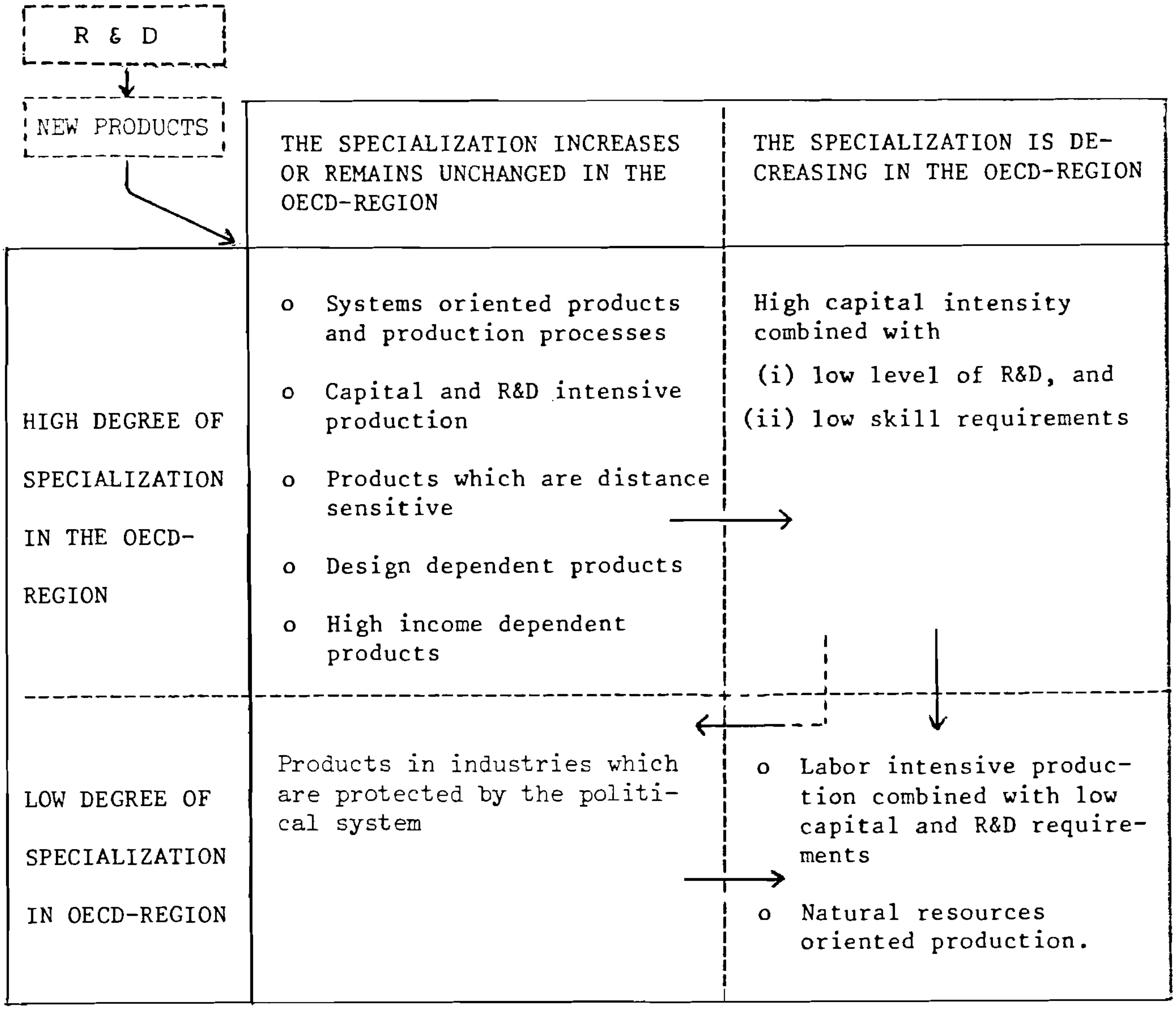


Figure 1:4 Characterization of products and associated production processes according to a product cycle description of OECD economies.

1.5 Remarks about Regional Specialization Theories

The problem with product cycle theory is the same as the problem with Schumpeterian development theory--it has not been properly formalized. In this paper we attempt to take some initial steps toward a formalization of product cycle theory. We also take into account the location theory of von Thünen which, quite differently from comparative advantage theory, explains specialization patterns in terms of distances to markets with prespecified location and size, and transportation technology needs of different commodities/activities. In our framework market sizes as well as resource requirements are allowed to change, while transport distances are kept as important parameters of analysis.

In our presentation we refer to various theories of interregional division of labor. These may be classified as follows:

- *General equilibrium theories:*

  (1) The classical theory of comparative advantage assumes factors of production as well as technologies to be trapped in regions. The analytical approach is comparative statics with general results for the case with 2 regions, 2 commodities, and 2 factors of production (see Ethier 1983).

  (2) The factor proportions theory relaxes the assumption about regionally trapped technologies. It assumes factors of production to have a fixed location and technological possibilities to be the same in all regions. Also in this case we are restrained to comparative statics analysis with general results for the 2x2x2 case (see Ethier 1983).

  (3) von Thünen's theory assumes the trading and information networks as well as the location and size of market demand to be given. In all other respects free location possibilities are assumed.

- *General disequilibrium theories:*

  (4) Schumpeter's theory (1951) assumes the innovation process to be driving the regional specialization. In his case, the innovation process also includes *changing networks* and *evolving demand densities*. However, Schumpeter treats research and development activities as exogenous. Disequilibrium is a fundamental prerequisite (see Day 1983).

  (5) Product cycle theory builds on the foundation of Schumpeter, but aims at making R & D activities endogenous.

2. DYNAMICS OF KNOWLEDGE INTENSITY IN PRODUCTION PROCESSES

2.1 Technology and Production Costs

In this section we outline a conceptual framework which can serve to make more precise statements about the various phases in the development of comparative advantages and product cycles. We concentrate on a simplified case in which a specific product is introduced and thereafter produced without any change but with successively reduced costs as new production processes are developed.

The location of production units is identified by a regional index r. Each production establishment is characterized by its cost function

$$c^r = \rho^r a + w^r b \tag{2.1}$$

where ρ^r and w^r are regional prices associated with the input coefficients a and b, respectively. The coefficient b is assumed to depend on the competence level and knowledge intensity which is required, while a is assumed to be invariant with respect to competence and knowledge. Let τ be a technology index so that the cost function is

$$c_\tau^r = \rho^r a_\tau + w^r b_\tau \tag{2.2}$$

Let $\tau=0$ be the initial production technique. As the technology matures with growing scale and routinized methods b is reduced so that $b_{\tau+1} < b_\tau$. When b_τ is still large compared with a_τ, cost minimization requires that the production is located in regions with a comparatively low price w^r. As will be demonstrated if regional prices ρ^r and w^r are fixed, a shift in location advantages will require that the b-coefficient is reduced at a faster rate than the a-coefficient.

To analyze the change process, the cost functions are not sufficient but have to be included in unit output profit functions such that

$$\pi_\tau^r = (1/x_\tau^r)\sum_s (p^s - c^{rs})x_\tau^{rs} - c_\tau^r \tag{2.3}$$

where for technique τ, x_τ^r denotes the production, c_τ^r the cost, x_τ^{rs} the delivery to region s and c^{rs} the associated transportation cost, and p^s the price in the importing region s. If $p^r = \sum_s (p^s - c^{rs})x_\tau^{rs}/x_\tau^r$, (2.3) reduces to

$$\pi_\tau^r = p^r - c_\tau^r \tag{2.3'}$$

The technology specific profit π_τ^r will be used in a subsequent section to determine the probability of entry and exit of production techniques.

