Wirtschaftsuniversität Wien
Vienna University of Economics and Business Administration

Working Papers Series:

Growth and Employment in Europe: Sustainability and Competitiveness

Working Paper No. 35

Economic Development, Variety and Employment

Pier Paolo Saviotti and Andreas Pyka

September 2003

This working paper series presents research results of the WU-Research Focus:
Growth and Employment in Europe, Sustainability and Competitiveness
The papers are available online under: http://www.wu-wien.ac.at/inst/vw1/gee/workp.html

ECONOMIC DEVELOPMENT, VARIETY AND EMPLOYMENT

by

Pier Paolo Saviotti
INRA, Université Pierre Mendés-France,
BP 47, 38040 Grenoble Cédex 9, France.
Tel: +33 4 76825831, Fax: +33 4 76825455.
E- mail: saviotti@grenoble.inra.fr
and IDEFI, CNRS, Sophia Antipolis,
Tel: +33/0 493 95 41 52, Fax: +33/0 493 65 37 98
E- mail: saviotti@idefi.cnrs.fr

and

Andreas Pyka
Seibersdorf Research, Austrian Research Centers
A-2444 Seibersdorf, Austria
and
Economics Department, University of Augsburg
D-86135 Augsburg, Germany;
Tel: +49/821-598-4178, Fax: +49/821-598-4229
E-mail: andreas.pyka@wiwi.uni-augsburg.de

Abstract

This paper studies qualitative change taking place during economic development. In the model presented qualitative change is created by the emergence of new sectors, each of which produces an output that is different from other sectors. A system with a variable number of sectors is simulated. The model predicts that under given conditions the evolution of a sector tends to follow a life cycle in both the number of firms and in terms of employment. The cyclical behavior is determined by the balance between the increasing intensity of competition, saturating demand and increasing returns to adoption. In its present form the model is a simplified representation of the economic system, but several improvements can be introduced in order to increase its degree of realism.

ECONOMIC DEVELOPMENT, VARIETY AND EMPLOYMENT.

Pier Paolo Saviotti (1) and Andreas Pyka (2)

(1) INRA, Université Pierre Mendés-France, BP 47, 38040 Grenoble Cédex 9, France. Tel: +33 4 76825831; Fax: +33 4 76825455. E-mail: saviotti@grenoble.inra.fr
and IDEFI, CNRS, Sophia Antipolis, Tel: +33/0 493 95 41 52, Fax: +33/0 493 65 37 98 saviotti@idefi.cnrs.fr

(2) Seibersdorf Research, Austrian Research Centers, A-2444 Seibersdorf, Austria and Economics Department, University of Augsburg; D-86135 Augsburg, Germany; Tel: +49/821-598-4178, Fax: +49/821-598-4229, e-mail: andreas.pyka@wiwi.uni-augsburg.de

1) INTRODUCTION AND CONCEPTUAL BACKGROUND.

One of the main observable features of the process of economic development that has taken place since the industrial revolution is the creation of new objects, for example new products and services, of the activities required to produce these new objects and of the required institutions (Saviotti, ,1996; Freeman, Louça, 2001; Perez 2003). Thus, economic development cannot be reduced to a simple growth in the efficiency of all existing activities, that is to a purely quantitative growth, as it was often implicitly assumed in a number of previous growth models. The emergence of new goods and services is the result of the increasingly systematic use of innovation as a component of economic development and, in the mean time, it amounts to a process of qualitative change within the economic system. The new goods and services are often not substitutes of pre-existing ones, but provide consumers and users with functions hitherto unavailable in the economic system. During this process the composition of the economic system, intended as the list of objects, activities and actors required to describe the economic system, changes. In this perspective development is a process of transformation and not simply one of quantitative growth.

The previous considerations can have very important implications depending on whether the composition of an economic system at a given time is only the effect of previous economic development or also a potential determinant of future economic development. The attention and resources allocated by policymakers to the creation of new sectors point towards an implicit acceptance of their role as catalysts of future economic development. Economic growth models are of limited help in this context. The creation of qualitative change by innovations is a phenomenon very difficult to model. Some endogenous growth models (e.g. Romer, 1987,1990; Aghion, Howittt, 1998; Lucas, 1993) have shown an awareness of the problem. For example, in Romer (1987,1990) the number of sectors producing capital goods increases with as a result of R&D activities. Aghion and Howitt (1998) developed a multisectoral model with inter-sector flows, but with a *given* number of sectors. A greater awareness of the presence and of the role of structural change has in the past been shown by a number of publications that can be called structuralist. For example Pasinetti's (1981,1993) sophisticated multi-sector model leads us to foresee the emergence of bottlenecks in the development of the economic system and the creation of new sectors as a way of overcoming such bottlenecks. A series of empirical studies (Salter, 1960; Cornwall, 1977; Fagerberg, Verspagen, 1999; Fagerberg, 2000) analysed the features and impact of structural change for periods ranging from the 1920s to the 1990s. All these papers show the considerable importance that structural change had throughout most of the XXth century. Furthermore, the importance of structural change can be documented for the period following the industrial revolution (Freeman Louça, 2001; Perez, 2003; Freeman Clark, Soete, 1982). In all the previous models there is a tension between the need to treat economic history as the field of observation supplying us with the events to be explained (our explanandum) and the attempt to model the process of economic development. The simplifications inherent in modelling tend to hide the complexity of the real processes of historical development. Often if not always models correspond to specific requirements and are useful in limited contexts. For example, in a short run model it makes sense to neglect qualitative change, since it occurs over very long periods of time. If, however, we were interested in explaining the evolution of the economic system in the period since the industrial revolution, the same assumption would be highly unrealistic. The problem then becomes to explain precisely the change in composition of the economic system, which in this perspective cannot be neglected. All our models involve approximations and the approximations that are effective for a short run model are not necessarily the best ones for a model intended to explain the long range evolution of the system.

The process of economic development previously described can be analysed in terms of two basic concepts in economics, division of labour and coordination. The creation of new objects and of the corresponding activities increases the extent of division of labour in the economy. New occupations are added to the pre-existing ones. This form of division of labour goes side by side with the increasing number of production stages in pre-existing activities. However, all the new activities raise new coordination problems that can be sorted out only gradually by means of learning in the economy. Very often the required coordination is not only between the firms producing new goods and services and the pre-existing ones. Coordination is required in other interfaces, for example between producers and users. Frequently new infrastructures, institutions, regulations and policies are required in order for new activities to develop and to acquire their full economic weight. In other words, the process of qualitative change leading to a changing composition of the economic system amounts to the co-evolution of technologies and institutions (Nelson, 1994, xxxx;) These processes take place over long periods of time, sometimes amounting to long cycles in economic development (Freeman, Louça, 2001; Perez, 2003). Summarizing, while innovation and qualitative change increase the extent of division of labour in the economy by creating new objects and the corresponding production activities, the solution of the coordination problems thus raised often requires new institutions and is spread over long periods of time. In our model for the time being all these complex institutional structures and coordination mechanisms are subsumed under the term FA_i, financial availability. As we already pointed out, financial availability depends both on the quantity of money available in an economy and on the knowledge required to judge the development potential of that sector. What is particularly important here is that FA_i multiplies AG_i, the adjustment gap. This means that even if a very large potential market were to exist, no development would take place unless a non zero FA_i was present. This is a general property of co-evolution as opposed to single factor explanations: all the required ingredients have to be present jointly if development is to take place. Furthermore, the mixture of different development factors is important as well: if one factor is present in non zero but very small quantities it will constitute the bottleneck slowing down overall development. The term FA_i can then be considered a simplified representation of those factors that co-evolve together with the adjustment gap.

