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GENERALIZED BARRIERS TO ENTRY AND ECONOMIC DEVELOPMENT

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Abstract:

In this paper we are going to analyze the dynamics of barriers to entry at the international level. In our model economic development takes place and continues in the long run due to the emergence of new sectors, which can compensate for the diminishing ability of mature sectors to create employment and growth. Each new sector is created by a pervasive innovation, which creates a new market and into and out of which there are entry and exit of firms. Depending on the inter-temporal coordination of the maturation of older sectors and of the maturation of new ones our model can give rise to development paths with growth rates ranging from high to negative, to fluctuations, to bubbles and to chaos. In the construction of our model we found inspiration in a number of growth models, both endogenous and evolutionary as well as on empirical work on structural change. The model also bears some similarity of style to history friendly models. Its unique feature is that it gives rise to an endogenously variable number of sectors. Unless new sectors are exact substitutes of older ones the model gives rise to growing variety. In fact, the main objective for which the model was initially constructed was to test some propositions implying that variety growth is a necessary requirement for long term economic development. Within our model the ability to create new sectors at the right times is the crucial determinant of the growth potential of an economic system. Thus, inter country differences in the barriers to entry into new sectors can be expected to give rise to different rates of growth and in the end to increasingly skewed world income distribution.

1) Introduction

Barriers to entry are a concept often used in the study of industrial organization and dynamics. Typically they are used at the micro or meso economic levels of aggregation for firms or for industrial sectors. The concept of barriers to entry can be adapted to the study of international economic development to analysis processes of imitation of innovations and of catching up with more advanced countries. The barriers existing at this level are not the same as those existing within a sector and within a country. These international barriers to entry will be affected by differences in resources and institutions between the innovating countries creating the innovations and the less developed countries (LDCs) attempting to imitate the same innovations and to catch up with the leaders. Of course, the same barriers existing at the sectoral level in an innovating country are likely to exist also in an LDC, but they will be accompanied by the international barriers referred to above. We can expect these international barriers to be affected by the distance of LDCs from the technological frontier they are trying to reach. In this paper we are going to analyze the dynamics of barriers to entry at the international level using our model of economic development by the creation of new sectors (Saviotti, Pyka, 2004a, 2004b, 2008a, 2008b). In what follows we first discuss the concept of generalized barrier to entry and the related concepts of resources and of technological frontier, then we present the general features of our model and the way in which it need s to be modified to include the barriers we are discussing here. Finally, we present some results and their implications for technological innovation and for economic development.

2) Generalized barriers to entry

Typically at the sector level barriers to entry are due to factors such as scale economies, accumulation of knowledge etc. In general they are examples of increasing returns to adoption which tend to favor incumbents with respect to late entrants. Furthermore, such barriers to entry are not constant in the course of time but evolve dynamically. A pattern which is often observed is the increase in barriers to entry during the life cycle of industrial sectors. For example in the life cycles of Abernathy and Utterback (1975) as well as in the recent ones by Klepper (1996) the scale of an average plant increases in the course of time thus forcing late entrants to start with a larger plant size than the earlier entrants. Barriers to entry are not limited to static scale economies. Other types of barriers can arise from various types of increasing returns to adoption (Arthur, 1989). Furthermore, in knowledge based economic systems the acquisition of the required knowledge base can constitute an important barrier. As a consequence late entrants can be expected to face a higher barrier into the same sector compared to an early entrant. However, entry can occur even in what seem relatively mature sectors as a consequence of windows of opportunity due to the emergence

of new technologies which can be more easily mastered by potential new entrants than by incumbent firms. Typical examples are given by knowledge intensive industries such as the pharmaceutical, biotechnology, information and communication sectors. In these cases rapid advances in knowledge in a field radically different from the one in which the knowledge base previously used by incumbents, generally large, firms was located can favor the emergence of start ups specialized in the emerging knowledge field (see Hagedoorn, 1993, 1995; Saviotti, Catherine, 2008) We do not discuss this case here but we limit ourselves to the situation of industrial sectors which evolve from a large population of entrant firms to an oligopoly, as predicted by the Industry Life Cycle (ILC) literature (See Klepper, Jovanovic etc).

When we move from the sectoral & national level to the international one, sectoral barriers to entry still exist but they are combined with other barriers to imitation. It is in this sense that we talk about generalized barriers. We can conceive international development as due to leading countries behaving as Schumpeterian entrepreneurs and introducing innovations in the expectation of achieving a temporary monopoly. According to Schumpeter (1912, 1934) the introduction of an innovation should be followed by a bandwagon of imitators. However, the international imitation of the new technologies and production processes introduced in leading countries since the time of the industrial revolution has been very slow. As a consequence international income distribution has become increasingly skewed (Cantner et al. 2004). The still persistent asymmetries in technological and production capability amongst countries in the world economic system imply that international barriers to entry are very different from the corresponding intra-country sectoral ones. In other words, the study of the diffusion of technologies and of production processes at the international level requires a modification of the concept of barriers to entry.

The discussion which follows is based on the concept of co-evolution of technologies and institutions (Nelson, 1994, Perez, 2002, 2007, Freeman Perez, 1998). Each new and pervasive technology in order not only to be created but to acquire its economic weight, that is, to diffuse largely throughout society and to have an important impact on income and employment generation, needs the development of *appropriate* institutions. These institutions are in fact *complementary* with respect to the technologies and production processes considered. The time path of the emergence of technologies, of production processes and of the complementary institutions required is crucial for the success of catching up processes. The dynamics of imitation and of catching up processes can be studied by means of the two related concepts of generalized barriers to entry and of resources. In our model these two are combined into a function which determines the probability of entry into new sectors. Furthermore, co-evolutionary processes can be represented by a term in the entry equation, which involves the product of the expected market size and of the complementary

institutions which lead to technology and market growth.

In fact, what determines the probability of entry into a sector in any country of the world economic system is the ratio of barriers to resources. The concept of resources here needs to be interpreted broadly to include, for example, educational, research and financial institutions. The co-evolutionary process envisaged here can be described as follows. The initial development of a technology, whether it is its first creation or its adoption in an imitating country, requires the combination of a set of complementary resources, such as competencies, education, research and financial resources. In the early phases of both the creation or the imitation of a technology such resources may not be embodied in formal institutions but they may be supplied in an entrepreneurial form. Within the initial set of resources entrepreneurs play a fundamental role. They create innovations in a virtually a-institutional world. However, the diffusion and the adoption of a technology cannot go beyond a limited extent without the creation of formal complementary institutions and resources. For example, if an important scientific discovery were suddenly to show the existence of a wide range of potential Industrial applications, new university departments might need to be created to supply the required competencies, new government departments to monitor and to regulate the outcomes, new financial institutions to fund the new firms to be created. The creation of all these complementary institutions and of the resources they can generate (e.g. human competencies etc) represents a barrier for any country. However, when the barriers are overcome and the complementary institutions are created the output of the new production processes grows, thus generating a higher income per head. This provides the basis for the further growth of both production processes and complementary institutions until the new markets thus created become saturated.