2.2 Dynamics of Demand and Market Shares

The product cycle analysis requires a spatial dimension which was introduced in the preceding subsection as demand regions $s \varepsilon R$ and supply regions $r \varepsilon R$. The growth of demand in region s, $d^s(p^s,t)$, is assumed to follow a logistic path such that

$$d^s(p^s,t) = N^s(p^s,t)[1+He^{-ht}]^{-1} \tag{2.4}$$

where $N^s(p^s,t)$ denotes the potential demand level at time t, and where H and h are positive parameters.

As shown in (2.3) the delivery patterns (or established market channels) may play a significant role, at least in the short term, for the realized profit levels of various production units. Let β_τ^{rs} denote a delivery pattern for τ such that

$$x_\tau^{rs}(t) = \beta_\tau^{rs}(t)d^s(p^s,t) \tag{2.5}$$

In an aggregate analysis in which r refers to a country or a group of countries, an average version of (2.5) can be used

$$x^{rs}(t) = \beta^{rs}(t)d^s(p^s,t) \tag{2.5'}$$

where $\beta^{rs} = \Sigma_\tau \beta_\tau^{rs}$.

In section 3 such an aggregate approach is used to define the degree of specialization in a region as

$$\sigma^s = \beta^{ss} = 1 - \sum_{r \neq s} \beta^{rs} \tag{2.6}$$

The delivery coefficients β^{rs} or β_τ^{rs} may be interpreted as the expected (or most "probable") values of a probability distribution over delivery patterns. Alternatively, they may reflect the outcome of a perfect competition allocation as described in Takayama and Judge (1971).

Letting $\beta^{rs}(t)$ denote the pattern during a time period, indexed by t, which is long enough to allow for price adjustments, $\beta^{rs}(t)$ has to satisfy the following constraints:

$$\begin{aligned} &\sum_s x^{rs}(t) \leq \bar{x}^r(t) \\ &\sum_r x^{rs}(t) \geq d^s(p^s,t) \end{aligned} \tag{2.7}$$

where $\bar{x}^r(t)$ will be price sensitive also in the short term in case p^r is reduced so that exit of unprofitable technologies τ occurs. The coefficients $\beta^{rs}(t)$ then are determined by the regional distribution of supply capacities and demand levels as well as the corresponding price adjustments. In addition the adjustments of the β^{rs}-coefficients may be influenced by inertia or resistance to change.

2.3 Profit Criteria for Market Entry and Exit

If there is inertia in a trade pattern β_τ^{rs}, this may imply that an obsolete production technique τ may survive some time because of favorable β_τ^{rs}-coefficients (good market channels). We may disregard this by using $\pi_\tau^r = p^r - c_\tau^r$ in (2.3') when analyzing exit and entry or by introducing

$$\pi_\tau^{rs} = p^s - c^{rs} - c_\tau^r \tag{2.8}$$

Let ξ_τ^r denote the exit frequency of the capacity $\bar{x}_\tau^r$. In the following analysis we assume that this frequency increases as π_τ^r is reduced so that

$$\xi_\tau^r = \xi(\pi_\tau^r), \text{ and} \qquad (2.9)$$
$$\partial\xi / \partial\pi_\tau^r < 0$$

Exit is usually a delayed process, but still more price responsive in the short term than entry, since new production units and new technologies have to be introduced by starting an investment activity with a gestation lag. Let $E_\tau^r(t)$ denote the decision in period t to introduce new capacity with τ-technology. Then we assume that there is a threshold level, $\bar{\pi}_\tau^r$, such that for $E_\tau^r = E(\pi_\tau^r - \bar{\pi}_\tau^r)$

$$E_\tau^r = 0 \text{ if } \pi_\tau^r \leq \bar{\pi}_\tau^r \qquad (2.10)$$

where $\bar{\pi}_\tau^r$ depends on the investment costs and the associated interest rate. If $\xi_\tau^r \approx 0$ for $\pi_\tau^r \geq 0$, we can see an asymmetry between exit and entry, since entry requires that $\pi_\tau^r \geq \bar{\pi}_\tau^r$ while exit is zero as long as $\pi_\tau^r \geq 0$. In the latter case an earlier investment is associated with sunk costs.

Consider the adjustment of prices and β^{rs}-coefficients as the outcome of an interaction between (2.7), (2.9) and (2.10). Let $\{\tilde{p}^s(t)\}$ and $\{\tilde{\beta}^{rs}(t)\}$ be such a solution when the supply is $\{\tilde{x}^r(t)\}$. Then we assume the following mechanism to function

> If $x^r(t) > \tilde{x}^r(t)$ and if $x^r(t) - \tilde{x}^r(t)$ is offered to region s at a price $\pi^{rs}+c^r+c^{rs}<\tilde{p}^s(t)$, then the outcome is a disturbance of the initial solution such that $p^s(t) < \tilde{p}^s(t)$ and $\beta^{rs}(t) > \tilde{\beta}^{rs}(t)$. (2.11)

The assumption in (2.11) ensures that if a technique τ becomes available and $p^r(t)-c^r-c^{rs} > \bar{\pi}_\tau^r$ for $p^r(t) < p^r(t-1)$, it is possible to introduce the new capacity and capture a large share of the market in region s. This rather weak assumption forms the basis of the subsequent analysis.

2.4 Some Product Cycle Mechanisms

Let $\tau=0$ denote the technology for the initial phase of a new product. Larger values of the index represent succeeding production techniques. This indexation of techniques relates to the fundamental assumption which together with (2.11) provides the basis for the *product cycle switching mechanism*. The fundamental assumption is

> As the scale of a production unit is expanded, the production technique is "trivialized" so that $b_\tau < b_{\tau-1} < \dots < b_o$ (2.12)

As a first step we illustrate how at a constant demand structure new technologies are delayed due to the profit criteria in (2.9) and (2.10).

Consider the following situation. Technology τ_o is already established and gives region r its lowest value $\pi^{rk}_{\tau o}>0$ on market k. For region s, $\pi^{sk}_{\tau *}>0$ is the highest value that τ_* can obtain on market k. Given this we may state

> *Remark 1.* Assume that $\xi^r_{\tau o}=0$ when for each k $\pi^{rk}_{\tau o} \geq 0$. Assume also that $\beta^{sk}_{\tau *} > 0$ only if $\pi^{sk}_{\tau *} - \bar{\pi}^s_{\tau *} \geq 0$. Assume finally, in view of (2.9), that technology τ_* in s can capture a market share in region k by forcing the price p^s down to a level at which $\pi^{rk}_{\tau o} < 0$. Then $\pi^{sk}_{\tau *} > \pi^{rk}_{\tau o}$ is not a sufficient condition to ensure that τ_* in s can capture a share from region r on market k.

Proof: Let p^s be the price at which $\pi^{sk}_{\tau *} = p^s - c_{\tau *} - c^{sk} > \pi^{rk}_{\tau o}$ and $\pi^{sk}_{\tau *} = \bar{\pi}^s_{\tau *}$. If at the same price $\pi^{rk}_{\tau o} = p^s - c^r_{\tau o} - c^{rs} > 0$, τ_o can retain its market share even if p^s is further reduced.

Let a technology switch be a pair of production techniques 1 and 2 such that

$$\rho^s a_1 + w^s b_1 + \bar{\pi}^s_1 > \rho^r a_1 + w^r b_1 + \bar{\pi}^r_1$$
$$\rho^s a_2 + w^s b_2 + \bar{\pi}^s_2 < \rho^r a_2 + w^r b_2 + \bar{\pi}^r_2 \qquad (2.13)$$

Proposition 1. Assume that $w^r < w^s$ and $\rho^r > \rho^s$. Given this, if $\bar{\pi}_1^s = \bar{\pi}_1^r$ and $\bar{\pi}_2^s = \bar{\pi}_2^r$, a technology switch, (2.13), can occur if and only if the b-coefficient is reduced at a faster rate than the a-coefficient.