If we accept that the composition of the economic system is a determinant of future economic development, we need to represent the composition analytically in order to be able to introduce it into development models. The concept of variety defined as follows provides us with one way to achieve this analytical representation:

Variety is the number of actors, activities and objects required to describe the economic system.

It must be pointed out that in this context variety is used at a higher level of aggregation than the one traditionally used in much of the economic literature on the subject (see for example Lancaster, 1975, 1979). While traditionally variety measured the degree of differentiation of a product group, in the present paper it is used to measure the degree of differentiation of economic systems at different level of aggregation, starting from a firm or an individual product and ending with the world economy. In this paper then variety is a measure of the extent of differentiation of the economic system. Used in this sense the concept of variety resembles more that of diversity as used by biologists than the variety that has traditionally been found in the economics literature.

Two hypotheses link variety to economic development (Saviotti, 1996):

Hypothesis 1: The growth in variety is a necessary requirement for long-term economic development.

Hypothesis 2: variety growth, leading to new sectors, and productivity growth in pre-existing sectors, are complementary and not independent aspects of economic development.

These two hypotheses can be justified by the imbalance between productivity growth and demand growth (Pasinetti, 1981,1993). If productivity keeps increasing all the time while the demand for new goods and services reaches a saturation point, an imbalance arises. If the economy were constituted by a constant set of activities, in presence of growing productivity it would become possible to produce all demanded goods and services with a decreasing proportion of the resources used as inputs, including labour. This imbalance would then constitute a bottleneck for economic development. The addition of new goods and services to the economic system, that is, a change in composition leading to a growth in variety, can be a form of compensation for the potential displacement of labour and of other resources. Variety growth is then required for the long term continuation of economic development. On the other hand, new goods and services can only be generated by means of search activities. The resources required for these activities can only come from the increases in productivity in pre-existing sectors in a way similar to what happened during the process of industrialisation. At that time productivity growth in agriculture created the resources required for industrialisation (Kuznets, 1965). Similarly productivity growth in pre-existing sectors creates the resources required for search activities and thus for the generation of new products and services. In a Schumpeterian fashion, the growing productivity of the routines constituting the circular flow creates the resources required for innovation, without which economic development would come to a halt (Schumpeter, 1912, 1934).

2) THE MODEL

2.1) THE DEFINITION OF A SECTOR

In the model described in this paper an industrial sector will be defined as the collection of firms producing a unique but (in some cases highly) differentiated product. An industrial sector can thus be represented graphically, though in an approximate way, in characteristics space. The representation of a sector follows from that of a product by means of two sets of characteristics (Saviotti, Metcalfe, 1984; Saviotti, 1996) (Fig.1), representing the internal structure of a product (technical characteristics) and the services performed by the products for its users respectively. The distinction between the two sets of characteristics can be considered an extension of Lancaster's (1966) approach in order to better take into account the interaction between demand and supply in the process of innovation.

$$\begin{pmatrix} X_1 \\ X_2 \\ . \\ . \\ . \\ X_n \end{pmatrix} \Longleftrightarrow \begin{pmatrix} Y_1 \\ Y_2 \\ . \\ . \\ . \\ Y_m \end{pmatrix}$$

Fig. 1. Twin characteristics representation of products. The left set (Xs) represents the technical characteristics, corresponding to the internal structure of the product, and the right set (Ys) represents the services supplied to the users of the product.

The internal structure of a product is provided by producers and it is the only part of the product that can be *directly* produced. Services are linked to technical characteristics by a pattern of correspondence (or imaging), which must be known to producers. Consumers on the other hand are interested only in services, and in principle do not need to know about technical characteristics. Thus, we can expect that only service characteristics should enter the demand function. Accordingly the industrial sector will be represented here by the distribution of product models in *service* characteristics space (Fig. 2). Since firms produce differentiated products the distribution of their models in a simplified two characteristics space will be a 'cloud' or population separable from that of any other sector. Thus, different industrial sectors will be represented as separable populations of product models either in the same or in different dimensions of characteristics space. It must be noticed that two sectors defined in the same dimensions of characteristics space do not necessarily produce substitutes. The existence of two separable sectors in the same dimensions of characteristics space is usually the result of a process of specialization, in which an initially undifferentiated product technology gradually separates into two (or more) distinguishable product technologies. Cars and trucks provide a useful example. Of course, technological change and innovation continuously reshape the boundaries between existing sectors. We wish to stress that this definition of industrial sector does not correspond to those normally used by statisticians. In fact, he definitions of industrial sectors used in industrial statistics are due more to pragmatic considerations than to the use of an adequate theoretical framework. The concept of industry has never been a simple one to use. We can classify firms as belonging to the same industrial sector if they have same similar features. For example, whether implicitly or explicitly, the similarity of products (or more in general of outputs) is a very often used criterion. The automobile, shoes, watch, computers etc. industries are defined according to this criterion. However, an alternative if perhaps less often used criterion, classifies firms in the same industry when they carry out similar activities. For example, the chemical industry produces an extremely wide range of quite heterogeneous goods belonging to different markets. In this case the similarity refers to the processes, or activities, used by firms rather than to their products. Both these criteria have been used and mixed in industrial statistics. A variant of the first definition is adopted here, to the extent that services sufficiently similar to be included in the same population are supplied by products having qualitatively similar internal structures. Of course, it is possible for technologies having different internal structures to provide similar services (e.g. mechanical and electronic watches, trains, buses and planes) and this is indeed one of the reasons for introducing the separation between technical and service characteristics. In this paper we are assuming that the coexistence within the same population of product technologies having qualitatively different internal structures but supplying similar services is a shot run phenomenon and that in the long run each product technology will specialize in a separate subset of characteristics space. Whatever the taxonomic ambiguities involved in the coexistence within the same sector of product technologies with qualitatively different internal structures, the fact that we define a sector based on the services supplied by their products, implies that an industrial sector coincides with a market. Consumers and users can generally be expected to choose a product based on the services it supplies and not on its internal structure. Thus, a market and an industrial sector will be defined as the firms producing a set of products supplying services contained in a *separable* subset of characteristics space. Of course, we realise that this definition still leaves some room for ambiguity. The process of specialisation, involving the separation of one into two or more populations, is not instantaneous and it is likely to give rise to periods, even relatively long, during which the initial population becomes heterogeneous and asymmetric but it is not completely separate. We consider that it will be easier to work out these more complicated cases after we implement our model assuming completely separable sectors and markets.

