ON THE CO-EVOLUTION OF INNOVATION AND DEMAND: SOME POLICY IMPLICATIONS[1]

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Long term economic development is characterized not only by increasing efficiency of economic activities but also by qualitative change within industries and increasing variety concerning the existence of different industries. Traditional economic growth models do not cope with the complex amalgam of these three trajectories of economic development nor could comprise the interactions among them. Furthermore, economic development is not a process which is spurred by supply-side effects but driven by the co-evolutionary interplay of supply and demand side forces. With our TEVECON model we analyze economic development driven by efficiency and quality improvements together with structural change and the co-evolution between innovation and demand. The first part of the paper introduces to the basic model and some general results. The second part of the paper deals with policy experiments which are undertaken by comparing different numerically analyzed scenarios.

Keywords: Economic Development, Qualitative Change, Co-Evolution, Simulation.

The main objective of this paper is to establish that innovation could not have contributed to economic development unless a demand for the goods and services created by innovation existed. We explore the conditions required for such a demand to exist and argue that the process which gave rise to the observed path of economic development was the co-evolution of demand and innovation. Furthermore, we explore how the co-evolution of demand

1. The research leading to these results has received funding from the European Union Seventh Framework ProgrammeFP7/2007-2013 under grant agreement n° SSH-CT-2010-266959.

and innovation changed the capitalist economic system from one in which most people could afford only bare necessities to one in which most people have a highly and increasingly varied pattern of consumption, including a growing proportion of items which cannot be judged necessities, and which are of higher quality than in the past. Finally, we study the possible impact of economic policies on the above co-evolutionary process. We carry out these explorations by means of an extension of our TEVECON model of economic development, which is described in the following part of the paper.

1. 2. Conceptual background

1.1. Co-evolution and economic development

The concept of co-evolution has recently been used in the innovation literature to analyze the co-evolution of technologies and institutions. In this section we make a brief reference to this literature and propose a more general concept of co-evolution. Technologies cannot develop in an institutional vacuum but need appropriate institutions (Nelson, 1994). Such institutions are required to support the collective interests of a new technology and of the corresponding industry, to lobby the industry, to regulate it, to establish intellectual property rights, to create the required infrastructures etc. Examples of such co-evolution are mass production in the United States car industry, the emergence of synthetic dyes in Germany (Murmann, 2003), biotechnology in the USA (Nelson, 2008).

The need for new institutions becomes evident when new technologies emerge. There are even institutions which might be appropriate at a level of aggregation higher than that of an individual industry. For example, a set of interconnected technologies sharing common resources could require a set of institutions appropriate to the whole set. Perez (1983) used the related concept of techno-economic paradigm (1983) to encompass a technological paradigm (Dosi, 1982) and the institutions appropriate to it. She maintained that the creation of the appropriate institutions was likely to be a longer and more complex process than the initial creation of a given technology, or technologies, corresponding to a

given technological paradigm. Other scholars stressed that a country which had been successful in creating a given set of technologies and the appropriate institutions might be unable to do the same for a subsequent set of technologies. Veblen (1915) had already remarked how British industry, which was very successful in the early part of the industrial revolution, could not adopt the institutions appropriate to the new technologies that Germany developed much more successfully. Lazonick (1990) maintained that the organization of work and the institutions for training labor which had underpinned successful development of Britain in the late 18th and early 19th century became a handicap in the 20th century. At a higher level of generality Polanyi (1944) maintained that capitalism would require the creation of institutions which were capable to compensate the harsh if efficient nature of capitalist societies.

A more general interpretation of the concept of co-evolution can be proposed at a system level. A system is constituted by different and interacting components. Co-evolution exists when two different components (C_1 and C_2) interact in such a way that changes in one of them, say C_1, affect C_2 and that changes in C_2 affect C_1. Typically, for co-evolution to exist this relationship of mutual interaction must last for several periods, giving rise to a sustained feedback loop.

The dynamics we can imagine for an economic system consists of the early emergence of an innovation in a pre-institutional form, that is, without institutions specific to the new technology. This would be followed by the creation of institutions which, for example, would provide the rules for the new technology to be used for the advantage of society at large avoiding as much as possible negative side effects, and of infrastructures which would allow the market for the new technology to grow. A clear example is given by cars and roads: the scope for cars has been considerably enhanced by the construction of roads. Thus, the more the new technology develops, the more the appropriate institutions need to grow giving rise to a feedback loop which would slow down only when the market(s) for the new technology were completely saturated.

The type of co-evolution we are going to be concerned with in this paper is between innovation and demand. Thus, it would be

the co-evolution of two different economic variables, mutually influencing each other during the course of economic development. In TEVECON this co-evolutionary process occurs because sectoral search activities, which increase with sectoral demand, affect output price, quality and differentiation, which in turn affect demand. A positive feedback loop can be established which can give rise to a faster growth of both demand and innovation than it would have been possible if the two variables had not been influencing each other. In this sense co-evolution works as autocatalysis (Nicolis and Prigogine, 1989) by using the output of one stage of the process as the input of the following stage.

1.2. Trajectories and patterns of economic development

Models of economic development need to be able to explain patterns of long run development and growth. Here long run is intended to indicate a period such as the one from the industrial revolution to the present. Focusing on such a period requires understanding the broad features which occurred in it. First, we had the emergence of manufacturing industry. Second, within manufacturing there was a progressive differentiation, beginning with sectors such as textiles, energy (steam engine), railways, steel and following with chemicals, electricity, cars, planes etc. During this process manufacturing industry became increasingly differentiated, with newer sectors coexisting with older ones. Third, the employment share of services overtook that of manufacturing.

Any model of economic development which is in principle capable of interpreting events which occurred since the industrial revolution needs to explain why such structural change occurred. The fundamental ingredient which gives rise to growth and development in our work is innovation. The emergence of innovations is due to search activities, which provide the knowledge required to create and modify innovations. Innovations affect economic development because entrepreneurs fund new firms to exploit the outcomes of search activities and because consumers and users purchase the products and services embodying such innovations. In this process the economic system becomes increasingly differentiated. The addition of new sectors to the economic system not only contribute to structural change but to a structural change occurring in a particular direction, that of increasing differentiation.

The above processes can be described in terms of three trajectories and of two periods.

Trajectory 1: The efficiency of productive processes increases during the course of economic development. Here efficiency must be understood as the ratio of the inputs used to the output produced, when the type of output remains *constant*.

Trajectory 2: The output variety of the economic system increases in the course of time. Here such variety is measured by the number of distinguishable sectors, where a sector is defined as the set of firms producing a common although highly differentiated output.

Trajectory 3: The output quality and internal differentiation of existing sectors increases in the course of time after their creation. This means that if during the period of observation the type of output changes what we will observe is a combination of growing productive efficiency and of quality change.

From now on we will use the term variety as a synonym of diversity, although the two are in principle not identical. Such variety can exist at the inter-sectoral as well as at the intra-sectoral level. Thus, two sectors will produce completely different types of output while one sector will produce a diversified output. In the literature these two types are often described as vertical and horizontal differentiation respectively. Such long run trajectories do not emerge separately but exist due to a complex pattern of interactions within the economic system.

These trajectories occur at a level of aggregation higher than that of an individual industrial sector or a technology. The ratio can be calculated in value or in volume terms. Growing productive efficiency is the oldest and, until the industrial revolution, the most developed of the three trajectories. For example, the efficiency of food production increased with the transition from hunters and gatherers to settled agriculture (Diamond, 1997). However, any such increases in productive efficiency were very slow and not necessarily cumulative. Productive efficiency started growing in a cumulative fashion only after the beginning of the industrial revolution (Maddison, 2007). Simple recent examples of this trajectory can be found in the falling number of workers required to produce a unit of output in the steel, chemicals or car

industries. Of course, these are just examples and the phenomenon is far more general. Growing productive efficiency is certainly one of the factors which contributed to economic growth since the industrial revolution. However, the observed patterns of economic development could not have been produced by growing productive efficiency alone. In this case we would produce today Ford Model T like cars with much smaller quantities of all the inputs required. As even the most casual observer would have noticed, today's cars are not only produced much more efficiently than those of the early 20th century but they are also of a much higher quality. Hence, growing productive efficiency and growing output quality were combined in the patterns of economic development which we can observe today.

During the industrial revolution output differentiation (trajectory 2) was very limited. At the beginning it occurred mostly at the level of capital goods (new textile and engineering equipment, railways equipment etc.) and only considerably later at the level of consumer goods. The increasing internal differentiation and output quality of consumer goods and durables started increasing during the 19th century and in particular after the beginning of the 20th century. Growing output variety can be observed at the inter-sector level. A clear example of this is the large number of completely new sectors which emerged during the 20th century, such as cars, aircraft, television, computers, telecommunications etc. All of these not only constituted completely new sectors but underwent a very high degree of internal differentiation.