Proof: The b-coefficient is reduced more than the a-coefficient if $(a_1/b_1) = ka_2/b_2$ where $k > 1$. Consider now the first part of (2.13) which implies

$$a_1/b_1 > (w^s-w^r)/(\rho^r-\rho^s) \tag{2.14}$$

The second part implies that

$$a_2/b_2 < (w^s-w^r)/\rho^r-\rho^s) \tag{2.15}$$

Evidently, (2.14) and (2.15) can be simultaneously true iff $a_1/b_1 = ka_2/b_2$ for $k > 1$.

Proposition 1 states that two conditions are essential for a product cycle switch (which is a pre-condition for a relocation). These conditions are (i) the b-coefficients (knowledge and competence dependent inputs) must be reduced at a faster rate than the a-coefficients, and (ii) the regions to which the production successively is relocated must have a relative price structure such that ordinary inputs (represented by the a-coefficient) have a low price compared with the price of competence dependent inputs.

In order to examine further aspects related to Proposition 1 we use the notation $\pi^{i\ell} = p^\ell - c_j^i - c^{i\ell}$ where $c_j^i = \rho^i a_j + w^i b_j$. To simplify we consider the case in which the investment threshold level is the same in all regions so that $\bar{\pi}_j^i = \bar{\pi}_j$ for every i. Consider then two links (rk) and (sk), and let a *link catastrophe* for this pair of links be (i) a price reduction from p^k to $p^k - \varepsilon(\varepsilon>0)$ together with (ii) the emergence of a new technology, 2, which competes with a technology, 1, which is established in region r, in such a way that the following conditions hold simultaneously

$$\pi_1^{rk}(p^k) > 0, \text{ and } \pi_1^{sk}(p^k) - \bar{\pi}_1 \leq 0$$

$$\pi_1^{rk}(p^k-\varepsilon) < 0, \text{ and } \pi_2^{sk}(p^k-\varepsilon) > \bar{\pi}_2 > \pi_2^{rk}(p^k-\varepsilon) \tag{2.16}$$

Proposition 2 shows that a link catastrophe as defined in (2.16) presupposes that the change from technology 1 to 2 satisfies $c_1^r + c^{rk} > c_2^r + c^{rk} > c_2^s + c^{sk}$. It also shows that technology 2 must be profitable enough to satisfy $p^k - \varepsilon - c_2^s - c^{sk} > \bar{\pi}_2$ at a price $p^k-\varepsilon$ such that $\pi_1^{rk}(p^k-\varepsilon) < 0$. From this it is obvious that the emergence of a link catastrophe also depends on transportation cost differences $c^{rk}-c^{sk}$.

Proposition 2. Consider an existing technology, 1, such that $x_1^{rk} > 0$, $\pi_1^{rk}(p^k) > 0$ and $\bar{\pi}_1^{sk}(p^k) \leq \bar{\pi}_1$. Assume that a new technology, 2, becomes available with an investment threshold value $\bar{\pi}_2$ such that $p^k - c^{sk} > \bar{\pi}_2 + \varepsilon$, $\varepsilon > \bar{\varepsilon}$, and $\pi_1^{rk}(p^k - \bar{\varepsilon}) = 0$. Then for fixed input prices (ρ^i and w^i) one can specify a reduction of the input coefficients from (a_1,b_1) to (a_2,b_2) such that a link catastrophe obtains if in addition $c_2^s - c_2^r < c^{rk} - c^{sk}$.

Proof: The first part of (2.16) is satisfied in the proposition by assumption. Let $\pi_1^{rk}(p^k-\bar{\varepsilon}) = 0$ and let $\varepsilon > \bar{\varepsilon}$. According to assumption $p^k - \varepsilon - c^{sk} > \bar{\pi}_2$. Then we can find a value of c_2^s such that $\pi_2^{sk}(p^k-\varepsilon^*) = p^k - \varepsilon^* - c^{sk} - c_2^s = \bar{\pi}_2$ for $\varepsilon^* > \varepsilon$. Observe now that $c_2^s - c_2^r < c^{rk} - c^{sk}$ or $c_2^s + c^{sk} < c_2^r + c^{rk}$. Hence, we can find ε^{**} such that (i) $\varepsilon^* > \varepsilon^{**} \geq \varepsilon$, and (ii) $\pi_2^{rk}(p^k-\varepsilon^{**}) = p^k - \varepsilon^{**} - c^{rk} - c_2^r < \bar{\pi}_2$. Also, $\pi_2^{sk}(p^k-\varepsilon^{**}) > \bar{\pi}_2$. Hence, all conditions in (2.16) are satisfied if $c_j^i = \rho^i a_j + w^i b_j$, where $i = s,r$, and $j = 1,2$.

The two basic forces which cause a link catastrophe are identified in the following two remarks

Remark 2. If $c_2^s = c_2^r$, a link catastrophe can only obtain if $c^{sk} < c^{rk}$.

Remark 3. If $c^{sk} \geq c^{rk}$, $\rho^r > \rho^s$ and $w^r < w^s$, a link catastrophe requires that the shift from technology 1 to 2 satisfies the criterion for a technology switch in (2.13), which means that $a_1/a_2 > b_1/b_2$.

Proof: Remark 2 is self-evident. The statement in Remark 3 follows from the fact that with $\rho^r > \rho^s$ and $w^r < w^s$, $a_1/a_2 > b_1/b_2$ implies that $c_2^s < c_2^r$.

Proposition 2 specifies conditions which make it possible for a region, s, to introduce a new technology and capture a higher market share in region k by reducing the offered price in this region. In (2.11) we have assumed that it is possible to press down the price in this way. A spatial relocation of production may be conceived as the result of a set of simultaneous link catastrophes.

2.5 Knowledge Intensity and the Labor Force

Consider the cost function in (2.2) and define in relation to this the best practice cost function in period t as

$$c_*^r(t) = \rho^r a_*(t) + w^r b_*(t) = = \min\{\rho^r a + w^r b : (a,b) \in A^r(t)\} \tag{2.17}$$

where A(t) denotes the set of technological pairs (a,b) which is available in region r in period t. Hence, $(a_*^r(t), b_*^r(t))$ is the pair which, given (ρ^r, w^r), minimizes $c^r(t)$. With this notation we indicate two things:

(i) The available technology sets $A^r(t)$ and $A^s(t)$ may differ in specific periods because of delayed diffusion of the production knowledge

(ii) When $(\rho^r, w^r) \neq (\rho^s, w^s)$, the best practice solution may also be different so that $(a_*^r(t), b_*^r(t)) \neq (a_*^s(t), b_*^s(t))$.

One important characteristic of a metropolitan region is often its concentration of employment categories with a high knowledge and competence intensity. With a high R & D intensity a region r may also for long periods retain an advantage by enlarging $A^r(t)$ in a cost favorable direction at a faster rate than competing regions.

The effect of knowledge intensity related directly to the labor force may be illustrated as follows. Let $0 < u(t) < 1$ denote the proportion of the employment with a high knowledge intensity, and let $\bar{u}(t)$ be the lowest possible value of $u(t)$ in period t such that when $u(t) < \bar{u}(t)$ the production cannot be performed. Also let $\ell(t)$ be the average labor input coefficient. Then we may specify the cost component $w^r b(t)$ as follows

$$w^r b(t) = \ell(t)[v^r(1-u) + z^r u] \tag{2.18}$$

where v^r is the unit price of employment with low knowledge requirements and z^r the unit price of employment with high knowledge intensity, and $u \geq \bar{u}(t)$. Assumption (2.12) may then be restated as

> *As the production scale increases and the technology matures, the coefficient $\bar{u}(t)$ is correspondingly reduced.*

With this specification of the problem we may formulate a second version of a link catastrophe. Let, in this case, $\pi^{ik} = \pi^{ik}(\bar{u}) = p^k - c^i - c^{ik}$, and $c^i = \rho^i a + \ell[v^i(1-\bar{u}) + z^i\bar{u}]$. Assume also[1)]

$$z^r < z^s \text{ and } v^r > v^s \tag{2.19}$$

1)This formulation is based on the assumption that $a^r = a^s = a$ and $\ell^r = \ell^s = \ell$ which is used only to reduce the number of indexes.