The process described above can be autocatalytic. The outcome of the process in an early period (limited output of a new product based on a new technology) can induce the creation of complementary institutions and resources, which in a subsequent period induce an increased output of the initial product. This feedback loop can continue until the new market thus created reaches saturation and encounters diminishing returns. The interesting feature of such a co-evolutionary process is that it can give rise to a wide range of development paths. In the best possible circumstances fast and generous investment quickly follows the initial output due to the new technology, thus giving rise to a high rate of growth of output and to the further creation or amplification of complementary institutions. Alternatively, if the human resources required to launch the initial phase of the innovation are absent and/or the complementary institutions cannot be created, the same co-evolutionary process can lock particular economic systems into *development traps*. The same process which can be auto catalytic in some circumstances can be auto retarding in

other circumstances. This wide range of possible development paths seems to correspond to the experience of the last two hundred years in which some countries manage to catch up and develop while others remain persistently behind.

The wide range of possible development paths can be further amplified by the dynamics of sectoral barriers to entry. Such barriers can vary in the course of time. When they grow a late entrant faces a higher barrier into the same sector compared to an early entrant. The higher barriers to entry can provide a negative inducement to the creation of complementary institutions and thus stunt the adoption of the new technology and of the corresponding production processes. Institutional set-ups which offer windows of opportunity in a highly developed country can constitute barriers impossible to overcome in a less developed one. A country which systematically fails to adopt new technologies and to develop the corresponding production processes as more and more new sectors are created elsewhere can remain so short of resources as to be unable to adopt any further innovation, thus falling into a generalized development trap .

3) A model of economic development by the creation of new sectors

The model of development that we describe in this section has been developed over the past seven years and has already undergone a number of modifications (see Saviotti, Pyka, 2004a, 2004b, 2008a, 2008b). We will give first a brief description of the model and then introduce the equations most central for this study. For a detailed description of the formal structure we refer to the respective references.

In the model each sector is generated by an important innovation. Such innovation creates a potential market and gives rise to what we call an adjustment gap. The term adjustment gap is due to the fact that as soon as a potential market it is created it is in fact empty: neither the productive capacity nor the demand for the innovation is present. They are gradually constructed during the life cycle of the new sector. As the new sector matures the adjustment gap tends to fall: a productive capacity which in the end matches demand is created. When this happens the sector enters its saturation phase. The productive capacity is generated by Schumpeterian entrepreneurs establishing new firms initially induced by the expectation of a temporary monopoly and of the related supra normal profits. The success of the innovation gives rise to a band wagon of imitators. The number of firms in the new sector gradually rises, but this also raises the intensity of competition in the sector, thus gradually reducing the inducement to further entry. After the intensity of competition in the new sector reaches levels comparable to those of established sectors the new sector is no longer innovating but becomes part of the circular flow. When a sector achieves maturity in the way described above an inducement exists for Schumpeterian entrepreneurs to set up a new niche, which

can eventually give rise to the emergence of a new industry. In other words, the declining economic potential of maturing sectors induces the creation of newer and more promising ones. Competition plays a very important role in this process of creation of new industries. Entrepreneurs are induced to establish new firms by the expectation of a temporary monopoly, that is, by the absence of competition. However, the new sector would not achieve its economic potential unless imitative entry took place. In this way the intensity of competition rises, thus reducing the inducement to further entry. An additional contribution is made to the dynamics of our artificial economic system by inter-sector competition. Inter-sector competition arises when two sectors produce comparable services. Inter-sector competition is an important component of contestable markets (Baumol et al, 1982) and can keep the overall intensity of competition of the economic system high even when each sector achieves very high levels of industrial concentration.

In our model the variety of the economic system plays an essential role. Economic variety is approximated by the number of different sectors. By raising variety the creation of new sectors provides the mechanism whereby economic development can keep occurring in the long run. In this way the economic system can escape the trap generated by the imbalance between rising productivity and saturating demand (Pasinetti, 1981, 1993; Saviotti, 1996) which would occur in a system at constant composition. This also affects the macroeconomic employment situation: In particular, this artificial economic system can keep generating employment even when employment creation is falling within each sector (Saviotti, Pyka, 2004b).

In order to illustrate qualitatively the developments generated by our model figure 1a shows the development of the number of firms in a certain industry. Within a wide range of conditions the number of firms in each sector grows initially, reaches a maximum and then falls to a fairly low value. Within these conditions each sector seems to follow a life cycle, similar to the ones detected by Klepper (1996), Klepper and Simons (2005), Jovanovic and MacDonald (1994), Utterback and Suarez (1993). However, in our model this industry life cycle is created by variables very different from those used by the previous authors in their models and including increasing returns to R&D, radical innovations or the emergence of dominant designs. In our case the cyclical behaviour is caused only by the combined dynamics of competition and of demand. We do not wish to say that cyclical behaviour cannot arise under the conditions identified by the previous authors. We simply say that cyclical behaviour can arise also from the interplay of competition and of demand. Figure 1b displays the development of the intensity of competition and one clearly sees the impact of intra-industry dynamics as well as the additional effect of inter-sector-competition after the emergence of new sector. Figure 1c then shows the course of development of employment in a single industry - which first strongly increases but in the shake-out period also is reduced considerably – and the trend of

the aggregate employment on the macroeconomic level which can be positive despite the decrease of sectoral employment.

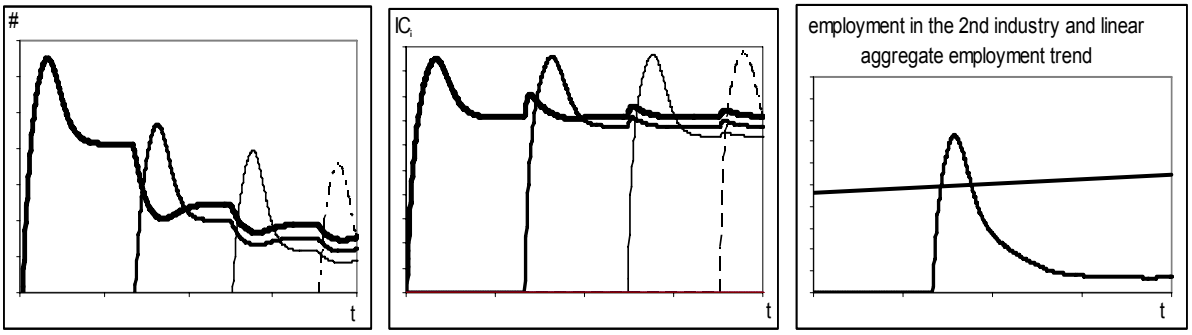


Fig. 1a) number of firms fig. 1b) intensity of competition fig. 1c) employment

In the following paragraphs we describe briefly the main formal aspects of our model. A complete description can be found in Saviotti and Pyka (2004a, 2004b). The main equation governing the dynamics of each sector in the model is:

$$dN_i^t = k_1 \cdot FA_i^t \cdot AG_i^t - IC_i^t - MA_i^t \qquad (1)$$

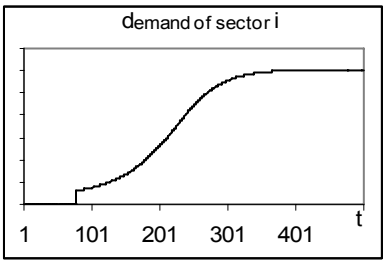
where dN_i^t is the change in the number of firms in sector i at time t, AG_i^t is the adjustment gap at time t, IC_i^t is the intensity of competition at time t, and MA_i^t is the number of mergers and acquisitions at time t. Equation (1) represents the rates of entry ($FA_i^t \cdot AG_i^t$) and exit (IC_i^t, MA_i^t) into and out of sector i. Thus, ΔN_i^t is the net entry of firms in sector i at time t. In this equation co-evolution is represented by the term $FA_i^t \cdot AG_i^t$.

