WORKING PAPERS

Investigação - Trabalhos em curso - nº 139, Março 2004

On evolutionary technological change and economic growth: Lakatos as a starting point for appraisal

Sandra Tavares Silva

FACULDADE DE ECONOMIA

UNIVERSIDADE DO PORTO

www.fep.up.pt

Faculdade de Economia do Porto - R. Dr. Roberto Frias - 4200-464 - Porto - Portugal
Tel . (351) 225 571 100 - Fax. (351) 225 505 050 - http://www.fep.up.pt

On Evolutionary Technological Change and Economic Growth: Lakatos as a starting point for appraisal*

Sandra Tavares Silva

Faculdade de Economia do Porto
Rua Dr. Roberto Frias
4200-464 Porto, Portugal

email: sandras@fep.up.pt

Abstract

This paper proposes a reflection on evolutionary technological change and economic growth theory, which starts from the Lakatosian methodology of scientific research programmes (MSRP) as an appraisal criterion. As the persistence of some inflexibility on the approach made difficult to capture fundamental features of that scientific endeavour, it was undertaken an analysis using an alternative framework developed by Hoover (1991). This last frame is used not as a formal methodology but as a language to find patterns in these theories. This exercise evolved then towards some considerations about the confrontation of these evolutionary theories with what can be seen (in a loose sense) as their 'rival research programme', the new neoclassical growth models.

Keywords: *Evolutionary, economic growth, technological change, Lakatos, Kuhn, research programme.*

Resumo

O presente artigo propõe uma reflexão sobre a teoria evolucionista do crescimento económico e progresso tecnológico, que parte da metodologia científica de *research programmes* de Lakatos como critério de avaliação. Como a presença de alguma rigidez nesta abordagem tornou difícil captar características fundamentais daquela linha teórica, foi desenvolvida uma análise baseada num quadro de trabalho alternativo proposto por Hoover (1991). Este último é usado não como uma metodologia formal mas como uma linguagem para encontrar padrões nestas teorias. Este exercício evoluiu depois para algumas considerações sobre o confronto destas teorias evolucionistas com o que pode ser entendido (num sentido livre) como o *research programme* rival, os novos modelos de crescimento neoclássicos.

Palavras-chave: *Evolucionismo, crescimento económico, progresso tecnológico, Lakatos, Kuhn, research programme.*

* This paper was produced within the course on History of Economic Thought that composes the doctoral programme on economics offered by the Faculty of Economics of Porto. I am grateful to Professor Roger Backhouse who helped to improve enormously this work.

1. Introduction

My first incursions into the field of economic growth provided the contact with the Solow's model (1957) and a set of models generally considered as the archetypes of endogenous growth theory (Romer 1986 and 1990; Lucas 1988; Aghion and Howitt 1992). For some time I was clearly inside mainstream when thinking about economic growth and mainstream is neoclassical growth modelling. However, at some point I was confronted with an alternative theorizing, the evolutionary economics, which conducted to an investigation of the state of the art of a distinct and rather puzzling framework for theoretical and empirical research within economics. Evolutionary economics has a large range of research areas such as economic growth, industrial organisation, game theory, learning dynamics and bounded rationality, organisation theory, financial markets and the interactions between economics, law and culture (Silverberg and Verspagen 1997a). Faced with this wide theoretical frame, I was forced to look for a more clear definition of evolutionary theorizing on technological advance and economic growth.

Beyond a review of literature on this topic I think it is important to analyse it using an appraisal criterion. Lakatos's methodology of scientific research programmes (MSRP) seems a helpful starting point, despite the strong criticisms pointed to the Lakatosian framework[1], to deal with a significant set of questions about the nature and growth of economic knowledge (Backhouse 1998). Based on this conviction, the need for getting a more unambiguous picture of what is evolutionary technological advance and economic growth theorizing conducted me to an analysis of the subject using Lakatos's view of the history and methodology of science, exploring the development of this school within Lakatos's framework and investigating if it constitutes a scientific research programme.

However, after using Lakatos as a starting point, I depart from there as the Lakatosian approach does not seem to confine some fundamental features of the scientific endeavour in study. I follow Hoover (1991) who, at a certain extent inspired by Kuhn, provides an alternative framework to attempt a description of scientific process. Hoover used this approach to analyse the new classical macroeconomics. I develop an effort to

[1] This approach dominated the debate on economic methodology until the late 1980s (Backhouse 1998). However, by the end of the decade, the MSRP was already out of fashion, reflecting strong criticisms regarding this methodology. For a detailed analysis on Lakatos see Backhouse, 1998.

apply the same approach to my case having in mind its use as a language or a way of thinking to find some patterns in evolutionary theories, and not as a formal methodology. At last, some considerations are made regarding what can be seen as the ‘rival research programme’ (in a loose sense) of that theorizing: the new neoclassical growth models.

2. An Evolutionary Economic Growth Research Programme

An analysis of evolutionary growth economics based on the MSRP means the coming out of several questions about this field. It is possible to ask if it constitutes a distinct programme; if so, find out what is the programme and how it has been developing. As Hoover (1991) stresses when talking about the new classical macroeconomics, the answer to those questions within Lakatos's spirit requires offering a ‘programmatic interpretation’ (Hoover 1991: 365). To construct this programmatic analysis I will start with an attempt to define the hard core and the heuristics of evolutionary growth economics, assuming it can be interpreted as a research programme. For that purpose I will recall some literature on this field that I consider crucial to support such an attempt.

Nelson and Winter's *An Evolutionary Theory of Economic Change* (1982) is categorized as the benchmark in evolutionary economics. They propose an evolutionary theory of the capabilities and behaviour of business firms operating in a certain market environment, sturdily indicating the return of biological analogies to economics. In this theoretical frame there is a selection process operating on firms' internal routines and the routines are appreciated as the suitable and effective behaviours in a certain setting. They are the product of processes characterised by profit-oriented, learning and selection. The routines that a firm uses at any time can be seen as ‘the best it knows and can do’. The rationality in this employment rests in that sense, even if the firm did not make any effort to balance its existent routines with all possible alternative ones (Nelson 1995: 69). Nelson and Winter see the routines as repositories of knowledge and skills with the ability to replicate, for example by imitation and personal mobility. The concept of routine is vital to understand economic evolutionary thought.

Another concept that emerges from evolutionary economics is search which Nelson and Winter identify as ‘the counterpart of that of mutation in biological evolutionary theory’ (Nelson and Winter 1982: 18). Their model of economic growth demonstrates this concept. Search is conceived as Research and Development (R&D) actions developed by firms. If firms are profitable enough they only try to keep their routines and so they do not enter into search. If a chosen level of profitability is not observed firms invest in R&D and take on actions to discover new techniques having as purpose to restore their profitability[2]. One more biological analogy present in evolutionary economics consists in the idea of natural selection and market competition (Hodgson 1999).

Although the presence of biological analogies, Nelson and Winter's theory is categorized as "unabashedly Lamarckian: it contemplates both the 'inheritance' of acquired characteristics and the timely appearance of variation under the stimulus of adversity" (Nelson and Winter 1982: 11)[3].

The explanation of the economic system comprises random and mechanic elements. The first ones generate some variation among the variables in analysis and the second ones win systematically on the existing variation (Silverberg and Verspagen 1997a). So, on the evolutionary framework, as Andersen (1994) stresses, it is assumed that the economic system is characterized by changing diversity and evolving processes of adaptive behaviour, where novelty has a fundamental role. This emphasis on dynamics and bounded rationality clearly is not compatible with the traditional neoclassical concepts of equilibrium and optimisation.

While the evolutionary thinking is constructed on an open-system approach where not all relevant variables and relationships are knowable, consenting for a range of possible combinations of methods, the neoclassical framework is typically characterised by a closed-system approach where all variables and relationships between them are predictable, allowing for representation in a formal mathematical model (Dow 2000).

The literature on evolutionary technological change and economic growth is wide and I could continue to outline it. However, after highlighting some topics on the subject regarded as important to understand the following exercise, I point to Dosi et al. (1988) and their systematisation effort, which suggests a set of archetypal characteristics of evolutionary economic thought that have been used as a reference in most modelling efforts developed on the field. This methodical sum up provides a set of assumptions

[2] Nelson and Winter used Herbert Simon's concept of 'satisfacing behaviour'. Therefore, agents do not optimise; they try to achieve an 'aspiration level'.

