Economic development, qualitative change and employment creation

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Abstract

In this paper we analyse the implications of a model of economic development by the creation of new sectors for employment. In the model each sector follows a life cycle determined by the interplay of competition and of market saturation. In each sector the number of firms first rises up to a maximum and then gradually falls. Sectoral employment follows a similar path, increasing first and then declining. The model shows that, even if within each sector there is an intrinsic tendency for employment to fall, aggregate employment can still keep rising if new sectors are created at the right times.

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1. Introduction

The starting point of this paper can be considered a stereotyped version of the concept underlying traditional models of economic growth. According to this view in the course of time economic systems become more efficient in the production of a given set of goods and
services, thus creating a growing output per unit of population. This efficiency enhancing trend is undoubtedly present in economic development, but it is not the only one.

The most impressionistic observations of long term economic development, starting for example from the time of the industrial revolution, show that the emergence of completely new goods and services is another, equally important, trend. The new goods and services are qualitatively different from those that preceded them. Accordingly, qualitative change during the process of economic development can be considered our first stylised fact.

Furthermore, the new goods and services do not always substitute pre-existing ones but quite often are added to those which are already there. As a consequence, the variety of the economic system is likely to increase in time, which is considered our second stylised fact.

Thus, economic development can be considered as resulting from two processes, leading on the one hand to efficiency growth and on the other hand, to variety growth and qualitative change. Other stylised facts that seem to be important to us and are deserving attention within a model of economic development are the observed saturation of demand within given industrial sectors and the existence of industry life-cycles.

To the extent that the central role of qualitative change is accepted, it is almost self-evident that in models of growth, changes in the composition of the economic system due to the emergence of qualitatively new goods and services should be an endogenous feature. In other words, within the artificial economic system represented by a model there must be inducements to the creation of new goods and services coming from the previous evolution of the system.

In this light, the aim of our model, to be introduced in this paper, is to reproduce endogenously these stylised facts. In what follows we provide the conceptual background for the model, then we describe the nature of the model and the results obtained in some simulation experiments. Finally, we analyse the results and conclude on further work to be pursued.

2. Economic development, qualitative change and transformation processes

2.1. The meaning of qualitative change and composition

The composition of the economic system can be defined as the list of all the entities that are required to describe the system itself. For example, we could describe an economic system by providing a list of the industrial sectors that it contains at a given time, supplying for each sector values of its important properties (output, trade, etc.) and of their relative importance, as measured by the sector’s share of each property. Such a description could be provided at different levels of aggregation, for example by providing the internal composition of each sector, as given by the product groups contained in the sector itself. Further disaggregation would be possible by breaking down each product group into gradually more elementary components. By moving to lower and lower levels of aggregation we expect heterogeneity to be present even at the lowest levels. The structure of a product model, as defined by its components, changes in the course of time, for example by adding new components, in such a way as to make the identification of the model itself problematic. Changes in the composition of the economic system take place all the times and at all levels of aggrega-
tion during the process of economic development. These changes are qualitative in nature because the new entities are often completely different and non-comparable with respect to the pre-existing ones. The new entities require different variables and concepts to be described.

We can observe that economic development is accompanied by changes in the composition of the economic system. The component of these changes referring to the relative weight of industrial sectors has been studied under the heading of structural change. However, general studies of structural change, due to the level of aggregation of the data they had to rely on, did not take into account changes occurring within a sector or a product group. Thus, qualitative change is more pervasive than structural change. We do not wish here to emphasize our difference with respect to studies of structural change. On the contrary, we consider our work to be an extension of such studies. When we say that qualitative change is more pervasive than structural change we simply mean that change occurs at all levels of aggregation and that the best possible analysis we can conceive involves to calculate aggregate properties starting from those of the components of the system at the lowest possible level of aggregation. Of course, we recognize the value of purely aggregate treatments, for example the types of early macro-economic growth models (see later for a discussion of these). By concentrating on the relationships of aggregate variables of the system they greatly simplify its analysis. This is a useful approximation but it completely eliminates the composition of the economic system. Even a treatment carried out at the level of industrial sectors can only be successful to the extent that the sectors themselves are homogeneous.

2.2. Previous literature

Existing models of growth started from an exclusively macro-economic basis. In other words, they are only concerned with the relationships between aggregate variables of the system investigated. Thus, the composition of the economic system is by definition not taken into account by these models. Perhaps the most prominent of this vintage of models is that of Solow (1956). Starting from the late 1980s a series of growth models attempting to take into account both the emergence of new goods and services and the endogenous character of technological change were developed. Notable examples of the first type are Grossman and Helpman (1991a, 1991b), Stokey (1988, 1991), Young (1991), Lucas (1988, 1993). Examples of the second type are Romer (1987, 1990), Aghion and Howitt (1998). In Grossman and Helpman the new goods, typically introduced in already developed countries, occupy higher positions than pre-existing goods on a quality ladder. For Stokey (1988) the variety of goods produced in an economy are indexed by $s$, where a higher value of $s$ means a better good. A similar approach is adopted by Lucas (1993). In the endogenous growth models of Romer, R&D activity creates new types of capital goods that are added to the pre-existing ones. For Stokey (1988) the variety of goods produced in an economy are indexed by $s$, where a higher value of $s$ means a better good. A similar approach is adopted by Lucas (1993). In the endogenous growth models of Romer, R&D activity creates new types of capital goods that are added to the pre-existing ones. In Aghion and Howitt (1998) R&D contributes to the creation of new capital goods, but the new ones can in principle replace some of the pre-existing ones. Aghion and Howitt developed also a multi-sectoral version of their model, although there the number of sectors is given ex ante. All these different developments show that the composition of the economic system starts to be taken into account. However, with respect to our aims these models while constituting very interesting developments in the process of
incorporation of innovation into economic activity, do not provide the endogeneisation of changes in the composition of economic activity.