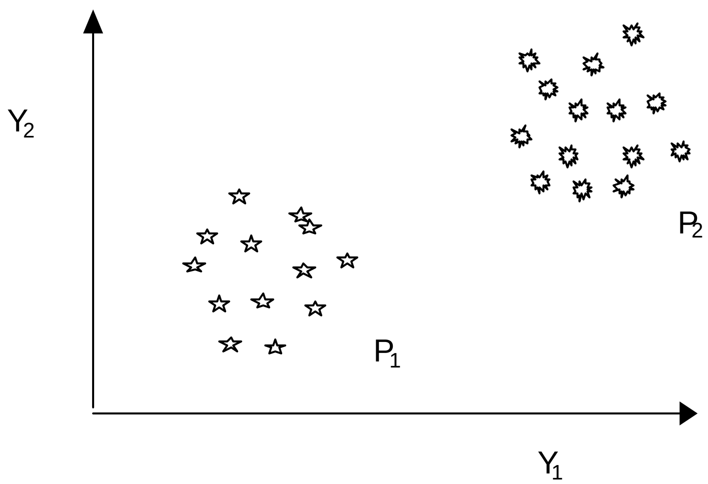

Fig. 2. Representation of two product populations (P_1 and P_2), corresponding to two industrial sectors, in service characteristics space.

It is who emphasizing that our definition is very similar to the one used in models of the industry life cycle (ILC), in which the sector is usually created by an important product innovation (see for example Klepper, 1996; Jovanovic, MacDonald, 1994; Utterback, Suarez, 1993). Our definition is more coherent, but it cannot be easily related to existing production statistics.

2.2) THE ADJUSTMENT GAP OR THE SIZE OF A POTENTIAL MARKET.

In our model an important innovation creates an 'adjustment gap', because at the moment the innovation is created there are neither production facilities nor any of the other conditions required for the development of the market. The setting up of production facilities, of complementary industries and institutions usually takes a long time, giving rise to a lifecycle. The adjustment gap at a given time can be defined as the difference between the maximum possible demand ($D_{max,i}$) and the instant demand for the given product (D_i). We can then imagine the life cycle to occur as the gradual construction of the production facilities and of the other conditions required for the full development of the sector, ending when the actual demand will have caught up with the maximum possible demand. However, the adjustment gap cannot be expected to decrease all the time. Even the maximum possible demand can grow as a result of technological change, either by making the product cheaper or by improving the services it supplies. Both improvements can increase the size of the population of potential users, that is the size of the market. Many fewer cars would be sold today if they had remained at the level of the Ford Model T. Although in intermediate stages the size of the adjustment gap can grow, in the end it will tend to reduce itself to zero or near zero. At that point what was initially an innovating niche will have transformed itself into one more routine of the economic system (Schumpeter, 1912, 1934). The achievement of this state of saturation of the sector would obviously reduce its potential for further growth. We expect that even in presence of a rising income per head the demand for the outputs of the sector will not increase in volume, although it might increase in value by moving upmarket. Nevertheless, this is unlikely to provide the same opportunities for growth and for profits as the emergence of a new sector. Thus, in the long run the possibility of sustained growth will depend on the capacity of the system to create new sectors.

2.3) COMPETITION.

The concept of competition used in this model is different from the one often found in economics textbooks. First, it can be divided into intra-sector and inter-sector competition. The existence of inter-sector competition is due to the fact that different industrial sectors can produce products supplying some common services. Such sectors are different because their internal structures and thus their technical characteristics are qualitatively different. However, some sectors which are different on the basis of their internal structures produce some common services. For example, trains, planes, cars, buses have different internal structures but all supply transport services. This does not mean that the industries based on these technologies produce perfect substitutes, otherwise they would be the same industry. The substitutability of the services supplied by these products is limited to particular subsets of their external environment. For example, trains and planes can compete over distances ranging from about one hundred kilometres to about seven-eight hundred kilometres. For longer distances planes would become the only possible choice. Inter-sector competition is often, but not always, the result of the process of specialisation of sectors. We could say that transport technologies can by definition be expected to supply a common set of services because they arose from the specialisation of the same function. However, telecommunications and transport technologies can in some cases be substitutes. A telephone call or a teleconference can sometimes replace a trip. Thus, many industrial sectors can be expected to show inter-sector competition. It is worth pointing out that inter-sector competition is an important component of market contestability (Baumol etc, 1982), but that it does not share some of its extreme assumptions. For example, there is no need for zero entry or exit costs. A new sector can be created as a niche and it may not initially be competing with some established sectors. The subsequent evolution of the new sector is likely to widen the range of services it supplies and to make it a competitor of 'incumbent' sectors.

Intra-sector competition is more familiar since it resembles the type of competition usually found in economics textbooks. The population of products corresponding to a given sector (Fig. 2) may be more or less differentiated depending on how similar the services of its products are. In the extreme case in which the products of all producers supply the same levels of services they would all be represented by a point in service characteristics space. This situation, corresponding to zero differentiation, would constitute the multi-dimensional analogue of perfect competition. Differentiation could then be progressively introduced leading to an expansion of the population and to a fall in its density. We can then expect the intensity of intra-sector competition to increase with the density of the population of products of the sector. By the same reasoning we can expect the intensity of inter-sector competition to be inversely proportional to the distance between two sectors in service characteristics space. Thus:

$$IC^t{}_i = f\left(N^t{}_i; r^t{}_i; D^t{}_y(i,j)\right) \qquad (1)$$

Where N_i is the number of firms in sector i, ρ_i is the density of sector i in service characteristics space, and $D_y(i,j)$ is the distance between the services supplied by sectors i and j in service characteristics space. In this for simplicity we take into account only the interaction between sector i and another potentially competing sector j. In a more general version the interactions between i and all the other potentially competing sectors would have to be taken into account.

In addition to being constituted by two components competition plays a very important role in our model. A new sector is created by an entrepreneur who, by means of an innovation, establishes a niche where he/she has a temporary monopoly. If the innovation is successful the niche expands into a market by entry and imitation. The process of entry increases the intensity of competition and gradually reduces the inducement for further entry. The process continues until the intensity of competition reaches a value comparable to that of mature sectors in the same economy. At that point there is no further inducement to enter and inducement to exit begins to dominate. This mechanism is clearly Schumpeterian and it transforms what was initially an innovation into one more routine of the circular flow of the economic system (Schumpeter, 1912, 1934).

3) THE ANALYTICAL STRUCTURE OF THE MODEL.

In this model the dynamics of each industrial sector is determined by the balance between the entry and the exit of firms. As previously pointed out, entry is determined by the adjustment gap AG_i. This is understandable since AG_i represents the percentage of the market demand for a good/service i that is still unsatisfied. Furthermore, entry is also determined by financial availability FA_i. Financial availability here carries the subscript i because it is dependent on the features of sector i. For a given availability of financial capital in the economy as a whole, the quantity that is allocated to sector i depends on the size of the sector and on its perceived potential. The latter element is likely to play a greater role in emerging sectors, where there is a limited or non existent track record and where, therefore, investment is essentially based on future prospects. Thus FA_i does not depend only on general financial availability, but also on the ability of economic agents other than the founders of firms to evaluate the prospects of new sectors. In fact, at constant general financial availability FA_i is likely to increase as a sector grows and as the knowledge about it becomes more widespread in the economy. FA_i is likely to depend also on the capacity of an economy to adapt its current institutions to new tasks or to develop completely new institutions. An example of this would be the emergence of venture capital in response to the needs of high technology firms. As already pointed out, this is an example of the co-evolution of technologies and institutions. That financial capital can play a very important role in the processes of diffusion of new technologies has recently been stressed by Perez (2003).