[3] To sustain this classification the authors stress the inexact correspondence between routine and gene. Routines are relatively robust in socio-economic terms but not so durable as the gene in biology. Also, the new features associated to the change of routines can be imitated and inherited by imitators or subsidiary firms (Nelson and Winter 1982).

commonly accepted as indisputable by researchers working within this theoretical framework. Also, Silverberg and Verspagen (1997b) offer a survey of evolutionary economic growth that confirms the somewhat "hard" nature of such assumptions.

All these citations appear as a strong support to construct the hard core of the (assumed) programme. It follows a list of the propositions:

- Economic agents are heterogeneous;
- Agents are never perfectly informed and they have to optimise (at best) locally rather than globally;
- Decision-making processes are generally bounded by rules, norms and institutions;
- Agents may imitate the routines of other agents, being able to learn and to create novelty (mutation or search);
- The processes behind innovation and imitation are characterised by cumulativeness and path dependency[4], although they can be broken by sporadic discontinuities;
- Agents interact in disequilibria contexts.

The same citations are very helpful for the selection of the rules that may constitute the negative and positive heuristics of the programme. As the negative heuristic it seems reasonable to adopt Hoover's (1991) point of view as electing a summed up rule in the injunction 'do not violate any hard core propositions', containing propositions such as:

- Do not construct theories in which the economic system is static and automatically in equilibrium;
- Do not construct theories in which agents have optimising behaviour;
- Do not construct theories with deterministic, closed outcomes.

The typical features of evolutionary economic growth can be condensed in the positive heuristic, which propositions may be as the following:

- Construct dynamic, non–deterministic models;
- Work with an heterogeneous population of economic agents;

[4] Rosenberg (1976, 1982), Freeman (1974), Nelson and Winter (1977), Dosi (1988), Vincenti (1990) and others devoted to the analysis of technology suggest the existence of different evolutionary tracks that go into distinct directions. The movement along one of those may block movement down another (Nelson 1995). This line of argumentation highlights concepts as irreversibility and path dependency, which are very important in evolutionary theorizing.

- Introduce a mechanism that generates novelty in the population, that is mutation (generally identified with technical innovations);
- Introduce a mechanism that generates selection, associated to the population's economic environment, typically operating on firm's internal routines.

At this point it seems pertinent to recall Hoover's concern about his own investigation on a possible new classical research programme: 'The reader may nonetheless get the impression that it is essentially arbitrary. The propositions convey a real sense of the nature of the new classical macroeconomics, but it is difficult to say that there are not other sets of propositions and injunctions that differ in some points of substance and form that would serve equally well as a description of a new classical program' (Hoover 1991: 366). This difficulty, following Hoover, emerges because Lakatos's approach implies a very sharp division between what is in the programme and what is not. This feature of the Lakatosian framework makes Hoover strongly doubt about the existence of research programmes in that sense.

First, Hoover argues with 'the problem of individuation' as 'How many research programs are there in economics?' (Hoover 1991: 367). As he points, some economists consider the existence of a few competing programmes while others regard each sub-discipline as a research programme. Also, some adopt a broad view, for example assuming neoclassical economics as a big programme, while others have a narrow perspective regarding it as a set of specialized programmes not in direct competition (Hoover 1991). Hoover tries to refute Lakatos's MSRP not only with the difficulty to identify the hard core of a programme irrefutably or to assume the unchangeable nature of it, but also with the arguments that the negative heuristic is not unbreakable and that usually the positive heuristic is not well-defined as to allow the theoretical task it must attain in Lakatos's framework.

The definition of evolutionary economic growth as a research programme is vulnerable to the critics made by Hoover. A first element that sustains the idea of some arbitrariness on the construction of the hard core and the heuristics is the disseminate use of the term 'evolutionary' in economics as stressed by Hodgson (1999). He identifies six principal groups using the term: the Institutionalists in the tradition of Veblen and Commons; Schumpeter's followers; the Austrian School; various writers such as Adam Smith, Marx and Marshall; evolutionary game theory; the Santa Fe

Institute in the USA. As Hodgson (1998) emphasizes, there is not still consensus on what the term 'evolutionary economics' should mean and, at the same time, there is an increasingly use of it. Therefore, it is important to clarify what is the approach behind the employment of the word 'evolutionary': 'nothing is more guaranteed to generate confusion and to stultify intellectual progress than to raise a muddled term to the centrepiece of economic research, while simultaneously suggesting that a clear and well-defined approach to scientific enquiry is implied' (Hodgson 1998: 161).

These varieties of evolutionary economics increase the probability of overlapping programmes. Hodgson highlights this fact by proposing a classification of approaches to 'evolutionary economics' according to four philosophical criteria - an ontological criterion related to novelty; a methodological criterion associated to reductionism; a temporal criterion concerned with gradualism; a metaphorical criterion related to the presence of biological analogies - which gives 16 possible classifications (Hodgson 1998). Dosi et al. (2002) emphasize the overlapping between 'evolutionary' and some 'socio-economic' analyses of the "fabrics and changes of both technological knowledge and economic structures. (…) they all share microfoundations grounded on heterogeneous agents, multiple manifestations of 'bounded rationality', diverse learning patterns and diverse behavioral regularities" (Dosi et. al. 2002: 3).

Faced with the high probability that distinct approaches may be very close in terms of a Lakatosian characterization as 'hard core and heuristics', I think it may be useful to adopt another framework to capture the main characteristics of scientific process within evolutionary technological change and economic growth. Theories of technological evolution such as Metcalfe (1988) and theories of economic growth such as Silverberg (1988) appear to share the elements of the Lakatosian programme. Therefore, the most adequate approach seems to be assuming an enlarged research programme for evolutionary technological change and economic growth. However, even assuming this broad programme, the narrowness associated to the idea of a fixed hard core means that some models widely accepted as evolutionary would be out of the programme. For example, as it was identified above, the hard core involves a proposition that accounts for the typical presence of decision making procedures (understood as bounded by certain elements) on evolutionary economic theorizing. Models as Silverberg et. al. (1988) and Metcalfe (1994) do not have explicit decision rules (though the former has investment procedures) and nevertheless they are still considered as evolutionary.

Also, there are two important lines of research within this field that do not observe many of the heuristics defined for the programme: Freeman (1988) is the crucial reference on 'Innovation systems literature' and Fagerberg (1988) is the benchmark on 'Technological gap literature'. Although this literature assumes as indisputable the propositions identified above as the hard core of the programme, they use different rules to guide their research. Is that sufficient to consider these theories as distinct programmes even sharing the same hard core (and here there is room for bias on the limitation of the hard core itself)? Hoover (1991) recalls that Lakatos is not coherent on this subject as he argues that distinct programmes may have a common hard core, being separated only by their positive heuristics (Hoover 1991: 368). However, Hoover considers this possibility as one more problem to the project of the Lakatosian interpretation of economics since Lakatos supposes that the positive heuristic should be not only partially articulated but also established as to press forward the development of more complex models. Hoover stresses the highly improbability that positive heuristics are partially articulated in the detail demanded by Lakatos as 'neither the scientist nor the commentator can see how models will develop' (Hoover 1991: 368). So, Hoover considers that the positive heuristic usually cannot be well enough defined to be able to satisfy the Lakatosian theoretical task.

Therefore, I will invoke once more Hoover (1991) and his 'Tribe and Nation' point of view for appraising the evolutionary technological change and economic growth in the next section.

