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Labour Decisions and Industrial Dynamics in an Evolutionary Model: A Neglected Modelling Approach

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Abstract

Within evolutionary economics only a few models have dealt with labour issues. Although some evolutionary models consider distinct types of human capital they do not introduce labour market dynamics. Building a computer simulation model which deals with the nature and evolution of the knowledge that guides firms' efforts to improve their "institutional settings," we show that a firm's ability to change this setting is crucial for its survival. Our model sheds new lights on the process of firm survival and labour market. The probability of survival depends on the firm's hiring efficiency, and there is a learning rate which depends on each firm's accumulated non-routine workers. The results seem to imply some 'lock-in' paths. Firms with initially low values of relative non-routine workers have lower chances of survival. However, firms with initially high values of relative non-routine workers will survive if and only if they rapidly improve their hiring efficiency. Therefore, the model proposes a formal mechanism to establish a bridge between macro regularities and micro behaviour which is coherent with well known stylized facts from the labour market.

Keywords: evolutionary, industrial dynamics, learning, labour decisions.

1. Theoretical Background

Neoclassical economic growth theory has been mainly concerned with aggregate models. Conversely, evolutionary economics has mostly focused on micro behaviour, rejecting the notion of representative agents and building on diversity and selection (Nelson, 2004; Carlaw and Lipsey, 2004).

The understanding of economic aggregate growth patterns is a fundamental goal in economic growth theorizing. However, the micro constructions are strongly linked to industrial dynamics and economic growth, and cannot be neglected in this process.

Our intention to understand macroeconomic regularities based on assumptions that are not too far from empirical evidence on individual behaviour and microeconomics, guided

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our choice in terms of the theoretical paradigm relevant for the analysis. We selected the evolutionary economic theory as our reference theoretical matrix. Therefore, the economy is conceived as a complex and evolving system; agents are bounded rational and heterogeneous in almost all their attributes; there are open-ended search spaces and novelty is endogenous; the economy is by definition "out-of-equilibrium" at any time (for example, Nelson and Winter, 1982; Dosi, 1988; Andersen, 1994; Nelson, 1995; Nelson and Winter, 2002). Within this theoretical frame, there are no constraints imposed by equilibrium concerns and endogenous structural change is allowed. Also relevant for our investigation is a strand of literature originating within sociological theory — The Population Ecology of Organizations (Hannan and Freeman, 1977, 1984, 1989). In fact, this theoretical approach provides macro-level explanations for changing rates of organizational populations, focusing on the relations between the population of firms and the environment. According to Hannan and Freeman (1989), the population ecology perspective is interested in describing the variety of organizational forms and in explaining this variety. Therefore, it seems highly pertinent when understandings about industrial evolution and economic growth are under examination.

Both the evolutionary approach and the population ecology theory put selection, together with heterogeneity and variation as the premises for selection, at the core of their argumentation. Moreover, although autonomous and distinct research programmes, evolutionary theory and population ecology of organizations share several convergent points, for example, in terms of the cognitive capacity of economic actors and the importance of path dependency in strategic action (see Durand (2001) and Silva *et al.* (2005)).

Within this broader research context, we seek a formal mechanism to establish a bridge between macro regularities and micro evolutionary behaviour. We believe that such a quest is important even if ultimately it turns out to be just a satisfactory reflection on economic growth and development theorizing.

It is widely recognized that firms are mainly treated as a black-box in neoclassical theory, even though this literature does acknowledge the essential role that firms play in the growth process since they allocate resources among the economy's sectors and promote innovation (Martimort and Verdier, 2003). However, the main perspective adopted by the mainstream conceives firms as simply transforming inputs into outputs and internal constraints are ignored. The most common assumption made in this stream of the literature is that the relations between the elements of the firm are efficiently designed to maximize and redistribute wealth among them. This means that the distribution of intra-firm rents does not run into profit maximization and so has no influence on the growth process. Questions related to the organizational arrangements that sustain the feasibility of productive activities and to the incentive contracts which support the objectives of the firm's members are mostly ignored (Martimort and Verdier, 2003).

The neoclassical mainstream is not insensitive to the questions raised above. As Martimort and Verdier (2003) stress, several recent efforts have been made to build a theory of the firm that puts the organization of the production process and the structure of contractual transactions at the core of the analysis. This theory is particularly interested in the discussion of how agency problems influence the firm's profit, focusing on the consequences several informational problems within the firm can have for its global performances.

These contributions are very important since they show a concern within mainstream economic growth theory to adopt more realistic concepts of the firm in their formal growth models. Nevertheless, by pushing the new insights into the general economic growth framework, they still ignore or only touch superficially on economic structural dynamics. We consider this omission a major flaw in economic growth studies. As Nelson (2004, p. 4) recalls, "Schumpeter explicitly took issue with the tendency of economists, who had fastened on GNP as a measure of an economy's output, to ignore what was happening underneath the macroeconomic statistics. He argued that one could not understand the processes driving economic growth without consideration of what was going on in different economic sectors". Of course, a central component of economic growth analysis is the question of how the economic system "as a whole fits together as it moves over time" and so it is useful to have an aggregate measure of economic production and of the rate of economic growth. However, the analysis must address the very distinct rates of progress across sectors because "the real economy consists of many different economic sectors, and (...) economic growth involved in an essential way the rise of new industries and sectors and the decline of old ones. Creative destruction is not simply about firms, but about industries" (Nelson, 2004, pp. 4, 8–9). Therefore, our research mostly relies on the evolutionary paradigm since it focuses on economic dynamics, with particular relevance for the study of economic growth.

In order to explore this link between macro regularities and micro evolutionary behaviour, we adopt the framework proposed in Dopfer *et al.* (2004), based on a distinct conceptualization of evolutionary economic analysis that sets three analytical domains — micro–meso–macro, instead of the traditional micro–macro division. This framework has the capacity to intersect distinct parts of evolutionary economics. For example, it enables us "to connect evolutionary microeconomic work on organizational learning and adaptation to evolutionary macroeconomic work on, say, institutional coordination or economic growth and development" (Dopfer *et al.*, 2004, p. 268). The concept of a meso trajectory is outlined as the fundamental unit of economic evolution and a meso unit is defined as a "generic rule and its population of actualizations" since knowledge is itself seen as a rule structure (Dopfer *et al.*, 2004: 267).[1)]

This perspective of economics involves dealing with connections between elements that exist both within and beyond the economic system. When the focus is upon a single generic rule and a particular carrier, a "micro" perspective on the rule in its local environment is present. At this specific level, research concerns the "nature of the connective structure between the carriers of the rule, with the efficiency and efficacy of the rule in relation to particular processes, and with the socio-psychological processes that shape the origination, adoption and adaptation and retention of a rule in a carrier. The meso perspective abstracts from that detail in order to focus on the population of rule actualizations." Hence, the meso approach is associated with "matters such as the size of the population and the state of development of the meso units (in terms of what we shall identify as a "three-phase meso trajectory") and the composition of the carrier population" (Dopfer *et al.*, 2004, p. 267).