Summarising, in this model the rate of entry depends on the adjustment gap and on financial availability.

Exit is determined by the increasing intensity of competition and by mergers and acquisitions. As Schumpeter (1912,1934) pointed out, the first entrepreneur to create a new sector enjoys a temporary monopoly, in part shared by early imitators. However, as imitative entry continues to occur, the intensity of intra- industry competition gradually increases until the temporary monopoly is completely eliminated. As the new and innovating sector looses its special features and becomes another routine of the economic system the inducement to enter disappears and it is eventually replaced by an inducement to exit. Furthermore, as the sector approaches saturation and in presence of increasing returns to adoption, the rate of mergers and acquisitions contributes to reducing the number of firms in the sector. It can be observed that failure has not been included amongst the mechanisms contributing to exit. While it is clear that firm failure is an exit mechanism, its rate is likely to increase based on the same factors that affect IC_i and MA_i. As a consequence, in the interest of simplicity, the same term represents mergers, acquisitions and failures. The part of the model discussed so far is related to the analysis of one sector. The interactions between different sectors occur at two levels: first, the increasing intensity of competition as a sector i approaches saturation leads to exit and contributes to the inducements to create niches that will eventually become new markets; second, the intensity of competition includes an inter-industry component, that depends on the degree of substitutability of the outputs of different sectors. Of course, the inducement to leave a pre-existing sector will not lead to the creation of a niche or of a market unless the technological opportunity for the creation of the new sector exists. In other words, economic development will proceed smoothly only if there is co-ordination between the evolution of old sectors and the emergence of new ones. Specifically, since it takes time and other resources to perform the search activities required for new technological opportunities, this co-ordination implies that a range of search activities required to prepare new sectors be performed in advance with respect to the emergence of the new sectors and that their results have created an economically exploitable knowledge base. Were this not to happen, the decline of a mature sector would not necessarily be compensated by the rise of an emergent one and temporary bottlenecks could arise in economic development. Economic development then depends not only on the intrinsic potential of each sector but also on the coordination of the emergence and growth of different sectors, point that will be discussed again in section 4. We now pass to the detailed description of the model.

The basic equation gives the rate of growth of firms within a given population:

(2) $$\frac{dN^t{}_i}{dt} = k_1 \cdot FA^t{}_i \cdot AG^t{}_i - IC^t{}_i - MA^t{}_i$$

Where FA_i represents financial availability, AG_i the adjustment gap in sector i, IC_i the intensity of competition in sector i and MA_i the rate of mergers and acquisitions in sector i. The definition of the adjustment gap is:

(3) $$AG^t{}_i = D^t{}_{i,\max} - D^t{}_i$$

Maximum demand is determined by the level of search activities:

(4) $$D^{t}{}_{i,\max} = SE^{t}{}_{i}$$

This means that the population of potential adopters of a given good or service is not fixed, but can change in the course of time. Demand itself is assumed to be equal to total output at all times:

(5) $$D_i^t = \begin{cases} N_i^t \cdot Q_i^t & for \quad D_i^{t-1} \leq D_{\max}^i \\ D_{\max}^i & else \end{cases}$$

Where Q_i^t is the average output per firm.

Search activities are expected to grow in the course of time during the life cycle of the sector. We expect them to grow more rapidly at the beginning of the life cycle of the sector and their rate of growth to slow down as it becomes progressively more difficult to exploit the technological opportunities left in the sector. Thus we use for SE_i^t the following expression:

(6) $$SE_i^t = 1 + k_4\left[1 - \exp\left(-k_5 D_{acc,i}^{t-1}\right)\right]$$

Where $D_{acc,i}^{t-1}$ is the total accumulated demand in sector i at time t-1. The presence of accumulated demand corresponds to the learning effects that take place during the life cycle of the sector. The constant k_5 measures the rate of learning. The higher the value of k_5, the faster SE_i^t increases for a given level of accumulated demand. On the other hand k_4 measures the technological opportunities existing in the sector, that is the capability that the major innovation establishing the sector has to create demand.

The output of each firm can be expected to increase in the course of time as firms learn and as they exploit the spillovers created by the search activities performed in the sector. The average output per firm is then given by:

(7) $$Q_i^t = 1 + g^i\left[1 - \exp\left(-k_{11} \cdot SE_i^t\right)\right]$$

Where [1-exp(-$k_{11}SE_i^t$)] represents the contribution of search activities to output growth and γ_i the cumulated effect of learning by doing. Expression (7) can be considered as sort of technical progress function.

The intensity of competition IC_i in population i is due to the combined effects of the number of firms N_i, of the density ρ_i of the product population in service characteristics space, and of the average distance between product populations i and j in service characteristics space (eq (2)). An explicit expression for IC_i containing these variables is difficult to derive given that the density and the distance in service characteristics space are not easy to measure and that, even if they could be measured, they would add to the number of variables present in the model. In order to overcome these difficulties we tried to express IC_i only in function of the number of firms. The approximate expression that we used for IC_i is given in equation (9):

$$IC_i^t = k_8 \cdot \frac{N_i^{t-1} \cdot N_{tot}^{t-1}}{k_6 \cdot N_i^{t-1} + k_7 \cdot N_{tot}^{t-1}} \tag{8}$$

Financial availability FA_i, is not simply the amount of money available, but it represents the financial resources that can be invested in sector i. Such resources can be invested if a sufficiently accurate assessment of the probability of success of the investment can be made. In turn, such assessment requires knowledge of the activities upon which the population or sector is based. In the case of a radically new technology the knowledge is likely to relatively scarce at the beginning of the life cycle of a sector. We can expect this knowledge to increase as the sector develops, and thus financial availability to grow as the sectors matures. Thus FA_i is given by the following expression:

$$FA_i^t = k_3 \cdot C^t \tag{9}$$

Where C^t is total financial capital available in the economic system at time t and k_3 measures the propensity of investors to place capital in sector i at time t. Thus, the value of k_3 can increase during the life cycle of the sector as more knowledge, allowing to assess more effectively the prospects of the sector, accumulates.

The rate of mergers and acquisitions can be expected to increase with the returns to adoption and with the extent of saturation of the sector. Thus we use the following expression:

$$MA_i^t = k_9 \cdot \frac{N_i^{t-1} \cdot MC_i^{t-1}}{AG_i^t} \tag{10}$$

It is to be noticed that MC_i^{t-1}, returns to adoption can include static and dynamic economies of scale, network externalities, learning effects etc.