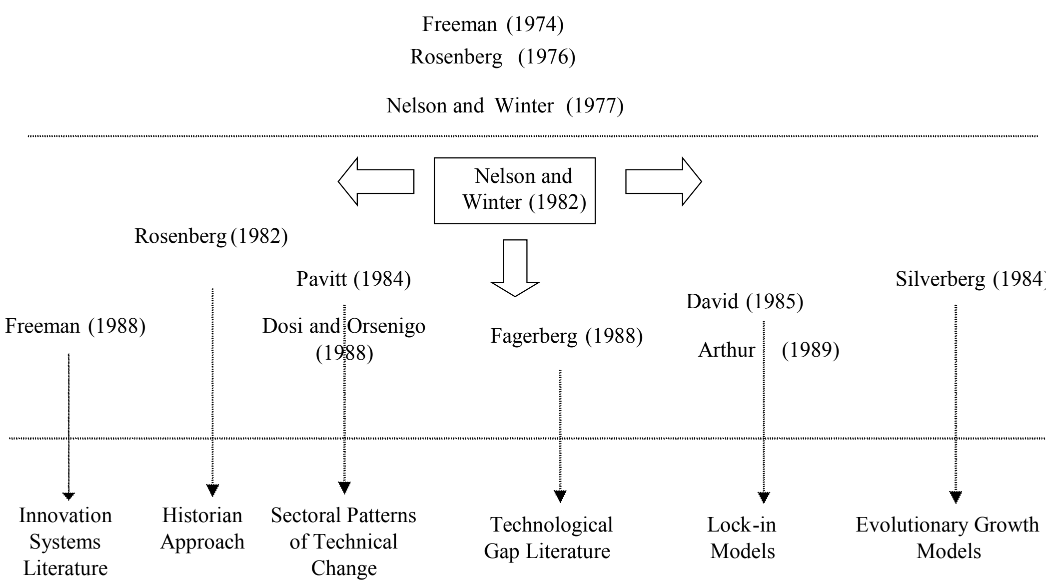
3. Getting Away from Lakatos: Hoover's 'Tribe and Nation' Perspective

Hoover (1991) inspires himself in Kuhn (1970) to propose a distinct method for appraising economic theories: his 'Tribe and Nation' perspective. He stresses that Kuhn identifies the two main meanings associated to the term 'paradigm': 'On the one hand, (paradigm) stands for the entire constellation of beliefs, values, techniques, and so on shared by the members of a given community. On the other, it denotes one sort of element in that constellation, the concrete puzzle-solutions which, employed as models or examples, can replace explicit rules as a basis for the solution of the remaining puzzles of normal science' (Kuhn 1970: 175 quoted from Hoover 1991: 372). The second sense, identified by Kuhn as the deeper of the two, at least in philosophical terms, is not the one usually associated to the term 'paradigm'. Hoover is interested in this second sense which Kuhn latter associated to the word ‘exemplar’, adopting a picture of scientific practice as specific models serving as concrete exemplars. From here Hoover considers that other models may appear only as elaborations or variations of the exemplars; others may borrow crucial assumptions or techniques even if distinct in purpose; some may import only the ‘spirit’ of the exemplar. Hence, scientific practice is conceived as groups of correlated and in some measure overlapping models and practices (Hoover 1991).

An analogy is suggested by Hoover to compare his own perception of science and Lakatos’s MSRP: ‘Lakatos’s methodology of scientific research programs sees science as a collection of nation-states. Each program is defined by its hard core and protective belt – a constitution, and police and military. The negative heuristic defines its borders with a surveyor’s precision, while the positive heuristic stands guard ready to protect the nation from unwanted anomalies or adversarial nation-states. (…) In contrast, the view I advocate sees science as a collection of tribes. Models and theories are united by ties of kinship and consanguinity’ (Hoover 1991: 375).

Hoover uses then what he calls an anthropological metaphor to assess scientific endeavour as a systematic investigation of the relations of kinship and consanguinity among the exemplars of the new classical economics. I will try a similar exercise, using Hoover’s metaphor not as a formal methodology but as a language to investigate for patterns in evolutionary theories. Figure 1 constitutes a tentative step to such an investigation, representing a kind of family tree of evolutionary technological change and economic growth. The entries correspond to papers (or books) seen as important in the development of that field. The goal is not to make an exhaustive list of the literature but as Hoover stresses, to use the papers as exemplars of the most important lines of research within the relevant area. The arrows provide some information about the direction of influence without reproducing the complete interrelationships between the exemplars scheduled. The bottom cells of each column show six families of currently lively research within the *tribe* of evolutionary technological change and economic growth: Innovation systems literature; Historian approaches; Sectoral patterns of technical change; Technological gap literature; Lock-in models; Evolutionary growth models.

Figure 1 – 'Kinship and consanguinity': on evolutionary technological advance and economic growth



The seminal work in this *tribe* is Nelson and Winter's *An Evolutionary Theory of Economic Change* (1982), with links all over it. The book is a synthesis of Nelson and Winter's previous analyses and offers the reference framework to research through the birth of the consanguinity until our days. Andersen et. al. (1996) emphasize that, with this book, Nelson and Winter 'formulated a research programme' (Andersen et. al. 1996: 1), also highlighting that 'the models included in this book were clearly designated to create the outlines of scientific paradigm for evolutionary economics' (Andersen et. al. 1996: 1). Therefore, it seems reasonable to consider that evolutionary technological change and economic growth, strongly lying in Nelson and Winter (1982), is a research programme in a loose sense and is clearly an exemplar.

About the *foundation of the tribe*, the main account appears to be some 'literary fabrications'and not 'folk tales'[5] (Hoover 1991: 379). As a matter of fact, the elements of the *tribe* believe that their origins lie on an earlier age, looking back to authors like Joseph Schumpeter, Armen Alchian and Herbert Simon. Andersen (1997a) helps to sustain this idea when he stresses that Nelson and Winter (1982) have used the

[5] Hoover (1991: 379) develops a brilliant exercise discussing the existence of foundation myths on the basis of every culture and how this idea applies to new classical economics.

computer to make a synthesis of earlier contributions, namely Simon's work on behaviour for sustaining a mechanism of transmission; the developments made by Schumpeter on the study of invention and innovation to construct a mechanism of variety and creation; and Alchian's work on natural selection to conceive the mechanism of selection.

Nelson and Winter (1982) is the reference guide in research within the *tribe* offering at the same time a new modelling strategy which is closely followed by some researchers and an emblematic force for providing some answers, in open terms, to questions such as what is expected of the research, how to behave and how to model. Among those contributions that closely follow Nelson and Winter some are almost stick to their seminal work, presenting extensions to Nelson and Winter' models (Winter 1984; Winter et. al. 2000) while others develop the same type of programmatic approach but introducing distinguishing features. For example, Silverberg started in the 1980s a distinct stream of analysis identified with contributions such as Silverberg (1984, 1988) and Silverberg and Verspagen (1994, 1997a). A particular characteristic of these last models is that they conceive technological progress embedded in vintage capital. Dosi is responsible for another approach, which is based on 'bottom-up' simulations (Chiaromonte and Dosi 1993; Dosi et. al. 1994, 1995). The main purpose of this line of research is to begin with the basic mechanisms of industrial development without making assumptions about the properties of the system and to get the stylized facts of development from the co-working of those mechanisms. Kwasnicka and Kwasnicki (1992) adopt a similar proceeding. At last, several models may be identified as evolutionary and are clearly influenced by the elder elements of the *tribe* but in a more indirect way. Recent contributions that seem to be featured by this type of kinship are, for example, Andersen (1997b) and Windrum and Birchenhall (1998). The first offers a model based on the scheme of structural economic dynamics brought by Pasinetti including an evolutionary microeconomic foundation. The second presents a model with two populations (firms and consumers), which are able to learn about the preferences of each other and to adapt. This adaptive learning is reconciled by technological designs traded on the market. The selection mechanism is based on this adaptive learning capacity of both populations. Still within the 'spirit' of the exemplar (as Nelson and Winter, 1982), Eliasson (1989) develops a simulation model with micro foundation of national economy, calibrated to explain the evolution of the Swedish economy.

Also, once more picking on Hoover, a diachronic analysis can highlight the common origins of the current lines of research within the *tribe* above identified, all of them beginning with Freeman's, Rosenberg's and Nelson and Winter's earlier works.