These three trajectories are not independent. None of them could have occurred taken place alone without the other two. Thus, a continuous increase in productive efficiency, if not accompanied by the emergence of new sectors and by their internal differentiation and rising quality could have led the economic system to a bottleneck in which all demanded output could have been produced by a declining proportion of the labor force (Pasinetti, 1981). Such a bottleneck, determined by the imbalance between continuously increasing productive efficiency and saturating demand, could have been overcome by the emergence of new sectors (Pasinetti, 1981). While the assumption of demand saturation and the neglect of the internal differentiation of sectors limited the possible generalization of Pasinetti's approach, we have

shown (Pyka and Saviotti, 2012) that both the emergence of new sectors and their increasing quality and internal differentiation provided additional scope for further growth and allowed its continuation in the long run. In this context, full demand saturation is unlikely to occur within any sector as long as new sectors keep being created (Saviotti and Pyka, 2010). Furthermore, both the emergence of new sectors and their growing quality and internal differentiation can compensate the diminishing capability to create employment of incumbent and maturing sectors.

In the previous sections we described the period from the industrial revolution to the present as the transition from necessities to imaginary worlds. This description emphasizes that until the end of the 19th century most people, even in countries which were for the standards of the time relatively rich, could not purchase anything but bare necessities. All throughout the 19th century British working class households spent about ninety percent of their income on food, clothing and housing. Only during the 20th century, and in particular after the 1930s, the share of income spent on the above three categories started falling (Hobsbawm, 1968, diagrams 45 and 46). By the 1950s the share of necessities fell to about 60 percent, leaving about forty percent to be spent on other, presumably higher, goods and services. The compression of the combined expenditure on necessities (trajectory 1) created the disposable income required to buy the new goods and services which were gradually being created. Starting from the beginning of the 20th century new goods and services emerged (trajectory 2) and their quality and differentiation increased constantly (trajectory 3). This combination of trajectories contributed to a mechanism which allowed the capitalist economic system to create growing wealth for most of the population of industrialized countries.

1.3. TEVECON

1.3.1. Modeling philosophy

Our model, which we call TEVECON, can be considered an Agent Based Model (ABM) for a number of reasons. First, it is not an analytical model in the same sense as the more orthodox models, because it lacks *closure conditions*. The most important of

such conditions is the presence of general equilibrium. Our model has an endogenously varying number of sectors, and thus an endogenously variable composition. In these circumstances, as Kaldor (1957) had already well understood, there can be no general equilibrium. However, we do have sectoral equilibrium in the form of a feedback mechanism ensuring that demand does not deviate too much from supply. Also, TEVECON agents are not optimizers but only improvers possessing bounded rationality (Pyka and Fagiolo 2007), since learning mechanisms (mainly learning by searching) play a central role in TEVECON.

TEVECON has a number of agents, but sometimes they are implicitly or lightly represented only. The central agents of TEVECON are sectors, defined as the collection of firms producing a unique though highly differentiated type of output. Firms are present and one of the most important modeling outcomes of TEVECON is the evolution of the number of firms in time. Although reduced, such a presentation of firms gives rise to the very interesting prediction of the existence of an Industry Life Cycle (ILC) under a very wide range of conditions. However, the representation of firms can be considerably expanded by including firm characteristics, internal structure and distributional properties. An agent which is present only implicitly is the Schumpeterian entrepreneur, who is creating new firms by exploiting important innovations induced by the expectation of a temporary monopoly. The role of the entrepreneur is extremely important in TEVECON but its representation at the moment is reduced to the action of open up new sectors. Thus, the central agents of TEVECON are industrial sectors as previously defined.

Another important feature of Agent Based Models (ABM) is the reconstruction of the macro-economic states of the system from its micro-economic ones (Pyka, and Fagiolo, 2007). In this sense TEVECON is best defined as providing aggregation from micro to meso and from meso to macro. Firms (micro) are aggregated to sectors (meso) and sectors are aggregated to the macroeconomic state of the system. In the present version of the model the meso to macro aggregation is better specified than the micro to meso one.

Sectors are very considerably heterogeneous in TEVECON. They can differ on a very large number of dimensions, such as expected market size, technological opportunity, investment patterns, wage

rates etc. Furthermore, TEVECON satisfies most of the conditions required to be considered an evolving complex system (ECS) (Pyka and Fagiolo, 2007, p. 474) since it is a highly interactive model in which new interactions are continuously being introduced between existing variables. One such interaction that was present from the very early versions of the model is that between search activities and demand, where there is a feedback mechanism from rising demand to rising search activities to further rising demand in following periods. More such interactions are continuously being introduced. Again, these interactions contribute to the emergence of complex properties out of repeated interactions among simple entities (Kirman, 1998).

TEVECON shows Endogenous and Persistent Novelty (Pyka and Fagiolo, 2007, p. 475). It is non stationary in the sense that its composition is continuously changing. New sectors produce outputs that are qualitatively different from the pre-existing ones. This means that in principle the outputs of different sectors should not be substitutable. In reality our model includes two types of competition, intra- and inter-sector. The latter exists if different sectors produce comparable services out of non comparable internal structures (Saviotti and Metcalfe, 1984; Saviotti, 1996). Thus, the qualitative difference lies mostly in the internal structure of sectoral outputs and in the sector's knowledge base.

As a consequence of the above, TEVECON shows 'true dynamics' (Pyka and Fagiolo, 2007, p. 475). Some form of dynamics is present in orthodox models simply because they include equations which show the time paths of the system. This form of dynamics does not take into account qualitative change and is not affected by the emergence of new entities. One of the most important differences between evolutionary and ABM models on the one hand, and orthodox models on the other hand, is the emergence of new entities, qualitatively different from pre-existing ones. The true dynamics which is more difficult to represent and yet vital to understand the long run evolution of the economic system is the one including qualitative change.

If the above considerations allow us to consider TEVECON an ABM model, we can still situate it within the wide range of modeling techniques which are in principle compatible with the ABM definition. TEVECON bears a close similarity to dynamical systems

since its basic framework is constituted by a set of simultaneous difference equations. Although complete closure conditions such as general equilibrium are absent, the equations used are in most cases similar or identical to those which are used in orthodox analytical models. Given the absence of closure and the nature of the equations involved, TEVECON cannot be analytically solved but needs to be simulated. Thus, amongst all ABM modeling techniques TEVECON could be described as having a partly analytical, not entirely computational, structure but needing simulation to find solutions. This gives TEVECON both advantages and disadvantages. With respect to orthodox analytical models it has the advantage of allowing us to include a greater number of variables and interactions while having a greater similarity to orthodox analytical models than purely computational ABM models. TEVECON's disadvantage with respect to purely computational ABM models is its lower adaptability to model institutions and policies.

1.3.2. The model

In TEVECON the economic system is composed of an endogeneous variable number of sectors. The emergence of new sectors is due to the dynamics of the incumbent ones and the main source of economic growth consists in the emergence of new sectors. Each sector is created on the basis of an important, pervasive, innovation taken up by entrepreneurs who start new companies and thereby provide the basis for a new industry. The innovation creating the sector gives rise to an adjustment gap AG_i, a variable intended to capture the size of the potential market established by the innovation. However, this market is initially empty because neither the production capacity nor a structured demand for the new products exists. Both the production capacity and the evolution of the demand will take place during a (possibly long) period of time, by means of a gradual interaction of producers and users. Thus, the adjustment gap measures the extent to which the market is far from saturation. When the market becomes saturated, the adjustment gap is reduced to zero or to a small and constant value. The adjustment gap is very large right after the creation of the sector, and later it decreases gradually, although not continuously. 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.

Each sector has a dynamics given by the entry and exit of new firms. Schumpeterian entrepreneurs create new firms to exploit a pervasive innovation induced by the expectation of a temporary monopoly. The following bandwagon of imitators raises the intensity of competition and gradually eliminates any further inducement to enter. Thus, the once innovative sector is transformed into a part of the circular flow (Schumpeter, 1912) or into one additional routine of the economic system. This happens when the incumbent sector saturates, a condition which in TEVECON is attained when the adjustment gap AG_i, becomes zero or reaches a very low and constant value (Saviotti, Pyka 2004a, 2008). The saturation of incumbent sectors induces entrepreneurs to search for new niches which could subsequently become new markets. The dynamics briefly outlined above provides a mechanism for the endogenous generation of new sectors which allows the process of economic development to continue in the long run.

A very important role is played in TEVECON by search activities, a general analogue of R&D (Nelson, Winter, 1982). Search activities can be defined as all the activities which try to better understand our external environment and which can provide the basis for the emergence of new routines. Thus, search activities are the source of new innovations and we can expect a positive relationship between the resources allocated to such activities and the rate of creation of innovations. In TEVECON the resources allocated to search activities are expected to increase with accumulated demand:

$$SE_i^t = SE^0 + k_4^i \cdot [1 - \exp(-k_5 \cdot Dacc_i^t)] \qquad (1)$$

The combination of the emergence of new sectors and of their increasing quality and internal differentiation leads to an increasing differentiation of the economic system during the process of development. However, this combination can occur in many different proportions giving rise to many development paths. The analysis of the paths is one of the objectives of the present paper. A more detailed description of our TEVECON model

can be found in Pyka and Saviotti (2011) and in previous papers (Saviotti and Pyka, 2004a, 2004b, 2008).