What has been described so far refers to the dynamics of a particular population. However, the presence of an intra- and of an inter-population term in the intensity of competition links the dynamics of different populations. So the saturation of one population, say i, will induce the creation of a subsequent population, say (i+1). Furthermore, the intensity of competition within each population will be influenced by other populations. As a consequence, entry conditions for the creation of new sectors will be:

$$N_i^t = \begin{cases} 0 & for \quad D_i^t \le D_{\max,0}^i \\ N_i^t & else \end{cases} \tag{11}$$

Important elements required to define the dynamics of new sectors are the time at which such sectors will start developing and the relationship that they will bear to pre-existing sectors. For what concerns the former question, we have assumed that the new sector will start developing only after a pre-existing one has reached saturation, that is after the adjustment gap has fallen to zero. For what concerns the second question this model is unable to define the relative levels of demand of subsequent sectors. To treat effectively this problem we need to combine this model with a more sophisticated model of demand (Saviotti, 2001). We intend to do that in our future research. Although we do not yet have a criterion to predict the relative demand levels of different sectors, we have explored some of the factors affecting these demand levels. For example, we found that increasing the technological opportunity of some sectors we raise their demand levels relative to those of other sectors (Saviotti, Pyka, 2002).

The dynamics of employment enters this model by means of the expected relationship between firm size and employment per unit of output. We assume employment per unit of output to fall as total output increases within each sector:

(12)
$$l_i^t = \frac{k_i}{Q_{ia}^t} = \frac{k_i}{\frac{Q_i^t}{N_i^t}} = (k_i \cdot N_i^t)/Q_i^t$$

Where l_i is average employment per unit of output in sector i, k_i is a constant proportional to the capacity of sector i to create employment at any given level of output, and Q_a is the average output of firms in sector i at time t and Q_i is the total output of sector i at time t, L_i is total employment in sector i and l_i is the reverse of labour productivity:

(13)
$$l_i^t = \frac{L_i^t}{Q_i^t}$$

The constant k_i measures the intrinsic capability of sector i to create employment at equivalent output.

As a consequence of the previous assumption we can expect employment creation within each sector to be higher in the early stages of the life cycle. Average output per firm can be expected to increase during the life cycle, at least after the maximum number of firms has been reached.

In this paper the variety of the economic system is measured by its informational entropy. This entropy function has been used by biologists to measure the diversity of a biological habitat and it has been applied by Frenken et al (1999) to measure the variety of different technologies. The entropy function H has been developed by Shannon and Weaver (1949) to measure the information content of a message. The possibility to apply the function H to measure the variety of an economic system depends on the fact that the greater the number of distinguishable entities contained in a system, the greater the amount of information that will be required to describe the system. Thus, we can expect H to increase when the variety of the economic system increases. The form taken by the entropy function in a mono-dimensional case is:

(14)
$$H_i = -\sum_{i=1}^{n} p_i \cdot \log p_i$$

where p_i is the probability of existence of entity i within the system. When this formula is applied to measure the variety of a biological habitat or of an economic system, p_i is the fraction of observations corresponding to entity i.

4) RESULTS

To simulate our model we initially tried to obtain results that correspond to some stylised facts of economic development. First, new sectors are created at given times and, while they may in some cases replace existing ones, very often they are added to them. Second, the rate of growth of output of new sectors is not uniform, but tends to be higher in the early phases of their life. Third, the development of sectors is never completely regular, but often it follows a life cycle. Of course, we do not expect the development of all sectors to follow strictly these patterns under any circumstances. Rather, we wish to start by simulating a situation that can be observed frequently, in order to subsequently explore ranges of the parameter space of the model in which the previous patterns are not followed. In other words, in this paper we intend to reproduce a series of frequently observed patterns of behaviour, in order to subsequently explore the ranges of stability of thee same patterns. The results of our initial simulations, which we called our standard scenario, constituted the basis for further explorations of our artificial world. The values of the constants used in the standard scenario are given in Table 1.

Constant	**Interpretation**	**Value used in the standard scenario**
k_1	entry conditions	1
k_3	weight for financial availability	0.01
k_4	technological opportunities	50
k_5	learning rate	0.01
k_6	intraindustry competition	100
k_7	interindustry competition	1
k_8	weight for competition	1
k_9	weight for mergers & acquisitions	0.1
k_{11}	learning curve effect	0.00005

Table 1: Parameter values of the standard scenario

Figs 3, 4 and 5 represent the dynamics of the number of firms N_i in each sector (Fig.3), the output of each sector Q_i (Fig. 4), and the intensity of competition IC_i in each sector (Fig. 5).

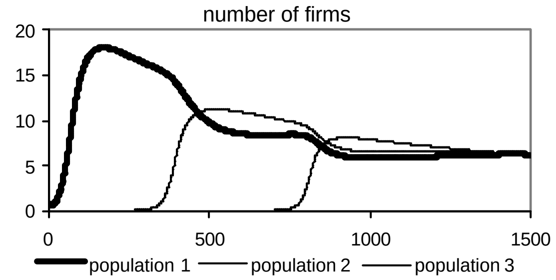

Fig. 3. Number of firms for three populations in the standard scenario.

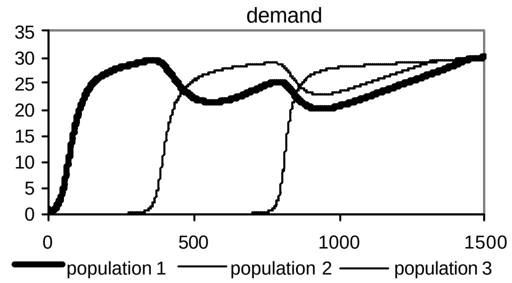

Fig. 4. Variation of sectoral demand in standard scenario.

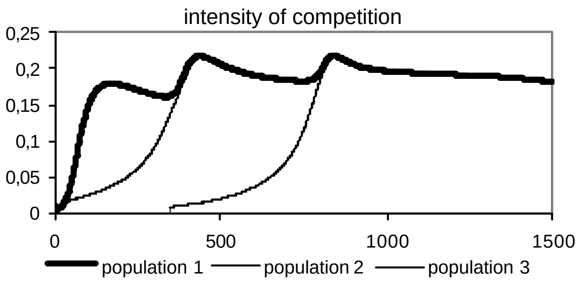

Fig. 5. Variation of the intensity of competition in different sectors.

The number of firms in each sector increases initially, reaches a maximum and then falls. Output for each sector first rises, reaches a maximum, falls in the short run and seems to pick up again in the long run. The intensity of competition starts at very low values in the phase of temporary monopoly of the first entrepreneur, increases as imitation and entry begin, reach a maximum and then starts falling as the number of firms decreases. It can be observed that the dynamics of each sector is due both to internal factors and to inter-sector interaction. Thus, the number of firms would tend to reach a maximum and then to fall as a consequence of a rising intensity of competition if the sector were to remain isolated. The existence of inter-sector competition accelerates the process of exit by adding inter-sector competition to intra-sector competition. This effect is demonstrated by the rapidly changing slope of the curves of N_i, Q_i and IC_i for sector 1 as sector 2 arises.

