TECHNICAL CHANGE, LOCATION AND TRADE

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Abstract. The difference between the slow adjustment of localized resources and the faster processes of technical change and product renewal cause a relocation pressure on existing production. Introduction of new products, techniques and establishments is stimulated by opportunities to attain temporary monopoly profits and is restrained by sunk costs in older vintages and competition for local resources. Introduction is more frequent in nodes with a rich and varied importstructure. The process can be modelled as a chain of import, production and export cycles with relocation. Conditions for introduction and change of location are analysed by means of a spatial vintage model.

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1. INTRODUCTION

The analysis in this paper is focused on the interplay between technological development, locational advantages and trade as a dynamic adjustment process. Attention then has to be paid to the differences in adjustment speed between located resources and flows of commodities.

One background to this type of analysis can be found in the static models of comparative advantage and spatial economic equilibrium. Another source of inspiration is vintage production theory which emphasizes rigidities and temporal aspects of technical change as regards location and investment decisions. We outline a framework which brings together the various aspects of technical change, location and trade in a time-space scheme with the help of a hypothesis about the interaction between import and export cycles, generation of innovations, relocation and growth. Thoughts along the last line has earlier been put forward by Jacobs (1984).

Section 2 contains a discussion of static and dynamic aspects of trade, location advantages and the adjustment speed of located resources. Here we introduce the interaction between import, production and export cycles in spatial nodes. In Section 3, some initial steps are taken towards a spatial vintage simulation model of the processes discussed in Section 2. An example of how to model discontinuous shifts in location advantages as products matures and new technology is introduced follows in Section 4. Finally, in Section 5 we discuss measures of cycles in a search for indicators of the development stage of nodes in a spatial network.

2. LOCATED CAPACITIES AND TRADE IN STATIC AND TEMPORAL ANALYSES.

Analyses of international and interregional trade has for decades developed side by side, each group with its own problems. The interregional trade tradition has clung onto either gravity-type or input-output models, both adhering to quantity frameworks with weak representation of the price formation and location processes.

International trade theory has got its inspiration from the comparative advantage paradigm and the Heckscher-Ohlin-Lerner-Samuelson tradition. This approach aims at explaining the specialization, export and import structures of countries while simultaneously solving for corresponding price structures.

The Takayama-Judge (1971) approach represents an example of a model formulation which is thought of as applicable both in a setting of large world regions and small regions within a nation. In a similar spirit, interregional gravity and input-output models have been applied to international trade (Nagy, 1979; Leontief et al, 1977).

The Takayama-Judge type of models have been extended to certain intertemporal formulations (Nagurney, 1986). However, the overall perspective remains, as in the international and interregional trade tradition, static with a given network of nodes and links which are assumed fixed over time. One reason for this is its ties to comparative advantage assumptions based on a given spatial pattern of immobile resources.

An analysis of trade and location must rely on the fact that certain resources have a fixed location while produced goods and services are mobile by means of trade between nodes of varying size in the spatial system. Many of these located resources are on the

other hand created. Hence, their spatial structure can be changed by means of investments. This is true for production plants, infrastructure including transportation systems and the labour force competence profile. Therefore, a dynamic analysis must also recognize that the location pattern of these resources is adjusted, although at a slower pace than the faster transformation of trade, migration and price structures.

The identification of different time scales in the analysis makes it possible to introduce arguments derived from product cycle theory (Dean, 1950; Vernon, 1966; Hirsch, 1967; and Pasinetti, 1981). The latter is based on an assumption that the technology changes at a faster rate than those localized resources which dominate in the cost considerations of location decisions. This is an important factor in the analysis of how the production of already existing products is relocated. It is equally important for the analysis of in which locations new products emerge.

In comparison with recent contributions to spatial dynamics one should observe that we are not constraining the analysis to nodes representing large cities as in Dendrinos & Mullally (1981). Moreover, in contrast to Casetti (1981) we do not identify regions and aggregate economic change in regions. In our framework space is represented by a network of nodes of varying size, and we focus on the development of individual sectors in a multisector, multinodal setting.