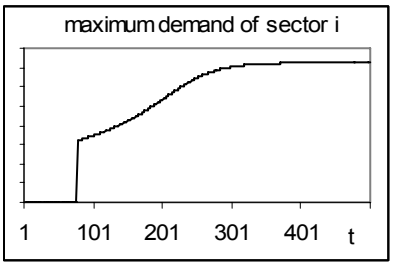
The exit term IC_i^t includes inter- and intra-industry competition (for a detailed description see Saviotti and Pyka, 2008a). The second exit term MA_i^t includes besides exits via mergers and acquisitions also failure and bankruptcy (see Saviotti, Pyka, Krafft, 2007).

$$AG_i^t = D^t{}_{\max i} - D_i^t \qquad (2)$$

The adjustment gap AG_i^t (exemplarily displayed in figure 2c) is very large right after the creation of the sector, and later it decreases gradually, although not at all times. It is in fact possible for the adjustment gap to grow during certain periods if innovations following the one creating the sector improve either the performance of the product or the efficiency with which it is produced, or both. In our model search activities affect both the maximum possible demand ($D^t_{max,i}$) and the instant demand (D^t_i) in a sector i. If we consider that analytically the adjustment gap (equation 2) is defined as the difference between these two types of demand, we can understand that the time path of the

adjustment gap depends on those of $D^t_{max,i}$ (fig. 2b) and of D^t_i (fig. 2a). During particular periods it is possible for $D^t_{max,i}$ to grow more rapidly than D^t_i, thus enlarging the adjustment gap, or delaying the saturation of the market. In the long run we expect the adjustment gap to be reduced to zero or to a constant value, or the market to become saturated.





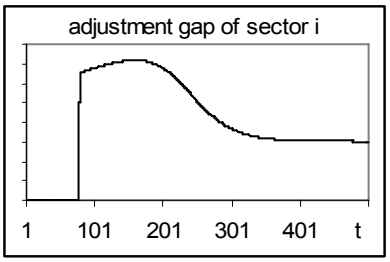


Fig. 2a) Demand Fig. 2b) Maximum demand Fig. 2c) Adjustment gap

FA_i^t represents financial availability, the amount of money present in the economic system that financial institutions are prepared to allocate to sector i at time t. Thus, FA_i^t depends on money as well as on the presence of financial institutions capable of judging the prospects of growth and development of sector i at time t. It is in principle possible for an economic system to have enough money but to lack the financial institutions capable of assessing the potential of a new sector. The role of financial institutions has been crucial in the process of economic development and financial innovations have been required several times to adapt these institutions to changes in the economic environment (Perez, 1983, 2002, 2007). AG_i^t , the adjustment gap, is the size of the potential market of sector i at time t. Co-evolution of the technology of sector i and of FA_i^t occurs when FA_i^t grows with AG_i^t and AG_i^t grows with FA_i^t.

Starting from the behaviour of microeconomic variables, such as the previously described ones, we can calculate the curves for aggregate variables. Fig. 3 shows the time path of aggregate employment, obtained by aggregating the employment curves of individual sectors.

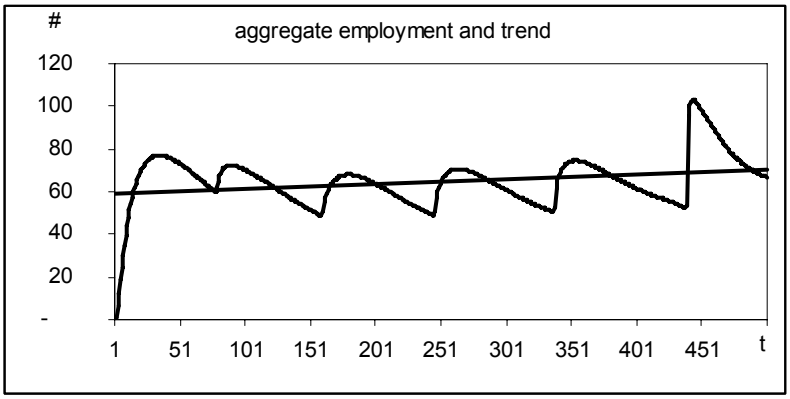


Fig. 3) Aggregate employment curve obtained by adding up the employment created by individual sectors

As can be seen in Fig 3, the aggregate employment curve, constituted by the superposition of the individual sectors employment curves, can give rise to a constant or growing employment even when the ability of each sector to create employment declines. Using the number of sectors in the economic system as an approximate (by defect) measure of variety it can be seen that these results support the hypothesis that variety growth is a necessary, although not sufficient, condition for the long term continuation of economic development (Saviotti, 1996). In the rest of the paper the slope of the quasi linear part of the aggregate employment curve will be used as a measure of the performance of the economic system. In our model economic development takes place and continues in the long run due to the emergence of new sectors, which can compensate for the diminishing ability of mature sectors to create employment and growth. Each new sector is created by a pervasive innovation, which creates a new market and into and out of which there are entry and exit of firms. Depending on the inter-temporal coordination of the maturation of older sectors and of the maturation of new ones our model can give rise to development paths with growth rates ranging from high to negative, to fluctuations, to bubbles and to chaos.

In the construction of our model we found inspiration in a number of growth models, both endogenous (Romer, 1990, Aghion, Howitt, 1998) and evolutionary (Silverberg, Verspagen, 1993; Dosi et al, 1994, Windrum, Birchenhall, 1998) as well as on empirical work on structural change (Fagerberg, Verspagen, 2002). The model also bears some similarity of style to history friendly models (Malerba et al 1999). Its unique feature is that it gives rise to an endogenously variable number of sectors. Unless new sectors are exact substitutes of older ones the model gives rise to growing variety. In fact, the main objective for which the model was initially constructed was to test some propositions implying that variety growth is a necessary requirement for long term economic development. Within our model the ability to create new sectors at the right times is the crucial determinant of the growth potential of an economic system. Thus, inter country differences in the

barriers to entry into new sectors can be expected to give rise to different rates of growth and in the end to increasingly skewed world income distribution.

Our model is non linear and strongly interactive, with most variables interacting with one another. In it the dynamics of firms in each sector is represented by an equation of entry and exit. The probability of entry into each sector can be made to depend on several types of barriers.