On the other hand, a synchronic analysis can identify competition between some families such as Technological gap literature and Evolutionary growth models. The first family, strongly drawing on Fagerberg (1988), follows a more appreciative theorizing approach[6] while the second lies on formal modelling procedures usually (but not necessarily) helped by simulation languages. Both families fall inside the *tribe* and both try to answer the question of what can explain economic growth, highlighting the role of technological change. The former emerged as a need to overcome the failure of formal growth theories to recognize the role of innovation and diffusion of technology on economic growth. On one of the topics in recent growth theory's agenda – the convergence of productivity levels – these 'technology gap' theories consider that convergence is provoked by the international diffusion of technological knowledge. Typically the theoretical contributions on this family are appreciative, being very close to empirical work. Also, this literature considers not useful the distinction between 'economic' and 'non-economic' factors for explaining economic growth. It is emphasized the idea of 'social system' composed by distinct 'domains' such as the techno-economic domain and the institutional domain, being crucial the influence between them (Verspagen, 2000)[7]. The later, closely following the initial work of Nelson and Winter, is based on a formal, programmatic approach. As Andersen (1997a) puts it, Nelson and Winter's synthesis gave rise to a new modelling strategy: '(1) Define the minimum environmental characteristics, including input and output conditions as well as the spaces in which search for new rules are performed. (2) Define the state of the industry at time t as a list of firm states, which include physical and informational characteristics as well as behavioural rules and meta-rules. (3) Calculate by means of (1) and (2) the activities of the industry in period t as well as the resultant state variables (including possible changes of rules) which characterize the system at the start of period $t+1$. (4) Make similar calculations for a series of periods and study the evolution of the

[6] Nelson and Winter (1982) suggest two levels of theorizing: formal theory and appreciative theory. The former is conceived as logical and mathematical and the latter is considered as being closer to empirical work, offering guidance and interpretation to it.
[7] Innovation Systems Literature is also a less formal theorizing, focusing on evolution driven by firms and institutions as a process of qualitative change with a historical context.

application of different rules as well as other characteristics of the industry (economy)' (Andersen 1997a: 7).

Having started with Lakatos's MSRP and trying to go beyond that by following Hoover's 'Tribe and Nation' perspective conducted to a more comprehensive picture of what is evolutionary technological change and economic growth. It may be seen as a research programme, although in a more loose sense than in the Lakatosian original interpretation, materialized on the *tribe* of interrelated models of economic growth and dynamics, with most *families* adopting wider scientific processes than the strict tracking of the programmatic approach designed by Nelson and Winter. The table of kinship and consanguinity (figure 1) tries to account for that.

The next section intends to bring in, although in preliminary terms, the discussion around the rivalry between the *tribes* that may have been fighting for the economic growth *territory*. Returning to Hoover's picture there seems to exist a *tribe* that dominates the territory and some others (tolerated by the dominant one? Unquestionably enemies?) that occupy a few *lands* and struggle for their *philosophies of science*. This dominant *tribe*, which has been assimilating many of the physical and mental elements of others located in attractive and fertile sights, is the neoclassical endogenous growth theory. One of the smallest (rebellious? already dominated?) is evolutionary economic growth and technological change.

4. NEOCLASSICAL ENDOGENOUS GROWTH THEORY AS THE RIVAL (DOMINANT) *TRIBE*

Most economists consider a pleonastic verbalization talking about economic growth theory and neoclassical growth theory. When an economist thinks about growth theory usually he has in mind the question: 'what is the balanced, steady-state, long-run equilibrium growth path of an economy, balanced in the sense that all the critical variables in the growth model – output, capital, labour, saving and investment – change at a constant exponential rate into the indefinite future?' This is the case though economies observe more or less continuous structural changes in their sectoral and industrial composition of output, not growing in balanced steady states even for short periods of time (Blaug 2000b: 1).

It is widely known that the theory of economic growth has been dominated by the work of Solow in the 1950s and the subsequent modifications of his neoclassical general equilibrium steady state model. One stream of development within this framework has been the new growth theories that began with Romer and Lucas in the 1980s usually labeled as endogenous growth theory in contrast with exogenous growth theory in Solow's tradition. This description is associated to the fact that seemingly growth is explained in the theory as a product of growth itself, namely as the result of the profit-driven activity of private firms[8], while in the old growth theory technical progress is not itself explained (Blaug 2000b).

The new neoclassical growth models capture several of the understandings about technical advance well recognized by empirical studies developed since the 1950s (Nelson, 1998)[9]. However, the emergence of these new endogenous growth models took place long after the recognizing of technical advance as the key driving force of economic growth. Why this lag of more than a quarter of century?

Nelson (1998) argues that what he calls appreciative theory which interpreted and oriented empirical research on technological change since the fifties 'had a life of it's own, and that, if the researchers did not call attention to discrepancies they found with formal growth theory, no one else was particularly bothered by them. In some cases this required a certain obeisance on the part of the empirical researchers. But the appreciative theory did not presume any tight equilibrium, or perfect competition. If the empirical researchers made no fuss, what the formal theory said had only a minor influence on the empirical research and appreciative theorizing, and *vice versa*' (Nelson 1998: 505). Nevertheless, after some years, the neoclassical growth theory rehabilitated.

[8] Blaug (2000a) sums up the three paths developed to deal with the introduction of profit-motivated technical progress in the standard neoclassical growth model of perfect competition and constant returns to scale. One is based on Arrow's (1962) notion of 'learning-by-doing' which allows for endogenous growth even if homogeneous aggregate production functions are assumed. The other two employ the concept of externalities being first associated to Romer and Lucas: individual agents (firms, labourers) invest in some form of technological change (knowledge generated by embodied investment in R&D in Romer (1986) and by investment on actions as job-training and on more formally educated workers in Lucas (1988)) and the external effects of those investments are added to the inputs of all other firms. Therefore, it is possible to generate endogenous economic growth assuming constant returns to scale to any cumulative factor of production (physical or human capital) in a (perfectly) competitive economy by considering external effects to other firms, industries and countries. A weakness of the models such as Romer (1986) and Lucas (1988) is the omission of a clear microeconomic foundation for the production of knowledge itself, that is, for explaining the way externalities and the decision to invest in technological change take place (Verspagen, 1993). A few years latter, papers like Romer (1990), Grossman and Helpman (1990) and Aghion and Howitt (1992) tried to overcome this limitation and technological change became explained from the perspective of the market structure and price relations. It is now assumed that part of the effects of innovation can be appropriate by some degree of monopoly power and the other part corresponds to external effects. For a detailed review on neoclassical endogenous growth models see Verspagen (1993) or Aghion and Howitt (1998).

[9] Freeman (1982) offers a fine survey of such understandings.

As Blaug (2000b) recalls, many scholars like Solow (1991) consider that the evidence behind the efforts of Romer and Lucas to create the endogenous growth models was the widely recognition in the 1980s that there had been divergence rather than convergence between countries, at least at a global level, while the old growth theory (*à la* Solow) suggested the so-called 'convergence hypothesis'. Though, Romer (1994: 11 quoted from Blaug 2000b: 8) disdained at this idea about the origins of the framework: 'My original work in growth was motivated primarily by the observation that in the broad sweep of history, classical economists like Malthus and Ricardo came to the conclusions that were completely wrong about prospects for growth. Over time, growth rates have been increasing, not decreasing'.

Clearly emerging in the 1980s inside the neoclassical economics, the endogenous growth models searched for inspiration in an earlier past. Blaug points to Allyn Young, Laughlin Currie and Nicholas Kaldor as progenitors of these models. In the early 1920s they advocated already 'the cumulative, self-propelling approach to growth theory' (Blaug 2000b: 9). Also, the ideas that technical advance usually is the outcome of previous investments in R&D or that education reflects itself in human capital were present in economics long before their incorporation in formal models. Nelson (1998) puts great emphasizes on Abramovitz (1952) who, writing a few years before the publication of the Solow model, highlighted the absence at that time of a coherent modern growth theory able to guide research at the empirical level. He understood that economic growth was, on one level, the result of changes in the 'immediate determinants of output' (land, labour, capital), arguing that this level of analysis was not sufficient and that a reasonable growth theory should try to deal with the forces behind the immediate determinants. One of Abramovitz's strong statements was that technical advance explained a very large share of the growth of output, a conviction that would be coherent with latter exercises of growth accounting such as Schmookler (1952), Kendrick (1956) and Abramovitz (1956). For Abramovitz, technical advance emerged largely from investments implemented to promote it, so he already conceived technical advance as endogenous, also recognizing that the investments responsible for new proprietary technology engender as well externalities at least associated to the gain of experience and the widespread of the new ability (Nelson 1998). A final point to highlight the earlier Abramovitz's contributions to economic growth is the way he conceived the relations between technical advance and the growth of other factors: a clear interdependence which was itself a source of economic growth. At this level he stressed the role of enterprises and institutions, identifying modern corporations as crucial actors in technical progress and in the investment at the equipment level. Also, he stated the importance of the broader cultural and institutional factors that constituted the context where the enterprise was inserted, recognizing the importance of political, psychological and sociological forces for understanding economic growth (Nelson 1998).