Import generated Innovations

Observations throughout modern history verify that for each selected time period one can find a limited number of spatial nodes in which the frequency of product development and innovations in general is much higher than elsewhere. Such parts of a spatial

system may be called creative economic regions (Andersson, 1985; Jacobs, 1984). It has been suggested by a series of researchers that the innovation nodes are characterized by a concentration of R&D activities, a high proportion of knowledge-intensive employment categories, and efficient infrastructure for personal interaction (Andersson and Johansson, 1984; Malecki, 1981; Nelson and Norman, 1977; Noyelle, 1983).

We shall not question the above characterization. However, we want to add a very specific hypothesis about the spatial dynamics of the innovation process. We suggest that a prerequisite for a node to function as a frequent birth place of new products is a rich network of import channels. The reason for this assumption is almost selfevident: any node in the world economy - including places like Tokyo and New York - is only a small fraction of the entire system. As a consequence, only a fragment of all innovations will be created even in the most innovative nodes. Hence inflow of new ideas in the form of new products and new technical solutions through a rich import network will generally be magnitudes larger than what is generated as in-house ideas.

Import and export cycles

Given that a node has a rich import network, the node's ability to develop new products of its own will depend on the located resources and systems properties of the node. A large share of new products are purchased by industries and used as current inputs or equipment. Hence, a node which functions as an import centre for a region and has a variety of production with a large spectrum of inputs will be exposed to a rich import flow. If the located industries have a fast adoption rate with regard to new technical

solutions, new products will reach the import centre as young products.

Novel and technically advanced products need specialized, organized and dense import networks. Information gathering about new products/techniques and scanning for such products are knowledge-intensive activities. The future delivery of the products follows a time pattern which reflects the alertness and competence of customers in the various regions served by an import centre for new products. Gradually the sales find their ways to customers/industries with lower engineering competence. This process is illustrated in Figure 1. The critical element in the process is called "innovative response to import flows".

FIGURE 1. Chains of import and export cycles.

If the import node and its surrounding region of smaller nodes has a sufficiently rich production structure, embedded in an active R&D environment, and with access to a knowledge oriented and creative labour force, then this together with the import of new products constitute a prerequisite for successful innovations. The latter may range from new products in the form of imitations and modifications of imported products adapted to local demand over to creation of products which are complementary to developing import flows. When this type of response is successful, it brings about the birth of local product cycles. As these expand they will (as described in Figure 1) be relocated to other nodes with ties to the innovating node. The final stage is specialization and expanding export cycles in such regions of follower nodes. Our hypothesis suggests the formulation of technological diffusion functions where the independent variables reflect the richness and novelty of the import network, the R&D activity and time. In a similar way we may express the demand for a new product as a function of the import structure, income and prices.

In the following Section we outline essential properties of a simulation model of nodal structural change. The model describes a recursive adjustment process, in which each phase involves an optimization problem. The phases can be connected by intertemporal feedback functions reflecting changes in the structural variables which adjust at a slower pace.

3. OUTLINE OF AN INTERTEMPORAL SPATIAL VINTAGE MODEL

In the original Takayama & Judge spatial equilibrium model, location advantages are solely represented by supply function differentials among regions. This is a non-observable phenomenon

that puts a cover over local resources. An analysis of how the supply behaviour changes over time requires that located resources and their change are made explicit. This may be done by introducing supply functions derived from an existing vintage structure.