The composition of the economic system has for a long time been taken into account in the literature on structural change. Important examples of this research are the work by Salter (1960), by Cornwall (1977), and more recently by Verspagen (1993, 2002), Fagerberg (2000) and by Fagerberg and Verspagen (1999). Perhaps the most important attempt to formulate a theoretical model linking structural change and economic growth was made by Pasinetti (1981, 1993). The work of all these authors takes structural change into explicit account and they provide an important inspiration for our work. However, this past work on structural change still leads to a number of problems, at least some of which we aim at overcoming. First, the definition of structural change used by the previously quoted authors refers to the emergence of new sectors, to the disappearance of older ones and to their changing weights in the economic system. Aspects of qualitative change taking place at a lower level of aggregation, although having impacts at the sectoral level, are not taken into account. In this paper the term qualitative change refers to a wider range of changes in the composition of the economic system. This aspect will be clarified in the subsequent discussion of variety. Second, the possibility to detect structural change and to study its effects depends heavily on the availability of statistical data about production and above all on the definition of industrial sectors used. Statistical classifications of production are changed infrequently and in ways that do not necessarily reflect the real changes taking place in the economy. Thus, as it emerges clearly from the work of Fagerberg and Verspagen (1999, 2002), the industrial classification that they have to use in order to compare a large number of countries hides some types of structural change. Third, these studies on structural change have remained somewhat separate with respect to the macro-economic growth models. Fourth, even the most sophisticated model linking structural change and economic growth, that of Pasinetti, has very limited dynamic features: it leads us to the conclusion that in the long run the economic system cannot follow a balanced growth path unless new sectors emerge and ‘absorb’ the resources potentially displaced by the evolution of older sectors, but it does not tell us anything about the dynamics of emergence of new sectors or about their relationship to older ones. In other words, the model tells us that the continued development of the economic system can be assured only by the existence of inducements to the creation of new sectors, but the nature of these inducements and the dynamics by means of which they give rise to innovations and to new activities which gradually acquire economic weight is not analysed. Our paper aims at laying the foundations for a model of economic development that includes qualitative change amongst its main determinants and in which changes in the composition of the economic system are endogenously generated and behave as determinants of future economic growth. Thus, we hope to contribute to a better understanding of the role of qualitative change and to bridge the gap between macro-economic growth models and structural change studies. In what follows the conceptual nature of the present model will be explained, followed by the presentation of the more technical aspects of the model and by its results.

2.3. Variety

The considerations of the previous paragraph acquire a considerable importance if we accept that the composition of the economic system at a given time is not only an effect
of previous economic development but it is also a determinant of its subsequent economic development. The resources allocated by governments to emergent high technology sectors show that politicians implicitly accept that the composition of the economic system is expected to have a positive influence on its growth potential. Emerging high technology sectors are expected to have higher rates of growth and of profit than mature ones, to contribute by supplying inputs and knowledge to other sectors, etc. If new sectors, resulting for example from important innovations, had a rate of growth of demand, of output, of employment, etc. considerably higher than the average for all the sectors in the economy, then the composition of the system at a given time would also be a determinant of its future growth path.

The implication of this conclusion is that the composition of the economic system must be included as one of the variables in models of economic growth and development. An analytical representation of the composition of the economic system can be obtained by means of the concept of variety, defined as the number of actors, activities and objects required to describe the economic system. It must be pointed out that in this context variety can be used at a higher level of aggregation than the one traditionally used in much of the economic literature on the subject. While traditionally variety measured the degree of differentiation of a product group (Lancaster, 1975, 1979, 1990; Dixit and Stiglitz, 1977), in the present paper it is used to measure the degree of differentiation of economic systems at different levels of aggregation, starting from a firm or an individual product and ending with the world economy. In this paper variety is a measure of the extent of differentiation of the economic system.

In our model two hypotheses link variety to economic development:

**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. Then 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. In this paper the number of sectors existing in our artificial economic system at a given time will act as a proxy for variety. Thus, conditions leading to a faster rate of creation of new sectors will enhance the rate of variety growth.

It is to be noted that the previous Hypothesis 2 can be considered as the complementarity of efficiency and creativity. Whereas in older models economic growth was implicitly based only on increasing efficiency, our model attempts to show that creativity, as represented by the ability of the economic system to create new goods and services, is an equally important determinant of economic development. Thus, the process of economic growth is not due only to a quantitative change in which the increasing efficiency of given processes provides an increasing quantity of goods and services at constant resources and composition. On the contrary, in our view growth and development are transformation processes which generate both qualitative and quantitative change, these two aspects being combined in such a way that any instance of qualitative change provides the scope for further quantitative improvements.