4) The model with barriers to entry

In the version described in the previous sections the model represents a closed economy. In order to deal with the dynamics and impact of generalized barriers at the international level we would need to open it up into a North-South model. While this is in our plans in this paper we use a simplified approach to the problem. We compare the time paths of an innovating and of an imitating country , where the innovating country develops the innovation giving rise to the new sector first and the imitating country starts creating the same sector with a delay. Although, contrary to what would happen in a proper North-South model, most of the time the development paths of the two countries will not interact, there is a crucial interaction which we can simulate. If sectoral barriers to entry can be expected to change in the course of time then the imitating country will face an initial barrier to entry into a sector different from the one faced at an earlier time by the innovating country. In what follows we are going to show that barriers to entry are likely to increase in the course of time. In this case an imitating country is likely to face a higher barrier to entry into the same sector than the innovating country faced earlier. The implications of this point for economic development are considerable. First, the fact that the barrier to entry into a sector in an imitating country depends on the evolution of the corresponding barrier to entry in the innovating country means that the economic systems of the two countries are interacting. This would happen in an international economic system in which there are competition and trade but it would not happen in a system in which countries practiced industrialization by substitution of imports. In the latter case a country would not need to worry about being at or near best practice but could develop at its own pace, even if this pace might be much slower than that of the countries at the technological frontier. Second, the presence of an interaction between the evolution of technologies in different countries implies that the external environment faced by imitating countries is never the same as the one faced by innovating countries. Although this might seem natural it must be remembered that many theories of economic growth and development implicitly or explicitly assume that different countries go through the same stages of development at different times. Rostow's theory of growth (1960) is a case in point but several more recent models of growth have the same implicit assumption. Here on the contrary we maintain that the development of a technology in an innovating country changes the

economic environment and makes it easier or more difficult for an imitating country to catch up. In the easier case the advantages of backwardness (Gershenkron, 1962) would predominate while the more difficult case would correspond to a scenario similar to the one presented in the 1970s by dependency theories (see for example Frank 1967, Dos Santos, 1973). As it will be shown later, our model is compatible with any of these outcomes. In fact, in the real experience of economic development in the last two hundred years there are both examples of countries getting persistently stuck in development traps and successful examples of catching up. In what follows of this paper we will concentrate predominantly on the difficulties facing imitating countries trying to catch up but, although we are now focusing mostly on barriers, our model encompasses also mechanisms to overcome these barriers.

4.1) INTRA-SECTOR BARRIERS

Barriers to entry were introduced by multiplying by an exponential term EB_i^t the entry term in the equation (1) for the number of firms (Eq. 3).

$$dN_i^t = EB_i^t \cdot FA_i^t \cdot AG_i^t - IC_i^t - MA_i^t \quad (3)$$

where:

$$EB_i^t = k_1 \cdot \exp\left[-\frac{B_i^t}{R_i^t}\right] \quad (4)$$

B_i^t and R_i^t are the barrier to entry into sector i and the resources available at time t respectively. As previously pointed out, barriers to entry are not constant but have a tendency to grow (Eq: 5).

$$B_i^t = B_0 + k_B \cdot \left[1 - \exp\left(-k_{BQ} \cdot Q_{acc,i}^t\right)\right] \quad (5)$$

In this version the resources required to overcome the barrier are given by human capital (Eq. 6).

$$R_i^t = HC_i^t \quad (6)$$

and the accumulated output by eq 7:

$$Q_{acc,i}^t = \sum_{t=1}^{m} Q_i^m \quad (7)$$

Fig 4 shows the evolution of the barrier to entry B_i^t. Starting with its initial value B_i^0 the barrier grows until it reaches a constant value as the sector life cycle approaches maturity.

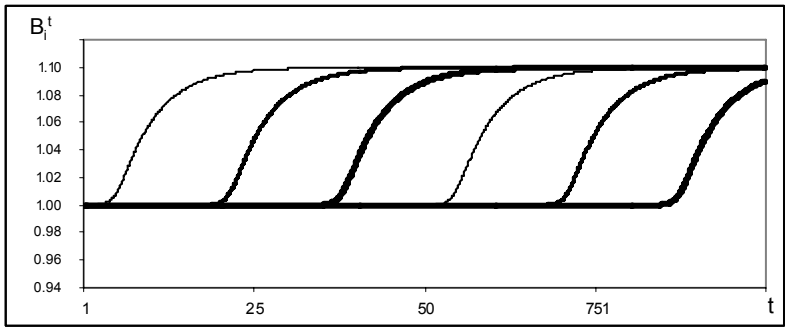


Fig 4: evolution of barriers to entry for subsequent sectors

The entry term EB_i^t. (Fig 5) rises very rapidly to its highest value and then falls to lower values. Thus entry barriers increase as the new sector matures and as a consequence the rate of entry at equivalent financial availability and adjustment gap falls.

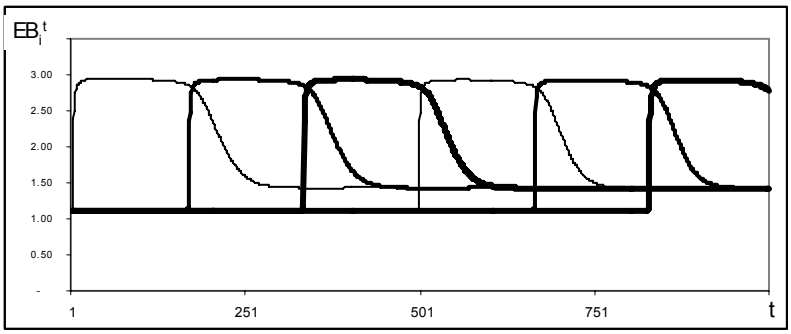


Fig 5. Evolution of barriers to entry into sector i. $B_i^0 = 0.5$, $k_B = 0.1$, $k_{BQ} = 0.000025$

The effect of B_i^t on the dynamics of the economic system can be expected to depend on the parameters determining its time path, B_i^0, k_B and k_{BQ}. The results of a number of experiments in which these parameters are varied are shown in figs 6-10). Figs 6a, 6b and 6c show the effect of varying the initial barrier to entry B_i^0 on the shape of the curve for the number of firms N_i^t.

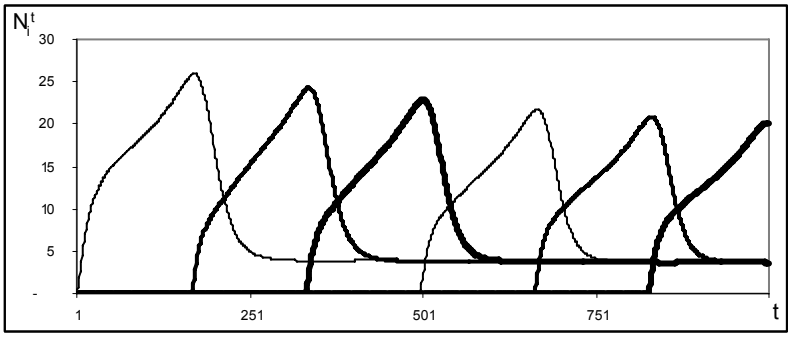


Fig 6a. Curve for the number of firms N_i^t. $B_i^0 = 0.5$.

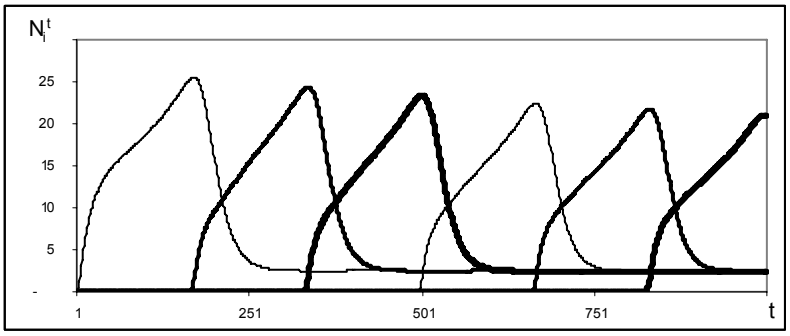


Fig 6b. Curve for the number of firms N_i^t. $B_i^0 = 1.0$.