Proposition 3. Let (2.19) hold, and let $\rho^r a \geq \rho^s a$ and $c^{rk} \geq c^{sk}$. Finally let $\pi^{rk}(\bar{u}) - \pi^{sk}(\bar{u}) = \mu > 0$. Then there is always a shift from $\bar{u}$ to $(\bar{u} - \Delta\bar{u})$ with $\Delta\bar{u}>0$ such that $\pi^{rk}(\bar{u} - \Delta\bar{u}) - \pi^{sk}(\bar{u} - \Delta\bar{u}) < 0$.

Proof: Observe that

(i) $c^{sk} + \rho^s a - c^{rk} - \rho^r a = \delta \leq 0$

(ii) $\pi^{rk}(\bar{u}) - \pi^{sk}(\bar{u}) = \mu = \delta + \ell(1-\bar{u})[v^s-v^r] + \ell\bar{u}[z^s-z^r]$

This implies that $\mu < \ell\bar{u}(z^s-z^r)$, and then there must be a positive $\varepsilon < \bar{u}$ such that $\Delta\bar{u} = \bar{u} - \varepsilon$ yields

(iii) $\mu < \Delta\bar{u}\ell(z^s-z^r)$

Hence, $\pi^{rk}(\bar{u}-\Delta\bar{u}) - \pi^{sk}(\bar{u}-\Delta\bar{u}) = \pi^{rk}(\bar{u}) - \pi^{sk}(\bar{u}) +$

$$+ \ell\Delta\bar{u}\{(v^s-v^r) - (z^s-z^r)\} =$$

$$\underbrace{\mu - \ell\Delta\bar{u}(z^s-z^r)}_{<0} + \underbrace{\ell\Delta\bar{u}(v^s-v^r)}_{<0} < 0$$

Q.E.D.

2.6 Additional Aspects of Product Cycle Dynamics

In this subsection we present some remarks on factors which may increase respectively decrease the introduction of a certain production in a new region.

Consider first the development of demand as specific in (2.4). As long as the demand grows fast in region k existing capacities will in most periods be too small to match demand. In such phases new capacities may emerge without involving any link catastrophes. Let in period t, $\Delta d^s = d^s(p^s(t),t) - d^s(p^s(t-1),t) > 0$, for some $p^s(t) \leq p^s(t-1)$, be the demand expansion in region s. Suppose that this additional demand can be matched by introducing new capacity in region k and/or region r with the link specific unit profit values π_*^{ks} and π_*^{rs}, respectively. Let β_*^{ks} and β_*^{rs} be the market share of Δd^s in the two regions.

Remark 4. Suppose the demand expansion $\Sigma_s \Delta d^s$ has to be satisfied by new production capacities. Then (2.10) can be used to define a *link advantage* for region k as

$$(\pi_*^{ks} - \bar{\pi}_*^k) - (\pi_*^{rk} - \bar{\pi}_*^r) > 0$$

If $\bar{x}_*^k$ is the capacity (scale) associated with technology *, it will be profitable (in the short run) to introduce the capacity in region k only if

$$\Sigma_s \pi_*^{ks} \beta_*^{ks} \Delta d^s \geq \bar{\pi}_*^k \bar{x}_*^k$$

The assumption about demand in (2.4) implies that if the potential demand, $N^s(p^s,t)$, becomes time invariant, the growth in demand will gradually slow down for a region s in which the phase of rapid expansion has elapsed. In such a phase the frequency of link catastrophes should be expected to increase. Factors which will reduce the pace at which the corresponding relocations will be realized is (i) *delayed knowledge diffusion,* (ii) *market channel rigidities and market organization investments,* (iii) *capital market differentials.*

We may use (2.17) to illustrate how the knowledge distribution to region k may be delayed. In such a case we have that $(a_*^r(t), b_*^r(t)) = (a_\tau, b_\tau) \in A^r(t)$ and at the same time

$$\rho^k a_\tau + w^k b_\tau < \rho^r a_\tau + w^r a_\tau \text{ , and}$$

$$(a_\tau, b_\tau) \notin A^k(t)$$

Regional differences in the capital market may delay the introduction of a technology in region k if $\bar{\pi}_*^k > \bar{\pi}_*^r$.

Market channel rigidities means that the mechanism in (2.11) is weak so that the β^{rs}-coefficients have a low price-sensitivity. This may, for example, be caused by marketing efforts and investments in the market organization by maturing firms.

It may be conjectured that metropolitan regions often have a communication network which gives them an advantage in addition to their advantage as regards product development and similar

R & D investments. This means that firms in such regions have the option to substitute market investments for R & D investments. However, a switch from a product development policy to a market investment oriented strategy represents a qualitative change in the long-term dynamics of the industry in a region.

3. PROPOSITIONS, HYPOTHESES AND EMPIRICAL OBSERVATIONS

3.1 Product Cycles Hypotheses

The characterization of product cycle dynamics in section 2 is made for a stylized case in which the development pattern is examined for one specific non-differentiated product. In this abstract case only one aspect of the change process is analyzed, i.e., the change of the production technique--with routinization, increased scale, reduced requirements as regards knowledge intensity and with regional cost differentials of the type found in the factor proportions theory.

When referring to the product cycle theory we should also recognize that the product itself may be changed with better quality as well as new and diversified attributes. Moreover, the emergence of new substitutes forms the basis for renewing the economy of a metropolitan region. Also these aspects of product cycles can be illuminated by means of analytical models. However, before steps in this direction are taken the theoretical outline in the preceding section has to be given a more complete and closed form. It should also be confronted with systematic examinations of empirical data on product cycle development.

In section 3 we provide some empirical evidence as regards the relevance of the proposed approach to analyze industrial dynamics in metropolitan regions. It is then important to recognize that generally one can only observe cycles for products which do not remain unchanged over time but rather constitute groups of differentiated products which are continuously developed and changed in response to changes in the competition and perceived link catastrophes. Hence, our observations comprise all three components of industrial dynamics: (i) *product*, (ii) *process*, and (iii) *market change*.

The above considerations imply that it may be illusory to attempt a proper testing of the model outlined in sections 1 and 2, in particular at a global level. However, some of the available trade statistics can be used to check the consistency between empirical observations and (i) the model propositions in section 2 as well as (ii) the empirical hypotheses in section 1.

We will proceed in two steps. First we examine four macro propositions at three levels of regional resolution, i.e., the OECD region, Sweden, and the Stockholm metropolitan region. These propositions may be formulated as follows:

1. *Knowledge and competence.* High knowledge intensity requirements in production is an important predictor of specialization in favor of highly developed regions.
2. *Relocation of production.* Change in location patterns is intensified as the sectoral production technology becomes increasingly well known.
3. *Protection.* When a sector is maturing technologically and the market shares are stagnating or falling, government measures are used at the national and regional level to protect the production.
4. *Switch from R & D to market channel investments.* As the technology in a sector matures and its demand stagnates the ratio between market oriented and R & D investments increases.

The above hypotheses can be partially tested at the global level with the help of aggregate sectoral data. Finer tests require a more disaggregate specification of both regions and products.