The focus on Abramovitz and his contributions to economic growth meant to create a background to understand some of the limitations pointed to new neoclassical growth models. Following Nelson (1998) a first critique is that, although these formal models seem more close to economic 'reality' in the sense that they capture at least some of the characteristics of growth strongly enhanced by technical advance, the phenomena they incorporate in analysis 'scarcely represent new insights or ideas' (Nelson 1998: 498). Even faced with the counter-attack by the propellers of these new models based on the conviction that a causal argument is well treated only when it is formally articulated, Nelson still considers relevant to ask what are the gains obtained by the 'formalisation of existing unformalised understandings' (Nelson 1998: 498).

On this point, I think it is essential to recall the importance of formalisation to the emergence and consolidation of modern economic growth as the subsequent work to the Solow model shows. Even being aware, as Nelson stresses, that the work of Solow in the 1950s did not fill an 'intellectual vacuum', it remains unquestionable its main role in the origins of growth theory (Blaug 2000b) and this relevance, as Nelson himself recognizes, is associated to the fact that Solow's analysis "was structured by a 'formal' theory, whereas the theorizing in these earlier pieces was more 'appreciative and looser' (Nelson 1998: 504). Similarly, the formalisation of already existent ideas by the new neoclassical growth models was crucial to the renewed interest in economic growth observed since the mid 1980s.

Therefore, one important part of the agenda for new growth theories seems to correspond to the formalisation of understandings about technical change and economic growth (Nelson 1998). Being so, it may be 'useful to ask why certain ideas have been picked up and formalized and others not' (Nelson 1998: 499). According to Nelson the answer to this question could be the relevance of the understanding as it was the case for the inappropriateness of the assumption of perfect competition when confronted with the features of endogenous technical change. That criterion would mean, in Nelson's perception, that because uncertainty in a Knightian sense is also very important for modelling technical advance and economic growth, the new models should also pursue the task of formalizing this concept; that did not occur[10]. Also, they do not seem attracted to explore the evidence that firms have different capacities and strategies or that national economic institutions, for example the university research system, are crucial determinants of economic growth. For Nelson these ignored issues are the proof that another important part of the agenda of the new growth theory is 'to hold the modelling as close as possible to the canons of general equilibrium theory' and that, as a result of these choices, the new neoclassical contributions are still operating at the first level for understanding economic growth, the level of the 'immediate determinants' (Nelson 1998: 499).

On this topic Blaug (2000b: 12) states that the modelling is "ingenious but it simply reeks with *ad hoc* assumptions that sound plausible and may even be true but we are given no hints of how to discover whether they are in fact true'. This statement is, at a certain extent, recognized by economists operating inside the mainstream on the topic of economic growth. Solow (1991) himself makes the so-called internal critique to the neoclassical growth theory clearly affirming that most of the special assumptions made on these new models (about technology, the nature of research activity or the formation of human capital, among many others) 'have been chosen for convenience, because they make a difficult analytical problem more transparent. There is no reason to assume that they are descriptively valid, or that their implications have significant robustness against equally plausible variations in assumptions' (Solow 1991: 412). Also, Aghion and Howitt (1998: 65) consider as 'quite severe and having nothing to recommend them except tractability' some of the assumptions made to ensure the existence of a steady state with balanced growth. This situation is present not only in the Solow-Swan model with technical change but also in models where technology is endogeneized[11]. These

[10] Even when these new models allow for uncertainty about the future, they treat it as a well-known probability of possible future events. For example, Aghion and Howitt (1992) present a model where the research sector is modelled considering that technological advances are stochastic. They use a Poisson distribution to represent the probability of success of the research efforts meaning that the arrival rate of research success in a given period relies on the intensity of such efforts and on the parameters of the distribution. Although they introduce a stochastic approach to innovation able to capture the perspective of innovation as a search process with an uncertain result, the decision problem to decide on R&D spending level is represented as a patent race with a known probability of draw an innovation as a function of R&D effort (Silverberg and Verspagen 1997b).

[11] For more detail on this topic see Aghion and Howitt (1998).

rigid assumptions eliminate important phenomena from the analysis and the answer to important questions is made only by allegation (Aghion and Howitt 1998). One of the limitations stated by Aghion and Howitt is the lack of attention given to institutions and transaction costs by the neoclassical endogenous growth literature. They also consider that the discard of the representative agent assumption would allow the models to "incorporate the *political dimension* of 'creative destruction'" (Aghion and Howitt 1998: 67). The comments of this nature made by researchers located inside the mainstream seem to subtract relevance to Nelson's perspective about the agenda for this line of research as it appears that at least some economists (seen as neoclassical) are very well aware of the existence of limitations within their research rules and are open to deal with them, benefiting from the insights given by other theoretical approaches or by the empirical work. Nevertheless, the options that have been made by neoclassical (optimal) formal modelling since World War II may give some support to Nelson's view: the choice of the understandings introduced in formal models is very much connected with 'the culture in economics as with the particular power of formal modeling' and the formalisation of more understandings about technical advance and economic growth will be difficult while formal growth theorizing kept constrained to the principles of equilibrium theorizing.

After drawing on some ideas with the purpose of understanding the origins and the present characteristics of the dominant *tribe*, the new neoclassical growth models, let's return to evolutionary theorizing and to the context where its main contributions on the topic of technological advance and economic growth emerged.

The empirical research on growth during the 1950s and 1960s strongly contributed to the recognition of some general features of technological advance: first, important uncertainties were present in the research developed to attain advantage over the current technology, being highly different the associated risks to distinct agents; second, as a result of divergent opinions and insights among experts in a certain field, different entities or organizations promote distinct efforts at each moment, being in competition with each other and with the current technology; third, it is only after the commitment of important resources by the rivals that occurs the definition of the winners and the losers as the outcome of competition. 'These features, together, naturally suggested evolutionary language and led to the development of explicit evolutionary theories of technological advance' (Nelson and Winter 2002: 38). As figure 1 presented in section 3 meant to show, there is a general body of understanding around the idea that technological advance is an evolving phenomenon, which has been growing since Freeman's, Rosenberg's and Nelson and Winter's earlier contributions and is nowadays present in distinct research *families*. Within this *tribe* it is important to highlight three main common features (Nelson and Winter 2002: 39): first, the recognition of the motion of technology and industry structure as a 'co-evolution'; second, 'technology must be understood as involving a body of artifacts, or practice, and a body of understanding. (…) more generally, artifacts, practice and understanding co-evolve'; third, there has been increasing recognition of the range of institutions involved in technological advance.

The 'evolutionary technological advance and economic growth' *tribe* does not believe on the research programme adopted within the mainstream. The *trib*e sees the emergence of the new neoclassical growth models as a corroboration of the failure of the neoclassical rules of research, considering that "these 'new' neoclassical models are 'mechanical' in the same sense as are the old ones. They do not address the problems with neoclassical growth theory felt by the authors of evolutionary alternatives" (Nelson 1995: 68). In these 'new' approaches the conceptual tools are essentially static, for example optimal rationality, production functions and equilibrium systems based on Newtonian mechanical analogies, and it is offered a weakly explanation of the process of technical change (Northover 1999). Therefore, the *tribe* keeps the faith in its scientific endeavour and continues the hostilities against the mainstream even if its domains are narrow, being constrained to some centers of research, specially in Europe, for example, the DRUID, Danish Research Unit for Industrial Dynamics, in Denmark; the MERIT, Maastricht Economic Research Institute on Innovation and Technology, in the Netherlands and the LEM, Laboratory of Economics and Management, in Italy, and to their own specific journals as the Journal of Evolutionary Economics, the Research Policy and the Industrial and Corporate Change.