An important role is played in our model by demand. Structural change cannot occur only in production. In order to acquire economic weight new goods and services need to be created by innovations, produced and purchased by consumers and users. Unless preferences for radically new goods and services exist before they are created, something we consider unlikely, a long term analysis of economic development requires a theory of the formation of preferences, that is a dynamic theory of demand. Although no theory can claim to be able to predict the evolution of demand over very long periods, some relevant theoretical frameworks exist. More complete treatments of this problem can be found in Wadman (2000), Gualerzi (2001). In what follows we use a simplified version of a hierarchical theory of wants (Menger, 1950; Maslow, 1954). Sectors are classified as ranging from the most fundamental ones, occupying the lowest positions in the hierarchical ladder, to the most sophisticated ones, occupying higher positions and having been generally created later. We assume that the consumption of goods and services occupying higher positions can only begin after a ‘critical income’ (Bonus, 1973) had been attained (Saviotti, 2001). Furthermore, here again we take inspiration from the work of Pasinetti, and in particular from his emphasis on the imbalance between productivity growth and demand growth within given sectors. The observed tendency of demand to saturate while productivity keeps growing, a generalization of Engel’s law, can be considered an important stylised fact providing inspiration for the construction of our model. To model effectively a process of economic development in which the composition of the system changes in the long run involves the use of a theory of demand which explains how the preferences for new goods and services are created. A hierarchical theory only tells us that wants can be classified in a particular way, but it does not help to predict the nature of future goods and services. We do not have such an accomplished theory, but we agree with Schumpeter (1934) that it is producers that have to educate consumers to the use of the new goods and services created by an innovation. This is equivalent to saying that preferences are not well formed before the new goods and services are created, but that they are created gradually by means of a process of mutual learning of producers and consumers (Saviotti, 2001). In our model we use the concept of ‘potential’ demand, corresponding to
a potential market that can be created by an innovation (Gualerzi, 2001). The emergence of a pervasive innovation (Freeman, 1991; Verspagen, 1993, 2002) creates what we call an adjustment gap, that is a potential market that at the beginning is completely empty because there is no production capacity for the new goods and services created by the innovation. The adjustment gap is measured by the difference between the maximum potential demand for the goods and services created by the innovation and the actual demand at any given time. We can expect that immediately after the emergence of the innovation actual demand will be much lower than maximum demand because consumers have not yet learned the properties of the new goods and services and the contribution that they can make to their utility function. Furthermore, even producers only gradually learn to fine tune their offer to evolving consumers preferences. Thus, a well formed demand for the outputs of a given sector can only be created with a delay with respect to the creation of the sector itself. The characteristics approach that we previously described is also relevant. In general characteristics help us to understand the choices made by consumers within given product groups rather than between different product groups. However, in this paper different products belonging to different sectors can have some common service characteristics and be partially substitutable.

2.4. Stylised facts

A number of stylised facts can be derived from the previous considerations. First, the composition of the economic system changes in ways that are both results of the previous evolution of the system and determinants of future evolution. As a consequence a model of economic development should be capable of generating endogenously changes in the composition of the economic system. Second, the composition changes in a particular direction, that is towards increasing the variety of the system. Third, a typical pattern of evolution of demand can be detected, which can be considered a generalization of Engel’s law, according to which the demand for given goods and services increases less rapidly than income per head, thus leading to a saturation of demand in the sectors based on such goods and services. Fourth, in some cases a typical pattern of evolution of industrial sectors can be detected, according to which some properties of the sector, such as the number of firms, the ratio of product to process innovation, etc. change in a systematic fashion during the life of the sector.

An adequate model of economic development should take these stylised facts into account. This can be done in two ways: first, some of the stylised facts can be used to construct the hypotheses of the model; second, the model itself should be able to predict the existence of some of these stylised facts, although, of course, not of those that have been used to construct the hypotheses. This paper is an attempt to create a model in which economic development is created by the emergence of new sectors. The composition of the economic system changes endogenously because the saturation of given sectors induces the creation of the following ones. The basic features of the model are common to a previous version (Saviotti and Pyka, 2004). In the present paper we explore the implications of the model for the growth of employment. In what follows we start by presenting the basic features of the model and we then proceed to describe the results of our calculations of the employment implications of the model.
3. A model of economic development by the creation of new sectors

3.1. Conceptual background

3.1.1. Adjustment gap

In this model a new sector is created by a pervasive (Freeman, 1991; Verspagen, 2002) innovation, that establishes an adjustment gap, that is a potential market (Gualerzi, 2001). At the time the innovation is first introduced this potential market is empty because there is no production capacity for the goods or services created by the innovation. The adjustment gap is precisely the size of the potential market, and it can be defined as the difference between the maximum possible demand and the actual demand at a given time:

\[ AG_t^i = D_t^{i,\text{max}} - D_t^i \]  

where \( D_t^i \) is the demand for the output of sector \( i \) at a given time and \( D_{t,\text{max}}^i \) is the maximum expected demand at the same time. In other words, \( D_{t,\text{max}}^i \) is a potential demand, which at the beginning of the life of a new product or service can be estimated with considerable uncertainty. Nevertheless, it acts as a strong inducement for entrepreneurs to create firms producing the new good or service. If \( D_{t,\text{max}}^i \) were to remain constant, \( AG_t^i \) could be expected to have its maximum value at \( t = 0 \), that is at the origin of the sector, and to decline gradually in the course of time. In the long run we expect the adjustment gap to close and the corresponding market to become saturated. The concept of the adjustment gap embodies the hypothesis of the eventual saturation of demand. However, even if the adjustment gap eventually closes this does not mean that it will fall at all times. The innovation that creates a given sector does not remain constant in the course of time, but it can keep improving. So-called post-innovation improvements (Metcalfe et al., 1988; Georghiou et al., 1984) can both reduce the price of the innovation and improve its quality, thus expanding the population of potential adopters. In our model \( D_{t,\text{max}}^i \) increases with the extent of the search activities performed within the sector. Furthermore, consumers’ demand \( D_t^i \) is only gradually created as they learn how the new goods and services can improve their utility. Thus, it is even possible for \( AG_t^i \) to increase during certain periods after the emergence of the sector.