Here we describe an extension of our TEVECON model having two objectives. First we want to study the co-evolution of demand and innovation in the process of economic development; second, we want to study the effect of output variety and of output quality and differentiation on economic development paths. Most existing models of growth, including the endogenous growth ones (Aghion and Howitt, 1992; Romer, 1990, Grossman and Helpman, 2001), are supply based and they pay no attention to demand. However, innovation would not have had any impact on economic development if the products embodying specific innovations had not been purchased by consumers and users. Even evolutionary economics, which owed its origin to the difficulties encountered when attempting to use neoclassical economic theory to explain the nature and impact of innovation on economic development, is until predominantly concerned with the supply side. On the other hand, models which focus on demand tend to stress structural change and to belong to a neo-Keynesian approach (Kaldor, 1957; Pasinetti, 1981; Aoki and Yoshikawa 2002). Recently a growing attention has been paid to demand in models of economic growth, both orthodox (Murphy, Shleifer and Vishny, 1989; Matsuyama, 2002; Foellmi and Zweimuller, 2006) and evolutionary (Bianchi, 1998; Andersen, 2001, 2007; Aversi *et al.*, 1999; Metcalfe, 2001; Saviotti, 2001; Witt, 2001; Ciarli *et al.*, 2010). An even more recent paper by Nelson and Consoli (2010) makes the brave attempt to sketch a broad outline of such a demand theory. They explore the use of routines by consumers to guide their choices. In this approach the mechanisms whereby routines are constructed are of crucial importance. In demand as in supply innovation creates uncertainty. Thus, consumers' knowledge is not just likely to be imperfect but to become more so when new types of goods and services completely unknown to them are introduced into the economic system. Especially at the beginning of the life cycle of the emerging goods and services very few consumers are likely to be able to overcoming this uncertainty. In fact, in these circumstances consumers can be expected to act as innovators but to require a threshold level of human capital to do that (Saviotti, 2001).

With respect to these papers ours differs for a number of aspects. First, this paper is part of a research program, the initial objective of which was to prove that economic development has occurred by means of a growing differentiation of the economic system. This objective placed our model not only within evolutionary economics but also with the research tradition of structural change. Furthermore, from the very beginning we were interested in long range patterns of economic development. The relationship between demand and innovation was always present in our model as the potential imbalance between saturating demand and continuously growing productive efficiency (Pasinetti, 1981). However, the specification of demand changed considerably in subsequent versions of TEVECON by first incorporating product quality and differentiation (Saviotti and Pyka, 2008) and becoming for the first time fully endogenous in this paper. The distinguishing features are:

— It does not share most of the assumptions of orthodox models, such as general equilibrium or optimizing behavior, but it only considers economic agents as potential improvers engaged in learning activities.

  The type of structural change that is at the center of the process of economic development leads to a growing output variety of the economic system. Thus, there is in TEVECON an arrow of time continuously raising the differentiation of the economic system. Interestingly, this feature of TEVECON finds a growing validation in recent empirical work (Acemoglu and Zilibotti, 1997; Imbs and Warcziag, 2003; Saviotti and Frenken, 2008; De Benedictis *et al.*, 2009).

— The mechanism whereby disposable income is created is closely related to the growing differentiation of the economic system.

— The growing product quality and differentiation within each sector contributes together with growing output variety to the compensation of the falling ability of mature sectors to create employment.

None of these features is present in the orthodox models referred to above. Furthermore, some of the objectives of the papers referred to above are similar to those of our paper, but they differ in a number of ways. Murphy, Shleifer and Vishny (from now on MSV) (1989) rescue the theory of the big push put forward

by Rosenstain and Rodan (1943) in the 1950s by developing a multi-sectoral model in which simultaneous investment in the different sectors of the economy can lead to growth even if no sector individually breaks even. The contribution of simultaneous investment to growth comes from the pecuniary externalities generated by each sector, which increase purchasing power in all sectors. Moreover, growth occurs by each sector shifting from constant returns to scale in cottage industry to increasing returns to scale in factory production. In this sense for MSV it is a change in process technology which gives rise to growth while in TEVECON it is the emergence of new sectors which differ for the type of output they produce. Thus, in MSV neither the type of output of sectors nor the direction in which structural change can be expected to vary, for example towards growing output variety, are defined. On the other hand, we find similarity between the ways in which MSV and our paper deal with demand: in both cases it is the income generated by the investment in industrialization (MSV) or in the emergence of new sectors (TEVECON) which creates the required demand.

With Matsuyama (2002) we share the interest for a similar transition. What we call the transition from necessities to imaginary worlds and the closely related one from low to high quality are very similar to Matsuyama's rise of mass consumption societies. However, with respect to Matsuyama our model differs for (i) the types of learning mechanisms, different types of search activities (fundamental and sectoral in TEVECON) compared to only learning by doing in Matsuyama, (ii) the specification of preferences, non-homothetic for Matsuyama, differing for consumers' propensity to move up or down a hierarchical ladder of goods or services in TEVECON, (iii) the impact of income distribution on development, which is present in Matsuyama and so far not in our model. As for MSV Matsuyama does not characterize the outputs of different sectors, and only allows them to be gradually adopted by different sections of the consumer population as the effect of learning by doing reduces the output cost of each sector making it affordable for larger and larger sections of the consumer population. Thus, Matsuyama includes a form of co-evolution (he talks about two-way causality) and a mechanism which is very similar to our trajectory 1 (growing productive efficiency). However, he has

neither any direction of structural change (trajectory 2, growing output variety) nor of growing output quality and differentiation (trajectory 3).

Foellmi and Zweimuller (FZ) (2006) use non-homothetic preferences, hierarchically ordered goods and investigate the effect of income distribution on growth. Their paper differs from Matsuyama (2002) for its learning mechanism, learning by doing in Matsuyama and industrial R&D in Foellmi and Zweimuller, and from MSV due to their claim to apply a more general nature of a preference system and also due to the more dynamical character of their model.

All the three above papers investigate the effect of income distribution on growth but they reach different and sometimes opposing conclusions. For example, FZ find that falling income inequality reduces growth for MSV whereas it increases growth for FZ.

In summary, our paper is part of a research program, one of whose most important objectives is to investigate the process of progressive differentiation which accompanies, and we maintain partly determines, economic development. None of the above papers shares this objective. The extent of differentiation is given. Change occurs by a transition in process technology (MSV), by learning by doing (M), or by industrial R&D technology (FZ). Given this difference in objective, TEVECON is the only model in which the number of sectors is endogenously variable, thus stressing the direction of structural change. From the very beginning the interaction between demand and supply has been at the center of TEVECON in the form of the imbalance between saturating demand and continuously increasing productive efficiency. Aoki and Yoshikawa (2002) share part of this approach. Yet our specification of the co-evolution of demand and innovation has been completed only in recent versions of TEVECON by including disposable income in the sectoral demand function. The goods and services of TEVECON are hierarchically ordered, but what determines the order is the action of entrepreneurs creating new sectors in the expectation of a temporary monopoly. Consumers do not have the ability to anticipate the emergence or nature of future sectors but react to their existence by purchasing their goods and services to the extent that their disposable income and preferences allow them to do. In particular, the preferences of our consumers

differ for their propensity to reduce or discard the consumption of older goods and services to start consuming new ones. With respect to MSV, M, and FZ we do not have included in our analysis income distribution but only calculate the average disposable income available for the consumption of new goods and services. The creation of such depends on the growing productive efficiency of older sectors (trajectory 1) and on the income created by the investment in the new sectors.

A further modeling approach which deserves to be discussed for both its similarities and differences with respect to TEVECON is that of Amendola and Gaffard (AG) (1998). AG share with TEVECON the out of equilibrium nature of the model and their emphasis on qualitative change. They include an interesting discussion of the nature of money but in the whole the sources of disequilibrium and the representation of technology are very different from TEVECON. For example, while they talk about qualitative change they do not take into account the non-comparable nature of the product and process technologies which emerge in the course of economic development.

The comparison of ours and of the above papers shows that each of these models investigates different aspects of the economic system and thus that they are not strictly comparable. Within this set of models the specificities of ours are that: (i) it is much 'lighter' in terms of its assumptions than orthodox models since it does not include closure conditions such as general equilibrium or optimizing behavior; it has a particular representation of structural change as leading to a growing output variety; (iii) it has an explicit analysis of the co-evolution of innovation and demand; (iv) it has an explicit representation of product quality and differentiation; (v) it has a more complete representation of search activities, including both fundamental research and sectoral applied research.

The previous references explored the mechanisms of creation of demand in relation to innovation at a micro economic level. In this paper we are more concerned with the joint dynamics of innovation and demand at a meso-economic level of aggregation. Two conditions are required in order for demand for new products or services to emerge:

(i) Consumers must have a disposable income which allows them to purchase the new goods and services;

(ii) Consumers must have or develop preferences which make them value positively the new goods or services.