Therefore, the meso level corresponds to a rule and its population that is made of other levels—micro- and is used to allow the identification and conceptualization of the dynamic building blocks of an economic system. In this framework the macro domain involves an abstraction being studied as a quasi-statistical exercise, not associated with the micro domain in an analytical sense. There is no such analytical connection even if it is possible, in an ex-post statistical logic, to sum micro value added to obtain macro value added. The behaviour of the economic system is still interpreted and understood in terms of micro–meso–macro perspective.

Hence, the micro-meso-macro division proposed in Dopfer *et al.* (2004) emerges as a better way of thinking about coordination and change in economics. These authors propose an economy conceived as an open, complex, and self-transforming system, and understand economic evolution as a process of knowledge growth. Hence, the economy is a complex system of rules that evolves over time, whereas the process by which new

1) Rule structures are defined as bundles of rules that allow complementary relationships with each other and can be studied using network theory (Kirman, 1997; Potts, 2001).

rules originate and are adopted and diffused into an economic system constitutes the driving force of economic evolution. The working systems of rules, which are present, for example, in the division of labour or in an organizational structure, are at the core of the knowledge-based economy.

In terms of economic evolution, both micro analysis, for example, the complex structures of rules that build systems as firms, and macro analysis, such as industries or the whole economy (complex structures of rule-populations), are perspectives built upon a meso view (Dopfer *et al.*, 2004).

Another research avenue we explore with our model emerges from the awareness that both the mainstream neoclassical literature and evolutionary economic theory have ignored or largely neglected the importance of the evolution of "social technologies" in the economic growth process. As Nelson (2004) states, "economic growth needs to be understood as a process driven by the coevolution of physical and social technologies" (Nelson, 2004, p. 15), where "social technologies" is the concept proposed by Nelson to label business practices, organizational forms and institutions in general.

By analyzing the co-evolution of firms' performances and their respective industry, we develop an evolutionary model relating the micro, meso and macro levels of analysis, where the firm is seen as an organization in the sense proposed by Stinchcombe (1965, p. 142): "a set of stable social relations deliberately created, with the explicit intention of continuously accomplishing some specific goals or purposes". We are concerned with institutional choices at the firm level and with how these choices interact with the evolving industrial process. In this context, we adopt the definition of "institution" as "a regularity of behaviour or a rule that is generally accepted by members of a social group, that specifies behaviour in specific situations, and that is either self-policed or policed by external authority." It is important to distinguish between general social rules (sometimes called the institutional environment) and particular organizational forms (sometimes called institutional arrangements). Although organizations can also be thought of as sets of rules, those rules only apply internally. Organizations have constitutions, are collective actors and are also subject to social rules (Rutherford, 1994, p. 182).

In our paper the institutional analysis is based on the choices firms do concerning the characteristics of their workers. Clearly, a formal attempt to work with such a complex system could not deal with the entire universe of firms' decisions. Our option for the decisions regarding the labour market is not arbitrary. In fact, the structure of labour markets or, as Stinchcombe (1965, p. 164) puts it, "institutions or practices by which men are distributed among organizations changes over time and crucially affect the options made by firms. When taking decisions about its workers, firms must deal with the nature of the norms that govern workers, the quality of the competencies which can be recruited and the bases of the motivation to work". Since decisions about labour involve the permanent interaction between distinct human actors, they appear as the main component of what we call firm's "institutional setting". The specificity of labour amongst the firm's inputs is clear as it carries imprinted relations and constitutes the core of the firm's routines. Moreover, as mentioned before, very few models within evolutionary economic literature have dealt with labour issues. Some exceptions are Fagiolo *et al.* (2004) and Tesfatsion (2001). Even if some evolutionary studies consider distinct types of human capital (for example, Carreira, 2004), they do not introduce labour market dynamics. Moreover, our model is designed such that the implications of the firms' behaviour in the respective industry can be explored. Within the micro–meso–macro frame (Dopfer *et al.*, 2004), a single rule implemented in each firm's environment is micro; the rule and its population of actualizations carried on by each firm is meso, with knowledge on these proceedings being conceived as a rule structure; and the industry is macro. Specifically, we aim at answering the following research questions:

1. How does the variety of organizational forms interact with the apparent relative regularity of the institutional environment?
2. How does the firm's ability to change its "institutional setting" influence its survival and shape the industry's dynamics and composition?
3. How do the industry's characteristics in institutional terms influence the behaviour of the firms' population?

In the following section, we present the model and the microfoundations at the firm and industry level. Subsequently (Section 3), the simulation exercise is presented and the results discussed. In the Conclusions we systematize the key results of the research.

2. Baseline Model — Microeconomic Foundations

2.1 Some initial considerations

Our model considers that each firm *i* in a certain industry is associated with one specific "institutional setting" that can or not be relatively close to the industry's institutional frame.[2)] The likelihood of survival for each firm *i* depends on its ability to hire the

[2)] At the micro level, the model is inspired by the model of organizational culture presented in Carrillo and Gromb (2006). This paper intends to show that an organization is more productive if its agents "fit" its culture and that organizations choose agents who are "good fits" but do so in an imperfect way and over time.

suitable workers for its "institutional setting" and on its ability to react to environmental change (which are both connected with the transparency of the institutional environment). The "fitness" of each firm must be defined as a function of such abilities. In formal terms, this would mean a function of the type:

$$Probability\ (firm\ i\ survival) = F\ (firm\ i\ hiring\ efficiency, firm\ i\ reactions\ to\ environment).$$

In our framework firms cannot fully understand the complexity of the economic system. We adopt the concept of bounded rationality (Simon, 1955, 1956; March and Simon, 1958), which appears in opposition to the traditional neoclassical assumption of fully rational agents. Therefore, the decision-makers (in our model, the firms) must simplify the decision actions, adopting a "satisfacing" strategy, that is, a decision-maker will maintain the search until a good enough solution is found: "The player, instead of seeking for a "best" move, needs only to look for a "good" move" (Simon, 1955, p. 108).

Hence, following Simon's contributions on human rationality and decision-making, we assume that firms take decisions based on adaptive expectations, with decisions being revised periodically since their strategies are likely to be inconsistent.

In our model the actors in the economic system are the workers (which also represent the households) and the firms. They are held together by two markets: an output market and a labour market. A single good is produced in the industry. Therefore, there is no difference between the output of the firms in terms of quality. The good is sold and bought in the output market that takes place at the end of each period. Firms supply their maximum output and the output price is determined so it clears the market.