Any sector i , producing a homogenous good in a node r and during a given time period is assumed to be composed of a set of establishments. Each establishment has a given production technique τ and production capacity $\bar{Q}_i^r(\tau)$. If the prices of inputs are given, the variable cost per unit output is determined by the technique. Let $v_i^r(\tau)$ denote this cost and order $\tau=1,2,\dots$ in a sequence of monotonically increasing cost levels. The marginal cost level, $v_i^r(Q_i^r)$, associated with the production level Q_i^r is given by;

$$v(Q_i^r) = \min \{ v_i^r(\tau) : \sum_{\tau=1}^{\tau} \bar{Q}_i^r(\tau) \geq Q_i^r \} \quad (3.1)$$

A regional supply price $\tilde{p}_i^r = v_i^r(Q_i^r)$ is (See Figure 2) such that zero gross profits obtain for the marginal establishment τ .

FIGURE 2. Illustration of a vintage production structure

By assumption each establishment has a fixed capacity, production technique and location, neither of which can be changed without investment. By this we have implicitly introduced a temporal element, since supply functions will be transformed over time. Hence, the realized spatial pattern of production as well as delivery patterns are influenced by the diffusion of technological knowledge and investment in new capacity.

We may now formulate the temporal spatial allocation problem by introducing a unit gross profit function associated with each technique τ as follows:

$$\begin{aligned}\pi_i^r(\tau) &= p_i^r - v_i^r(\tau) \\ &= p_i^r - \sum_j p_j^r a_{ji}^r(\tau) - \sum_m w_{mi}^r l_{mi}^r(\tau) \quad \text{all } r, i, \tau\end{aligned} \quad (3.2)$$

where p_i^r denotes market price in node r , w_{mi}^r is the demand wage level for labour category m , $l_{mi}^r(\tau)$ the associated labour input coefficient and $a_{ji}^r(\tau)$ is an intermediate commodity input coefficient. From (3.2) the following net profit objective function is formulated;

$$\text{Max} \quad \sum_{r,i,\tau} \pi_i^r(\tau) Q_i^r(\tau) - \sum_{i,s,r} c_i^{rs} X_i^{rs} \quad (3.3)$$

where c_i^{rs} is the unit transportation cost and X_i^{rs} is the transported volume between r and s of good i . Constraints on the system are, together with associated shadow prices, one set of local resource constraints;

$$\bar{\sigma}_i^r(\tau) [\bar{Q}_i^r(\tau) - Q_i^r(\tau)] = 0 \quad \text{all } r, i, \tau \quad (3.4)$$

$$\mu_m^r [L_m^r - \sum_{i,\tau} l_{mi}^r(\tau)] = 0 \quad \text{all } r, m \quad (3.5)$$

and one set of material balance constraints;

$$\sigma_i^r [\sum_s x_i^{sr} - D_i^r] = 0 \quad \text{all } r, i \quad (3.6)$$

$$\tilde{\sigma}_i^r [\sum_\tau Q_i^r(\tau) - \sum_s x_i^{rs}] = 0 \quad \text{all } r, i \quad (3.7)$$

where σ_i^r is interpreted as the market clearing demand price and $\tilde{\sigma}_i^r$ as the market clearing supply price. We may note that it is possible to express the demand by

$$D_j^r(Q^r, p^r) = d_j^r(p^r) + \sum_{i \neq j} a_{ji}^r(\tau) Q_i^r(\tau) \quad \text{all } r, j \quad (3.8)$$

where the first component on the right hand represents a price dependent final demand and the second intermediate deliveries. The problem (3.3 - 3.8) contains a simultaneous solution of prices and quantities, where the price formation constraints includes

$$x_i^{rs} [\sigma_i^s - c^{rs} - \tilde{\sigma}_i^r] = 0 \quad \text{all } r, s, i \quad (3.9)$$

and

$$p_i^r \leq \sigma_i^r \Rightarrow \tilde{\sigma}_i^s \geq p_i^r - c_i^{sr} \quad \text{all } r, s, i \quad (3.10)$$

The solution can be characterized as a short run competitive equilibrium where production is allocated to nodes with favourable cost structures. The vintage formulation illustrates profit opportunities in young units and an incentive to undertake investments in new technology. In the next section we introduce investments into the model.