3.1.2. Sectors

The definition of industrial sectors used in this model does not coincide with that commonly used in statistical surveys. A sector is here defined as the collection of firms that produce a differentiated product. The meaning of that definition can be better understood by reference to a twin characteristic representation of products (Saviotti and Metcalfe, 1984; Saviotti, 1996) in which one set of characteristics represents the internal structure of a product technology (technical characteristics) and the other set represents the services performed for the users of the product (Fig. 1).

For what concerns the present model the twin characteristics representation is useful because only service characteristics affect users choices. Thus it is only service characteristics that affect directly demand and competition. In what follows we use only service characteristics to represent industrial sectors. In general we can expect different sectors to differ both for their technical and for their service characteristics. For example, cars and photographic cameras differ both for their internal structure and for the services they perform.
However, there can be cases in which sectors differing for their technical characteristics have some common service characteristics. For example, airplanes and trains have some common service characteristics. In this case two different sectors provide outputs that are partly substitutable and, as we will see later, they can be subject to inter-sector competition. A representation of such sectors would have to take into account the internal characteristics of firms, ranging from their strategy, organisation, financial aspects, competencies, etc., and the characteristics of their outputs, be they product or services. In what follows we concentrate on products, although a generalisation of this framework to services can be developed (Gallouj and Weinstein, 1997). Also, in the present version of the model we will concentrate exclusively on product space. Thus, a product model will be represented by a point in service characteristics space. To the extent that the producers in a given industry produce differentiated products, their product models will be represented by a distribution of points in service characteristics space. Such distribution of differentiated product models, or product population, is one of the possible representations of an industrial sector as defined in this paper (Fig. 2). The representation in Fig. 2 is particularly simplified because it uses only two service characteristics. This is done only to provide a graphic representation, which it would be impossible for any number of characteristics greater than three. Of course, this implies that the two sectors in Fig. 2 offer common services and differ only for the values of these common characteristics, a situation which is possible but not very general. In the most general case, that of two sectors not sharing any service characteristics, we would need at least four dimensions to represent their product populations. Fig. 2 is used to represent the two product populations (P1 and P2), corresponding to two industrial sectors, in service characteristics space. Y1 and Y2 could be size and speed for aircraft, or processing speed and the maximum size of the files that can be processed for a computer.
as an illustration, but the model is not limited to product technologies offering common services.

The fact that in this version of the model we use only service characteristics to represent product models, and thus industrial sectors, does not mean that we consider technical characteristics irrelevant. The true nature of a radical innovation consists in developing a new internal structure with novel technical characteristics, although the services it provides may show a continuity with existing services. For example, the advent of the jet engine in aircraft created a wholly new set of technical characteristics to provide more efficiently services common to previous aircraft engine types. In the present version of the model we concentrate on service characteristics because an industrial sector needs to have producers and consumers, service characteristics being the interface between the two. The superiority of a set of technical characteristics over another can only be judged by its ability to provide more efficiently services. This allows us to investigate some properties of our artificial economic system, and in the present version we concentrate on these properties.

Both technical and service characteristics are dimensions of product technology. Process technology is taken into account by means of improvements in productive efficiency due to a combination of learning by doing and of learning by searching (see Eq. (8)).

A number of trends can contribute to the evolution of industrial sectors in the course of time. For example, each population/sector can move away from the origin of the axes as the level of characteristics supplied increases gradually. Furthermore, a population can separate into two or more as the corresponding technology specialises. Finally, new technologies can be created in wholly new dimensions of characteristics space, for example supplying services that were previously not available.

### 3.1.3. Competition

An extremely important role is played in this model by the nature of competition. In this model competition has two components, intra- and inter-industry. The reason for the introduction of these two components is the need to take qualitative change into account. Following the twin characteristics representation described in the previous section, an industrial sector can be represented by a population of product models in service characteristics space. Amongst the most relevant features of the sector there is the density of product models in service characteristics space. The higher this density, the greater the similarity of the product models of different manufacturers and the higher the intensity of competition (IC). In the limiting case in which the product models of all producers are identical (have exactly the same characteristics levels) we have the multi-dimensional analogue of perfect competition. On the other hand, a progressive differentiation of product models would increase the average distance between product models and thus reduce density and intensity of competition. This representation of competition is capable of encompassing within the same model perfect competition and monopolistic competition. As we move from one to the other the density of the population, and thus the intensity of intra-industry competition, falls gradually.