In the labour market we have L workers ($j \in L$) of two distinct types. There are the "routine-workers," $L^R = \{1, \ldots, L^R\}$, corresponding to agents that do not have the capability to deal with activities involving innovative procedures since they lack the minimum attributes to cope with unexpected change. We assume that these workers have attributes that make them "fit" in activities marked by routine or standard procedures. Then, we have the "non-routine workers," $L^{NR} = \{1, \ldots, L^{NR}\}$ and $L = L^R + L^{NR}$. These latter agents have attributes that make them "fit"' in activities where the reaction to change and learning-by-thinking are crucial. Therefore, the non-routine workers have more ability to deal with activities involving problem-solving and task complexity, being highly "fitted" to organizational forms that demand team work and job rotation.[3)] Routine workers are individuals with severe difficulties in adapting to new situations whereas the non-routine ones are highly flexible. Flexibility has been a major topic within the literature on operations management and strategy. In broad terms, we can understand flexibility as an absorber of environmental uncertainty and variability (Gerwin, 1993; DeToni and Tonchia, 1998). Its value lies in offering protection against an unpredictable future, through resources that are fundamentally adaptable as well as constructing a set of routines that allow for a quick reorganization in response to unstable markets (Beach *et al.*, 2000). Whilst sheltering from external disorders may be crucial for survival, an organism must have internal mechanisms to ensure a degree of reliability and coherence when facing environmental change. In reality, total flexibility makes it impossible for the organization to keep a sense of identity and continuity (Weick, 1982; Adler, 1988; Loasby, 1999). Therefore, organizations must deal with a trade-off concerning flexibility and stability, in order to survive but, at the same time, avoid disruption in the continuity of organizational processes.

Our categorization of workers is different from the one usually proposed in the literature as unskilled and skilled workers (e.g., Galor and Tsiddon, 1997), although they are highly correlated. High-skilled jobs require professional or scientific skills at the level of high vocational or university education. Low-skilled jobs are associated with simple, routine tasks which mainly demand the use of hand-held tools and physical effort. In our division, a routine worker can have a higher degree of formal education and even so be unable to react to change. He/she can develop tasks that demand school

[3)] A large amount of psychology literature documents and characterizes the heterogeneity found in the way people react to a change in their environment (see, for example, Harrigton, 1998). In general, a person reacts to his/her environment following some regular behaviour across several circumstances. This pattern of behaviour reflects in part what the person is. He/She may usually change his/her strategies, being flexible in the sense that his/her behaviour is driven by the conditions of the environment. In contrast, a person may be rigid, showing a behaviour that is always close to some fundamental approach, being relatively unresponsive to the current environment. For example, some businessmen adjust their business strategy to new market conditions while others maintain a commitment to the original plans (Rosenthal, 1993; Harrigton, 1998). Within economics and management, several works focused on capabilities of workers and firms to be flexible and on the importance of these features on reaction to environmental uncertainty and on the ability to survive have been recently published (e.g., Lloréns *et al.*, 2005; Kraatz and Zajac, 2001). Moreover, very recent empirical work based on the literature dealing with the relation between organizational design and the capacity for adaptation and learning, putting in evidence distinct workers' features associated with different classes of work organization, have also been released (e.g., Lorenz and Valeyre, 2005; Lam and Lundvall, 2006; Holm *et al.*, 2010). All these works sustain our distinction between the routine and the non-routine workers.

training at a higher level but does not require flexibility in responses, being characterized by monotony, repetitiveness and work constraints. There is a strong correlation between the ability to deal with change and new situations and the degree of professional and scientific skills. In a categorization such as skill versus unskilled it is possible that high-skilled workers are more efficient than low-skilled ones in low-level jobs. In our typology we assume this is not the case. A non-routine worker is less efficient than a routine one if matched with a routinized set of tasks. This occurs because his or her attributes induce spending time looking for innovative procedures, which is a non-profitable behaviour within a routinized and inert activity. Although not standard in the literature, this categorization of routine and non-routine workers is in line with recent empirical work on workers' characteristics and types of work organization, for example Lorenz and Valeyre (2005) and Holm *et al.* (2010). These authors consider distinct organization forms that convey different levels of autonomy, task complexity, learning and problem-solving. Therefore, classes such as the "Learning Model" and the "Lean Model" demand non-routine workers, whereas the remaining classes, the "Taylorist Model" and the "Traditional Model" are associated with minimal learning dynamics, low complexity and low autonomy, that is, with mainly routine workers.

Firms employ labour in a one period contract. Therefore, wages are paid after one period of employment. We have distinct remunerations for each type of workers. For the L^R, unable to react to change, the wage is w^R, and for the L^{NR} the wage is w^{NR}, where $w^{NR} > w^R$. Therefore, on the one hand, there are workers who earn less, representing lower costs to firms, but are incapable of adjusting and so a firm with a high proportion of these workers is much more likely to perish when faced with an unexpected and significant environmental change than those with a higher proportion of L^{NR} workers. On the other hand, the other group of workers receives a higher wage, meaning a higher cost for the firm, but they are flexible and able to quickly adjust to changes. They are crucial for the firm when it has to react to these changes, to avoid bankruptcy or even to enable the firm's growth. Moreover, the level at which firms and production processes call for these types of workers is expected to vary across industries and occupations. Some firms will call for workers who on average are more flexible, innovative, and adaptive than others.

2.2 Model set-up

2.2.1 Firm level

We consider an industry — Ind_t-composed of a certain number of firms in each time period t, $N_t = \{1, 2, \ldots, N_t\}$. Firms are assumed to produce the same homogeneous good, with one production factor, labour, divided into two distinct types of workers.[4] In each period, a firm $i \in N$ produces X_{it} units of the homogeneous good, whose price is $p_{it} > 0$. We assume discrete time periods t, with $t = 0, 1, 2, \ldots$.

Ind_t is characterized by an exogenous institutional environment, which encompasses structural characteristics such as the importance of routine and non-routine workers in the employment structure that underlies the industry, represented by the variable $IInd_t$.[5] We consider that these structural features are pervaded by path dependency and inertia. At time t, each firm i in the industry is marked by a specific "institutional setting" represented by the variable I_{it}. The "institutional fitness" of the firm, at time t, is measured by $|I_{it} - IInd_t|$. The firm decides on a certain set of variables in each period of time:[6]

$$Firm_{it}(L_{it}^{R}, L_{it}^{NR}) \tag{1}$$

where

L_{it}^{R} corresponds to the number of workers associated with routine activities employed by the firm at time t;

L_{it}^{NR} corresponds to the number of workers associated with non-routine activities employed by the firm at time t;

The firm's output level at time t is a function of technological progress, A_{it} and of its workers, L_{it}^{R} and L_{it}^{NR}:

$$X_{it} = f(A_{it}, L_{it}^{R}, L_{it}^{NR}) \,. \tag{2}$$

We start by assuming a Cobb–Douglas production function,[7] with constant returns to scale (CRS)[8] associated with routine and non-routine labour:

[4] In our economy there are no training investments. In addition, we do not endogenize the labour supply in the model, so there are no actions that might contribute to alter the relative number of workers, such as education/training opportunities.

[5] The variable $IInd_t$ corresponds to the "institutional setting" of the industry at time t which is not merely the mean value of the firm-specific values. There are other determinants of this setting, not controlled by firms. In the computational model it will be an exogenous variable.