In a second step we illustrate how the regional specialization is correlated with the composition of the labor force. In particular, we examine the following hypothesis:

5. *Knowledge creation.* Occupations oriented towards creation and transmission of knowledge require a high intraregional accessibility (metropolitan characteristic).
6. *Knowledge transmission.* Consultancy occupancy is strongly concentrated on metropolitan areas.

According to the formulated hypotheses product cycles have a time profile of the kind illustrated in Figure 3.1. The first phase is described by a standard logistic introduction or market growth curve. The second part is a phase of decline which is usually slowed down by means of political protection measures. In a second phase of decline military defense arguments may be used to exercise protection which prevents the production in a country to fall below a politically safeguarded level. As already emphasized we should note that this whole pattern may be distorted in statistical records as new products enter under an old classification.

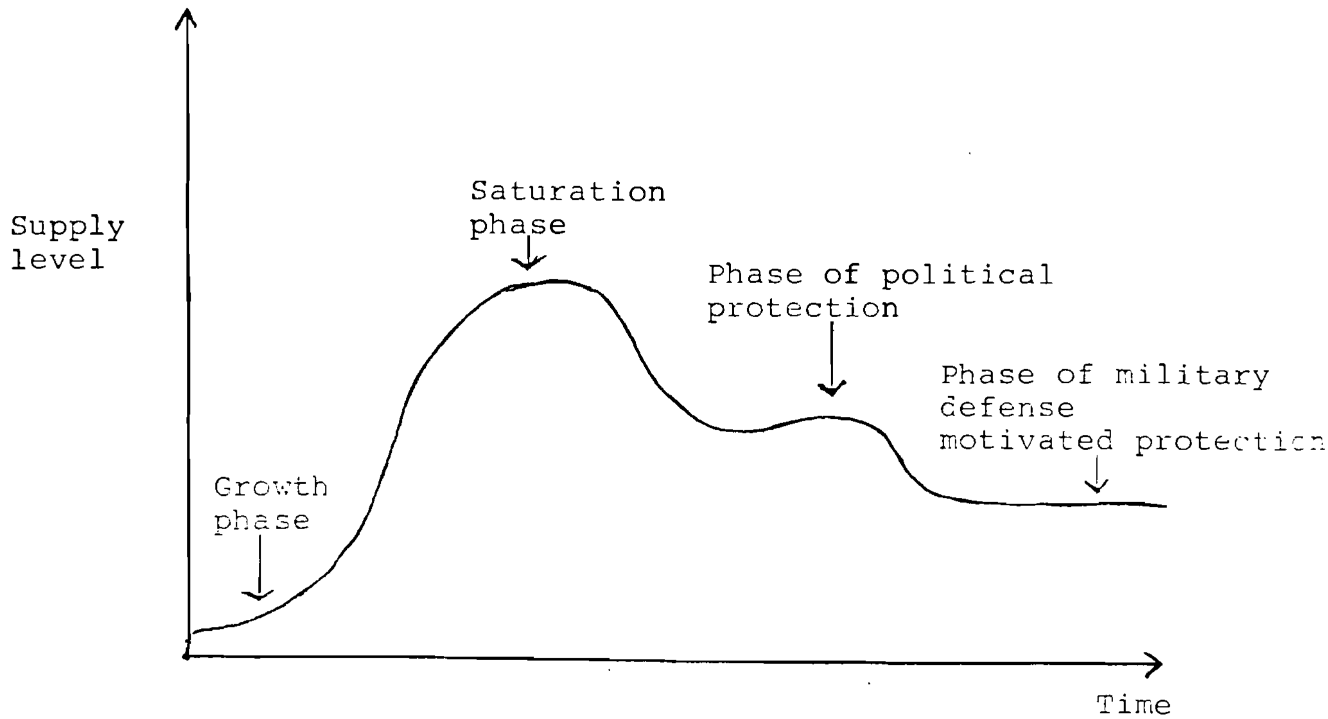


Figure 3.1. Expansion and decline profile of a country's supply of a specific product category.

3.2 Product Cycle Phenomena in OECD, Sweden and Stockholm

Consider the specialization coefficient in (2.6). This coefficient can equivalently be defined for each product group as follows:

$$\sigma_i = m_i/M_i \tag{3.1}$$

In Table 3.1 m_i denotes the import in OECD countries from other OECD countries (intraregional trade), M_i denotes the total import to countries of the OECD region, and σ_i then represents an indicator of the OECD specialization as regards product group i. Change in specialization between year t and t+τ is simply calculated as $\sigma_i(t+\tau) - \sigma_i(t)$.

Table 3.1 also illustrates the following indicator

$$\mu_i = \frac{\text{R\&D investments}}{\text{value added}} 100 \qquad (3.2)$$

where μ_i in this case refers to observations in Sweden. The coefficient μ_i indicates the R & D intensity of product i. The table illustrates clearly that high OECD specialization has a significant covariation with high R & D intensity in Sweden.

Table 3.1. Product cycles and specialization in the OECD region 1971-1977.[1)]

	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 $\bar{\sigma}(1977) = 0.95$ $\bar{\mu}(1980) = 6$	o Rubber products o Plastic products o Metal products o Iron & steel o Instruments $\bar{\sigma}(1977) = 0.93$ $\bar{\mu}(1980) = 5$
LOW SPECIALIZATION	o Shipbuilding o Clay & stone o Food products o Other manufacturing o Wood products o Wood o Non-ferrous metals $\bar{\sigma}(1977) = 0.74$ $\bar{\mu}(1980) = 2$	o Electric products o Textiles o Clothing o Mining o Crude rubber o Telecommunication o Petrol $\bar{\sigma}(1977) = 0.56$ $\bar{\mu}(1980) = 3$

Source: OECD trade statistics 1971-1977; SIND 1982:16

1) Compare this information with the characterization scheme in Figure 1.3.

Table 3.1 records the change in specialization for the period 1971-1977. During the following years 1977-1980 the overall σ-value decreased from 66 to 64 percent for OECD. As indicated in Table 3.2 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 building materials as well as for shipbuilding and other manufacturing, (ii) specialization in transport equipment decreased and iron and steel entered the group of protected production.*

Other marked changes during the late 70s are: *rapid increase in the σ-value for special machinery, civil engineering equipment, and data equipment.*