Maturing products, increasing returns and specialization

One part of product cycle theory states that products are ageing in the sense that market saturation develops over time and is followed by market decline. Two interacting processes are essential for the explanation of this phenomenon. One is the

development of new industry and household "production techniques" leading to decreasing input coefficients in modern establishments which produce ageing products. If the search for such input-reducing solutions is an ongoing process, it is natural that it reveals itself in the form of a maturity-depending evolution. The second explanation is the entry of new products and systems, often of a quite different nature but still with the capability of replacing maturing products and thereby making them gradually obsolete.

The above observations have severe implications for those nodes hosting export oriented production. To the extent that they are strongly specialized in this production, their local resources and infrastructure will be equally specialized and one-sided. Hence, the process of specialization creates captive nodes, with rigid local resources which cannot adapt to new production conditions at a speed which is compatible with that in competing nodes. There are several reasons for this. One is that the production scale of a mature production system will dominate the economic life more than emerging smaller scale operations. More important is that large scale and mature production units are export oriented. The advantages of their locations are based on (i) availability of labour with standardized competence, (ii) availability of land at a relatively seen low land use cost, (iii) a favourable position in the network for long distance transport. The local market is small compared to the production scale. Hence, the export orientation.

For given time intervals, zero or negative profits may also be prevented by means of oligopolistic price control. However, shrinking markets due to substitution competition from new products will make the ability to reduce the costs of production via investments vital.

With investment opportunities, (3.3)-(3.10) is extended to include new capacity $\bar{Q}_i^r(\tau^*) = Q_i^r(\tau^*)$ with technique τ^* , and a profit contribution to the objective function given by

$$[\pi_i^r(\tau^*) - \delta k_i] Q_i^r(\tau^*) \quad \text{all } r, i \quad (3.11)$$

where k_i is an investment coefficient and δ the pertinent rate of interest. The objective function (3.3), now including (3.11) implies an overall profit maximization with regard to existing capacities and investment allocation in potential units. Our approach reflects an assumption that the investment capital market is non-spatial so that investments are made in the most profitable locations.

A new technique τ^* must satisfy $p_i^r - v_i^r(\tau^*) - \delta k_i - \bar{\sigma}_i^r(\tau^*) = 0$ as $\bar{\sigma}_i^r(\tau^*) \geq 0$. For a given demand structure satisfied by already existing capacities, τ^* will be introduced if it can squeeze out another already installed, sunk cost technique τ^o which at the local price p_i^s will realize $p_i^s - v_i^s(\tau^o) - \bar{\sigma}_i^s(\tau^o) = 0$ as $\bar{\sigma}_i^s(\tau^o) \leq 0$. The sunk cost condition for installed capacities implies that a growing demand or reduced transportation costs is a prerequisite for the introduction of a new technique, if the latter is not sufficiently superior to the least profitable one in the economy considered.

The conclusion above may be related to Negishi's interpretation of Adam Smith's analysis of (i) increasing returns and diminishing costs, and (ii) the natural order of investment (Negishi, 1985). According to this, the equilibrium of a firm is characterized by a kink in the demand it perceives. This implies that the utilization of new techniques which can benefit from increasing returns to

scale is halted as long as it is not stimulated by growth in demand. With our vintage formulation, it is not sufficient that $\pi_i^r(\tau^*) = p_i^r - v_i^r(\tau^*) > \pi_i^r(\tau^0)$, where $\pi_i^r(\tau^0)$ represents a unit in any location s for which the transportation cost differentials have been considered when representing $\pi_i^s(\tau^0)$ by $\pi_i^r(\tau^0)$. Only when $\pi_i^r(\tau^*) > \pi_i^r(\tau^0) + \delta k_i$ the price p_i^r can be reduced to a level such that technique τ^0 leaves the market. Hence, existing capacities can apply a markup price, since potential entrants have to include capital costs in their price calculation. Moreover, this means that existing firms are capable of reducing their price level, and this implies a kink in every firm's demand curve.