Inter-industry competition exists because different sectors can provide qualitatively similar services, although possibly with a different efficiency. For example trains, planes, cars, buses, etc. can provide transport services and the telephone, fax, e-mail provide communication services. To the extent that these technologies are produced in different sectors there
will be inter-sector or inter-industry competition. In fact, the root of the differences between sectors in this case would be the different internal structure of the technologies underlying the sectors, as described by their technical characteristics. The importance of inter-industry competition lies in the limit that it places on the behaviour of monopolists. A monopolist is a monopolist because he/she is subject to no intra-industry competition. Yet, if the technologies underlying other sectors provide similar services, the monopolist faces some outside competition. A clear example of this is the competition that airlines or bus companies create for a railway company that is a national monopolist. However, it is not necessary for technology to have common service characteristics in order to compete. For example, teleconferencing can compete with travelling to go to meetings in spite of the fact that the service characteristics of the technologies used for teleconferencing have no services common to transport technologies. Furthermore, different leisure activities and the technologies on which they are based can compete at equivalent levels of income even when they have no common services. Relevant examples here are photography, theatre, sport, etc. Thus, while products providing common services are substitutes and can compete, substitutability does not necessarily require common services. Inter-sector competition is a phenomenon of a greater generality than the existence of different product technologies supplying common services. We can then expect the overall intensity of competition experienced by a firm in a sector \( i \) to depend on the interaction between inter- and intra-industry competition.

Clearly, inter-industry competition as represented shows some similarity with respect to market contestability (Baumol et al., 1982). However, inter-industry competition as represented here does not require the rather extreme assumptions of zero entry and exit costs. Two different sectors providing similar services can be established in very specialised niches, that compete very little. Furthermore, the competencies required to produce the two types of outputs are likely to be so different that firms in one of the two sectors cannot hope to internalise them efficiently. Thus we can expect two or more sectors providing similar services to emerge and to develop in presence of significant barriers to entry and to exit, but nonetheless to provide significant inter-sector competition to one another.

As a result of these considerations we cannot expect to be able to measure the intensity of competition by means of the number of firms \( N_i \) alone, but we need to combine \( N_i \) with the intensity of inter- and of intra-industry competition. The combined dynamics of inter- and intra-industry competition during the evolution of industrial sectors will give rise to a process in which competition is one of the elements driving economic evolution. This implies that we cannot measure the intensity of competition by the number of firms alone, but that we need to add the effects of intra- and of inter-industry competition:

\[
IC_i = f(N_i, \rho_i, D_y(i, j))
\]  

(2)

where \( IC_i \) is the intensity of competition, \( N_i \) the number of firms in sector \( i \), \( \rho_i \) the density of product models in service characteristics space, and \( D_y(i, j) \) the distance between sectors \( i \) and \( j \) in service characteristics space. In this model entrepreneurs by means of an innovation establish a niche in which they expect to have a temporary monopoly. If the innovation that they create is successful, imitating firms will enter thus raising the intensity of competition. As more firms enter the inducement to entry gradually falls to the point where it can become an inducement to exit. The saturation of already mature sectors will induce entrepreneurs to try and create new niches where they will again have a temporary monopoly. As it happened
for previous sectors, to the extent that the innovations creating the niches are successful, imitation will reduce the initial temporary monopoly and raise the intensity of competition. This model has a strong Schumpeterian flavour because each sector goes through a life-cycle leading from the innovation establishing the sector in conditions of temporary monopoly to the increasing intensity of competition due the bandwagon of imitators and finally to ‘saturation’ and maturity, at which point the sector has ceased to be innovative and has become part of the economic routines or of the ‘circular flow’ (Schumpeter, 1934; Andersen, 1999).

3.1.4. Returns to adoption

In this model returns to adoption can be varied from positive to negative. They can include learning by doing, network externalities, scale economies, etc. They exert an effect on the dynamics of entry and exit of firms by accelerating exit. The greater the returns to adoption, the greater the advantage of a prime-mover who is the first to either enter production or to expand its scale of output, thus putting other incumbent firms to a growing disadvantage. Exit is then caused both by increasing intensity of competition and by mergers and acquisitions, whose probability increases the higher are the returns to adoption.

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

Exit is determined by the increasing intensity of competition and by mergers and acquisitions. As Schumpeter (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
rate of failures has not been included in the model. 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 techno-
logical 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. We now pass to the detailed description of the model.

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

\[ N_{t+1}^i - N_t^i = k_1 FA_i^t AG_i^t - IC_i^t - MA_i^t \]  

(3)

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
. Maximum demand is determined by the level of search activities:

\[ D_{t,\text{max}}^i = SE_i^t \]  

(4)

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:

\[ D_t^i = \begin{cases}  
N_t^i Q_t^i & \text{for } D_{t-1}^i \leq D_{\text{max}}^i \\
D_{\text{max}}^i & \text{else} \end{cases} \]  

(5)

where Q
i
is the average output per firm.

The search activities SE
i
carried out in sector
i
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 more slowly as it becomes progressively more difficult
to exploit the technological opportunities left in the sector. Thus we use for SE
i
, search
activities in sector
i
at time
i
, the following expression:

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

(6)

where D_{\text{acc},i}^{t-1} is the total accumulated demand in sector
i
at time
i
− 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$_t^i$ increases for a given level of accumulated demand. On the other hand $k_4$ measures the technological opportunities existing in the sector because it determines the extent to which previous demand can lead to increasing SE.

The output of each firm can be expected to increase in the course of time as firms learn by a variety of mechanisms, including learning by searching and learning by doing an as they exploit scale economies. The average output per firm is then given by:

$$Q_t^i = 1 + \gamma_i[1 - \exp(-k_{SE}^i SE_t^i)]$$

(7)

where SE$_t^i$ represents the search activities carried out by firms in sector $i$, and $\gamma_i$ is a constant.