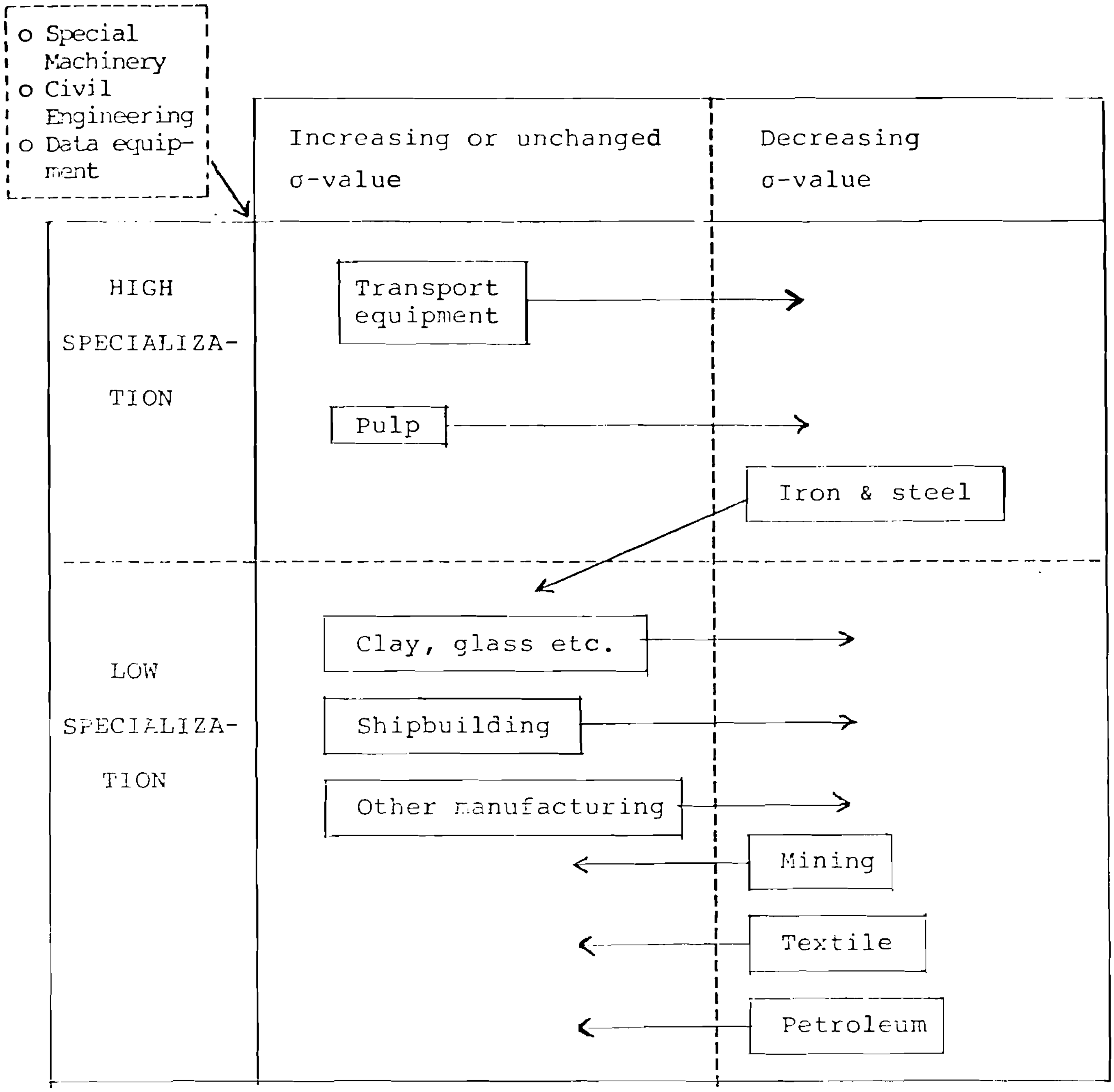
The tendency to favor market organization investments in situations of technological maturing may also be matched against observed patterns. Let η_i be an indicator of maturity for product category i

$$\eta_i = \alpha_i/\beta_i \tag{3.3}$$

where α_i signifies market channel investments and β_i R & D investments. As indicated in Table 3.3 the average Swedish η-coefficient was around 2 for products with a high OECD specialization, while its value was more than 4 for industries with a low OECD specialization. The table also shows that the OECD specialization pattern is well reflected by the pattern of employment changes (1970-1980) in corresponding Swedish industries. One may finally observe that the electrical products group deviates in Sweden from the general OECD pattern. In Sweden one may, in this case, identify very specific product innovations.

It is also possible to test the compatibility between the OECD pattern and the change pattern at a finer spatial disaggregation. Table 3.4 illustrates that industrial change patterns in the Stockholm region may be organized according to the degree of OECD specialization.

Table 3.2. Product categories with changing specialization classification between 1977 and 1980.



Source: OECD trade statistics 1977-1980.

Table 3.3. OECD specialization and maturity indexes for the Swedish industry.

EMPLOYMENT CHANGES IN SWEDISH INDUSTRIES	PRODUCT GROUPS WITH A HIGH OECD SPECIALIZATION	η(1980)	PRODUCT GROUPS WITH A LOW OECD SPECIALIZATION	η(1980)
Increase or slow annual decrease	o Plastic prod. o Printing " o Metal " o Chemicals o Machinery o Instruments o Transport equipm.	3.0 3.0 1.5 1.0 1.0 1.0 0.5	o Electrical prod.	1.0
Signifi-cant annual decrease	o Rubber prod. o Paper & pulp	3.0 2.0	o Wood prod. o Food " o Beverages o Textiles & clothing o Minerals o Mining o Iron & Steel	7.0 6.0 4.0 4.0 2.0 1.0 1.0

Remark: The maturity index η refers to the Swedish industry

Sources: Earlier tables and Swedish employment surveys (AKU) 1970-1980.

Table 3.4. OECD specialization and industrial change in the Stockholm region 1970-1980.

CHANGE PATTERN IN THE STOCK-HOLM REGION	HIGH OECD SPECIALIZATION	LOW OECD SPECIALIZATION
Increasing employment and pro-duction volume	o Plastic products o Chemical " o Printing " o Instruments	
Increasing production volume and decreasing employment	Rubber products Machinery	o Electrical prod. o Food "
Falling employ-ment and pro-duction volume	Metals	Iron and steel Shipbuilding Textiles Wood products Stone & clay

Sources: see Table 3.3 and Johansson (1982).

In a final table we have matched a specialization measure for the Stockholm region with the OECD specialization indicator. High specialization in Stockholm means in this case that the region is more specialized than an average region in Sweden. Hence, it may happen (as with transport equipment, excluding shipbuilding) that Stockholm is as highly specialized as OECD in general, but at the same time has a low specialization compared with Sweden as a whole.

Table 3.5. Specialization in OECD and Stockholm.

RELATIVE SPECIALIZATION IN STOCKHOLM (compared with Sweden)	OECD SPECIALIZATION HIGH	OECD SPECIALIZATION LOW
HIGH	Instruments Chemical products Printing " Machinery	Food products Electrical products
LOW	Plastic products Paper " Rubber " Metal " Transport equipm.	Wood products Textiles Clothing Iron and steel Shipbuilding Stone and clay

Source: Johansson (1982).

In table 3.5 one can see that four product groups with a high but falling OECD specialization have a relatively low specialization in Stockholm as compared with Sweden as a whole. These are plastic, rubber and metal products, and transport equipment. This observation suggests that

the product/production changes in metropolitan regions may function as "product cycle indicators", providing early signals about the direction of change.

3.3 Regional Specialization and Composition of the Labor Force

In section 1.3 the notions *information, knowledge, competence and creativity* were introduced. We also have followed a long tradition by assuming that metropolitan regions can gain a comparative advantage by forming an environment which supports the renewal and development of knowledge and competence (within the labor force and the management systems) which is congruent with technological progress. In this section this hypothesis is examined by studying *the labor force composition* in Swedish regions with varying characteristics. The labor force composition is observed in terms of occupation categories.

In addition the knowledge intensity and likelihood for creative processes is related to the (i) accessibility of R & D organizations and (ii) cluster effects as regards employment categories.

It is obvious that the communication and computer revolution has meant a large increase in the efficiency of information collection, processing and communication. It is however doubtful if it has had any deep influence on the development of knowledge, competence and creativity. 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. Concentration in metropolitan regions is only one organizational form to facilitate such communication.

In summary, from our earlier analyses one may derive the following empirical hypotheses:

(i) The transportation and telecommunication revolution has primarily had a decentralization effect on occupations involved in (i) producing and transporting goods, and (ii) transmitting information.

(ii) Persons involved in knowledge and competence transfers, and in creative activities have a strong tendency to cluster in metropolitan areas and other centers of extremely good accessibility.

In a dynamic context the above also means that information handling (especially when it is used to control goods processing and transportation) should be squeezed out of the areas with metropolitan characteristics to regions of lower density and lower short-distance accessibility.

A simple regression model is used in the following to illustrate how each employment category's share of total employment is correlated with (i) accessibility on long distances to all national markets, denoted by a_r, (ii) accessibility on short distances within a region, denoted by b_r.