Since both *tribes* were launched mostly in the 1980s and the neoclassical one had a much stronger impact in the economic science, we may conjecture that the other has already lost the war. However, it must be reminded that endogenous growth models were developed inside the mainstream and that fact sustains for itself an easier acceptance by the economists. Indeed, it is straightforward the conclusion that graduate training in economics emphasizes the neoclassical framework (Nelson 1998). Also, it is much easier to get into the more general and broadly read economic journals formal models, particularly those developed in the optimal and axiomatic neoclassical reasoning.

As well, we may wonder why did not the evolutionary approach visibly take off on a time characterized by the development of molecular biology. Perhaps we could picture a delay on the influence of these most recent developments inside biology to reach the economic sphere, for example in the importation of modelling tools. But most imperative to conceive the development and spread of the *tribe* seems to be the digital computer, although the influence of the computer in developments within economics is very young. Mirowski (2002: 4-5) highlights the rise of the cyborg sciences, which occurred mainly in the USA during the World War II, and its profound effects for the content and organization of natural and social sciences. He stresses the pressure exerted by the current scientific diaspora, caused by the disturbing impact that the end of the Cold War and the associated changes in the funding of scientific research had on physics ('the ubiquitous contraction of physics and the continuing expansion of molecular biology' (Mirowski 2002: 10)), for the beginning of the transformation of economic concepts. 'Increasingly, physicists left to their own devices have found that economics … has proved a relatively accommodating safe heaven in their time of troubles' (Mirowski 2002: 10). As a result of such interdisciplinary research, a different method of economics has emerged, based on a combination between computational languages and institutional themes. This birth resulted from 'the progressive realization that cyborgs and neoclassicals could not be so readily yoked one to another', converging to 'numerous tensions in fin-de-siècle orthodox economics' (Mirowski 2002: 11).

Mirowski's perspective may help to sustain a scenario featured by the strengthening of evolutionary economics, precisely because the development of computational methods has increasingly allowed for dealing with the complexity associated to its open-system approach. In the next section some final remarks are drawn.

5. Final Remarks

This essay was motivated by a need for enlightenment on what is evolutionary technological change and economic growth. The main goal was not to construct a survey but to develop a tentative step towards greater clarification or even towards appraisal of those understandings using as starting point Lakatos's MSRP. This was carried on even if I was (at a certain extent, at least) aware of the problems associated to such procedure such as 'how far the methodology chosen is appropriate for economics' or 'should the methodology explain everything. Would some other methodology, such as Kuhn's paradigms, have performed equally well?' (Backhouse 1998: 3-4).

As it was stated at the end of section 3, this task evolved to a point whereas my reasoning was willing to accept the existence of a research programme on the topic in appraisal but only in a more loose sense than the one offered by Lakatos's original frame. A more complete picture (though perhaps more descriptive and with many ambiguous elements) of the scientific endeavours that constitute evolutionary technological change and economic growth seemed to be achieved with the 'Tribe and Nation' perspective borrowed from Hoover (1991).

After that, the essay intended to introduce some discussion around the competition between the *tribe* until then in study and the neoclassical endogenous growth theory, widely interpreted as the mainstream – the dominant *tribe*. Therefore, on section 4 some considerations were made with three goals in mind: to better understand the origins of both theories, to submit to discussion the problems (widely ignored or neglected by most economists) that characterize what can be also assumed as the 'rival research programme' and the way evolutionists have been *evolving* in this environment.

An appraisal of any of these theoretical approaches – the evolutionary and the new neoclassical – based on the Lakatosian framework would be upsetting. Lakatos argued that a research programme should be appraised according to the way it evolved over time (Backhouse 1998). In the Lakatosian sense a programme is theoretically progressive if predicts novel facts. Since these predictions can be tested they offer a link between theoretical and empirical progress (Backhouse 1997: 103) and so the programme is empirically progressive if the new facts are corroborated. If we understand 'novel facts' as facts of which no one was aware when the predictions were made or facts not used in making the prediction surely the new neoclassical and the evolutionary growth theories should be appraised as degenerating programmes.

Blaug (2000b) develops a discussion comparing the old neoclassical growth theory and the new one that sustains a pessimistic appraisal result for the mainstream approach. He states that it is impossible to choose between these theories, at least as a choice based on arguments of realism or descriptive precision. 'It also turns out (…) that the two theories are observationally equivalent and even their growth-oriented policy implications are virtually identical. Clearly, if we must choose between them, we will have to base our choice on modelling grounds: the simplicity, elegance and tractability of one model over another' (Blaug 2000b: 4). Blaug also affirms that the new neoclassical growth theory has the same defects as the old one. 'A theory of an economy in constant exponential growth, not just in the aggregate but in all its essential components, can only be a mathematical toy, incapable in its very construction of bearing any resemblance to an actual economy' (Blaug 2000b: 13). Based on this judgment Blaug considers that the excitement about the new growth theories took place because they seem 'to explain what was previously left in the dark but, more importantly, it features a brand of theorizing that is at times analytically elegant and at all times analytically demanding. Indeed, much of the literature of the new growth theory is so exclusively preoccupied with the modeling requirements of neoclassical theorizing – (…) – that there is little space left for the consideration of empirical evidence' (Blaug 2000b: 12). Hence, on this point Blaug and Nelson (1998) seem to agree.

For the other *tribe* the conclusions in terms of appraisal are not less disappointing. As Andersen (1997a) stresses there are fundamental intrinsic difficulties within the evolutionary field: the outcome of evolutionary processes has very little predictability, which may block the falsification of evolutionary theorizing and the idea of eclecticism associated to the 'synthetic character of the evolutionary mechanism which forces evolutionary-economic theories to transgress the borders of different social-sciences disciplines' (Andersen 1997a: 2). On this point it may be useful to recall that the prediction power of this theory arises from the specification it does of systematic selection forces present on the dynamic processes (Nelson 1995). Typically evolutionary growth models rely upon stochastic technological change as the driving force of economic growth. The outcome of this stochastic path usually consists, after taking place a selection process, in the possibility of a wide range of economic patterns, with several of them seeming compatible with the stylized facts on economic growth (Silverberg and Verspagen 1997b). However, it is recognized the need for more accuracy on the feasible range of results predicted by these models and for more clarification of the general features of the patterns generated by the simulation procedures. The accomplishment of these needs demands more work on methodological issues such as the standing of simulation trials relative to analytical outcomes and also on the statistical evaluation of the outcomes created by computer simulations (Silverberg and Verspagen 1997b). If such efforts start to be seen as fundamental by evolutionists conducting to a greater ability to predict with accuracy, maybe will see some 'empirical progress' in economics, and if the language used by them becomes more clear maybe some 'theoretical progress' will be achieved (Blaug, 2000a). In such possible development it gains relevance the discussion by Mirowski and Somefun (1998: 1) around the convergence to 'an Automata approach of Institutional (and Evolutionary) Economics' and their expectation that the computational approach 'can foster a viable and rich institutional economics that encourages both mathematical rigor and historical relevance while avoiding the mechanical aspects of conventional neoclassical theory'.

REFERENCES

ABRAMOVITZ, M. (1952), 'Economics of Growth', in B. Haley (ed.), A Survey of Contemporary Economics, vol. II, American Economic Association: Homewood, pp. 132-178.

ABRAMOVITZ, M. (1956), 'Resource and Output Trends in the United States since 1870', American Economic Review, 46 (May): pp. 5-23.

AGHION, P. and HOWITT, P. (1992), 'A Model of Growth Through Creative Destruction', Econometrica, 60 (2): pp. 323-351.

AGHION, P. and HOWITT, P. (1998), Endogenous Growth Theory, Cambridge, Massachusetts: The MIT press.

ANDERSEN, E. (1994), Evolutionary Economics: post-Schumpeterian contributions, London: Pinter Publishers.

ANDERSEN, E. (1997a), 'Evolutionary Economic Development: Elements and Perspectives of Evolutionary Modelling', Readings for the ETIC course, Strasburg, 13-17 October 1997.

ANDERSEN, E. (1997b), 'Escaping Satiation in an Evolutionary Model of Structural Economic Dynamics', Readings for the workshop on Escaping Satiation: Increasing Product Variety, Preference Change and the Demand Side of Economic Growth, Max Planck Institute for Research into Economic Systems, Jena, 11-13 December 1997.

ANDERSEN, E., JENSEN, A., MADSEN, L. and JORGENSEN, M. (1996), 'The Nelson and Winter Models Revisited: Prototypes for Computer-Based Reconstruction of Schumpeterian Competition', DRUID Working Papers, nº 96-2.