If we confine ourselves to the conditions of the standard scenario, we can calculate the level of employment that is created by each sector and by the whole economy (Fig. 6). We can see

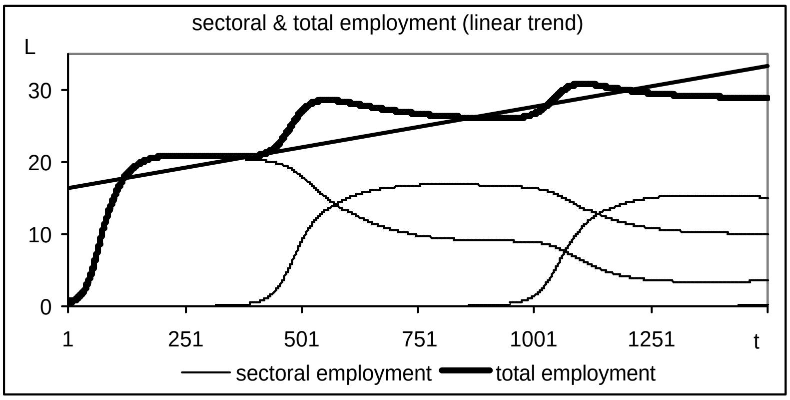

Fig. 6. Evolution of sectoral and total employment in the standard scenario

that in each sector employment rises at first, later reaches a maximum and then falls. However, the emergence of new sectors can compensate for the diminishing capacity of the older sectors to create employment. This would not be the necessary outcome under all possible conditions. As we will see later, it is possible for new sectors to be created and for aggregate employment to decline.

Fig. 7 shows that labour productivity increases while employment falls during the life cycle of a sector. The continuous process of structural change taking place in the economic system is reflected in the varying shares of output of each sector in the course of time (Fig. 8). Each sectoral share starts being very low, rises rapidly in the early phases of the life cycle and declines as newer sectors emerge. The decline of older sectors is only relative. There is no necessary reason for which their output should fall in absolute terms. It is in fact possible for older sectors' output to keep increasing while their share of overall output falls. However, older sectors' share of output is necessarily going to fall. The economic system has to compress past activities in order to make room for future ones.

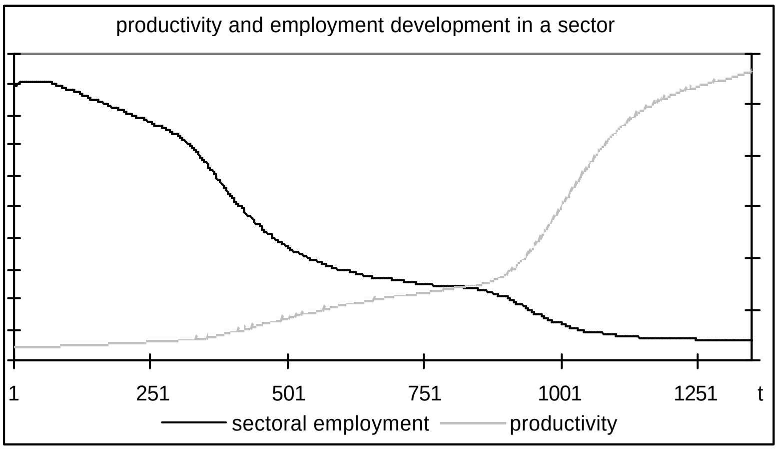

Fig. 7. Productivity and employment development in a sector.

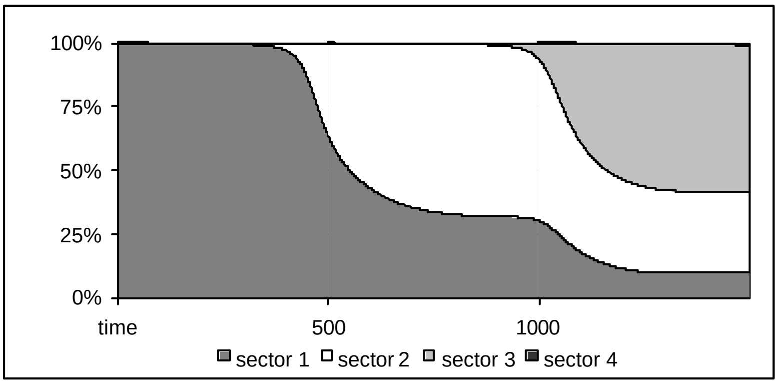

Fig. 8. Evolution of the sectoral shares of employment with the emergence of new sectors.

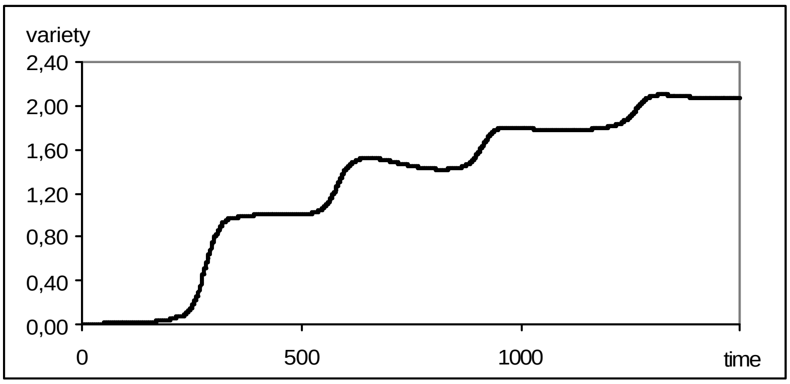

Fig. 9. Change in aggregate variety during the development of the economic system. A higher rate of learning than in the standard scenario has been used to display a greater number of sectors.

Starting from the sectoral shares displayed in Fig 8, we calculated the varieties of each sector and the aggregate variety of the economic system by means of the informational entropy function. As we can see in Fig. 9, the variety of the economic system generally increases during economic development as a consequence of the creation of new sectors. However, there are short periods during which variety remains approximately constant or falls. These periods correspond to the conjunction of the decline of mature sectors and of the growth of emerging ones. As it was previously pointed out, the birth of a new sector is triggered by the saturation of a previous one. Such a condition, amounting to an almost perfect inter-temporal coordination, is not necessarily present in real economic systems. It is possible for a new sector to emerge either before or after the complete saturation of a pre-existing one. In the former case we expect both employment and variety to grow at a faster pace than in our results, in the latter we expect employment and variety growth to slow down. The latter case would be an example of poor inter-temporal coordination in which the new sectors are not 'ready' when required. In order to display a greater number of sectors in the calculations performed to obtain this figure we accelerated the process of development with respect to that of the standard scenario by increasing the rate of learning k_5 (Saviotti, Pyka, 2002).

Fig. 10 shows the relationship between employment and variety. There is a general trend towards increasing employment as variety grows, but employment may fall during short periods, presumably when the rate of variety growth is lower. In fact, the periods of negative growth of employment in Fig 10 correspond to the periods when variety is either growing very slowly or falling in Fig 9. Thus, this figure seems to confirm the generally positive relationship between the variety of the economic system and the level of employment it can sustain.