Here the term disposable income must be understood to be the residual income, left over in a given period, after all the types of consumption of previous periods have been satisfied. A demand function had been introduced into TEVECON in a previous paper (Saviotti and Pyka, 2008). However, the demand function we used in that paper depended on output quality, on output differentiation and on price but not on income. This had the effect of overstating demand since high quality products are always preferred to low quality products irrespective of the consumer purchasing power. In this paper we use a demand function Equation (2) which depends on disposable income and on preferences in addition to product price, quality and differentiation.

$$D_i^t = k_{pref,i} \cdot D_i^0 \cdot D_{Disp,i} \frac{Y_i \cdot \Delta Y_i}{p_i} \tag{2}$$

where

$D_i^t =$ demand for product i at time t

$Y_i =$ services supplied by the product, measuring product quality

$\Delta Y_i =$ range of services supplied by the product, measuring product differentiation

$p_i =$ product price

$D_{Disp,i} =$ disposable income which can be allocated to purchase product i

$k_{pref,i} =$ parameter representing preferences

We calculate $D_{Disp,i}$ as the difference between the total income and the income required to satisfy the types of consumption of previous periods in period t.

To study how different preference systems can affect the time path of demand and of economic development we represent three very simplified preference systems which we call progressive, conservative and random. We realize that in a real economic system, preference systems of these different types would be distri-

buted within a consumer population and that they would not be immutable. Consumers can learn and change their preferences in the course of time. Our main objective here is simply to show that consumer preferences can affect directly demand and indirectly the macroeconomic growth performance of the economic system.

Consumers with a progressive preference system value more highly new goods and services than older ones. Consumers with a conservative preference system value more highly old goods and services than newer ones. Consumers with a random preference system will have preferences randomly distributed amongst the outputs of different sectors, old an d new. These three preference systems are represented as three different parameters in the demand Equation (1). $k_{pref,i}$ is a parameter which is constant for each sector in the course of time but can vary between different sectors. The three preference systems are then represented as follows:

— Progressive preference system: $k_{pref,\,i+1} > k_{pref,i}$

— Conservative preference system: $k_{pref,\,i+1} < k_{pref,i}$

— Random preference system: $k_{pref,\,i+1} >< k_{pref,i}$

The second objective of the paper consisted of comparing the economic development paths which would be obtained when product quality (i) remained unchanged or (ii) increased during the life cycle of each sector in TEVECON. This objective is attained by modifying the values of the parameters k_{14}-k_{17} linking search activities to product quality and differentiation Equations (3), (4)

$$Y_i^t = \frac{1}{1 + exp(k_{14} - k_{15} SE_i^t)} \tag{3}$$

$$\Delta Y^t{}_i = \frac{1}{1 + exp(k_{16} - k_{17} SE_i^t)} \tag{4}$$

When these parameters have extremely low values product quality and differentiation remain virtually constant during the evolution of the respective sectors. Values of the parameters k_{14}-k_{17} are varied by giving them extremely low values in the low quality (LQ) scenario and considerably higher values in the high quality (HQ) scenario. Thus, in the LQ scenario the saturation of each sector is attained much more rapidly due to the absence of quality change in sectoral outputs. In other words, in the LQ scenario

market saturation occurs only by volume (Saviotti, Pyka, Krafft, 2007). On the other hand, in the HQ scenario market saturation can occur much later, giving rise to longer industry life cycles (ILC) because the market can still expand after volume saturation has been attained by moving towards products of higher quality and thus of higher value.

By recalling that according to equation 1 search activities increase with accumulated demand and by combining equation 1 with equations 3 and 4 we can realize that search activities depend on demand and demand depends on search activities. This is the basis for the co-evolution of innovation and demand. The co-evolutionary loop is completed by equation 2 according to which demand is not only affected by three variables which are themselves affected by search activities (Y_i, ΔY_i and p_i) but also by the presence of a disposable income which can be used to purchase new goods and services.

Human capital is created by investment in education, which gives rise to an education capital stock (CS_{edi}), which in turn determines the quality h_i of human capital Equation (5). The parameter k_{ed} represents the effectiveness with which the investment in education is transformed into human capital. Hence, k_{ed} represents the quality of educational institutions in forming human capital. Overall human capital is obtained by multiplying sectoral labor by the quality h_i of human capital Equation (6).

$$h_i^t = k_{ed} \cdot CS_{ed\,i}^{\;t} \tag{5}$$

$$HC_i^t = labour_i^t \cdot h_i^t \tag{6}$$

Bearing in mind that sectoral output depends on human capital, we can realize that the time path of output depends on investment in education and on the effectiveness with which educational institutions improve the quality of human capital. Furthermore, the intensity of production is determined by the parameter k_{HQ} see Equation (7). Equation 7 also shows that human capital in a given period depends on investment in previous periods, which itself depends on output in previous periods. In turn, future output is affected by present human capital. Here we see some more examples of the co-evolutionary patterns included in TEVECON.

$$Q_i^t = Q^0 + \gamma \cdot (1 + \alpha_{ci}^t) \cdot (1 - exp(-k_{11} \cdot SE_i^t - k_{csplg1} \cdot CSphysical_i^t - k_{11} \cdot HC_i^t)) \quad (7)$$

$Q_i^t :=$ sectoral output

$\gamma :=$ scaling parameter

$\alpha_{ci}^t :=$ production adjustment

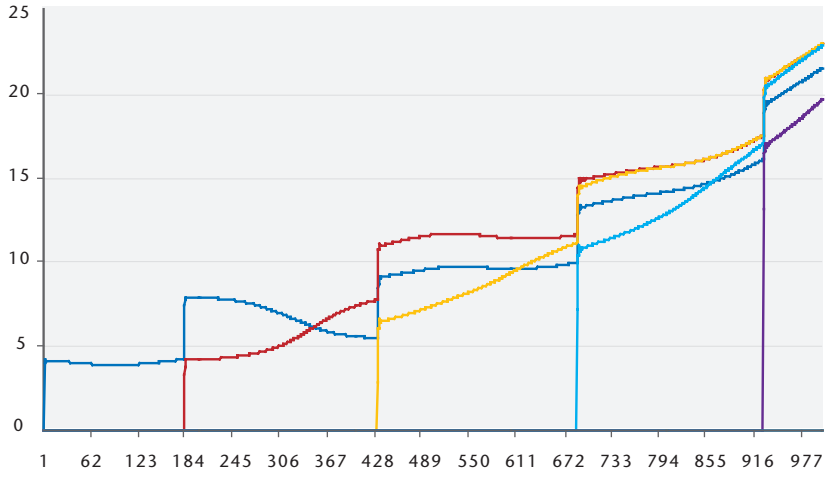
Wages depend on labor productivity and on a parameter, k_{wages}, Equation (8). The parameter k_{wages} leads to an increase or a decrease in wages at equivalent labor productivity. Thus, it could reflect the presence of particularly powerful labor unions, which would tend to raise it, or of reforms in the labor market, which could reduce it. We expect that at equivalent labor productivity a low value of k_{wages} increases the competitiveness of a sector or of a country.

$$wages_i^t = w_i^0 + k_{wages} \cdot \frac{Q_i^t \cdot P_i^t}{labour_i^t} \quad (8)$$

1.4. Disposable income for new sectors

Our calculations show that under a wide range of circumstances a disposable income can be created for new sectors, thus allowing consumers to purchase their output Figure 1.

Figure 1. Effect of product quality on the disposable income created in the economic system



Further, we can observe that while to purchase the output of sector 2 a reduction of the expenditures on sector 1 is required, such a sacrifice is not necessary for subsequent sectors. The development of the economic system manages to create enough resources in the system to allow consumers to purchase the new goods and services. The mechanisms by means of which such increasing purchasing power is created are related to the three trajectories described above. First, the growing productive efficiency in incumbent sectors (trajectory 1) reduces the cost of those sectors' goods and services and creates a surplus which can be used to fund the search activities and the investment required to produce the new goods and services. Second, the previous investment creates income for the labor employed in the production of the new goods and services. Third, as the average revenues of the population increase the possibility to make higher quality, more expensive and more profitable goods and services emerge. To the extent that such new goods and services fit consumers' preferences they will create new markets or enlarge existing ones. Thus, the growing quality and differentiation of goods and services (trajectory 3) together with the emergence of new sectors (trajectory 2) can compensate the falling ability of incumbent sectors to create employment and enable growth to continue in the long run. While this conclusion expands the range of possible growth mechanisms, in relatively wealthy economic systems it also introduces a source of uncertainty. In fact compensation can occur only if the innovations required to create new sectors are available when the saturation of pre-existing ones occurs. While this has been assumed so far in TEVECON there is no guarantee that in a real economic system this will always occur.

1.5. Preferences

The existence of an adequate disposable income is a necessary condition for consumers to be able to purchase the new goods and services which are created by innovation. However, consumers will do that only if they have an adequate set of preferences. In this section we study how the three different preference systems we suggested in the previous section can affect the time path of demand and of economic development. We realize that that these representations of a preference system are an approximation.

However, we consider that such an approximation is sufficient for our main objective here, which is to show that consumer preferences can affect directly demand and indirectly the macroeconomic growth performance of the economic system.