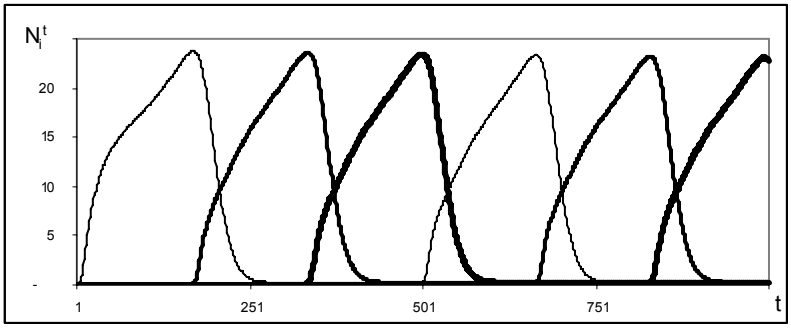


Fig 6c. Curve for the number of firms N_i^t. $B_i^0 = 5.0$.

The main effect of raising B_i^0 from 0.5 to 5 is the reduction in the number of firms remaining in the sector after the shake-out. The long run industrial organization of the sector varies from an oligopoly (5 firms) for $B_i^0 = 0.5$.to a more restricted oligopoly (2-3 firms) for $B_i^0 = 1.0$ to a monopoly for $B_i^0 = 5.0$. The same variation in B_i^0 has a much more limited influence on the maximum number of firms in the sector, which falls from approximately 25 for $B_i^0 = 0.5$ and $B_i^0 = 1$ to approximately 22 for $B_i^0 = 5.0$.

Increasing k_B raises the rate of growth of the the barrier B_i^t after the sector has been created and the converse happens when k_B is lowered. Unsurprisingly the main effect of k_B is to affect the industrial organization remaining after the shake-out : increasing k_B from 0.5 to 2.5 reduces the number of firms after the shake-out from 5 to 1. Thus, raising both B_i^0 and k_B increases the barrier to entry and leads to a more concentrated final industrial structure of the sector. k_{BQ} affects the rate at which the barrier grows but not its maximum value, as shown by Figs 6 an 7, corresponding to $k_{BQ} = 0.00000025$ and to $k_{BQ} = 0.0025$ respectively.

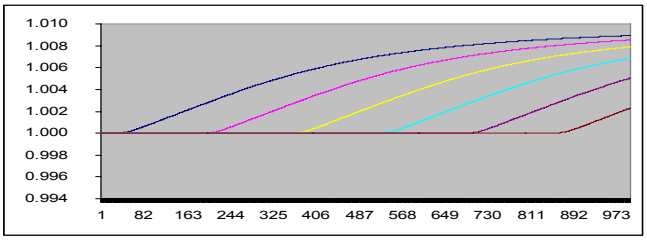


Fig 7. Evolution of the barrier to entry B_i^t for k_{BQ} = 0.00000025

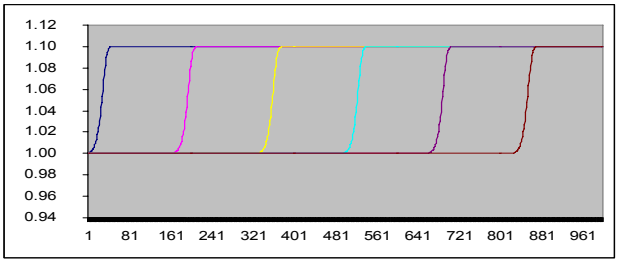


Fig 8. Evolution of the barrier to entry B_i^t for k_{BQ} = 0.0025

In summary, B_i^0 and k_B have a similar effect on the dynamics of an industrial sector in that when they raise the barrier to entry they increase the level of industrial concentration after the shake-out. k_{BQ} affects the rate of growth of the barrier to entry but has a much smaller effect on the overall dynamics of the sector.

Other experiments were carried out to explore the influence of barriers to entry into sectors on the the overall performance of the economic system. One of the most important dimensions of performance of the system is the rate of employment, which we measure by means of the slope of the linearised part of the aggregate employment curve (see Fig 3). Figs 9 and 10 show the effect of various combinations of B_i^0, of k^B and of k_{BQ}.

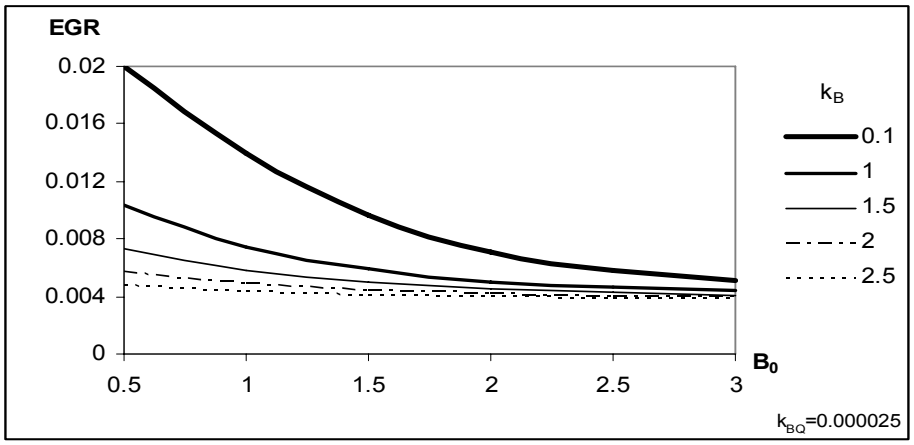


Fig 9. Employment Growth Rate (EGR) as a function of Bi0 for different values of k_B, k_{BQ} = 0.000025

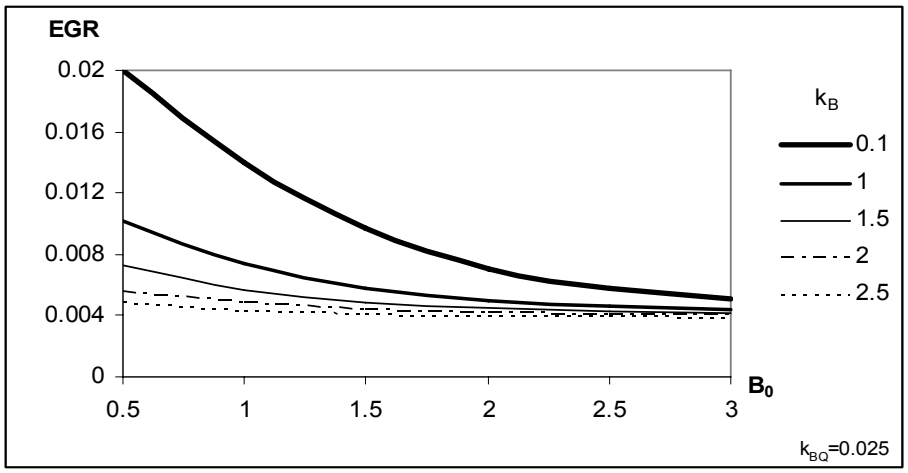


Fig 10. Employment Growth Rate (EGR) as a function of B_i^0 for different values of k_B, k_{BQ} = 0.025

Figs 9 and 10 clearly show that increasing B_i^0 reduces the Employment Growth Rate (EGR) and that increasing k_B has a similar effect. On the other hand, raising k_{BQ} from 0.000025 to 0.025 has only a marginal effect on the shape of the (EGR,B_i^0) curves but not on their absolute levels.