In the course of time $Q_t^i$ increases because SE$_t^i$ increases. Furthermore, increasing values of $\gamma_i$ lead to a higher rate of growth of $Q_t^i$. We can consider (7) a technical progress function in which the growth of $Q_t^i$ is due to combination of learning effects (learning by doing, learning by searching), scale economies, etc.

The intensity of competition IC$_t^i$ in population $i$ is due to the combined effects of the number of firms $N_t^i$ and of the density $\rho_t^i$ of the product population in service characteristics space, i.e. intra-industry competition as well as of the average distance between product populations $i$ and $j$ in service characteristics space (Eq. (2)), i.e. inter-industry competition. An explicit expression for IC$_t^i$ 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$_t^i$ only in function of the number of firms (see Saviotti and Pyka, 2004). The approximate expression that we used for IC$_t^i$ is given in Eq. (8):

$$IC_t^i = k_8 \frac{N_t^{i-1} N_t^{i-1}}{k_6 N_t^{i-1} + k_7 N_t^{i-1}}$$

(8)

Financial availability FA$_t^i$, 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 be 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 a sector matures. FA$_t^i$ is given by the following expression:

$$FA_t^i = k_3 C_t$$

(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 the number of people having the relevant knowledge grows, allowing the economic system to assess more effectively the prospects of the sector. In other words, in principle FA$_t^i$ is partly endogenous to the development of sector $i$. However, in the simulations covered in this paper FA$_t^i$ is held constant. FA$_t^i$ is thus a term representing the presence of institutions providing financing in the conditions appropriate to the development of sector $i$. Venture capital would be a relevant example in the emergence
and development of high technology firms starting from the 1970s. Furthermore, the product of the factors FA and AG in the entry term represents an example of the co-evolution of technologies and institutions. The potential market whose size is represented by AG could never be realized unless appropriate financial institutions existed.

The rate of mergers and acquisitions, MA, can be expected to increase with the returns to adoption and with the extent of saturation of the sector. We expect the probability of mergers to be proportional to the number of firms existing in the sector, N, to the returns to adoption MC−1, and to the extent of market saturation, measured by the inverse of the adjustment gap AG. It was previously pointed out that the higher the returns to adoption, the greater the advantage of a prime mover over its competitors, and thus the greater the number of firms that would be forced either to merge or to go bankrupt. It is to be noticed that MC−1, returns to adoption, can include static and dynamic economies of scale, network externalities, learning effects, etc. Failures represent another obvious exit mechanism. They are not included explicitly here because we expect them to be determined by the same factors as mergers and acquisitions. To the extent that this is the case, the only difference in Eq. (10) resulting from the explicit inclusion of failures would be a higher value of k. Thus, we use the following expression:

\[
MA_t = k N_t MC_{t-1} AG_t
\]

(10)

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, due both to the growing intensity of competition and to the saturation of demand, will induce the creation of a subsequent population, say i+1. As previously pointed out this inducement endogenizes the changes in the composition of the economic system represented by the emergence of new sectors. As a consequence, entry conditions for the creation of new sectors will be:

\[
N_{t+1}^i = \begin{cases} 
0 & \text{for } D_{t-1}^i \leq D_{t-1}^{max,0} \\
N_t^i & \text{else}
\end{cases}
\]

(11)

These entry conditions basically say that sector i+1 will not be created unless sector i has reached market saturation. This condition can be considered a very simplified representation of a hierarchical theory demand. The critical income required for sector i+1 to start developing will only be achieved when sector i becomes saturated. We do not imagine this to be a necessary requirement for economic development. It is certainly possible for such critical income to be achieved before sector i becomes saturated, thus leading to a higher rate of growth than we allow for in the present version of the model. Likewise, the critical income required for the creation of sector i+1 might only be reached with a delay with respect to the saturation of sector i. In this case, the development of sector i+1 would not start and the economy would undergo a period of slow growth or of recession. The entry conditions used in the present version of this model amount to an almost perfect inter-temporal coordination between the saturation of existing sectors and the emergence of new ones. Again, we do not assume this to be a necessary requirement for economic
development. We have chosen these conditions to start the simulation of the model. Further experiments are possible by introducing delays in the achievement of the required critical income in order to explore the effect of failures in inter-temporal coordination on the overall growth path of the system.

Another important element required to define the dynamics of new sectors is the relationship that they bear to pre-existing sectors. An important aspect of the relationship of different sectors is constituted by their relative values of $D_{\text{max}}$, that is by the relative sizes of their markets. Existing demand theories do not give us enough help for this purpose. As previously pointed out, we favour a hierarchical theory of demand in which goods and services of growing sophistication, occupying increasingly high places in a consumption ladder, require higher and higher values of critical income to be purchased. Yet even such a theory does not help us to define the relative values of $D_{\text{max}}$ for different sectors. In the present paper we assume $D_{\text{max}}$ to be constant for different sectors and we concentrate on investigating the dynamics of the number of firms, of demand, of the intensity of competition and of employment.

The dynamics of employment enters this model by means of the expected relationship between firm size and employment per unit of output. This relationship has been observed empirically in a very large number of cases and it is compatible with at least some of the models of industry life-cycle, such as those of Abernathy and Utterback (1975). We assume employment per unit of output to fall as total output increases within each sector:

$$l_i^t = \frac{k_i}{Q_i^t} = \frac{k_i}{Q_i^t/N_i^t} = \frac{k_i N_i^t}{Q_i^t}$$

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

$$l_i^t = \frac{L_i^t}{Q_i^t}$$

The constant $k_i$ measures the intrinsic capability of sector $i$ to create employment at equivalent output. Thus we can expect it to be related to the capital intensity of the sector.