In different experiments we vary the degree of progressiveness or of conservativeness of our consumers by changing the Δk_{pref} between sectors i and i+1. Thus, a large and positive Δk_{pref} between sectors i and i+1 indicate strongly progressive consumers while a smaller but still positive Δk_{pref} indicate mildly progressive consumers. Likewise, a large and negative Δk_{pref} between sectors i and i+1 indicate strongly conservative consumers while a smaller negative Δk_{pref} indicate mildly conservative consumers. The results of these experiments are summarized in figures 2 and 3 by plotting the straight lines which give the rate of growth of income (Figure 2) and of employment (Figure 3). Such straight lines are the best linear fit for the income and employment curves and their slopes give us the rate of growth of income (RIG) and the rate of growth of employment (REG) respectively (see Saviotti and Pyka, 2008).

Figure 2. Influence of the different preference systems on the rate of growth of income

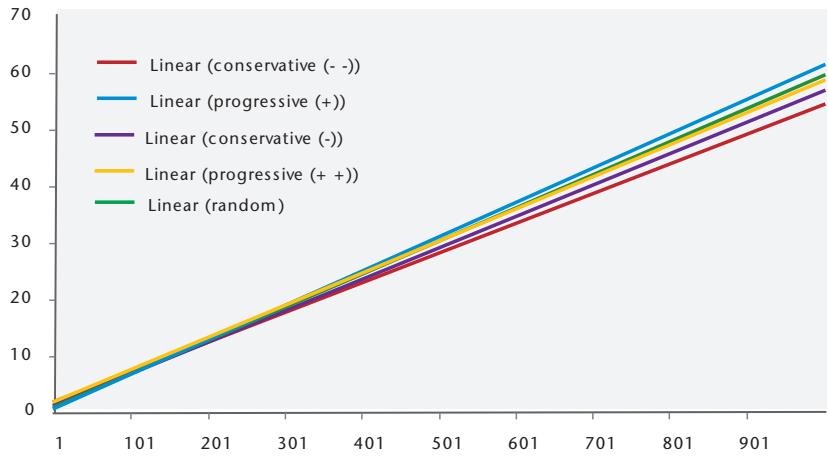
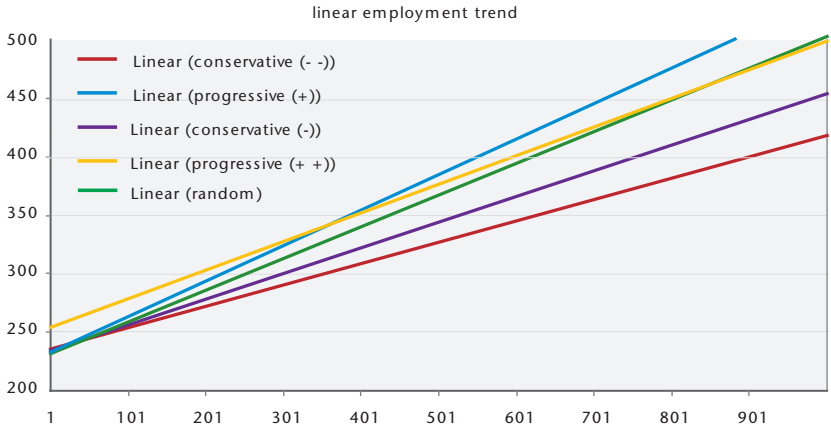


Figure 3. Influence of the different preference systems on the rate of growth of employment



These results show that both REG and RIG increase when preferences pass from conservative to neutral to progressive. However, as more preferences become more and more progressive both, REG and RIG start falling indicating the presence of a non-linear relationship between preferences on the one hand and employment or income on the other hand. Such non-linearity can be explained because the change from conservative to neutral to progressive preferences implies a transfer of resources from the purchase of old goods and services to that of emerging ones. While a moderate transfer can accelerate the emergence of new sectors, an excessive one can depress the demand for older goods and services and thereby reduce the overall growth of employment and of income.

The results of sections 1.4 and 1.5 show that (i) disposable income for new goods and services can be created by a combination of trajectories 1, 2 and 3, corresponding to the growing productive efficiency in incumbent sectors (trajectory 1), to the emergence of new sectors (trajectory 2) and to the growing quality and differentiation of goods and services (trajectory 3); (ii) consumer preferences can affect the macroeconomic performance of the economic system. We now pass to the second objective of this paper.

1.6. On the balance between the emergence of new sectors and the growing quality and differentiation of existing ones

To study this problem we define a set of parameter values which seem to give the type of regular pattern of development we had detected in previous papers. In other words, we started from a situation in which new sectors were regularly created and where the aggregate rates of growth of employment and of outcome were positive. We called this set of parameters our standard scenario.

Although many combinations of the emergence of new sectors and of the growing quality and differentiation of goods and services can be envisaged, we can in principle expect such different combinations to give rise to different development paths. To explore the relative impact of the emergence of new sectors and of the growing quality and differentiation of goods and services, we simulate two development scenarios, called high quality (HQ) and low quality (LQ) respectively. These scenarios are obtained by giving different values to the parameters k_{14}-k_{17} of Equations (3) and (4). These parameters determine the extent of product quality and differentiation corresponding to a given level of search activities. The LQ scenario is obtained by giving the parameters k_{15} and k_{17} values so low that product quality and differentiation are almost constant during the ILC of the sector. The HQ scenario is obtained by giving the same parameters considerably higher values. The results of this simulation show that the HQ and LQ scenarios give rise to very different development paths. The comparison HQ-LQ was explored by means of both micro- and macro-economic variables. In the LQ scenario, demand, human capital, wages and output remain substantially static or even declining while they increase in the HQ scenario (Figures 4a, b and c).

At an aggregate level:

— Disposable Income grows faster in the low quality case with respect to the high quality case (Figures 5 and 1)

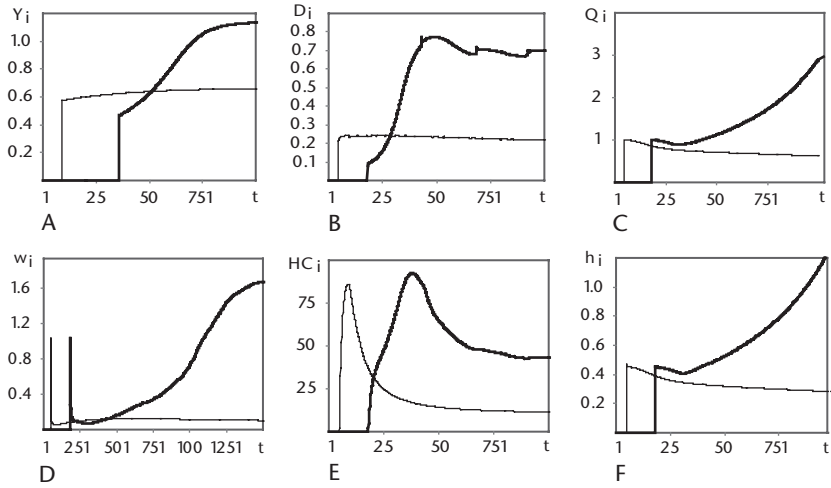
— Employment growth is always faster in the low quality case with respect to the high quality case (Figure 6b)

— The rate of creation of new sectors is higher in the low quality case with respect to the high quality case

— The rate of income growth (RIG) of the HQ scenario is initially lower but it overtakes that for the LQ scenario at a later time (Figure 6). We can also notice that RIG slows down

in the course of economic development for the LQ scenario while it accelerates for the HQ scenario.

Figure 4. Product quality



A - Product quality, as measured by the services supplied by a product (Yi) in the low quality (thin curve) or high quality (bold curve) case

B - Effect of product quality on sectoral demand

C - Effect of product quality on sectoral output

D - Effect of product quality on sectoralwages

E - Effect of product quality on thequantity of human capital used in a sector

F - Effect of product quality on thequality of human capital used in a sector

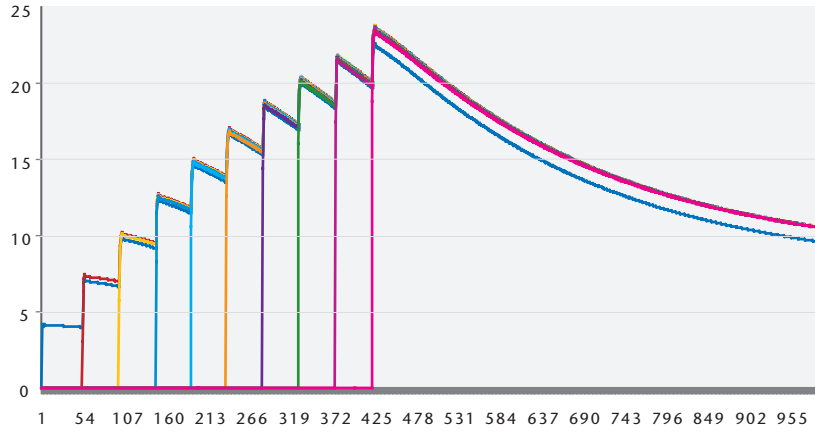
The above results can be explained as follows as follows:

Constant wages and constant human capital limit the scope for income growth in the LQ case. The absence of increases in quality and in sectoral differentiation in the LQ case, lead to shorter industry life cycles (ILC) and to a higher rate of creation of new sectors. Since the rate of employment growth (REG) is higher in the early phases of an ILC, the aggregate REG is higher for the LQ than for the HQ scenario, although such higher REG is obtained at the expense of lower wages, lower demand and lower human capital.