[6] Because our main aim is to assess the relevance of the mix between routine and non-routine workers for the performance of firms and, thereby, for economic growth, for the sake of simplicity and parsimonious modeling, we assume that capital stocks are equal for all firms and, therefore, ignore this variable in the production function.

[7] We consider that it is realistic to assume that an imperfect degree of substitutability between inputs exists. We assume that each firm has at least one worker of each type at each time t, adopting a certain proportion of L_{it}^{R} and L_{it}^{NR}, with $\alpha_{it} = L_{it}^{NR}/L_{it}^{R}$. Therefore, $\alpha_{it} \in]0, 1[$.

[8] The CRS replication argument is usually a reasonable assumption to make about technologies (Varian, 1992, p. 15).

$$X_{it}=A_{it}\cdot(L_{it}^{R})^{\beta_1}\cdot(L_{it}^{NR})^{\beta_2}\,. \tag{3}$$

where $\beta_1+\beta_2=1$, $\beta_1>0$ and $\beta_2>0$, and A_{it} correspond to the total factor productivity of the technique employed by the firms in each period t. For the sake of simplicity, we start by assuming that $A_{it}=A_{it}\,\forall\, i, t$. Dividing by L_{it}, we obtain the firm's product efficiency per unit of labour, x_{it}:

$$\frac{X_{it}}{L_{it}}=A\cdot\frac{(L_{it}^{R})^{\beta_1}\cdot(L_{it}^{NR})^{\beta_2}}{L_{it}}$$
$$x_{it}=A\cdot\left(\frac{L_{it}^{R}}{L_{it}}\right)^{\beta_1}\cdot\left(\frac{L_{it}^{NR}}{L_{it}}\right)^{\beta_2}$$
$$x_{it}=A\cdot l_{it}^{\beta_1}\alpha_{it}^{\beta_2} \tag{4}$$

where l_{it} represents the stock of routine workers per unit of total labour and the variable α_{it} corresponds to the relative importance of non-routine workers. The firm decides on changes in that ratio, $\Delta\alpha_{it}$, in time period t.

In this framework we consider the assumption that each firm aims to increase its survival probability by narrowing the "institutional fitness," adopting an "institutional setting" that is suitable to the institutional environment (the one that characterizes the industry where they belong). Population ecology theory argues that organizations which are well aligned with the environment will survive and grow, as the rest decline and perish (for example, Jovanovic, 2001). However, this theory considers organizations as complex systems with severe constraints in terms of flexibility and speed of response, that is, as inert systems (Hannan and Freeman, 1984). Such an argumentation, sustained by the existence of "imprinted" characteristics, highly resistant to change, within organizations (Stinchcombe, 1965), embraces the idea that eventually inertia may slow down learning processes and weaken performance. Moreover, even if a firm is well fitted in its environment, it may fall into a "competency trap" if the selection environment changes, since altering its position is not easy and it faces costs of adjustment (Carroll and Hannan, 1999, p. 259). Nevertheless, as discussed in Section 1, our analysis is also grounded in evolutionary economics. Hence, we consider that firms do have the potential to restructure by changing their routines, and so organizations may survive through adaptive behaviour (e.g. Nelson and Winter, 1982). The adjustment is systematic indicating that the firm learns with time how to reduce such a gap by, for example, implementing a more efficient screening of its workers.[9] We consider that each firm learns through the procedures related with the screening of its workers.[10] We may have distinct rates of learning in the screening growth rates for the firms, represented as, for each time period t, ζ_{jt}. To simplify, we assume only two rates of learning, ζ_1 and ζ_2, where $\zeta_1 < \zeta_2$. Firms with a relatively higher proportion of routine workers learn slower (rate ζ_1) whereas firms with a relatively higher proportion of non-routine workers learn faster (rate ζ_2); thus the ability to react to changes in the labour market is relatively higher in the latter firms. It is important to clarify that the speed at which firms learn are distinct and that ζ_{jt} represents the firm's screening learning rate at time t. We have:

$$\begin{cases} \zeta_1 & if\ \alpha_{ij} \leq 0,5 \\ \zeta_2 & if\ \alpha_{ij} > 0,5 \end{cases}$$

A crucial idea within our framework is that in order to efficiently work within the firm's "institutional settings," workers must have certain specific attributes. To acquire these attributes, the employer (the firm) screens the labour market for suitable workers and, furthermore, provides and pays for the enhancement of the required attributes among its workers by hiring the most appropriate workers in the market. The parameter ζ_{jt}, $j = 1, 2$ influences the efficiency of each firm in the screening and hiring procedures.

Since each firm has a set of rules or procedures to implement the screening of labour, it is reasonable to assume that it will learn during this activity. It will analyze its previous experiences so as to change its own perception of the labour market and its needs. Therefore, the measure of the "institutional fitness," $|I_{it} - IInd_t|$, is connected with this learning effect.

More specifically, we consider that firms have distinct degrees of efficiency in their activities of screening and hiring labour (for example, in the detection of adverse selection and moral hazard problems), which we represent as p^{ε}_{it}. Such efficiency improves with time since the firm benefits from its earlier experience. The pace of this learning process is influenced by each firm's learning rate. Additionally, this

[9] Screening corresponds here to firms testing in order to hire the most suitable workers and fire those that do not reach the desired standards. This happens because assessment of work is subject to error, whether random errors or systematic bias. In an institutionalist frame of economics, it is essential to assume that there are tools to measure the quality of work. In recruitment, there are psychological techniques that assist in measuring the skills of job applicants. There are other tools associated with screening, such as the application files of job applicants.

[10] Arrow (1962) stresses that "learning can only take place through the attempt to solve a problem and therefore only takes place during activity" (Arrow, 1962, p. 155).

measure of efficiency depends on the firm's "institutional fitness". We assume that, in a certain moment in time, the greater this gap the smaller this efficiency. In formal terms we have:

$$p_{it}^{\varepsilon}=\left(1-|I_{it}-IInd_{t}|\cdot e^{-\frac{1}{\zeta_{ji}\cdot T}}\right) \tag{5}$$

and $p_{it}^{\varepsilon}\in]0,1[$.

Note that I_{it} — the "institutional setting" of firm i at time period t, is a function of the proportion of types of workers (L_{it}^{R} and L_{it}^{NR}) and other factors that may also determine this setting but are not explicitly considered in our analysis. Therefore, we consider that the "institutional setting" of each firm (I_{it}) is represented by each firm's relative importance of non-routine workers (α_{it}), and by an ex-ante unobservable variable that sums up factors able to influence this setting but which are not controlled by the firm, Ψ_{it}.