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.

4. Results

We performed our calculations of the dynamics of interacting firms populations in the following order. First, we varied the values of the constants $k_1$–$k_{11}$ in the equations of the model and we tried to produce results that are compatible with some of the stylised facts described in Section 2. Thus, we found conditions under which the variety of the system can grow, sectors develop according to a life-cycle, employment grows. We did this by
calculating the curves for the main variables of the model, that is the number of firms and its rate of growth, demand, intensity of competition, and the rate of employment growth. We called these calculations the standard scenario. We did not perform a complete exploration of the parameter space of our model. Thus, our results cannot be interpreted as the necessary development path of our artificial economic system, but only as the type of development that occurs under particular conditions. In a previous version of this model (Saviotti and Pyka, 2004) we performed a number of experiments varying some parameters of the model, such as the technological opportunity $k_4$ and the rate of learning $k_5$. In this paper we concentrate on developing explicitly the implications of this model for employment.

The standard scenario was obtained by giving particular values to the constants $k_1$–$k_{11}$. The values of these constants are described in Table 1.

The calculations were performed for either three or five populations. Of course, this is not a realistic number for any economic system. Three is the minimum number of populations that we can take into account. This is due to the fact that both the first and the last of the sectors to emerge are very specific in terms of their interactions. The first sector in our artificial economic system for a while does not interact with any other sector. The last sector is truly artificial because we have ‘frozen’ the history of our system by eliminating from the last population the inducements to the creation of subsequent ones. Thus an intermediate sector would be the only one to be both preceded and followed by other sectors, as we expect to happen normally in economic development.

The number of firms within each population increases first and then decreases until it reaches an almost constant level while still falling slowly (Fig. 3). This behaviour is the result of the balance between entry and exit, with entry due to an adjustment gap which is very large at the beginning and gradually decreases, and with exit becoming progressively more frequent as the intensity of competition increases and as more mergers and acquisitions reduce the number of firms. We can also observe that the number of firms in each population falls more rapidly when a new population is created, as a consequence of increased inter-population competition. We can see that the rate of growth of the number of firms in each population (dN/dt) increases rapidly at the beginning and then slows down to almost zero, but it falls and becomes negative at the origin of a subsequent population.

Demand (Fig. 4) is seen to increase in each population after the initial entries that created the population itself until a relatively stable state is achieved. The phase of rapid initial rise

### Table 1

<table>
<thead>
<tr>
<th>Constant</th>
<th>Interpretation</th>
<th>Value used in the standard scenario</th>
</tr>
</thead>
<tbody>
<tr>
<td>$k_1$</td>
<td>Entry conditions</td>
<td>1</td>
</tr>
<tr>
<td>$k_3$</td>
<td>Weight for financial availability</td>
<td>0.01</td>
</tr>
<tr>
<td>$k_4$</td>
<td>Technological opportunities</td>
<td>50</td>
</tr>
<tr>
<td>$k_5$</td>
<td>Learning rate</td>
<td>0.01</td>
</tr>
<tr>
<td>$k_6$</td>
<td>Intra-industry competition</td>
<td>100</td>
</tr>
<tr>
<td>$k_7$</td>
<td>Inter-industry competition</td>
<td>1</td>
</tr>
<tr>
<td>$k_8$</td>
<td>Weight for competition</td>
<td>1</td>
</tr>
<tr>
<td>$k_9$</td>
<td>Weight for mergers and acquisitions</td>
<td>0.1</td>
</tr>
<tr>
<td>$k_{11}$</td>
<td>Learning curve effect</td>
<td>0.00005</td>
</tr>
</tbody>
</table>
within each population (e.g. population 2) leads to a fall in the demand level for previous populations. In this model there is no explicit representation of income, but we can assume income to be equal to total output. Thus in the short run income is redistributed towards the output of the new sector and the share allocated to old sectors falls. However, subsequently productivity gains in the economy raise the demand for all sectors of the economy.

The intensity of competition increases gradually as more firms enter, reaches a maximum and then falls gradually to an almost stable state as exit reduces the number of firms (Fig. 5). The creation of each subsequent population raises the intensity of competition in the pre-existing ones, due to increased inter-population competition. As we can see from the evolution of the number of firms (Fig. 3), the natural tendency of each population is to produce a rather concentrated industrial structure. However, this does not lead to a generalised fall in the intensity of competition in the whole economy. This is due to the effect of inter-population competition. If there were only intra-population competition IC would fall to a low and constant value as the number of firms falls and the industrial structure...
converges to an oligopoly. Such outcome is not obtained because every new sector adds an inter-population component to the IC of every other sector. The average level of IC is thus kept high by inter-population competition. It is to be noticed that in this version of the model the inter-sector intensity of competition can in principle be the same for any pair of sectors. This is a condition that can be removed. In this case sectors having a higher intensity of competition would be more contestable than others.