Initially the higher REG leads to a higher RIG for the LQ scenario. However, the rising wages and demand lead to a RIG which is not constant but increases in the course of economic deve-

lopment for the HQ scenario. The self-accelerating and self-limiting shapes of the RIG curves for HQ and LQ scenarios can be understood because in the former case an increase in demand leads to an increase in search activities, which in turn leads to an increase in output quality and differentiation, which is finally translated into an increase in demand. This feedback loop is considerably weakened in the LQ scenario because in this case search activities have a negligible impact on output quality and differentiation.

Figure 5. Effect of product quality on the disposable income created in the economic system for the low quality case

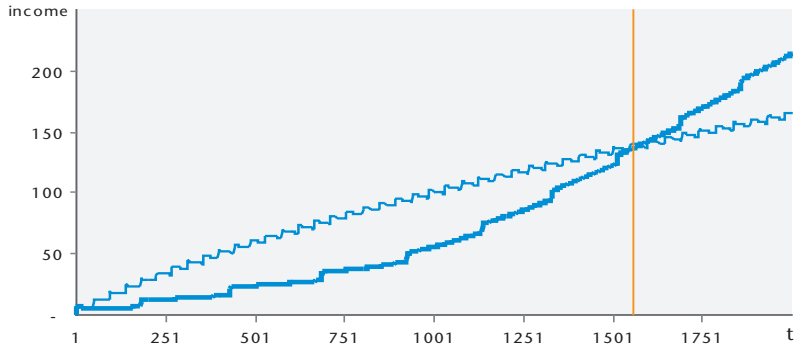


To interpret the previous results we note that empirical observations show that product differentiation started considerably after the beginning of the industrial revolution, probably towards the end of the 19th century, and initially only in relatively rich countries. Such transition proceeded by liberating a growing proportion of household income from necessities and thus making room for the purchase of new goods and services which were not necessary in the physical sense in which food or shelter are (see Hobsbawm, 1968, diagrams 45 and 46). Rather than being necessities, the result of adaptation to the external environment in which human beings live, the new goods and services shape the external environment in ways which were not necessary and along a development path which was not necessarily unique. Thus, we described the evolution of the capitalist economic system as the transition from necessities to imaginary worlds. This transition

could be interpreted as the result of a continuous, linear progress which constantly improves human welfare. We think that such an interpretation would be rather simplistic. We are more interested in understanding how the mechanisms which we explore in this paper, however oversimplified, could provide us with an explanation of how the capitalist economic system managed to survive since the industrial revolution by profoundly transforming itself. Every economic system, however successful at the time it is created, brings in itself the seeds of its own destruction. Such destruction need not necessarily occur if the economic system manages to transform itself enough.

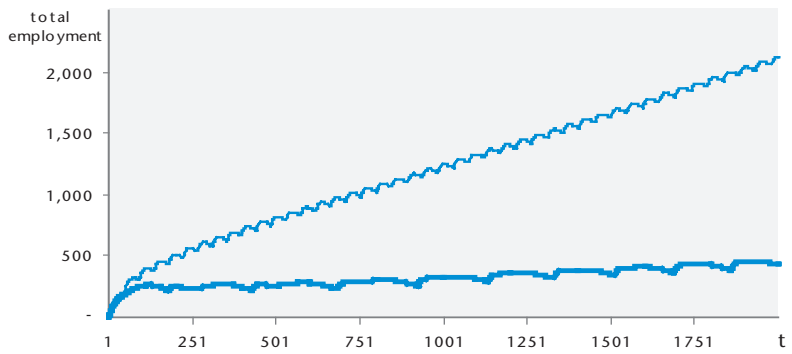
Figure 6. Effect of product quality on the aggregate rate of income growth

(a) Income



(LQ light curve, HQ bold curve); The vertical line indicates the time required for HQ income to catch up with and to overtake LQ income, which we call ICUT.

(b) Total employment



(LQ light curve, HQ bold curve)

The development mechanism we hypothesize began with the saturation of the markets for necessities, attained during the early part of the industrial revolution due to the growth of productive efficiency which occurred in that period. In turn, that saturation is likely to have induced efforts by producers to avoid it by opening new markets or by enlarging existing ones. Assuming that new technologies potentially giving rise to new markets could be created, as they were, the markets themselves would not come into being unless a large enough percentage of the population had the required purchasing power. A mechanism which could give rise to the coordinated emergence of production capabilities and of purchasing power is the following:

— The production of some of the new goods and services and the rising quality and differentiation of existing ones required higher levels of competencies and of human capital;
— such higher competencies required training and education;
— better educated workers had to be paid higher wages;
— new jobs were created in the training and education system;
— the new jobs and higher wages created the disposable income required to purchase the new goods and higher quality goods and services.

The combination of the above steps gave rise to a virtuous circle which could continue expanding the economic system as long as technologies and demand could co-evolve. This co-evolution allowed the capitalist economic system to escape the development trap which Marx and other critics of capitalism had foreseen. Of course, we think that the mechanism previously described is only a component of an overall repertoire. The capitalist economic system cannot have been saved only by an ever increasing shopping frenzy of new and more luxurious goods and services. Social innovations in pensions, unemployment benefits, health care etc. are likely to have co-evolved together with the mechanism described above to allow the capitalist economic system to transform and adapt. Thus, the real co-evolution included more mechanisms and steps than the ones we described above. However, we think our exercise is useful because it provides an analytical approach to the explanation of long range transitions in economic systems. The addition of further components to the co-

evolutionary process described above can be envisaged without substantial modifications of our approach.

Let us observe that the transition from low to high quality goods and services, henceforth (LQ → HQ) transition, is not identical to that from necessities to imaginary worlds. The former is from an economic system dominated by trajectories 1 and 2 to one dominated by tranjectories 1, 2 and 3, while the latter is from an economic development dominated predominantly by trajectory 1 for consumer goods but with trajectory 2 occurring in capital goods. In its present state TEVECON cannot accurately distinguish between consumer and capital goods. In spite of these differences the transition (LQ → HQ) is very similar to that from necessities to imaginary worlds, especially for what concerns the emergence of higher quality and internally differentiated goods and services. Thus, the study of the (LQ → HQ) transition can help us understand the mechanisms of capitalist economic development.

The analysis we carried out shows that long range processes of economic development cannot be explained only by the increasing productive efficiency, or even by the increasing output quality, of a constant set of activities, but that they intrinsically involve a very high degree of structural change. In this context structural change not only means the changing weight of different sectors but also other changes in the composition of the economic system, with the inclusion of completely new institutions and organizations and of their interactions. Structural change becomes more important for the explanation of processes of economic development the longer the time horizon chosen.

We now describe a set of policy relevant experiments carried out with TEVECON.

2. Policy experiments

In these experiments we explore the effects of changes in a number of TEVECON parameters on some aspects of the process of economic development. In particular, we focus on the role of human capital and of wages. According to the above described mechanisms we can expect that both human capital and wages had to increase to allow the economic system to generate the higher quality goods and services and the income required to

purchase them. Thus, we chose to modify some parameters which affect these two variables. First, we hypothesized that at least in some types of economic activities there could be a barrier in human capital. In these activities only human capital above this barrier could be employed. Second, we hypothesized that the weight of human capital in the production function could affect economic development processes. Third, we expected wages to affect economic development processes. In TEVECON wages are proportional to labor productivity according to a parameter k_w, henceforth called the wage parameter. Accordingly, in our experiments we vary the barrier in human capital, the weight of human capital in the production function and the wage parameter. We start by varying one parameter at a time and then we combined variations of two or more parameters (Table 1, Appendix).

The starting point of our experiments here was the comparison of the LQ and HQ scenarios described in Figures 6 a, b. These results show, that (i) the rate of employment growth (REG) is systematically higher in the LQ scenario, and that (ii) the rate of income growth (RIG) is initially higher for the LQ scenario but becomes higher for the HQ scenario at later times. In the following experiments we investigate the impact of the three above parameters on (i) the time required for HQ income to catch up and overtake LQ income, which we called ICUT, (ii) the relative REG for the two scenarios, and on (iii) the variance of income determined by the change from conservative (CP) to progressive (PP) preferences. ICUT was measured as the time at which the HQ income crossed the LQ income curve (see Figure 6a). ICUT is plotted as a function of the weight of human capital in the production function (Figure 7) and of the wage parameter k_w (Figure 8).

The most general trend observed is a fall in ICUT when both k_{Hi} or k_w increase. This means that the (LQ $\rightarrow$ HQ) transition would have occurred earlier if a higher intensity of human capital and a higher wage rate had been used in the economic system. However, the behavior of ICUT becomes more complex when the increases in the above two parameters are combined with increasing values of B_{hi}. In this case ICUT alternately rises or falls for different ranges of values of either B_{hi} or k_w. These more complex types of behavior could be understood by bearing in mind that the introduction of a human capital barrier excludes some workers from the labor force.