This attempt to assess location effects of short- and long-distance accessibility makes use of the following regression equation

$$S_r^k = \gamma_o a_r^{\gamma} b_r^{\sigma} \qquad (3.4)$$

where S_r^k denotes the employment in occupation k and region r. The following accessibility proxies are used

$$\begin{aligned} b_r &= \text{total employment within commuting distance}^{1)} \\ a_r &= \Sigma_r [S_r/\Sigma_r S_r] e^{-\beta drs} \\ S_r &= \text{total employment in region r} \\ d_{rs} &= \text{distance between regions r and s} \\ \beta &= \text{friction coefficient} \end{aligned} \qquad (3.5)$$

Table 3.6 summarizes the effect of local and national accessibility. The table organizes occupation subcategories into groups and measures in percent the number of subcategories per group which have a σ-coefficient (size elasticity) larger than unity[2]. Moreover, the occupation groups are characterized as being primarily in (i) service activities denoted by s, (ii) creation and transmission of knowledge denoted by k, (iii) manufacturing of goods. The table clearly indicates the clustering of knowledge creation and transmission activities in the large regions which provide high intraregional accessibility.

1) In principle the distance is determined by the time needed for commuting; the average distance over regions is approximately 45 kms.

2) The Appendix contains more detailed information about subcategories.

Table 3.6. 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 then unity	Average size elasticity	% share of subcategories with national accessibility elasticity larger than unity
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 (scientific)	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 3.7 provides further insights into the information in the earlier table. In the new table a well structured pattern is revealed; the table approaches a trangular matrix. The knowledge creation and transmission occupations are primarily clustered in the group with parameter values indicating a dominance of local access orientation. The service activities also have an accessibility-orientation, but in this case the orientation is to a large extent towards *interregional accessibility*. Finally, manufacturing of goods is dominated by activities which either are space consuming or embody already matured knowledge which allows for dispersed locations with a low population pressure on the land market. The associated chi-square measure for the whole table indicates that the above conclusions have a rather strong statistical support.

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 a product cycle. It is also clear that the development of new knowledge and its transmission is primarily concentrated in centers of high 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 goods manufacturing (in our case food processing, printing, instrument production and chemical processing) are clustered also in their manufacturing activities onto the knowledge centers. This is in accordance with our general analysis of the product cycle.

The above accessibility assessment needs to be complemented by an investigation of the importance of accessibility to R & D organizations and concentrated R & D activities. The following variables are used to examine the R & D effect on the location of knowledge intensive activities.

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, $\Sigma_i X_i^r = 1$. (3.6)

A^r = measure of interregional and national accessibility

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

Table 3.7. Location and occupational characteristics.

SPATIAL ORIENTATION	PRODUCT-PRODUCTION CHARACTER			
	Knowledge	Service	Goods	Sum
(I) Intraregional access orient	6	4	4	14
(II) Interregional access orient	1	5	6	12
(III) Dispersed and land oriented	0	1	7	8
Sum	7	10	17	34

Remark: $\chi^2 = 11$.

For each employment category i, the following equation is estimated:

$$Y_i^r = \log(Z_i^r/1-Z_i^r) = A^r + \alpha X_i^r + \beta B^r \qquad (3.7)$$

Introducing the standard deviation measures $\sigma_i(Y)$, $\sigma_i(X)$ and $\sigma(B)$, the following μ_i-coefficients can be calculated as

$$\mu_i(X) = \gamma\sigma_i(X)/\sigma_i(Y)$$
$$\mu_i(B) = \beta\sigma(B)/\sigma_i(Y) \qquad (3.8)$$

Sectoral values of the μ_i-coefficients are presented in Table 3.8 with regard to occupation categories with high specialization tendencies ($\mu_i(X)$-coefficient) and strong R & D dependency ($\mu_i(B)$-coefficient). The table combines categories which simultaneously are knowledge-oriented and have a specialization tendency. This reflects the overall pattern in the available data; knowledge-oriented activities which are clustered on the university towns also tend to be in regions with high degrees of specialization, i.e., high $\mu_i(X)$-coefficients. Thus, chemistry and physics science are strongly associated with centers of research and development; in addition they have a tendency to cluster in certain of these regions. However, the table also indicates that regional specialization of knowledge intensive activities can act as a substitute for location to the R & D centers.

Table 3.8. Employment with high specialization dependence, and the corresponding R & D effect.

AGGREGATE OCCUPATION CATEGORIES	SPECIALIZATION EFFECT $\mu_i(X)$-coeff.	R & D EFFECT $\mu_i(B)$-coeff.
Special technical and natural science occup.	0.73	0.11
Literature and art	0.70	0.0
Administration	0.69	0.27
Juridical professions	0.67	0.0
Accounting, etc.	0.66	0.30
Biological science	0.64	0.29
Technical science	0.58	0.43
Commercial science	0.57	0.36
Chemistry and physics science	0.51	0.35
Religious occup.	0.47	0.46
Medical science	0.46	0.44
Education	0.26	0.55

Source: Population surveys FOB 1970 and FOB 1975, SCB (Statistical Office of Sweden).

Remark: The μ-coefficients in this table represent median values of the subcategory coefficients for each aggregate category. The subcategory coefficients are with few exceptions significant at the 0.05 level.

3.4 The Role of Consultancy in the Knowledge Sector

In the preceding section we have empirically demonstrated the concentration of knowledge intensive occupations on regions with metropolitan characteristics and with universities and other research organizations. Creation and transmission of knowledge and R & D results is an activity which also takes place in consultancy firms. The employment in such firms is clustered on metropolitan regions in a very pronounced way.

In some countries there has been a dramatic expansion of information occupations (see Figure 3.2). The growth of the information and knowledge occupations in the advanced economies is not only a growth within the public sector and in R & D departments of manufacturing firms. As a way of overcoming the problem of indivisibilities of R & D resources and to further efficiency of technology and other knowledge transfer between research institutes and private firms, there has been an astonishingly fast expansion of the consultancy sector.