Sectoral and total employment calculated for the standard scenario is shown in Fig. 6. The dynamics of sectoral employment follows closely that of firm creation, with the rate of employment growth being particularly high in the early phases of the life of a new sector and then declining gradually. In Fig. 6 an aggregate representation has been superimposed on the sectoral curves by adding up the contributions to employment of the different sectors at each time. This aggregate representation is particularly useful if we are more interested in the impact of variables such as productive efficiency, technological opportunity, rate of learning, etc. on the aggregate properties of the system than in the internal mechanisms of each sector. What is immediately clear is that employment creation within each sector tends to decline and that overall employment can keep growing only due to the emergence
of new sectors. Thus, the process of qualitative and structural change is a determinant of employment growth. This conclusion is reinforced by Fig. 7, which displays the output shares of different sectors. As the shares of old sectors declines that of emergent ones rises first and then starts declining as the once new sectors move towards maturity. An interesting implication following from Fig. 6 is that a relatively stable macro-economic growth pattern is produced by a much more turbulent micro-economic evolution of individual sectors. To the extent that the patterns of sectoral evolution described here are common, the achievement of a stable macro-economic growth pattern can only be obtained by creating new sectors, that is by changing the composition of the economic system. In this sense the flexibility required of the economic system is the ability to create new sectors, or its creativity.

We can also notice (Fig. 8) that productive efficiency and employment change in opposite directions during the development of each sector: productivity rises as employment falls.

The basic features of the economic system simulated by this model seem to indicate the existence of an industry life-cycle (ILC). This life-cycle is essentially driven by competition. As a new innovation creates an adjustment gap, thus defining the scope of the sector,
early entrants find themselves in a situation of temporary monopoly. As imitation induces entry the intensity of competition increases, thus reducing further entry, and eventually stimulating exit. The intensity of competition does not only affect the dynamics of one population, but also of the subsequent ones. The attainment of very intense competition in a population induces the creation of new niches, where the early entrepreneurs will again enjoy a temporary monopoly. The process of economic development simulated in this model involves a set of overlapping and interacting populations/sectors. Let us also observe that the life-cycle predicted by the model is the result of the balance of entry and exit, as determined by the adjustment gap, by the intensity of competition and by mergers and acquisitions, without any reference to either dominant designs (Utterback and Suarez, 1993) or to the balance between product and process innovations (Klepper and Simons, 1997). Thus, our paper shows that, although industry life-cycles can be created by different factors, including dominant designs and increasing returns to R&D, an ILC can also be created by the joint dynamics of competition and demand. This is a genuine prediction since our hypotheses on competition and demand cannot be expected ex ante to produce a cyclical behaviour under all possible circumstances.

Another important feature of our model, not illustrated in this paper but import to understand its scope, is the possibility to test the two hypotheses on variety and efficiency (Section 2). In a previous paper we showed that growing values of $\gamma_i$ (see Eq. (8)), which can be interpreted as the relative productive efficiency of sector $i$, led to a faster rate of creation of new sectors. Thus, at a given time an economy having a higher average productive efficiency than another contains a greater number of sectors, that is a higher variety. This is a confirmation of the complementarity between efficiency growth and variety growth, although only for the direction of causality going from efficiency growth to variety growth.

5. Summary and conclusions

In this paper we described the employment implications of a model of economic development by the creation of new sectors. Economic growth is created by the emergence of new sectors, as old ones decline. Each sector is created by entrepreneurs based on a pervasive innovation that establishes an adjustment gap, that is an empty market whose potential demand is only gradually satisfied as the required productive capacity is created and as consumer demand is created. The dynamics of the number of firms in each sector is due to the balance between entry, as determined by the size of the adjustment gap and by financial availability, and of exit, as determined by increasing competition and by mergers and acquisitions. During this process the average size of firms increases within each sector. In this model employment creation is due to the combination of the creation of new firms and of the employment by firms per unit of output. While a growing number of firms creates increasing employment, firms employ less workers per unit of output as they increase in size. The distinguishing features of our model are: the endogenous character of the creation of new sectors, provided by inducements linking the decline of mature sectors to the creation of new ones; a novel concept of competition including both intra- and inter-sector competition; the possibility that it offers to test our hypotheses on variety and productivity growth (see Section 2); the prediction that under some conditions, different from those so
far considered by students of industry life-cycle (ILC), the evolution of industrial sectors will follow a cyclical pattern; the prediction that aggregate employment can grow even if there is within each sector a trend towards falling employment. Inducements to the creation of new sectors are provided by the joint action of intensity of competition, which rises as new imitators join the bandwagon created by the innovation establishing the sector, and by the saturation of demand, leading to a gradual closure of the adjustment gap. The concept of competition we use in this paper includes both intra- and inter-sector contributions. Intra-sector competition corresponds to the type of competition traditionally used by economists. Inter-sector competition occurs when the outputs of different sectors are at least partly substitutable and plays a role similar to that of market contestability. Variety can be measured in our model by the number of sectors existing in an economic system at a given time. In a previous paper (Saviotti and Pyka, 2004) we demonstrated that the number of sectors created in an economic system within a given time increases with increasing productive efficiency, thus providing confirmation for our Hypothesis 2. Amongst our results we found that under the conditions explored in this paper industrial sectors follow a life-cycle behaviour, mainly for what concerns the number of firms and employment. The interesting feature of this prediction is that a life-cycle occurs under conditions different from those usually considered in ILC models. An important general feature of this model is the connection between the micro- and the macro-levels of aggregation: aggregate figures for the variables contained in this model can be calculated starting from the corresponding micro-economic variables. In the case of employment this shows that a relatively stable macro-economic growth pattern is compatible with, and indeed may require, a much more turbulent micro economic behaviour of the same variable. The simulations described in this paper are far from exhaustive and we need further work both to explore more fully the parameter space of the model as well as to include further variables and inter-sectoral interactions.

References