More precisely, in each time period t, the variable Ψ_{it} results from the stock of "social capital"[11] measured as the value of the variable at time $t-1$ (approximated by α_{it-1}), the investment made at time t by the firm to improve its own "fitness" in the institutional environment represented by $\Delta\alpha_{it}$, and from an unobservable random variable Ψ_{it}. Note that $\Delta\alpha_{it}$ corresponds to the rearrangement of the proportion of workers through hiring and firing decisions associated with a screening process which appears only in ex-post terms.[12] Formally we have:

$$I_{it}=\Delta\alpha_{it}+\alpha_{it-1}+\Psi_{it} \tag{6}$$

The firm adopts an "institutional setting" that may reflect a set of bureaucratic and rigid norms and procedures (rigid "institutional setting") or a more flexible one marked by a flexible and innovative frame. In the first case, the firm chooses to have more L_{it}^{R} workers than L_{it}^{NR}. In the second case, the L_{it}^{NR} workers are crucial. Parameter α_{it} represents the firm's institutional choices at each time t. It should be noted that the firm has some clues

[11] In our model "social capital" corresponds to a broad interpretation enhancing all the relations that influence personal interaction. Within our model, these relations occur within the firm as an organization. Note that we certainly acknowledge that, despite the huge amount of research associated with the term "social capital," its definition remains somewhat vague (Durlauf and Fafchamps, 2005).

[12] The model deals with firms' different screening efficiencies from an ex-post perspective. Therefore, we do not work in particular with the asymmetries that might have led to such differences, for example adverse selection phenomena. The model does not consider the screening activity per se but the ex-post effects of different screening capacities.

but does not know perfectly the institutional setting of the industry since the agents in the model are bounded rational. Each firm faces a trade-off: it must choose the "better" proportion of workers, knowing that a very low α means low wage costs but low possibilities of adjustment, and that a very high α corresponds to high possibilities of adjustment but also to high wage costs that may not be compensated by the adjustment benefit. The decision is then: what's the "satisfacing" best α for the firm, given the industry's "institutional setting"?

Each firm i has a short-run profit function, π_{it}:

$$\pi_{it} = X_{it} \cdot p_t - c_{it} \tag{7}$$

where X_{it} is the firm's output in period t, p_t is the market price at time t and c_{it} is the cost function.

The costs of the firm depend on the workers' wage (w^R and w^{NR}) and on the "mix" of workers (α_{it}). They also depend on a "transaction cost" associated with the workers' competencies which is defined as $\tau_{it} = \Im(|I_{it} - IInd_t|)$. If the firm has a proportion of labour competencies close to the one that characterizes its environment, this means a lower "transaction cost". If not, this cost rises since the firm will have to, for example, subcontract thinking workers able to react to certain unexpected situations or deal with innovative procedures in industries marked by flexible "institutional settings". On the other hand, a firm within an industry characterized by a rigid "institutional setting" also faces high transaction costs if it has a very flexible "social capital". As a matter of fact, this firm has more costs, not only in the form of wages, but also costs related with the constant search for new possibilities in a very inert environment.[13] Formally, the cost function, c_{it}, is defined as:

$$c_{it} = c(w^R, w^{NR}, \alpha_{it}, \tau_{it}) \tag{8}$$

The wages for both types of workers are defined per worker and we assume that each worker supplies only one unit of labour. As already mentioned, we assume that $A_{it} = A \, \forall i, t$. This means that total factor productivity does not distinguish firms, being irrelevant in the cost function at the firm level. The total cost of firm i at time t is given by:

[13] These transaction costs may also be interpreted as a time delay associated with some "time to build" that firms must spend with their workers before they become productive. The higher the "institutional fitness" of the worker the lower this time delay.

$$c_{it} = (1+\tau_{it}) \cdot \frac{w^R \cdot L_{it}^R + w^{NR} \cdot L_{it}^{NR}}{p_{it}^{\varepsilon}} \tag{9}$$

2.2.2 Industry level

At the industry level, aggregate (real) output, X_t can be computed in each period of time as the sum of the output of all the firms in the industry at that time:

$$X_t = \sum_{i=1}^{N_t} X_{it} \,. \tag{10}$$

We assume that a short-term equilibrium price results from the confrontation of total supply with a constant price-elasticity demand function as in Jonard and Yildizoglu (1999):

$$p_t = \frac{D_t}{(X_t)^{1/\eta}} \,. \tag{11}$$

where $D_t > 0$ is the exogenous demand, η is the price elasticity demand, p_t is the market price and X_t denotes the market supply, all at time t, with $\lim_{X_t \to 0} p_t < \infty$ and $\lim_{X_t \to \infty} p_t = 0$. In each period t, the market price is determined by the equilibrium of the product market as in eq. (11). The number of firms operating in the industry in each time period t, N_t, is determined by the market demand and firm size. Following Carreira and Teixeira (2001), we compute $\bar{X}_t$ as the weighted average output per firm at time t:[14)]

$$N_t = \frac{D_t}{\bar{X}_t} \tag{12}$$

Figure 1 presents a structural scheme of the proposed model.[15)]

Our main goal with the above modelling frame is to explore the implications of firms' behaviour in their respective industry and answer the research questions proposed in Section 1. To achieve this purpose the next stage of our analysis corresponds to the construction of our model in computational terms.

14) In fact, as we will describe on Section 3, the number of firms operating in the industry at each time period t will be kept constant by assuming that the firms that leave the market are automatically replaced by an equal number of firms with characteristics close to the average of the features of the surviving firms in that period.

15) Inspired by Andersen (2001).

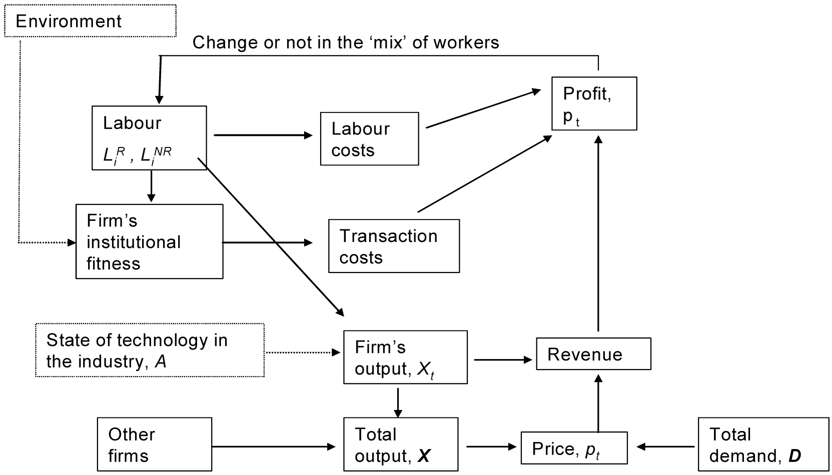

Fig. 1. Structural Diagram of the Model.

3. Simulation Exercise

3.1 Details on the computational model and simulation trials

Our computational model was built in Lsd (the "Laboratory for Simulation Development"), a free-use language for simulation models written by Marco Valente (for example, Valente, 1998; Valente and Andersen, 2002).[16] In a first approach, we have the following implementation stages in the simulation exercise:

1. We solve for the output and profits of firms, and the market price, given the initial position of the "institutional setting" of firms and the institutional environment in the industry at $t=0$.
2. Firms decide to maintain or change their "institutional setting" in the next period, according to the evolution of their profits and their market shares. This decision is materialized in the mix of their workers. If the profits in $t+1$ are higher than in t and, at the same time, the market share in $t+1$ is higher than in t, the firm does not change its mix of workers. Otherwise, the firm changes the mix.
3. After a certain number of runs, given profits, firms undergo a selection process. We define that firms that accumulate negative or nil profits during the last five time steps exit the market. We consider two scenarios concerning the entry of firms:

(a) There is no entry (the results are discussed in Section 3.2.1.);

[16] Lsd is written in C++ and every Lsd model is C++ compiled code.