ARROW, K. (1962), 'The Economic Implications of Learning-by-Doing', Review of Economic Studies, 29: pp. 155-173.

ARTHUR, W. (1989), "Competing Technologies, Increasing Returns, and Lock-in by Historical Events", Economic Journal, 99 (394), August: pp. 116-31.

BACKHOUSE, R. (1997), Truth and Progress in Economic Knowledge, Cheltenham and Lyme: Edward Elgar Publishing Limited.

BACKHOUSE, R. (1998), Explorations in Economic Methodology: From Lakatos to empirical philosophy of science, London and New York: Routledge.

BLAUG, M. (2000a), 'Is There Really Progress in Economics?', European Society for the History of Economic Thought, Graz, Austria, February 24-27.

BLAUG, M. (2000b), 'Endogenous Growth Theory', Research Memoranda in History and Methodology of Economics, 00-7, Universiteit Van Amsterdam.

CHIAROMONTE, F. and DOSI G. (1993), 'Heterogeneity, Competition, and Macroeconomic Dynamics', Structural Change and Economic Dynamics, 4: pp. 39-63.

DAVID, P. (1985), "Clio and the Economics of QWERTY", American Economic Revue, 75 (2), May: pp. 332-37.

DOSI, G. (1988), 'Sources, Procedures, and Microeconomic Effects of Innovation', Journal of Economic Literature, 26 (3): pp. 1120-1171.

DOSI, G., FABIANI, S., AVERSI, R. and MEACCI, M. (1994), 'The Dynamics of International Differentiation: A Multi-Country Evolutionary Model', Industrial and Corporate Change, 2 (3): pp. 225-241.

DOSI, G., FREEMAN, C., NELSON, R., SILVERBERG, G. and SOETE, L. (eds) (1988), Technical Change and Economic Theory, London: Pinter Publishers.

DOSI, G. and ORSENIGO, L. (1988), "Industrial Structure and Technical Change", in A. Heertje (ed.), Innovation, Technology and Finance, Oxford: Basil Blackwell.

DOSI, G., ORSENIGO, L. and LABINI, M. S. (2002), 'Technology and the Economy', LEM Working Paper Series, 2002/18.

DOW, S. (2000), 'Prospects for the progress of heterodox economics', Journal of the History of Economic Thought, June, 22 (2): pp. 157-170.

ELIASSON, G. (1989), 'Modelling Long-term Macroeconomic Growth as a Micro-based, Path dependent, Experimentally Organized Economic Process', Working Paper, The Industrial Institute for Economic and Social Research, Stockholm, Sweden.

FAGERBERG, J. (1988), 'Why Growth Rates Differ', in Dosi et. al. (1988).

FREEMAN, C. (1974), The Economics of Industrial Innovation, Hammondsworth, England: Penguin.

FREEMAN, C. (1988), 'Japan: A New National System of Innovation?', in Dosi et al.(1988), pp. 330-48.

GROSSMAN, G. and HELPMAN, E. (1990), 'Comparative Advantage and Long Run Growth', American EconomicReview, 80 (4): pp. 796-815.

HODGSON, G. (1998), 'Evolutionary Economics', in J.B Davis, D. W. Hands and U. Mäki (eds) The Handbook of Economic Methodology, Cheltenham and Northampton: Edward Elgar Publishing Limited, pp. 160-164.

HODGSON, G. (1999), Evolution and Institutions, Massachussetts: Edward Elgar Publishing.

HOOVER, K. (1991), 'Scientific Research Program or Tribe? A Joint Appraisal of Lakatos and the New Classical Macroeconomics', in N. de Marchi and M. Blaug (eds) (1991), Appraising Economic Theories: Studies in the Methodology of Research Programmes, Aldershot: Edward Elgar, pp. 364-394.

KENDRICK, J. (1956), 'Productivity Trends: Capital and Labor', Review of Economic Statistics, 38 (August): pp. 248-257.

KWASNICKA, H. and KWASNICKI, W. (1992), 'Market, Innovation, Competition. An Evolutionary Model of Industrial Dynamics', Journal of Economic Behavior and Organization, 19: pp. 343-368.

KUHN, T. (1970), The Structure of Scientific Revolutions, Chicago: Chicago University Press.

LUCAS, R. (1988), 'On the Mechanics of Economic Development', Journal of Monetary Economics, 22: pp. 3-42.

METCALFE, J. (1988), 'Trade, Technology and Evolutionary Change', University of Manchester, mimeo.

METCALFE, J. (1994), 'Competition, Evolution and Capital Markets', Metroeconomica, June, 45 (2): pp. 127-154.

MIROWSKI, P. (2002), Machine Dreams: Economics Becomes a Cyborg Science, Cambridge: Cambridge University Press.

MIROWSKI, P. and SOMEFUN, K. (1998), 'Towards an Automata Approach of Institutional (and Evolutionary) Economics', paper presented at the Fifth International Conference of the Society for Computational Economics, Boston.

NELSON, R. (1995), 'Recent Evolutionary Theorizing About Economic Change', Journal of Economic Literature, 33 (March): pp. 48-90.

NELSON, R. (1998), 'The Agenda for Growth Theory: a Different Point of View', Cambridge Journal of Economics, 22: pp. 497-520.

NELSON, R. and WINTER, S. (1977), 'In Search of a Useful Theory of Innovation', Research Policy, 6 (1): pp. 36-76.

NELSON, R. and WINTER, S. (1982), An Evolutionary Theory of Economic Change, Cambridge MA: Harvard University Press.

NELSON, R. and WINTER, S. (2002), 'Evolutionary Theorizing in Economics', Journal of Economic Perspectives, 16 (2), Spring: pp. 23-46.

NORTHOVER, P. (1999), 'Evolutionary Growth Theory and Forms of Realism', Cambridge Journal of Economics, 23: pp. 33-63.

PAVITT, K. (1984), "Sectoral Patterns of Technical Change: Towards a Taxonomy and a Theory", Research Policy, 13: pp. 343-73.

ROMER, P. (1986), 'Increasing Returns and Long Run Growth', Journal of Political Economy, 94 (5): pp. 1002-1037.

ROMER, P. (1990), 'Endogenous Technical Change', Journal of Political Economy, 98 (5): pp. S71-S101.

ROMER, P. (1994), 'The Origins of Endogenous Growth Theory', Journal of Economic Perspectives, 8, Winter: pp. 3-22.

ROSENBERG, N. (1976), Perspectives on technology, Cambridge: Cambridge University Press.

ROSENBERG, N. (1982), Inside the black-box: Technology and economics, Cambridge: Cambridge University Press.

SCHMOOKLER, J. (1952), 'The Changing Efficiency Of the American Economy', Review of Economic Statistics, 34, August: pp. 214-231.

SILVERGERG, G. (1984), "Embodied Technical Progress in a Dynamic Economic Model: the Self-organization Paradigm", in R. Goodwin, M. Krüger and A. Vercelli (eds), Nonlinear Models of Fluctuating Growth, Berlin, Heidelberg, New York: Springer Verlag.

SILVERBERG, G. (1988), 'Modelling Economic Dynamics and Technical Change: Mathematical Approaches to Self-Organization and Evolution', in Dosi *et. al.*(1988).

SILVERGERG, G., DOSI, G. and Orsenigo, L. (1988), 'Innovation, Diversity and Diffusion: A Self-Organisational Model', Economic Journal, 98: pp. 1032-1054.

SILVERBERG, G. and VERSPAGEN, B. (1994), 'Learning, Innovation and Economic Growth: A Long-run Model of Industrial Dynamics', Industrial and Corporate Change, 3 (1): pp. 199-223.

SILVERBERG, G. and VERSPAGEN, B. (1997a), 'Economic Dynamics and Behavioral Adaptation: An Application to an Evolutionary Endogenous Growth Model', Readings for the ETIC course, Strasburg, 13-17 October 1997.

SILVERBERG, G. and VERSPAGEN, B. (1997b), 'Evolutionary Theorizing on Economic Growth', Readings for the ETIC course, Strasburg, 13-17 October 1997.