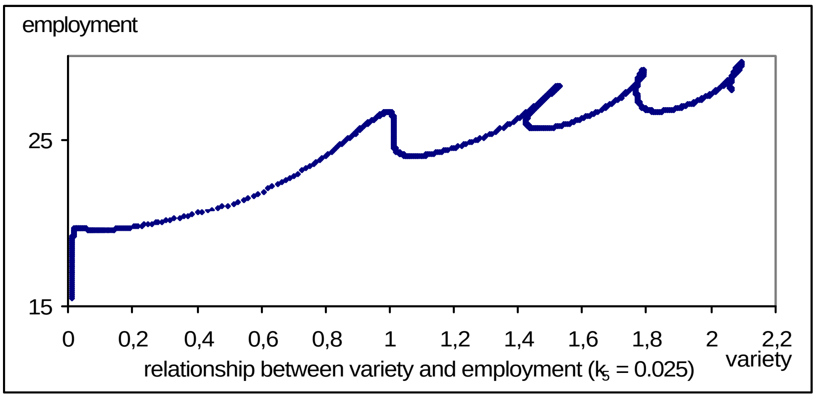

Fig. 10. The relationship between employment and variety.

In order to further test the relationship between variety and employment creation we calculated dL/dt as a function of variety. Different values of variety were obtained by varying technological opportunity, the rate of learning and productive efficiency. The rate of creation of new sectors, and thus the rate of variety growth, is accelerated by increasing each of these variables, but by different mechanisms. Increasing the rate of learning accelerates the emergence of new sectors but leaves almost unchanged the maximum demand of each sector. Increasing technological opportunity accelerates the rate of creation of new sectors and the maximum demand in each sector. Increasing productive efficiency accelerates the rate of creation of new sectors but reduces the number of firms that can supply even an increasing demand. We can expect variety growth obtained by these different mechanisms to have different effects on employment creation. If we remember that in this model variety depends on the number of distinguishable sectors in the economic system, we can understand that a higher level of demand or a lower number of firms can lead to different employment levels at equivalent variety. Figs 11 and 12 show the effect of variety on the rate of employment creation and Figs 13 and 14 the effect of variety growth on the rate of employment creation. Both higher levels of variety and higher rates of variety growth have a generally positive effect on the rate of employment creation, except for the case in which variety is increased by raising productive efficiency. In this case the positive effect of variety due to the increasing number of economic activities corresponding to the sectors is more than compensated by the rise in productive efficiency. As a result of these experiments our hypothesis N° 1 may need to be slightly modified. Variety growth is likely to be a necessary requirement for the continuation of long term economic development, and in most of the situations we explored it contributes positively to employment creation, but it is not a sufficient condition under all circumstances. It is still possible for productive efficiency to increase fast enough to compensate the positive effect of variety growth.

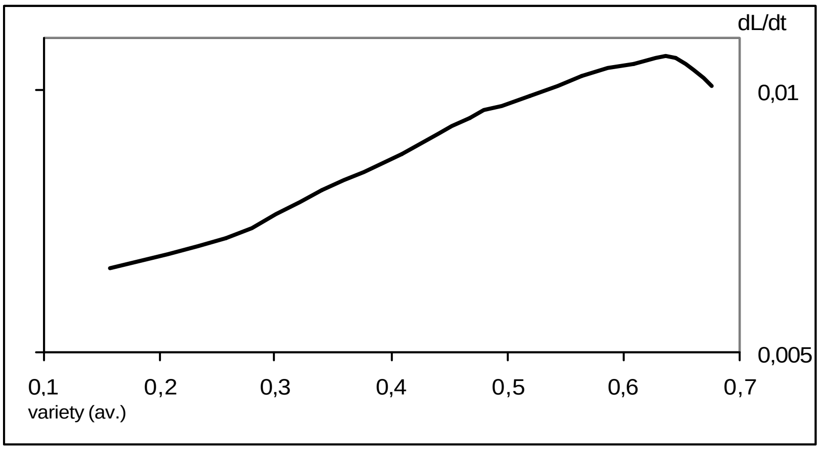

Fig. 11. Effect of variety on employment creation. The changes in variety are here obtained by changing the rate of learning.

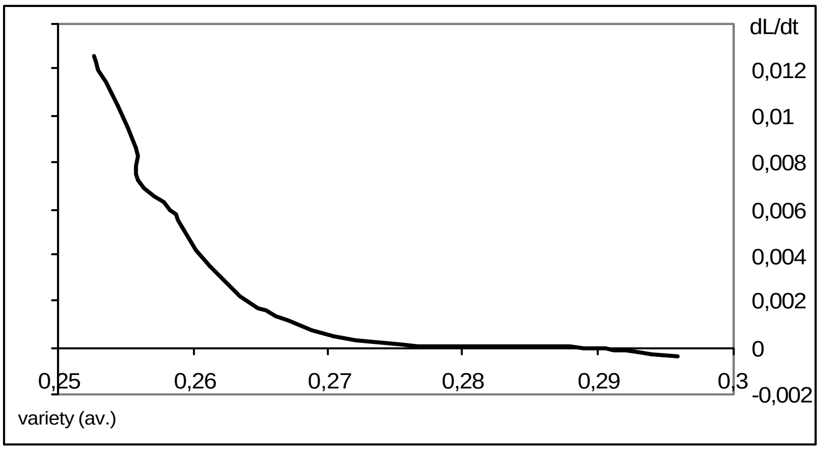

Fig. 12. Effect of variety on the rate of on employment creation. The changes in variety are here obtained by changing γ_i, the rate constant for learning by doing.

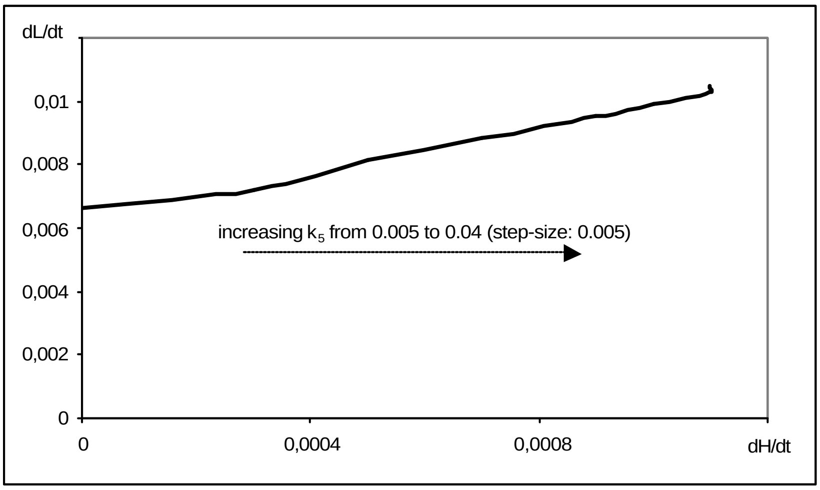

Fig. 13. The effect of variety growth on employment creation. Variety is changed by changing k_5, the rate of learning.