(b) The firms that leave the market are automatically replaced by firms with features that correspond to the firms' average of survival attributes in that period (Section 3.2.2.). The calibration work was guided by some available literature, for example Andersen (1996, 2001). A synthesis of the initial values employed and possible combinations defined for some relevant parameters are presented in the Appendix. The structure of the simulation model corresponds to one industry, comprising 10 firms. The industry is characterized by its "institutional setting," α_t (proxy for $IInd_t$), which is an exogenous variable, only partially observable by the firms. We do not consider changes in the environment and so $\alpha_t = \alpha$. For simulation purposes, we consider that α, the relative importance of routine and non-routine workers in the employment structure underlying the industry, is equal to 0.5.[17)]

Since the model does not incorporate labour supply determinants, we keep α constant as it corresponds to structural, institutional characteristics that remain remarkably stable over time.[18)] Therefore, the model considers that firms are able to change their "institutional settings" but maintaining the global, exogenous "institutional frame" stable.

In period $t=0$ we have each firm's mix of workers, α_{i0} and profits, π_{i0}. We assume for $t=0$ that all firms have zero profits. In addition, the initial values of each firm's "institutional setting," α_{i0}, were drawn from a uniform distribution in the $]0, 1[$ interval. We also set initial values for the common technology to implement the model (see the

17) Lorenz and Valeyre (2005), in a study based on the 3rd European Survey on Working Conditions in the 15 member states of the EU in 2000, offers one of the first systematic comparison of the adoption of new organizational forms across Europe. The authors stress the idea that phenomena of globalization and intensified international competition are leading to a restructuring of management practices in most European countries, as a way to achieve greater flexibility and cooperation in the workplace. Using factor analysis and hierarchical clustering methods, the authors try to measure the importance of distinct organizational forms in Europe. They conclude that two of their classes, the "Learning Model" and the "Lean Model," which correspond to organizational forms where variables measuring autonomy, task complexity, learning and problem-solving are over-represented, account for, respectively 39% and 28% of total employees. Also for 2000, the two remaining classes of the proposed typology, the "Taylorist Model" and the "Traditional Model," both associated with minimal learning dynamics, low complexity and low autonomy, account for, respectively 14% and 19% of total employees. Since the study is applied to the economy as a whole, and our model only concerns manufacturing, the value of 50% associated with non-routine sets of tasks seems a reasonable feature for the exogenous industrial environment.

18) The characteristics associated to skills and education employment structures are likely to present a high degree of persistence of inertia (see Baron *et al.*, 1996).

Appendix). We set a common fixed amount of labour input for the firms. Therefore, firms differ in the relative composition of this input, hiring non-routine and routine workers in distinct fractions. As it was already mentioned, each firm decides to change its mix of workers through time when facing bad performances. In the computational model the variable AlphaFirm measures the importance of non-routine workers in total workers for each firm,[19] at each time step, assuming values in the interval]0,1[. Since this variable is not completely in firm's control, we consider a normal random event in its computation to represent the influence of factors that also shape the "institutional setting" but are not controlled by the firm.

Each firm decides, according to a certain rule, to change or not the proportion of its workers. The firm's main goal is to improve its "institutional fitness" so as to increase its survival probability. If the decision is to change the action, the firm engages in search procedures to invest in its "institutional setting". This investment requires the presence of non-routine workers since these correspond to the firm's degree of flexibility.

In our simulation exercises we consider that the investment made by firms to improve their "institutional fitness" is governed by a uniform distribution around the relative value of non-routine workers for each firm. Therefore, the amplitude or sensitivity of the changes depends on the relative importance of the flexible, non-routine, more costly, workers.

For the model without the entry of firms, we have considered two main sets in the simulation exercise: a model without learning (NoLearn) and a model with learning (Learn). In the first situation, firms engage in searches for new "institutional settings" when they observe poor performances. However, there is no learning mechanism and we ignore that firms have distinct degrees of efficiency in the activities of screening and hiring labour, that is, we omit the variable p_{it}^{ε} from the model.

In the second case, we have a learning mechanism associated with p_{it}^{ε}. As represented in equation (5), each firm's efficiency in screening and hiring activities improves as time goes by. The pace of improvement of this efficiency depends on each firm's screening learning rate. This latter rate assumes a higher or smaller value according to the relative importance of non-routine workers in the firm. We assume two distinct values for this learning rate, one for firms with $\alpha_i \leq 0.5$ and the other for firms with $\alpha_i > 0.5$, respectively 0.5 and 1.5. In addition, each firm's "institutional fitness" also influences this efficiency measure.

[19] It corresponds to the variable α_{it} in the formal model.

We start by presenting the key results for a model without the entry of firms, with two main sets: NoLearn and Learn. Next, in Subsection 3.2.2, we compare the results obtained for the more realistic set, the Learn Model, in two distinct scenarios: a model without entry and a model with entry of firms.

In order to generate the dynamic properties of the model and study its robustness, we run several simulations of distinct time steps. The model shows robustness[20)] for distinct sets of time step runs, for several seed values[21)] and for several combinations of the parameters and the initial values.

3.2 Simulation Results

3.2.1 NoLearn set vs. Learn set in a model without entry

As could be reasonably expected, the industry's dynamics is different in the two main configurations defined, the NoLearn set and the Learn set.

In the first situation we have a selection mechanism that starts slowly, ending with a duopoly with less than 1000 time steps and a monopoly with 1100 time steps. Differently, the Learn set shows a much more striking selection mechanism at the beginning of the simulation, with the industry ending up with just 2 firms after 10 time steps and 1 firm for 300 time steps. Moreover, the presence of the learning mechanism implies more stability since the industry keeps the 2 most efficient and fitted firms from 10 to 300 time steps.[22)]

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20) It is important, before drawing conclusions based on the output of a certain model, to test whether or not such simulation results are unpredictable. Therefore, it is necessary to test if the observed results occur by chance or simply by the nature of the parametric set-up imposed on the model. This kind of test corresponds to a robustness test, which gives the researcher information about how the model varies according to input values such as initial conditions, parametric values and random (Reichstein, 2003).

21) The seed value influences the simulation if random numbers are used since the computer provides the so-called pseudo-random values which are series of values that appear as if they were drawn from a random function. If the researcher uses the same seed or code he/she has the guarantee that the series obtained are identical. This enables the recreation of (pseudo) random events. Running the simulation for different seed values allows the researcher to analyze the effect of random events. Each of the runs will register random events at distinct time steps and with distinct periodic patterns. When the general outcome of the model seems to be very different from the several runs with distinct seeds the researcher considers the model as being random events un-robust (Valente, 1998). After a systematic analysis, we identified the more relevant parameters for the resulting dynamics of the model and focused on them to develop the sensitivity studies. For more considerations about the processes and techniques associated with the validation and verification of simulation models see, for example, Sargent (1999).