Smith's consideration of increasing returns to scale may in this context be related to the product cycle assumption which states that as a technology matures, new techniques are developed utilizing large scale, standardized production systems with lower unit production cost. Figure 3 visualizes this idea.

FIGURE 3. Illustration of increasing returns to scale and restrictions to entry for two stages of technical knowledge.

Figure 3 depicts two techniques and their cost curves. Technique τ^* becomes available after technique τ has been established. The different cost curves, omitting sector and region indicies, are defined as

$$TC(\tau) = TVC(\tau) + TFC(\tau) = v(\tau)Q(\tau) + \delta k\bar{Q}(\tau) \quad (3.13)$$

$$ATC(\tau) = AVC(\tau) + AFC(\tau) = v(\tau) + \delta kQ(\tau)/\bar{Q}(\tau)$$

As the fixed capital cost for technique τ represents sunk costs, the new technique τ^* is profitable when its selling price is not below $p^* = ATC(\tau^*) \leq AVC(\tau) = p$. When this restriction to entry is binding, an increase in demand must occur before the introduction of τ^* becomes economically feasible. Technical change based on sequentially increased scale aggravates the necessity of expanding demand.

We may notice that the comparative advantage conditions under which a new large scale technology becomes profitable normally implies a change of location in relation to older techniques. Before we illustrate such a shift in locational advantage we shall study the case when a new product is introduced.

New Products and Temporary Monopolies

Our model formulation emphasizes the importance of the time element in competition. When expansion in demand is expected, the firm which reacts fastest obtains a definite advantage. Any follower must incorporate investment costs in its calculations when competing with the variable costs of the forerunner firm.

In particular, the introduction of new products is assumed to be stimulated by the existence of market solutions allowing for temporary monopolies with associated quasi-rents. Within the model

framework represented by (3.3)-(3.11) a new product has to be identified by an extra commodity index. Let us consider the production of such a commodity in node r . To simplify notation we formulate a lagrangian L which contains only the new commodity. All we need then is the spatial index. We also observe that $x^{ks} = 0$ for all $k \neq r$;

$$\begin{aligned}
 L = & \sum_s p^s(D^s)D^s - v^r Q^r - \delta k^r Q^r - \sum_s c^{rs} x^{rs} + \\
 & \tilde{\sigma}^r [Q^r - \sum_s x^{rs}] + \sum_s \sigma^s [x^{rs} - D^s] + \\
 & \bar{\sigma}^r [\bar{Q}^r - Q^r]
 \end{aligned} \tag{3.13}$$

where D^s denotes the demand in node s , $v^r Q^r$ the total cost of production in r , δ the rate of interest on investment, k^r the investment coefficient in r and $\bar{\sigma}^r$ the shadow price of the initial vintage with capacity $\bar{Q}^r$. With the formulation in (3.13) we assume that the introduced vintage which is located in r has a monopoly position. The constituents of such a solution are revealed by the Kuhn-Tucker conditions. By differentiating (3.13) with respect to D^s we can establish that for $D^s > 0$,

$$\sigma^s = p^s(1 + \phi^s) \tag{3.14}$$

where $\phi^s < 0$ denotes the elasticity of $p^s(D^s)$. Hence, σ^s equals the marginal revenue. Differentiation of (3.13) with respect to Q^r and x^{rs} yields together with (3.14);

$$\bar{\sigma}^r = p^s(1 + \phi^s) - c^{rs} - \delta k^r - v^r \quad \text{all } s \tag{3.15}$$

provided that $x^{rs} > 0$. As $\bar{o}^r \geq 0$ this represents a solution with monopoly profits. A monopoly position in node r may be based on factors of the following kind:

(i) Knowledge about the production technique associated with the new product is only available in node r . This means that $\bar{Q}^s = 0$ for all other nodes, except of node r .

(ii) The cost of acquiring the production knowledge is larger in other nodes, represented by $k^s > k^r$.

(iii) One or several production factors are not available in other nodes and only in limited amount in node r . In this case $\sigma^r > 0$ and $\bar{Q}^s = 0$ for other nodes.