Figure 7. Effect of changing the weight k_{Hi} of Hi in the production function for different values of barrier in human capital B_{hi}

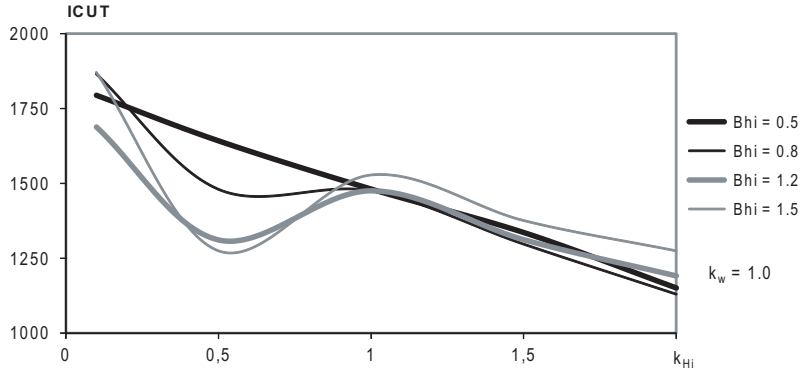
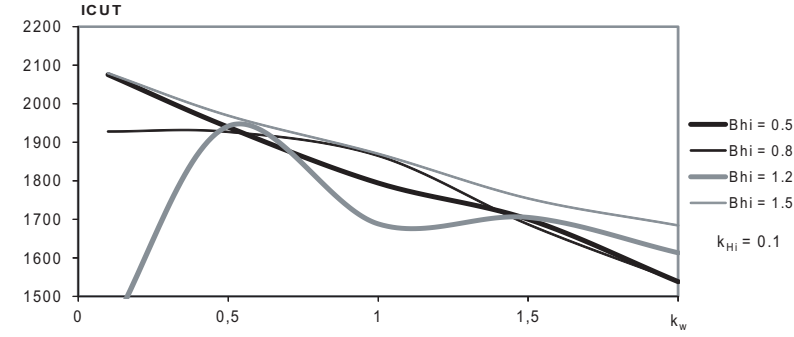


Figure 8. Effect of changing the wage parameter k_w for different values of barrier in human capital



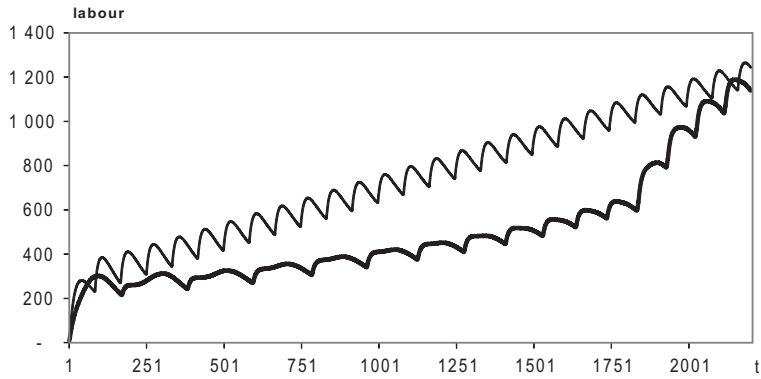
The resulting outcome would be due to the balance between the higher wages of the employed workers and the absent wages of the unemployed ones. The general point to be made here is that wages are both a source of costs and of revenues. The effect of rising wage rates and of rising levels and intensity of human capital depends on the balance of their effects on revenues and on costs. Also, we have to bear in mind that the introduction of an h_i barrier in the present state of TEVECON is equivalent to an internal differentiation of the labor force. Thus, introduction of a low h_i barrier into an economic system which has low wages and low human capital can have a very different effect than the introduction of a higher h_i barrier into an economic system which has high wages and high

levels and intensity of human capital. The effect of the human capital barrier on the ICUT falls for higher values of both k_{Hi} and k_w. Thus, a system which already has high wages and high levels and intensity of human capital is less affected by the introduction of a human capital barrier than a system which has low wages and low levels and intensity of human capital.

Finally, we can observe that the LQ income curve is virtually unaffected by the changes in the three above parameters. This is the result of the fact that human capital and output quality are almost constant in the LQ case.

The same set of experiments described in table 1 was carried out for the relative REG of the LQ and HQ scenarios. The result described in Figure 6b showed that REG(LQ) was systematically higher than REG(HQ). In fact, the two curves diverged continuously. Furthermore, both curves were approximately linear in time. In the vast majority of the experiments we carried out REG(LQ) was greater than REG(HQ). However, for particular values of the parameters used, REG(HQ) increased considerably showing an inflection point in the employment curve (see for example Figure 9).

Figure 9. Employment for the LQ (light line) and HQ (heavy line) scenarios for B_{hi} = 0.5 and k_{Hi} = 2.0.



After the inflection pint the HQ employment curve can sometimes overtake the LQ one. The inflection point occurs at very long development times, which correspond to high levels of economic development. In other words, similarly to what happened for

Income, the evolution of employment shows a self-accelerating character in the HQ which is absent in the LQ case. In the HQ employment case this self-accelerating character seems to arise fairly suddenly while in the HQ income case it was continuous. However, even in the HQ employment case we can see premonitory signs of the inflection in the shortening of the ILCs which starts occurring form the beginning, a phenomenon which does not occur at all for the LQ scenario. Such shortening of the ILCs can be explained by (i) the increasing quality and internal differentiation of goods and services which lengthens the life cycles of the sectors producing them, as it can be seen by comparing the LQ and HQ cases (see also Saviotti, Pyka and Krafft, 2007); (ii) the increasing quality and internal differentiation of output can be become faster the more knowledge creating resources are present in the economic system. As in the income case the employment curve of the LQ scenario is almost unaffected by the changes in parameters used in our experiments. As for the income case this different sensitivity of the LQ and HQ cases to changes in parameters affecting human capital or wages can be explained by the much weaker feedback loop between demand and search activities existing in the LQ case.

The relative dynamics of income in the LQ and HQ scenarios is affected also by a change in preferences. Figures 10 and 11 compare the impact of preferences on the income curves for the LQ and HQ scenario with different parameter settings. Figure 10 corresponds to our standard scenario (Experiment 1 in Table 1) while Figure 11 corresponds to experiment 27. The results can be summarized as follows:

(i) The variance in income induced by a change of preferences from conservative (CP) to random (RP) and then to progressive (PP) for both the LQ and LQ cases increases in the course of time, that is the more highly developed an economic system is. In what follows we call this variance PIVI and we measure it as the difference between the income levels corresponding to PP and CP respectively at the maximum time at which we ran our model (the intercepts of the income curves with the vertical axis on the right of the diagram).

(ii) At equivalent times in our standard scenario (Exp 1, table 1) PIVI is larger for the LQ than for the HQ case.

(iii) When the barrier to human capital, the weight of human capital in the production function and the wage parameter are increased, either individually or in combination (Exps 2 – 44, Table 1) PIVI grows also for the HQ case and it can become comparable to that of the LQ case.

(iv) For very high values of k_{Hi} the income curve for the HQ case starts growing very rapidly at fairly long times and then abruptly stops. In these conditions the process of economic development becomes so unbalanced that it cannot proceed any further.

Figure 10. Income curves for the LQ (green curves) and HQ (blue curves) cases showing the impact of different preferences on income generation. The parameter settings correspond to the standard scenario

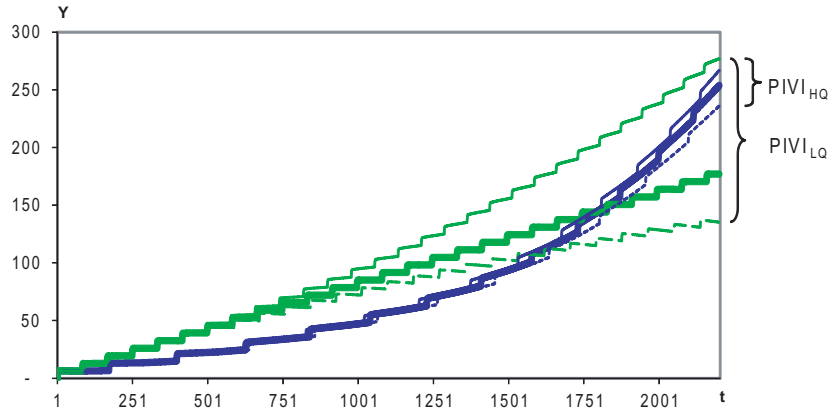
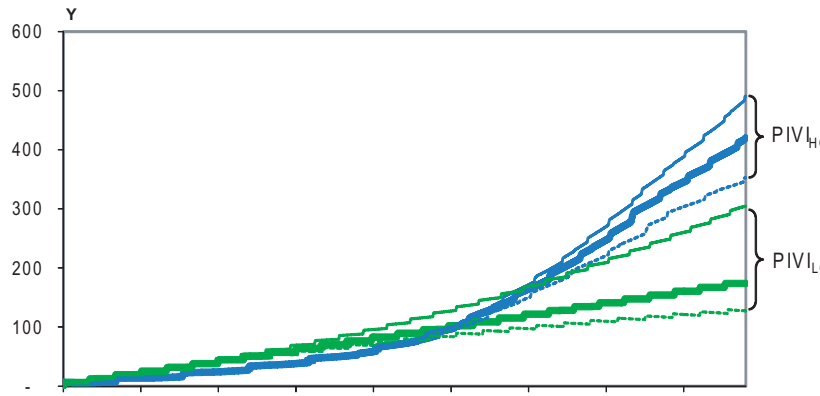