22) Despite the simulation values differing for different pseudo-random values, on average, the general results correspond to those described.

In brief, the learning scenario reveals a more rapid adjustment and more stable conditions in the industry. In the No Learn set the inverse of the Herfindhal Index[23) shows a more or less stable value, whereas in the Learn set the same index shows a reduction in concentration for an initial run of 10 time steps but then reveals only a small increase in concentration in the industry. Accordingly, the empirical evidence shows that the more concentrated industries seem to be characterized by more stable patterns (e.g. Caves and Porter, 1978; Davies and Geroski, 1997; Kato and Honjo, 2005). As Tables 1 and 2 show, the number of firms in the industry depends critically on the learning mechanism. In the scenario with no learning the exit is slow. The industry ends up with two firms for 1000 time steps (not shown in the table). The survival firms are firm 5 and firm 6, with an "institutional fitness" at $T=0$ of respectively 0.513 (very close to the average) and 0.854 (higher than average), respectively. In the second set, the Learn model, the most common trial result corresponds to only two firms remaining in the market for a run of 10 time steps: firm 5 (initial "institutional fitness" of 0.523) and firm 7 (initial "institutional fitness" of 0.659). For the 50 time steps run the same two firms survive. For a run with 300 time steps the industry is marked by a monopoly in almost all the simulations. The survival firm is firm 5, with a final "institutional fitness" of 0.315 (see Table 2).

Both tables show that, on average, the "institutional fitness" of the industry decreases at the beginning of the simulation runs and increases as the simulation runs keep on going.[24) It seems that in the selection phases the firms try to improve their fitness in the industry by choosing an AlphFirm a value close to the average. However, as the firms stand alone in the market, since there is no entry threat, they choose a very low AlphaFirm value because non-routine workers are more costly and firms do not expect any changes in the environment. They assume an inert behaviour in a stable environment. Thesmar and Thoenig (2000), based on past developments in the sociology of organizations, particularly in the contingency theory associated with Burns and Stalker (1961), argue that when the external environment is stable the internal organization is centralized, with the decisions made at the top, based on strict rules and a clear hierarchy

[23) The Herfindahl index corresponds to a measure of the size of the firms in relation to the industry, being computed as the sum of the squares of the market shares. It is a concentration index: an increase indicates a decrease in competition and an increase of market power.

[24) Recall that the industry's feature in terms of institutional setting, represented by the Alpha variable, is exogenous and constant. We are discussing here the evolution of the "institutional gap" for the population of surviving firms.

Table 1. NoLearn Model (No Entry).

Time steps	Number of the firms in the market	AlphaFirm of the survival firms at T=0 and at final T	Final average 'institutional gap' in industry (0.30456 at T=0)
T=10	6	Firm 1 (α_{01}=0.404 and α_{T1}=0.434); Firm 2 (α_{02}=0.312 and α_{T2}=0.286); Firm 3 (α_{03}=0.814 and α_{T3}=0.799); Firm 5 (α_{05}=0.523 and α_{T5}=0.719); Firm 6 (α_{06}=0.854 and α_{T6}=0.641); Firm 7 (α_{07}=0.659 and α_{T7}=0.410);	0.179962
T=50	5	Firm 1 (α_{01}=0.404 and α_{T1}=0.513); Firm 3 (α_{03}=0.814 and α_{T3}=0.414); Firm 5 (α_{05}=0.513 and α_{T5}=0.872); Firm 6 (α_{06}=0.854 and α_{T6}=0.589); Firm 7 (α_{07}=0.659 and α_{T7}=0.740);	0.188290
T=100	4	Firm 1 (α_{01}=0.404 and α_{T1}=0.623); Firm 3 (α_{03}=0.814 and α_{T3}=0.195); Firm 5 (α_{05}=0.513 and α_{T5}=0.437); Firm 6 (α_{06}=0.854 and α_{T6}=0.301);	0.166193
T=300	3	Firm 1 (α_{01}=0.404 and α_{T1}=0.301); Firm 5 (α_{05}=0.513 and α_{T5}=0.153); Firm 6 (α_{06}=0.854 and α_{T6}=0.06);	0.32453
T=500	3	Firm 1 (α_{01}=0.404 and α_{T1}=0.296); Firm 5 (α_{05}=0.513 and α_{T5}=0.100); Firm 6(α_{06}=0.854 and α_{T6}=0.062);	0.353796
T=1100	1	Firm 6 (α_{06}=0.854 and α_{T6}=0.071)	0.429319

of authority (the "mechanicist organization system"). Within rapidly changing environments, the internal organization is much more adaptive and flexible, where decision-making is decentralized (the "organicist organization system"). In our model, with an inert environment, the industry converges to a situation marked by a low number of non-routine workers (more flexible and able to fit in an internal organization such as the "organicist" proposed by Burns and Stalker (1961). The global outcomes show that the firm's ability to change its "institutional setting" is crucial for its survival. This

Table 2. Learn Model (No Entry).

Time steps	Number of the firms in the market	AlphaFirm of the survival firms at T=0 and at final T	Final average 'institutional gap' in industry (0.30456 at T=0)
T=10	2	Firm 5 (α_{05}=0.523 and α_{T5}=0.553) Firm 7 (α_{07}=0.659 and α_{T7}=0.736)	0.106119
T=50	2	Firm 5 (α_{05}=0.523 and α_{T5}=0.528) Firm 7 (α_{07}=0.659 and α_{T7}=0.189)	0.169722
T=100	2	Firm 5 (α_{05}=0.523 and α_{T5}=0.854) Firm 7 (α_{07}=0.659 and α_{T7}=0.228)	0.329301
T=300	1	Firm 5 (α_{05}=0.513 and α_{T5}=0.315)	0.215859
T=500	1	Firm 5 (α_{05}=0.513 and α_{T5}=0.076)	0.412041

ability is represented as a simple action in the computational model. Firms with poor performance in terms of profitability and market share engage in a search for a new configuration of its mix of workers. In a model without a learning mechanism the results seem much more irregular, unstable and with no strong connection to the firm's initial "institutional setting". To explain these results we must recall that when a firm decides to change its mix of workers, it engages in a random search. Therefore, even if the firm's past investments in non-routine workers influence the current choices, there is still scope for each firm to successfully change its "institutional setting". Additionally, we have non-observable, random disturbances which influence the firm's institutional characteristics. It is important to note that, as the simulation runs for different seeds show, the model with a learning mechanism is clearly more random events robust than the model without learning.