(iv) The price of necessary input factors are considerably higher in other nodes so that the marginal cost $v^s(Q^s) > v^r(Q^r)$ for all relevant levels $Q^s = Q^r$.

Monopoly caused by conditions like those above are temporary in nature to the extent that (i) production knowledge will diffuse over space as time goes by, (ii) the production technique is standardized and becomes transferable, (iii) input requirements are adjusted as the technique is improved so that scarce inputs can be replaced by standardized ones.

4. DISCONTINUOUS SHIFTS IN LOCATION ADVANTAGES

The maturity of a production process with an increasing standardization of the product and of the production process, results in disproportionally changing input coefficients with successively (i) a relatively seen larger land use coefficient, (ii) an increased ratio between labour with standardized competence and high engineering competence, and (iii) relatively higher ratio between long and short distance transportation of goods and persons. All this implies, as mentioned in Section 3, that the

location advantages will shift to the extent pertinent input prices vary for different nodes of varying size and network centrality. We shall in this Section further illuminate such a relocation process within a sector with a simplified example.

Following an outline in Johansson and Karlsson (1986) we consider a "line economy" extending from a center, $r = 0$, towards a periphery. The unit production cost of the potential, "best practice" technique τ^* at time t , in sector i at location r on the line, is denoted by $v_i^r(\tau^*, t)$. Let us introduce k as an indicator of the maturity of the production technique τ^* . As in the previous analysis we may assume that the potential technique available for installment changes over time, represented by a growing k . This process is then time dependent, but also dependent on the rate of technological diffusion in the economy, the adaptivity and innovativity in the economy etc. We have earlier assumed that this process is related to the trade pattern and import replacement activity in the economy.

The cost function contains three components: a location and maturity specified set up cost $b(r, k)$, and two input resource coefficients $l(k)$ and $a(k)$ with associated prices $w(r)$ and $p(r)$. Retaining the assumption about maturing product cycles we assume that as k grows the unit input $a(k)$ grows and $l(k)$ falls. We also assume that the local resource price $p(r)$ falls as r increases and that the price $w(r)$ increases as described in Figure 4.

FIGURE 4. Price pattern of the two localized resources.

FIGURE 5. Illustration of the set H.

To find location advantages we minimize the cost function $v_i^r(\tau^*, t) = v^*(r, k) = b(r, k) + l(k)w(r) + a(k)p(r)$. It has the following first and second order derivatives with respect to r : $\dot{v}^* = \dot{b} + l(k)\dot{w} + a(k)\dot{p}$ and $\ddot{v}^* = \ddot{b} + l(k)\ddot{w} + a(k)\ddot{p}$. The set of stationary points is

$$H = \{(r, k): \dot{v}^* = 0\} \quad (4.1)$$

With the price profiles in Figure 4, $\ddot{w}$ will change from a positive to a negative sign as r expands while $\ddot{p}$ is positive and decreasing. Hence, H will generally contain a relocation point (r^o, k^o) such that $\ddot{v}^* > 0$ in a direction from r^o to the center and $\ddot{v}^* < 0$ in an interval further away from r^o . For $\ddot{b} \approx 0$ (which is natural to assume) the switch occurs when $a(k)/l(k) = -\ddot{w}/\ddot{p}$.

Given that $\ddot{w}$ is gradually reduced further out from r^0 and that $\ddot{p}$ remains positive, the set H will have the type of configuration illustrated in Figure 5. As depicted in the figure, a discontinuous shift occurs as regards the most advantageous location. This location shifts from a central to a peripheral position.

The driving force of the described process is the time-dependent change in τ^* via k . This change is related to the set H by the condition $dk/dt = \ddot{v}^* \geq 0$. Relocation takes place at the bifurcation point where $dk/dt = 0$. We may also observe that the assumption about the input coefficients can be replaced by the condition that they both are reduced as k increases, while $l(k) > a(k)$ for young products and $l(k) < a(k)$ for larger values of k .