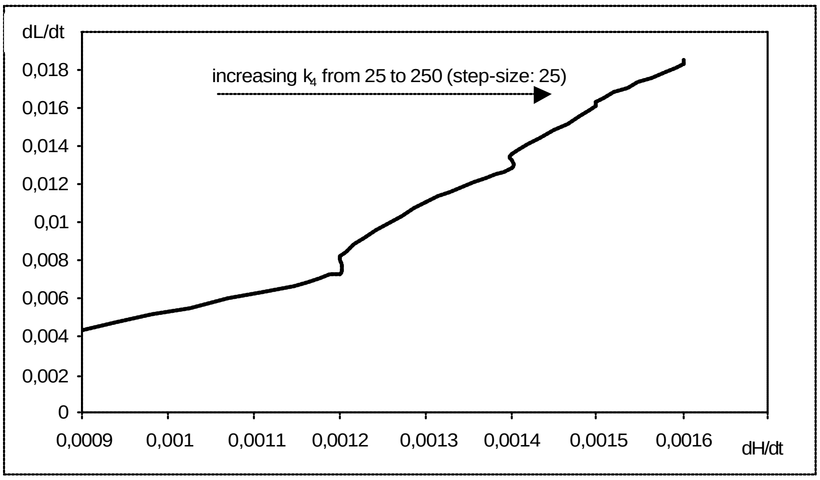

Fig. 14. The effect of variety growth on employment creation. Variety is changed by changing k_4, technological opportunity.

5) GENERAL CONCLUSIONS

In the model presented in this paper the creation of new sectors is the fundamental force that sustains economic development in the long run. If the composition of our artificial economic system were to remain constant, the process of economic development would run into a bottleneck, at least because the rate of employment growth would necessarily decline. In this case the economic system would undergo a fate not unlikely the one predicted by Marx for the capitalist system. In other words, at constant composition the rate of productivity growth would undermine the very same stability of the system. Adding new sectors to the system can compensate for the decreasing capacity of older sectors to create employment. New sectors, especially in their early period in which the rates of growth of both output and employment are high, can re-absorb the employment that could potentially be displaced by the dynamics of older sectors.

However, the possibility of compensation is neither automatic nor certain. Even in presence of growing variety employment can fall if productive efficiency increases more rapidly than the expansion of demand afforded by the emergence of new sectors. The first of our hypotheses, stating that the growth in variety is a necessary requirement for long-term economic development, might have to be reformulated saying that variety growth is a necessary but not sufficient condition for the continuation of long term economic development. The second hypothesis, stating that variety growth, leading to new sectors, and productivity growth in pre-existing sectors, are complementary and not independent aspects of economic development, turns out to be satisfied. Changes leading to an increasing efficiency of pre-existing sectors raise the rate of variety growth of the system.

In view of the observations about the first hypothesis we could expect the rate of productivity growth of an economy not to be a sufficient indicator of the development potential of that economy. We have seen that at constant composition increasing productivity growth sooner or later leads to a bottleneck. The fact that for a long time rates of productivity growth of an economy have been customarily used as an indicator of the growth prospects of an economy without any anomalies becoming apparent probably means that high rates of productivity growth in some sectors are usually accompanied by the emergence or fast development of other sectors. Thus, although the rate of productivity growth is not a sufficient indicator of the development potential of an economic system, by virtue of the complementarity of productivity growth and of variety growth, it may turn out to be an approximately good indicator.

In summary, in our model continued economic growth necessarily involves structural change. Economic development is not an exclusively quantitative change but it requires a transformation of the economic system occurring by means of changes in composition. A stable pattern of macro-economic growth can only be achieved by renewed micro-economic turbulence, although this turbulence need not occur at a constant rate in the course of time. The emergence of new economic activities creates the potential for future economic development, but it can only do so if older activities in the system are compressed, that is if their share of global output falls, to make room for novelty.

REFERENCES

Aghion P., Howitt P., (1998) Endogenous Growth Theory, Cambridge, Mass, The MIT Press.

Baumol W.J., Panzar J.C., Willig R.D., (1982) *Contestable Markets and the Theory of Industry Structure*, San Diego, Harcourt, Brace Jovanovich.

Cornwall (1977) *Modern Capitalism: its Growth and Transformation*, London, Martin Robertson.

Fagerberg J.(2000), Technological progress, structural change and productivity growth: a comparative study, Working paper N° 5/2000, Centre for Technology, Innovation and Culture, University of Oslo.

Fagerberg J., and Verspagen B. (1999), Productivity, R&D spillovers and trade, Working Paper N° 3/1999, Centre for Technology, Innovation and Culture, University of Oslo.

Freeman C., Clark J., Soete L., (1982) *Unemployment and Technical Innovation*, London, Pinter.

Freeman C., Louça F., *As Time Goes by*, Oxford, Oxford University Press (2001).

Frenken K. , Saviotti P.P., Trommetter M., Variety and niche creation in aircraft, helicopters, motorcycles and microcomputers, *Research Policy*, Vol. 28 (1999) 469-488.

Jovanovic B., Mc Donald, G. (1994), The life cycle of a competitive industry, *Journal of Political Economy*, 102, pp. 322-347.

Klepper, S. (1996), "Entry, exit, growth and innovation over the product life cycle", *American Economic Review*, 86, pp. 562-583.

S. Kuznezts, *Economic Growth and Structure*, New York, Norton (1965)

Lancaster K.J. , A new approach to consumer theory, *Journal of Political Economy*, Vol. 14 (1966) 133-156.

Lancaster K.J. , Socially optimal product differentiation, American Economic Review, (1975) 567-585.

Lancaster K.J. , Variety, Equity and Efficiency, New York, Columbia University Press (1979).

Lucas R.E., (1993) Making a miracle, *Econometrica*, 61, 251-272.

Pasinetti L.L. (1981). *Structural Change and Economic Growth*, Cambridge: Cambridge University Press.

Pasinetti L.L., (1993), *Structural Economic Dynamics*, Cambridge, Cambridge University Press.

Perez C., (2003) *Technological Revolutions and Financial Capital: The Dynamics of Bubbles and Golden Ages*, Cheltenham, Edward Elgar.

Romer P., Growth based on increasing returns due to specialization, *American Economic Review*, Vol. 77 (1987) 565-62.

Romer P., Endogenous technical progress, *Journal of Political Economy*, Vol. 98 (1990) 71-102.

Salter W.E.G., (1960), *Productivity and Technical Change*, Cambridge: Cambridge University Press

Saviotti P.P., *Technological Evolution, Variety and the Economy*, Aldershot, Edward Elgar (1996).

Saviotti P.P., (2001) Variety, growth and demand, *Journal of Evolutionary economics*, Vol.11 (2001) 119-142.

Saviotti, P. P., Metcalfe J. S., (1984) A Theoretical Approach to the Construction of Technological Output Indicators, *Research Policy*, Vol. 13 141-151

Schumpeter, J. (1934, original edition 1912) *The Theory of Economic Development*, Cambridge, Mass, Harvard University Press.

Shannon C E and Weaver W , *The Mathematical Theory of Communication*, University of Illinois Press, Urbana, (1949)

Utterback J.M., Suarez F.F., Innovation, competition and industry structure, *Research Policy*, Vol 22, (1993) pp. 1-21.