SOLOW, R. (1957), 'Technical Change and the Aggregate Production Function', Review of Economics and Statistics, 39, August: pp. 312-320

SOLOW, R. (1991), 'Growth Theory', in D. Greenaway, M. Bleaney and I. Stewart (eds.), Companion to Contemporary Economic Thought, London: Routledge, pp. 393-412.

VERSPAGEN, B. (1993), Uneven Growth Theory Between Interdependent Economies, Aldershot: Avebury.

VERSPAGEN, B. (2000), 'Economic Growth and Technological Change. An Evolutionary Interpretation', ECIS and MERIT, April.

VINCENTI, W. (1990), What engineers know and how they know it?, Baltimore: Johns Hopkins Press.

WINDRUM, P. and BIRCHENHALL, C. (1998), 'Is Product Life Cycle Theory a Special Case? Dominant Design and the Emergence of Market Niches through Coevolutionary-Learning', Structural Change and Economic Dynamics, 9: pp. 109-134.

WINTER, S. (1984), 'Schumpeterian Competition in Alternative Technological Regimes', Journal of Economic Behavior and Organization, 5: pp. 287-320.

WINTER, S, KANIOVSKI, M and DOSI, G. (2000), 'Modeling Industrial Dynamics with Innovative Entrants', Structural Change and Economic Dynamics, 11: pp. 255-29.

Working papers mais recentes

Nº 138	Maria Manuel Pinho, *Political models of budget deficits: a literature review*, March 2004
Nº 137	Natércia Fortuna, *Local rank tests in a multivariate nonparametric relationship*, February 2004
Nº 136	Argentino Pessoa, *Ideas driven growth: the OECD evidence*, December 2003
Nº 135	Pedro Lains, *Portugal's Growth Paradox, 1870-1950*, December 2003
Nº 134	Pedro Mazeda Gil, *A Model of Firm Behaviour with Equity Constraints and Bankruptcy Costs*, November 2003
Nº 133	Douglas Woodward, Octávio Figueiredo and Paulo Guimarães, *Beyond the Silicon Valley: University R&D and High-Technology Location*, November 2003.
Nº 132	Pedro Cosme da Costa Vieira, *The Impact of Monetary Shocks on Product and Wages: A neoclassical aggregated dynamic model*, July 2003.
Nº 131	Aurora Teixeira and Natércia Fortuna, *Human Capital, Innovation Capability and Economic Growth*, July 2003.
Nº 130	Jorge M. S. Valente and Rui A. F. S. Alves, *Heuristics for the Early/Tardy Scheduling Problem with Release Dates*, May 2003.
Nº 129	Jorge M. S. Valente and Rui A. F. S. Alves, *An Exact Approach to Early/Tardy Scheduling with Release Dates*, May 2003.
Nº 128	Álvaro Almeida, *40 Years of Monetary Targets and Financial Crises in 20 OECD Countries*, April 2003.
Nº 127	Jorge M. S. Valente, *Using Instance Statistics to Determine the Lookahead Parameter Value in the ATC Dispatch Rule: Making a good heuristic better*, April 2003.
Nº 126	Jorge M. S. Valente and Rui A. F. S. Alves, *Improved Heuristics for the Early/Tardy Scheduling Problem with No Idle Time*, April 2003.
Nº 125	Jorge M. S. Valente and Rui A. F. S. Alves, *Improved Lower Bounds for the Early/Tardy Scheduling Problem with No Idle Time*, April 2003.
Nº 124	Aurora Teixeira, *Does Inertia Pay Off? Empirical assessment of an evolutionary-ecological model of human capital decisions at firm level*, March 2003.
Nº 123	Alvaro Aguiar and Manuel M. F. Martins, *Macroeconomic Volatility Trade-off and Monetary Policy Regime in the Euro Area*, March 2003.
Nº 122	Alvaro Aguiar and Manuel M. F. Martins, *Trend, cycle, and non-linear trade-off in the Euro Area 1970-2001*, March 2003.
Nº 121	Aurora Teixeira, *On the Link between Human Capital and Firm Performance. A Theoretical and Empirical Survey*, November 2002.
Nº 120	Ana Paula Serra, *The Cross-Sectional Determinants of Returns: Evidence from Emerging Markets' Stocks*, October 2002.
Nº 119	Cristina Barbot, *Does Airport Regulation Benefit Consumers?*, June 2002.
Nº 118	José Escaleira, *A Procura no Sector das Artes do Espectáculo. Tempo e Rendimento na Análise das Audiências. Um Estudo para Portugal*, June 2002.
Nº 117	Ana Paula Serra, *Event Study Tests: A brief survey*, May 2002.
Nº 116	Luís Delfim Santos and Isabel Martins, *A Qualidade de Vida Urbana - O caso da cidade do Porto*, May 2002.
Nº 115	Marcelo Cabús Klötzle and Fábio Luiz Biagini, *A Restruturação do Sector Eléctrico Brasileiro: Uma análise comparativa com a Califórnia*, January 2002.

Nº 114	António Brandão and Sofia B. S. D. Castro, *Objectives of Public Firms and Entry*, December 2001.
Nº 113	Ana Cristina Fernandes and Carlos Machado-Santos, *Avaliação de Estratégias de Investimento com Opções*, December 2001.
Nº 112	Carlos Alves and Victor Mendes, *Corporate Governance Policy and Company Performance: The Case of Portugal*, December 2001.
Nº 111	Cristina Barbot, *Industrial Determinants of Entry and Survival: The case of Ave*, October 2001.
Nº 110	José Rodrigues de Jesús, Luís Miranda da Rocha e Rui Couto Viana, *Avaliação de Pequenas e Médias Empresas e Gestão de Risco*, October 2001.
Nº 109	Margarida de Mello and Kevin S. Nell, *The Forecasting Ability of a Cointegrated VAR Demand System with Endogeneous vs. Exogenous Expenditure Variable: An application to the UK imports of tourism from neighbouring countries*, July 2001.
Nº 108	Cristina Barbot, *Horizontal Merger and Vertical Differentiation*, June 2001.
Nº 107	Celsa Machado, *Measuring Business Cycles: The Real Business Cycle Approach and Related Controversies*, May 2001.
Nº 106	Óscar Afonso, *The Impact of International Trade on Economic Growth*, May 2001.
Nº 105	Abraão Luís Silva, *Chamberlain on Product Differentiation, Market Structure and Competition: An essay*, May 2001.
Nº 104	Helena Marques, *The "New" Economic Theories*, May 2001.
Nº 103	Sofia B. S. D. Castro and António Brandão, *Public Firms in a Dynamic Third Market Model*, January 2001.
Nº 102	Bernard Friot, Bernadette Clasquin & Nathalie Moncel, *Salaire, Fiscalité et Épargne dans le Financement de l 'Emploi et de la Protection Sociale: l'Example Européen*, January 2001.
Nº 101	Paulo Beleza Vasconcelos, *Resolução Numérica de Modelos Macroeconómicos com Expectativas Racionais*, 2000.
Nº 100	Luis David Marques, *Modelos Dinâmicos com Dados em Painel: Revisão da Literatura*, 2000.
Nº 99	Rui Henrique Alves, *Da Moeda Única à União Política?*, 2000.
Nº 98	Paulo Guimarães, Octávio Figueiredo & Doug Woodward, *A Tractable Approach to the Firm Location Decision Problem*, 2000.
Nº 97	António Brandão & José Escaleira, *Trade Policy and Tacit Collusion with Price and Quantity Competition*, 2000.
Nº 96	Sandra Silva & Mário Rui Silva, *Crescimento Económico nas Regiões Europeias: Uma Avaliação sobre a Persistência das Disparidades Regionais no Período 1980-95*, 2000.
Nº 95	José Manuel Moreira, *Ética, Estado e Desenvolvimento Económico. Heterodoxia e Ortodoxia*, 2000.
Nº 94	Rui Pedro Esteves & Fabiano Ferramosca, *O Mecanismo dos Câmbios em Padrão-Ouro. Estabilidade Cambial e Violações dos Pontos de Ouro, 1854-1891*, 2000.

Editor: Prof. Aurora Teixeira (ateixeira@fep.up.pt)
Download dos artigos em:
http://www.fep.up.pt/investigacao/workingpapers/workingpapers.htm

1762 VIRTUS UNITA FORTIUS AGIT 1911