4.2) INTER-COUNTRY BARRIERS

In our model each new industrial sector i is created with a delay after the preexisting ones (i-1), (i-2) etc . In what follows we will assume that the inter-sector delay is larger for the imitating than for the innovating country ($\varphi_{i,im}^t > \varphi_{i,In}^t$). The inter- country delay in creating sector i would then be:

$$t_{im}^0 - t_{in}^0 = \varphi_{im} - \varphi_{In} \quad (7)$$

During the period $\varphi_{im} - \varphi_{In}$ the innovating country has already created sector i but the imitating country has not yet started. During this period we can expect the barrier to entry into sector i to grow since it is mainly due to increasing returns to adoption. By the time the imitating country starts creating sector i it will face a higher barrier to entry than the one initially faced by the innovating country. The higher barrier $B_{i,im}^0$ faced by the imitating country at time t_{im}^0 will then be equal to the value the barrier of the innovating country has already reached at the same time (Eq 8):

$$B_{i,\mathrm{Im}}^0 = B_{i,in}^0 + k_B \cdot \left[1 - \exp\left(-k_{BQ} \cdot Q_{acc,i,in}^{t_{i,in}^0 + \varphi_{im} - \varphi_{in}}\right)\right] \quad (8)$$

In this case the imitating country would be facing a permanently higher barrier to entry into sector i than the innovating country. In our model two effects can contribute to the emergence of a development gap between innovating and imitating countries: (i) the presence of a delay ($\varphi_{i,im}^t > \varphi_{i,In}^t$) between innovating and imitating countries in starting any sector will by itself lead to a lower rate of accumulation of resources, which will make more difficult to overcome the same barrier to

entry into to a sector, (ii) the presence of a higher barrier to entry into a sector in the imitating country will increase effect (i). In both cases a slower process of resource accumulation induced by late entry will make more difficult to overcome any further barriers to entry, which in turn will slow down subsequent processes of resource accumulation. This path, if not corrected by compensating mechanisms, will lead to a development trap in which the imitating country would gradually and irreversibly lose the capacity to develop. The development path which has been introduced so far and which will be further described in the rest of the paper is not the only possible one. Examples of successful catch up strategies exist in growing numbers. The mechanisms used can vary from low initial wages to particular investment strategies and policies. Here we focus on a set of circumstances leading to the emergence of a development trap because this time path corresponds to the one observed for long periods of time in many less developed countries. To understand how such traps are generated and how they can be overcome is still of paramount importance. In future papers we plan to explore the strategies which would allow less developed countries to escape a development trap. Now we describe the results of calculations exploring the effect of (i) late entry by an imitating country and of (ii) the additional entry barrier into the same sector which would be faced by an imitating country as a consequence of late entry.

4.2.1) The consequences of late entry

To explore the consequences of late entry we compared two runs of our model differing exclusively for their inter-sector delay ($\varphi_{i,im}^{t} > \varphi_{i,In}^{t}$). The results of these calculations (fig.11) show that

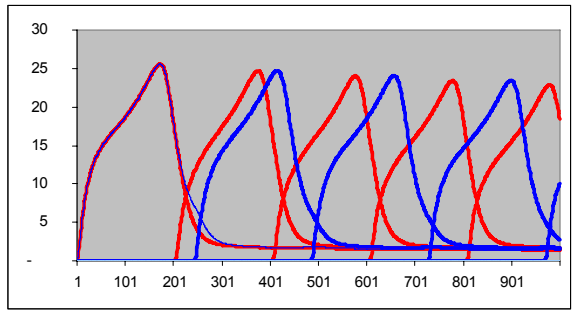


Fig. 11. Number of firms for the innovating (red curve) and imitating (blue curve) countries. $\varphi_{i,In}^{t}$ = 40, $\varphi_{i,im}^{t}$= 80

the delay in the creation of sector N° 2 gives rise to a growing delay in the emergence of all subsequent sectors. The cause of this growing delay is likely to be the slower process of resource generation following from an initial entry delay. For example, we know that the inter sector delay is reduced by a factor related to the amount of fundamental search activities (SEF) carried out in the economic system. In turn, SEF increases with the rate of investment which depends on the rate of

growth of output and employment. Thus, an initial delay in the creation of a sector slows down the subsequent process of resource generation, which leads to a growing delay in the emergence of all future sectors and to further slow down in the process of resource generation. The simple presence of a delay in the creation of a sector by an imitating country can give rise to a retardation in the process of development. This behavior is due to the highly interactive and non linear nature of our model which can be auto-catalytic or auto-retarding depending on the circumstances.

4.2.2) Facing a higher initial entry barrier

In the calculations described in this section the imitating country cumulates a late entry into a sector with a higher initial barrier for entry into the same sector than the innovating country ($B_{i,im}^{0} \geq B_{i,in}^{0}$) (see eq 8). Tables 1 and 2 show the times at which each sector is created in the innovating and in the imitating country, the inter-country delays (Table 1) and the initial entry barrier into each sector for the imitating country (Table 2) when the inter-sector delay for the creation of the second sector is 40 for the innovating country and 80 for the imitating country.

Table 1. Times at which each sector is created in the innovating and in the imitating country and inter country delays in the creation of each sector

sector	**1**	**2**	**3**	**4**	**5**
Innovating country	1	204	406	607	808
Imitating country	1	244	486	728	970
Inter country delay	0	40	80	121	162

Table 2. Initial entry barrier into each sector for the imitating country

sector	**1**	**2**	**3**	**4**	**5**
B for the innovating country at the time when the imitating country enters	0	1,29	1,35	1,39	1,42

As a consequence of cumulating late entry and a higher initial barrier into each sector the imitating country has (i) a late start of each sector (ii) a lower rate of creation of firms in each sector(Fig 12),

(iii) an exponential entry term EB_i^t which starts later, reaches a lower maximum value and falls to lower minimum value in the long run (Fig 13),.(iv) a persistently higher barrier for entry into the same sector (Fig 14).