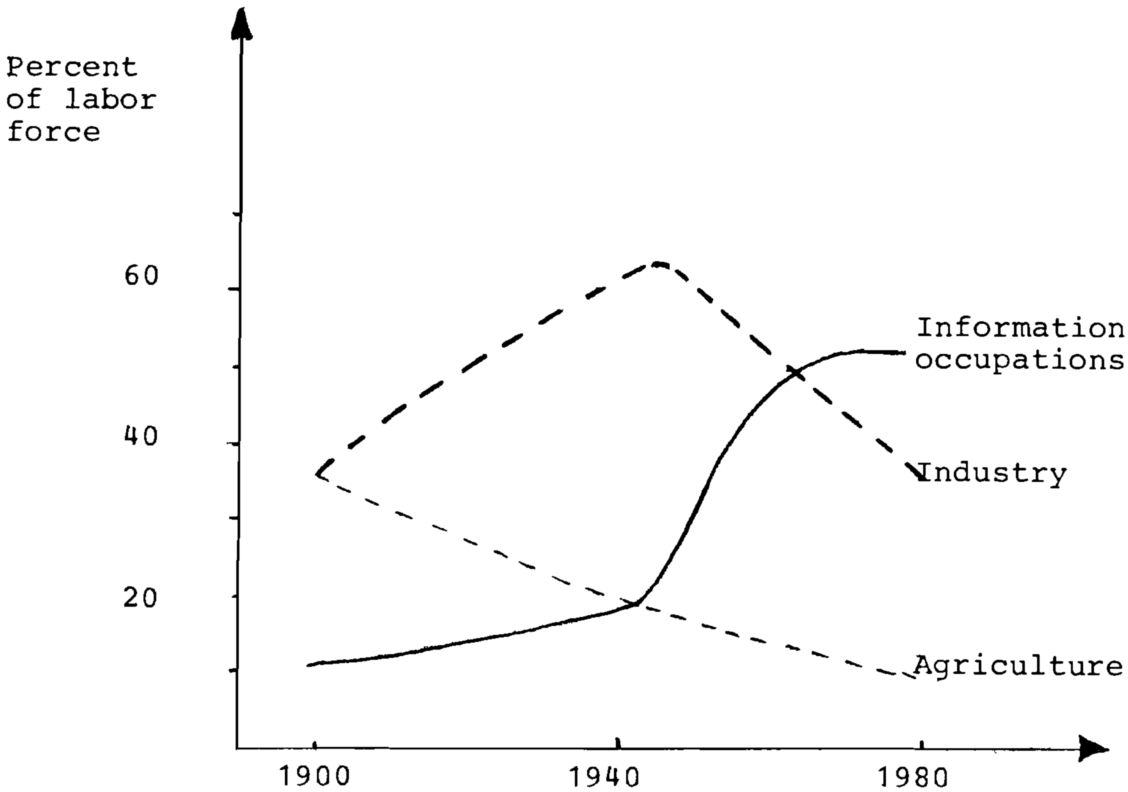


Figure 3.2. Labor force composition in the USA
Source: Adapted from R.C. Dorf (1983)

The consultancy sector in Sweden has grown at an annual rate of 4.3 percent in the 1970s which is a period otherwise characterized by stagnating employment and steadily rising unemployment rates. The spatial pattern of consultancy employment has been highly concentrated in comparison with the general location pattern of employment. This is illustrated in Table 3.9.

Table 3.9. Employment pattern in Sweden 1980 (percent)

REGION	TOTAL EMPLOYMENT (1)	CONSULTANCY EMPLOYMENT (2)	(1)/(2)
Capital region	20.3	39.3	194
Other metropolitan regions	25.5	25.1	98
Other university regions	10.3	7.0	68
Other regions	43.9	28.6	64
	100.0	100.0	

Source: Background material for the Swedish Long-Term Economic Survey 1984 (F. Snickars, Ministry of Industry)

As shown in Table 3.9 consultancy was, in 1980, concentrated in metropolitan and university regions although there were clear tendencies in the 1970s of decentralization of these activities in the process of rapid growth. This development is illustrated in Table 3.10.

Table 3.10 indicates that the severely unbalanced structure of 1970 has been counteracted by the spatial development pattern in the 1970s. This is likely to be a reflection of the dramatic improvements of the personal transportation systems that took place in this decade in Sweden.

In spite of the decentralization process of the 1970s, 64 percent of total consulting employment was still in 1980 located in the metropolitan university regions. Their share of total employment was at the same time 56 percent.

Table 3.10. Changes of consultancy employment share in Swedish regions 1970-1980

REGION	1970		1980		Annual growth rate of share in percent
Capital region	71.5	46.0	64.4	39.3	-1.6
Other metropolitan regions		25.5		25.1	-0.1
Other university regions		6.0		7.0	+1.5
Other regions		22.5		28.6	+2.4

Source: Background material for the Swedish Long-term Economic Survey (F. Snickars, Ministry of Industry)

It can be assumed that the concentration of high level scientific consultancy is even more concentrated in metropolitan regions. It is well known from the USA that the leading R & D transportation systems and applied mathematics consultancy firms are located in the North East Corridor and in the San Francisco Bay area and in a few other metropolitan conurbations. Some of the work of these consultancy firms is almost an "in-house" activity of the well known universities.

4. CONCLUSIONS

This paper presents a framework for analyzing comparative advantages in a dynamical context, and it develops certain aspects of a product cycle model adhering to this framework.

Regional advantages are assumed to be created and caused by the composition of located resources in a broad sense. The theory of comparative advantage is extended to comprise the creation and deterioration of such resources. The analysis also makes use of elements from

(i) von Thünen's location theory by analyzing the interplay between R & D activities, knowledge intensity and land values;

(ii) the factor proportions theory by analyzing cases in which the relative size of the supply of various categories of labor force is inversely related to the relative price of each such category;

(iii) models of technological progress, according to which a technology matures and becomes automated and less knowledge-intensive as the production scale increases.

The product cycle model in the paper is obtained by adding a dynamical dimension to a combination of (i) von Thünen's location theory, (ii) the theory of comparative advantages, (iii) the factor proportions theory, (iv) the theory of interregional trade.

One of the motivations for the paper is a desire to give a viable interpretation of the role that metropolitan regions play in a global economic system. It also represents a challenge for established approaches to analyzing interregional/international trade and the process of technological change by describing comparative advantages as product specific positions which a region develops and loses in a predictable way and as the result of a specific type of *dynamic process*. With this view of the theoretical constructions in preceding sections one may identify several aspects which are only touched upon in the paper and which require much deeper research and more elaborate modeling efforts. Such aspects are

- an extension of the analysis of birthplaces for new products/production
- construction of more complete dynamic models which make it possible to investigate structural stability properties
- systematic empirical investigations and organized tests of hypotheses derived from the product cycle models.

APPENDIX

A.1. Intraregional Accessibility and Urban Size Elasticity

Table 3.6 describes aggregate employment categories (occupation groups) and their corresponding tendency to cluster in locations with high intraregional accessibility, measured by urban size elasticity as defined in (3.4). In the following table estimation results are given for a set of *subcategories* with a *large urban size elasticity*.

SUBCATEGORY	ELASTICITY	MULTIPLE CORRELATION (R^2)
University teachers	2.3	0.58
Systems work & programming	1.8	0.66
Photo laboratory	1.8	0.71
Telegraph operators	1.7	0.80
Train operators	1.7	0.57
Economists, statisticians	1.6	0.87
Forwarding & insurance agents	1.6	0.88
Psychologists	1.6	0.77
Chemists and physical scientists	1.5	0.67
Computer operators	1.5	0.80
Solicitors	1.5	0.81

Source: Estimations based on Swedish censuses, FOB 1970, 1975.

The following table describes the employment change of sectors in Sweden (1970-1980) and Stockholm (1975-1980). The table shows for which sectors the employment growth is faster in Stockholm than in the country as a whole.

SECTOR	ANNUAL EMPLOYMENT CHANGE (%)		
	Sweden 1970-80	Stockholm 1975-80	Difference
Social care	6.3	6.7	+0.4
Real estate administration	4.9	2.3	-1.6
Cultural entertainment	4.5	4.9	+0.4
Health & care	4.3	3.8	-0.5
Education & research	3.8	2.8	-1.0
Consultancy & leasing	3.8	4.6	+0.8
Insurance & banks	2.8	1.7	-1.1
Postal & telecommunications	2.1	2.8	+0.7
Electrical industry	1.0	-3.9	-4.9
Metal	0.5	-6.0	-6.5
Transport equipment	0.3	-0.1	-0.4
*Printing	0.2	0.1	-0.1
*Machinery	-0.3	-2.6	-2.3
*Chemistry	-0.3	1.5	+1.2
Instruments	-0.3	-3.3	-3.0
*Paper	-1.1	-3.7	-2.6
Rubber & plastic	-1.2	-7.1	-5.9
Wood	-1.2	-9.9	-8.7
Food	-1.7	-1.5	-0.2
Iron & steel	-2.1	-12.0	-9.9
General construction	-2.6	0.0	-2.6
Mining	-2.9	-6.8	-3.9
Clay & stone	-3.7	-5.0	-1.3
Textiles	-3.9	-7.1 (Textiles and Clothing & leather combined)	
Clothing & leather	-7.0		

Remark: Sectors marked with a * have, during the period 1970-80, a high non-falling OECD specialization.

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