The example here aims to illustrate the role of located resources and their spatial price structure in the process of production relocation. More peculiar price patterns than the ones in Figure 4 will naturally increase the set of drastic relocation points. It should be emphasized that we have not investigated the relocation itself, since this process is also influenced by the sunk cost rigidities described in the earlier section and their interplay with changes in demand.

5. PRODUCT VINTAGES AND IMPORT CYCLES

The process described earlier in Figure 1 under the concept of import and export cycles and illustrated in the previous sections implies that the different stages of a product cycle can be analysed in terms of each product's vintage. An imported "young" product is primarily sold to local customers. As the product becomes older, it is spread to customers in other regions. In Table 1 the two initial stages of an import cycle are depicted with regard to information technology equipment trade in the Stockholm region.

TABLE 1. Sales of information technology equipment by technology trade firms in the Stockholm region 1986.

VINTAGE OF THE PRODUCT IN THE REGION	DOMINATING DELIVERY PATTERN	
	Local deliveries %	Deliveries to other regions in the country %
Younger than 2 years	65	42
2-5 years	31	34
Older than 5 years	4	24
Sum	100	100

Source: Anderstig, Hårsman, Odén (1986)

Remark: 'Dominating' signifies that more than 50 per cent of deliveries follows a certain pattern

In this final section we discuss the observability of such import cycles and measures of the import replacement process. Consider node r and a product i , and define

$$\begin{aligned}
 \theta_i^r &= \text{time at which the import of product } i \text{ starts in} \\
 &\quad \text{node } r, \\
 \mu_i^r &= \text{time at which the production of } i \text{ starts in} \quad (5.1) \\
 &\quad \text{node } r, \\
 \mu_i &= \text{time at which the first production starts in a} \\
 &\quad \text{global sense, i.e., in the world economy.}
 \end{aligned}$$

At time t the vintage of an import flow can be measured by $\theta_i^r(t)$

$= t - \theta_i^r$. The corresponding measure for production is

$\mu_i^r(t) = t - \mu_i^r$. The global vintage measure is $\mu_i(t) = t - \mu_i$.

Let Q_i^r , M_i^r and E_i^r denote production, import and export volume, respectively. In Figure 6 we have depicted three development patterns, indicated by (a), (b) and (c).

FIGURE 6. Illustration of import cycles.

As a response to the original import, we find in case (a) that node r initiates production which replaces the import and is followed by an export flow from the node. In case (b) production is established in the node and the import flow is reduced. As time goes by the production technique may be further routinized and node r loses its location advantage and, as in (c), the production disappears from the node, since it can now be imported at lower costs from new locations which have an advantage as hosts for the routinized production. A well known historical example of recurrent import flow would be the Boston region which replaced an initial import of textiles with "domestic" production which after a long period of specialization was terminated and thereby opened for a second wave of textile imports into the region.

Summing over all products we may form aggregate measures of the import, production and export vintage of a node. Such measures can be formulated so as to exclude reimported products, or they can be calculated only for subgroups of products. Indicators can also be formulated to provide aggregate measures of forerunners and followers in a worldwide multinodal system. We may note that (5.1) does not provide any information about the richness of the production and the import and export flows. Such dispersion could be brought in as complementary characterization. Of course, this also brings us to the questions: how do we define a new product vintage, how do we distinguish products and product groups? We suggest that properties and attributes of products should be related to the processes in which they are inputs - be it industrial, service or household production, the latter usually recognized as private consumption.

6. CONCLUSION

In this paper we have taken a small step in the direction of an integrated framework for analysis of the dynamics of location and trade in an environment of continuous technical change. Within an overall theory of import, product and export cycles we have suggested measures of such cycles.

Primarily, the "fast" part of the process has been discussed. In a more profound analysis the adjustment process of the "slow" resources must be examined more explicitly. Also, the connection between spatial and temporal scales must be analysed.

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