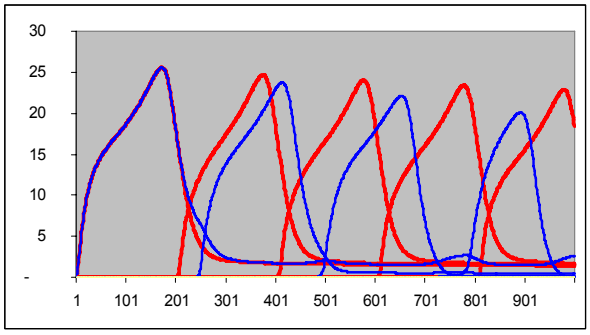


Fig. 12 The number of firms in each sector for the innovating (red curve) and for the imitating (blue curve) country in presence of late entry and higher initial barrier faced by the imitating country

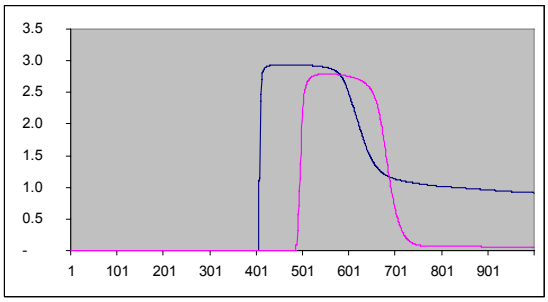


Fig 13. The exponential entry term EB_i^t for the innovating (blue curve) and for the imitating (pink curve) country for entry into the third sector

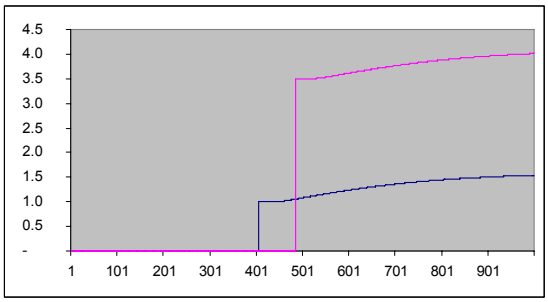


Fig 14 Barriers to entry into the third sector for the innovating (blue curve) and for the imitating (pink curve) country

In addition to the previous microeconomic consequences we calculated some macroeconomic implications of late entry and of a higher initial barrier into each sector for the imitating country. Thus we can show that the rates of growth of both income (Fig 15) and of employment (Fig 16) are systematically lower for the imitating than for the innovating country.

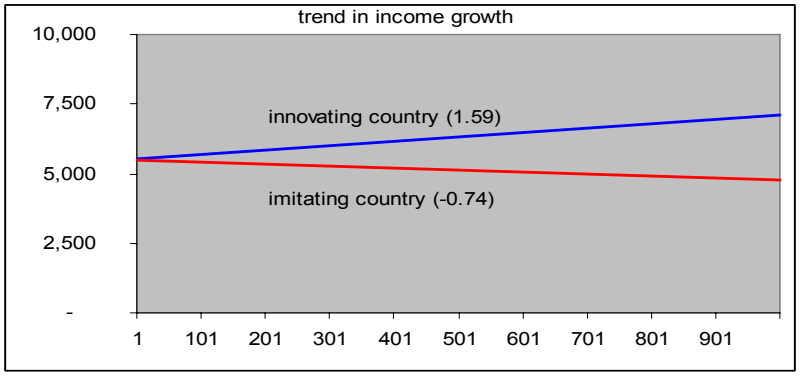


Fig 15. Rate of growth of income for the innovating (blue curve) and for the imitating (red curve) country when the imitating country has a late entry and faces a higher initial barrier into each sector

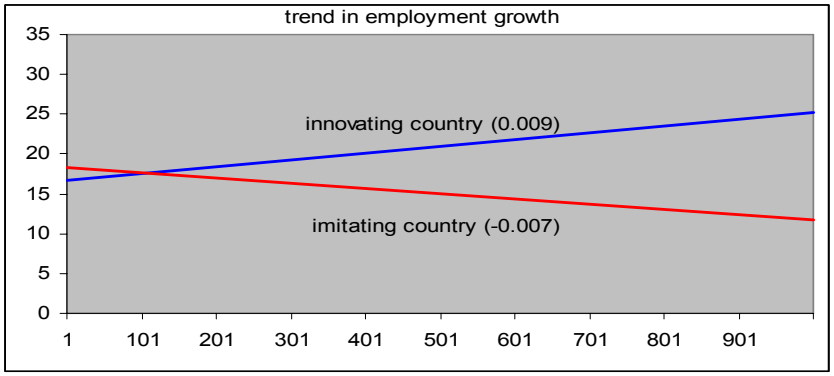


Fig 16. Rate of growth of income for the innovating (blue curve) and for the imitating (red curve) country when the imitating country has a late entry and faces a higher initial barrier into each sector

In summary, in this section we showed that the late entry of an imitating country into a sector can by itself lead to a lower rate of accumulation of resources which can subsequently slow down the rate of growth of the imitating country relative to that of an innovating country. This outcome would occur if the two countries were completely isolated and not interacting. If the two countries were interacting in competitive international markets the imitating country would be forced to remain close to the technological frontier of the time. In terms of our model this would mean to face the same barrier to entry into sector i that the innovating country is facing at the time the imitating country enters. Given that barriers to entry tend to increase in the course of time the imitating country will face a higher barrier to entry into sector i than the innovating country was facing initially. The late entry and the higher barrier effects combined lead the imitating country to a persistent and possibly increasing technological gap with respect to the innovating country. To the extent that development is driven by innovation this amounts to a development trap. The results of this section cannot be interpreted as implying that when a country remains behind it will never be able to catch up. Other strategies, based for example on low wages or on different investment patterns, can allow a less developed country to catch up. These strategies are not explored here. The results of this paper can only show that if countries could rely exclusively on innovation to develop they could easily fall into a development trap by being late to enter new and innovating sectors.

5) SUMMARY AND CONCLUSIONS

In this paper we extended the concept of barriers to entry from the sectoral context to the international context. Intra-sectoral barriers are mainly affected by factors internal to the sector while inter-country barriers are affected by a number of factors belonging to the rest of the economic system, such as financial, educational and research institutions. These institutions are present both in the innovating and in the imitating country but they are not independent of the creation and reproduction of an innovation. In fact, such institutions and the resources that they produce co-evolve with technologies in giving rise to new industrial sectors. This means that the institutions and the corresponding resources may be present in the innovating country when the innovation is created but they are themselves affected by the emergence of the innovation. Thus, the innovation induces the creation and the subsequent growth of these complementary institutions and resources. In the version of our model used in this paper entry into a sector is determined by the balance of barriers and resources. Barriers can then be conceived as the threshold level of resources required for the creation of firms in a sector.

In this paper we focused on the situation of firms in a less developed country attempting to imitate a technology which in an innovating country has already given rise to a new sector. This extension implies that the barrier to entry into a new sector by a firm in an LDC will be different from the corresponding barrier initially faced by a firm in the innovating country for two reasons: (i) even in the innovating country the barrier to entry into a sector tends to increase in the course of time, and (ii) the barriers to entry faced by a firm in an imitating LDC include factors other than those contributing to intra sectoral barriers. Both barriers and resources evolve in the course of time. In the country which pioneered the technology and the new sector barriers to entry can be expected to grow in the course of time since they depend mostly on increasing returns to adoption. Exceptions to this statement exist but they are not discussed in this paper. To the extent that barriers to entry grow in the course of time in the innovating country, firms in an imitating country can expect to face two types of disadvantage: (i) the delay in creating a new sector in an LDC (inter-country delay) slows down the rate of growth of the new sector in the LDC relative to that in the innovating country; (ii) firm s in the imitating LDC face an initial barrier to entry into the new sector higher than the one which was faced by firms in the innovating country. These two disadvantages reinforce each other by lowering the *relative* rates of growth of the new sector in imitating countries. In this way a development gap is opened up which, in absence of compensating mechanisms, grows in the course of time. Thus, a *development trap* into which an LDC could fall and be locked for long periods of time is created.