Figure 11. Income curves for the LQ (green curves) and HQ (blue curves) cases showing the impact of different preferences on income generation. The parameter settings correspond to higher values of the B_{hi} barrier in human capital and in the weight of human capital in the production function (Exp 27 in table 1)



The previous results can be interpreted as implying that the impact of changing preferences is likely to increase as economic development proceeds. In other words, differences in consumer preferences are likely to have a greater effect on the growth of income on those which are already rich than on relatively poor ones. In an economic system in which most people can just afford basic necessities the disposable income required to buy new goods and services would be absent or very scarce. In these conditions preferences could hardly exert any impact on income generation. Preferences can be expected to start exerting an impact when there is a disposable income with which consumers could choose to purchase different goods and services in addition to necessities.

While the previous conclusion makes sense in general it is not immediately clear why different preferences should have a greater impact on income formation in the LQ than on the HQ case. If we remember that in the LQ case the only choice consumers could have is that amongst different types of goods and services, but that within each type quality remains constant. As a consequence, ILCs would be shorter and the rate of growth of disposable income would initially be faster. Yet the effect of preferences on PIVI would still be lower even after HQ income had overtaken LQ income. PIVI for the HQ case can start growing and become comparable to that of the LQ case only after barriers to human capital, a higher weight of human capital in the production function and a higher wage rate had been introduced. Thus, although for both the LQ and the HQ cases different preferences start exerting an effect on the rate of growth of income, the time at which preferences start affecting income varies depending on the case and on the parameter setting used in the experiments. In particular, barriers to human capital, a higher weight of human capital in the production function and a higher wage rate seem to have a much higher impact on the HQ than on the LQ case. This in understandable because both levels of human capital and wages remain relatively flat in the LQ case, while they increase in the HQ case.

Let us conclude this section by pointing out that the term policy needs to be interpreted carefully in this context. Usually policies have a relatively short term orientation with respect to the time horizon we are envisaging in this paper. The parameters the influence of which we explored are related to human capital and to

wages, two variables the importance of which in modern economic systems is still, and is likely to remain, very high. We have seen that rising wages and rising levels and intensity of human capital played a fundamental role in capitalist economic development by allowing to create both the competencies required to produce goods and services of higher quality and internal differentiation and the disposable income required to purchase them. These results cannot be interpreted as implying that economic development will always be positively affected by raising wages and levels and intensity of human capital. There are many examples in which a reduction in wages can positively contribute to economic performance. What matters is not wages per se but the combination of wages, human capital and other variables. Thus, even if rising wages and levels and intensity of human capital are required to sustain the long term development of the economic system, short term adjustments in their *combination* can be required to compensate for temporary slowdowns or bottlenecks. What matters is not wages or human capital per se but the way in which their co-evolution can create in a coordinated way new demand and the required purchasing power and preferences.

As for preferences, it is quite clear from our results that their impact on growth and development becomes increasingly important as the economic system becomes richer. As a consequence, the scope for activities which help consumers to form preferences for emerging goods and services increases with the level of economic development. This is particularly true for high levels and intensities of human capital and for high wage rates. However, we must remember that if facilitating the formation of preferences for emerging goods and services can positively affect economic development, a balance must be maintained in the economic system between speeding up the introduction of new goods and services and reduce the weight of pre-existing ones.

3. Conclusions

In this paper we study the co-evolution of innovation and demand and try to understand how it could have contributed to the long run development of the capitalist economic system by means of our TEVECON model. We show that the economic system can create the disposable income required for consumers to be able to purchase the new, higher quality and more differentiated goods and services created by innovation. The creation of such disposable income is due to the combination of growing productive efficiency (trajectory 1), growing variety (trajectory 2) and growing output quality and internal differentiation (trajectory 3). Furthermore, we show that consumer preferences can affect observed macroeconomic development paths. In particular, we show that consumers with progressive preferences led to higher rates of growth of output and of income than consumers with conservative preferences, where progressive preferences imply a strong relative propensity to purchase new goods and services at the expense of older ones. Thus, our results confirm that demand matters and that observed patterns of economic development can be explained by the co-evolution of innovation and demand.

After having established this point we explore the economic development paths that could be generated by different combinations of growing variety (trajectory 2) and growing output quality and internal differentiation (trajectory 3). This is done by choosing two rather extreme scenarios, one including only growing variety, which we called low quality (LQ), and one including both growing variety and growing output quality and internal differentiation, which we called high quality (HQ). The HQ scenario gives rise to a slower but richer growth path. The LQ scenario has a higher rate of creation of new sectors and consequently a higher rate of growth of employment but at the expense of having lower wages, lower sectoral demand and lower levels of human capital.

An important result of our comparison was that the HQ income was initially lower than the LQ one, but that at later times the situation was reversed with HQ income becoming dominant. We called this phenomenon the (LQ $\rightarrow$ HQ) transition. This is important because it seems to map some observed paths of economic development, in particular what we call the transition from necessities to imaginary worlds. Admittedly the two transitions are not

identical but they both include the emergence of higher quality and more internally differentiated goods and services at a later stage of economic development. We then explore further the (LQ → HQ) transition to better understand long run mechanisms of economic development. To do this we vary some TEVECON parameters affecting human capital and wages. We find that growing wages and growing levels and intensity of human capital favour long run economic development. We then hypothesize that the (LQ → HQ) transition could have been the outcome of a virtuous circle in which growing human capital and growing wages provide both the competencies needed to produce higher quality and more internally differentiated goods and services as well as the disposable income required to purchase them. Our TEVECON model proves that this virtuous circle is possible but that it is not necessary. As in all co-evolutionary processes the necessary ingredients are required with the appropriate coordination.

Furthermore, we show that the LQ and HQ cases are both affected, although differently, by changing consumer preferences. In both cases, the variance in income produced by progressive (PP) and conservative (CP) consumer preferences tend to grow as economic systems become progressively richer. This points towards an important scope for policy, especially for those activities which help consumers to learn about new goods and services, a necessary condition to for them to have clear preferences.

We conclude this paper by pointing out that the policy implications we can derive here are long term. Thus, we have seen that growing wages and growing levels and intensity of human capital favour long run economic development. This conclusion cannot be translated into the short term prescription to keep raising wages and levels and intensity of human capital under any circumstances. What matters are not the individual values or trends of wages and of human capital but their combinations. Many adaptations can be required to overcome short term bottlenecks and to restore long run trends.

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APPENDIX

Table Appendix

	h_i entry Barrier (B_{hi}) a	Weight of H_i in Production Function(k_{Hi}) b	Wage Function Parameter (k_w) c	
1.	0.0	0.1	1	Standard
2.	0.5	0.1	1	Entry
3.	0.8	0.1	1	Barrier
4.	1.2	0.1	1	Experiments
5.	1.5	0.1	1	
6.	0.0	0.5	1	Production
7.	0.0	1.0	1	Function
8.	0.0	1.5	1	Experiments
9.	0.0	0.1	0.5	Wage
10.	0.0	0.1	1.5	Function
11.	0.0	0.1	2.0	Experiments
12.	0.5	0.5	1	a&b
13.	0.5	1.0	1	
14.	0.5	1.5	1	
15.	0.5	2.0	1	
16.	0.8	0.5	1	
17.	0.8	1.0	1	
18.	0.8	1.5	1	
19.	0.8	2.0	1	
20.	1.2	0.5	1	
21.	1.2	1.0	1	
22.	1.2	1.5	1	
23.	1.2	2.0	1	
24.	1.5	0.5	1	
25.	1.5	1.0	1	
26.	1.5	1.5	1	
27.	1.5	2.0	1	
28.	0.5	0.1	0.1	a&c
29.	0.5	0.1	0.5	
30.	0.5	0.1	1.5	
31.	0.5	0.1	2.0	
32.	0.8	0.1	0.1	
33.	0.8	0.1	0.5	
34.	0.8	0.1	1.5	
35.	0.8	0.1	2.0	
36.	1.2	0.1	0.1	
37.	1.2	0.1	0.5	
38.	1.2	0.1	1.5	
39.	1.2	0.1	2.0	
40.	1.5	0.2	0.1	
41.	1.5	0.1	0.1	
42.	1.5	0.1	0.5	
43.	1.5	0.1	1.5	
44.	1.5	0.1	2.0	
45.	0.5	0.5	0.1	a,b&c
46.	0.8	1.0	0.5	
47.	1.2	1.5	1.5	
48.	1.5	2.0	2.0	