In the present paper alternative development strategies which could help an LDC to escape the trap mentioned above have not been considered and they will be the object of a future paper. However, given the number of countries which have remained persistently behind the technological and industrial frontiers of the time and the length of time these traps persisted, mechanisms similar to those we discuss here are likely to have been occurring with a high probability. Although the mechanisms which were operating in world development were not necessarily identical to those we are exploring here and in spite of the oversimplification of our model with respect to the situation investigated, we believe that our paper outlines some general features of the of role of technological innovation in economic development. The success of an innovation in creating economic development does not depend only on the internal features of the innovation and of the industrial sector to which it gives rise but also on the ability of the economic system to create complementary institutions and resources. A delay in creating not only firms in the new sector(s) but also in the complementary institutions and resources would set the LDC on a slow growth path which would be amplified in the course of time if not corrected by adequate compensating mechanisms. As already pointed out, these features of the economic system represented by our model amount to the co-evolution of technologies and institutions (Nelson, 1994), or, in the long run to the construction of a techno-economic paradigm (Perez, 1983, Freeman, Perez, 1988, Perez, 2002).

Our model is inspired by the dynamical systems approach. It predicts that successful development has an auto-catalytic nature in that the emergence of an innovation at a given time induces the creation of complementary institutions and resources which in turn will accelerate the growth of the industrial sector based on the innovation. However, precisely these systemic features of our model imply that if the right conditions for an auto-catalytic development of our model are not created then the development process could become auto-retarding giving rise to persistent delays and development traps. We believe that the general features of our model are its systemic features, which are given by the high interactivity of all the model components and variables and of the feedback loops involved. Based on these systemic features the model predicts that an imitating country will not simply follow the same development path previously followed by an innovating country, but that the economic development of the innovating country modifies the economic environment in which LDCs have to develop and make it more difficult (or easier) for them to imitate.

As already pointed out, this is but a first attempt to explore a very complex issue. To pursue this exploration further we will need to include in the analysis other possible development strategies, based for example on low wages or on alternative types of investment. Furthermore, a more adequate treatment of the interaction of an innovating and of an imitating country requires the construction of a North-South version of our model. We plan to explore these issues in further extensions of our model.

REFERENCES

Abernathy W.J., J.M. Utterback, A Dynamic Model of Process and Product Innovation, *Omega*, Vol.3 (6) (1975) 639-656

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

Arthur, W.B. (1989a) `Competing technologies, increasing returns, and lock-in by historical events', *The Economic Journal*, 99, pp.116-131.

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

Dosi G, Fabiani S, Aversi R, Meacci M, The Dynamics of International Differentiation: A Multi-country Evolutionary Model, *Industrial and Corporate Change*, Vol 3 (1994) pp. 225-242

Cantner, U., Ebersberger, B., Hanusch, H., Krüger, J., Pyka, A. (2004), Twin Peaks in National Income: Parametric and Non-Parametritc Estimates, Revue Économique, Vol. 55(6), 1127-1144.

Dos Santos T.,The crisis of development theory and the problem of dependence in Latin America , In Bernstein H. (Ed) (1973) *Underdevelopment and Development* London, Penguin

Fagerberg J., and Verspagen B. (2002), Technology gaps, innovation diffusion and transformation: an evolutionary interpretation, *Research Policy*, 31, 1291-1304.

Frank AG., Capitalism and Underdevelopment in Latin America, New York, Monthly Review Press, (1967)

Freeman, C. and Perez, C. (1988), Structural crises of adjustment: business cycles and investment behaviour, in: Dosi, G. et al. (eds.), *Technical change and economic theory*, Pinter Publisher, London and New York, 38-66.

Gerschenkron A., *Economic Backwardness in Historical Perspective: A Book of Essays*. Cambridge, MA: Belknap Press of Harvard University Press, (1962)

Hagedoorn, J. "Understanding the Rationale of Strategic Technology Partnering : Interorganizational Modes of Cooperation and Sectoral Differences." *Strategic Management Journal*, 1993, *14*, pp. 371-85.

Hagedoorn, J. "Strategic Technology Partnering During the 1980s : Trends, Networks and Corporate Patterns in Non-Core Technologies." *Research Policy*, 1995, *24*, pp. 207-31.

Jovanovic, B., and MacDonald, G., 1994, "The life cycle of a competitive industry", *Journal of Political Economy*, 102, 322-347.

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

Klepper, S., Simons, K.L., 2005, "Industry Shakeouts and Technological Change", *International Journal of Industrial Organization*, 23(1-2), 23-43.

Malerba, F., Nelson, R.R., Orsenigo, L. and Winter, S.G. (1999) 'History friendly models of industry evolution: the computer industry', Industrial and Corporate Change, Vol. 8, pp.3–40.

Nelson R.R., (1994) Economic growth via the co-evolution of technologies and institutions, in Leydesdorff L., Von Besselaar P., (Eds) Evolutionary Economics and Chaos Theory: New Directions In Technology Studies, London, Pinter (1994) .

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., Structural change and the assimilation of new technologies in the the economic system, *Futures*, Vol. 15 (1983) 357-375.

Perez C., (2002) Technological Revolutions and Financial Capital: the Dynamics of Bubbles and Golden Ages, Cheltenham, Edward Elgar.

Perez, C. (2007), Finance and Technical Change: A long-term View, in: Hanusch, H. and Pyka, A. (eds.), The Elgar Companion to Neo-Schumpeterian Economics, Edward Elgar, Cheltenham, 820-839.

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

Rostow W., *The Process of Economic Growth*, Oxford , Oxford University Press (1960)

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

Saviotti P.P, Catherine D., *Innovation networks in biotechnology***,** forthcoming in *Handbook of Bioentrepreneurship*, Holger Patzelt, Thomas Brenner, David B. Audretsch (Eds) Heidelberg Springer (2008)

Saviotti P.-P. and Pyka A. (2004a), Economic development by the creation of new sectors, Journal of Evolutionary Economics, Vol. 14, Issue 1, 2004, 1-36.

Saviotti P.P., Pyka A. (2004b), Economic development, qualitative change and employment creation, *Structural Change and Economic Dynamics* Vol 15 (2004) 265-287.

Saviotti P.P., Pyka A. (2008a), Micro and macro dynamics: Industry life cycles, inter-sector coordination and aggregate growth, *Journal of Evolutionary Economics*, Vol 18 (2008) pp. 167-182

Saviotti P.P., Pyka A. (2008b), Product Variety, Competition and Economic Growth, forthcoming, *Journal of Evolutionary Economics*, Vol 18.

Saviotti P.P., Pyka A. and Krafft, J.(2007), On the Determinants and Dynamics of Industry Life Cycles, mimeo.

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

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

Windrum P. and Birchenhall C. (1998), Is life cycle theory a special case?: dominant designs and the emergence of market niches through co-evolutionary learning, Structural Change and Economic Dynamics, 9, pp. 109-134.

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