These results suggest that the presence of a learning mechanism is particularly striking in terms of the firm's behaviour and the industry's dynamics. As highlighted in our description of the model, the probability of survival depends on the firm's hiring efficiency, which is represented by p_{it}^{ε}, and on the firm's ability to react to environmental changes. This because the simulation results only offer some clues about the impact of the firm's learning and hiring efficiency on the probability of survival. A detailed analysis of the simulation iterations in p_{it}^{ε} (ScreenHire) shows that the survival firms, 5 and 7, were the most efficient, on average and in absolute terms. Tables 3 and 4 show this

Table 3. Time Descriptive Statistics ScreenHire (No Entry).

10 Cases	Average	Variance	Min	Max
ScreenHire 1_1 (6)	0.4185	0.0268803	0.122388	0.6067
ScreenHire 1_2 (6)	0.3935	0.0232631	0.109849	0.5469
ScreenHire 1_3 (6)	0.4828	0.0044371	0.352087	0.5530
ScreenHire 1_4 (6)	0.2887	0.0130640	0.078192	0.4116
ScreenHire 1_5 (10)	0.8016	0.0122708	0.506966	0.8863
ScreenHire 1_6 (6)	0.5782	0.0140175	0.331844	0.6899
ScreenHire 1_7 (10)	0.7262	0.0135778	0.431942	0.8229
ScreenHire 1_8 (6)	0.4348	0.0006993	0.379161	0.4581
ScreenHire 1_9 (6)	0.2906	0.0134186	0.076899	0.4148
ScreenHire 1_10 (6)	0.5501	0.0184940	0.270862	0.6948

for the run with 10 time steps (ScreenHire 1_i reports the value of the variable for each firm i, in the first simulation, and the numbers in brackets correspond to the time step at which the firm leaves the market).

Since the firm's hiring efficiency and its learning rate depend on its accumulated non-routine workers, the results seem to suggest some "lock-in" paths, as seems clear in the fact that the winning firm in the learning scenario is firm 5. Firms with initially low values of α have lower chances of survival. However, firms with initially high values of α will survive if and only if they rapidly improve their hiring efficiency. As mentioned previously, we must not forget that we also have random disturbances affecting the firms' behaviour. In the scenario without learning, chance is definitively more important in running results than in the learning set. At this point, we have results that support the idea that the firms' ability to change its "institutional setting" is crucial to their chances for survival. Therefore, this ability determines the composition and the dynamics of the industry structure. Additionally, the main feature of our industry in institutional terms shapes the behaviour of the firms' population. Indeed, firms' actions depend on their profitability which is influenced by the distance of the firm relative to the industry in what regards institutional features. In addition, the firms' reactions involve changes in these features. In the next figures some information is provided regarding the behaviour and survival paths of firms in the two sets, the NoLearn and the Learn, measured in terms of their profitability and their "institutional fitness," for $T=50$ time steps. It can be clearly seen that the levels of profitability are lower in the NoLearn set in comparison to the Learn scenario. The variance in regard to the evolution of both profits and "institutional fitness" is much higher in the NoLearn than in the Learn model. Moreover,

Table 4, ScreenHire Iteration Values (No Entry).

ScreenHire 1_1	ScreenHire 1_2	ScreenHire 1_3	ScreenHire 1_4	ScreenHire 1_5	ScreenHire 1_6	ScreenHire 1_7	ScreenHire 1_8	ScreenHire 1_9	ScreenHire 1_10
n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
0.122388	0.109849	0.352087	0.0781915	0.506966	0.331844	0.431942	0.379161	0.0768992	0.270862
0.308477	0.293057	0.450339	0.212318	0.706968	0.567308	0.600674	0.453935	0.213293	0.516204
0.414463	0.404989	0.504984	0.29521	0.783265	0.631745	0.72007	0.438219	0.297936	0.577631
0.502871	0.478216	0.534803	0.349288	0.826967	0.667332	0.761279	0.431706	0.351572	0.609966
0.556075	0.528364	0.553049	0.38579	0.856277	0.689886	0.788322	0.447814	0.388981	0.631111
0.606736	0.546911	0.501555	0.411566	0.835653	0.581351	0.800051	0.458104	0.414765	0.694794
n/a	n/a	n/a	n/a	0.86806	n/a	0.812588	n/a	n/a	n/a
n/a	n/a	n/a	n/a	0.877287	n/a	0.822855	n/a	n/a	n/a
n/a	n/a	n/a	n/a	0.886267	n/a	0.720789	n/a	n/a	n/a
n/a	n/a	n/a	n/a	0.86869	n/a	0.803774	n/a	n/a	n/a

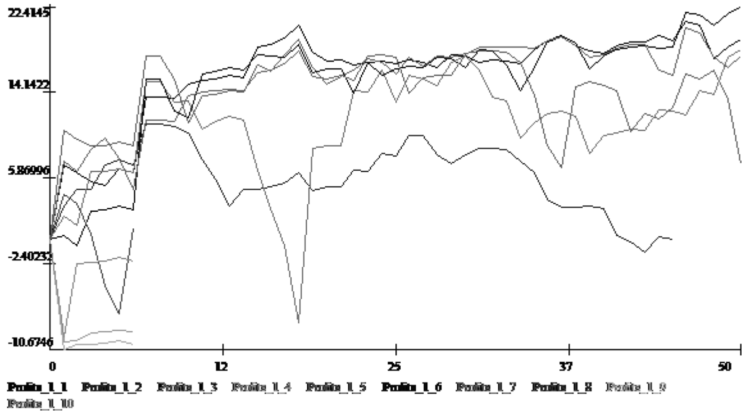

Fig. 2. Evolution of Firm's Profits NoLearn Model (T=50).

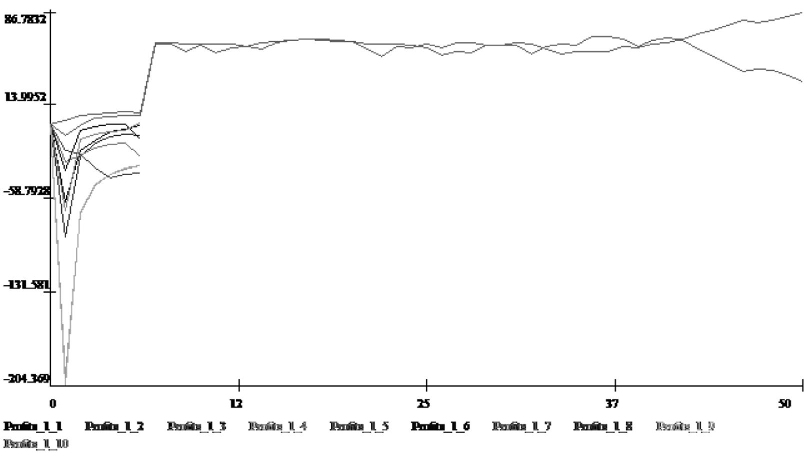

Fig. 3. Evolution of Firm's Profits Learn Model (T=50).

in both sets, the average "institutional fitness" of the industry increases as the trajectory reaches a monopoly. In the next subsection, we introduce the entry of firms in the model and we compare the main results with the situation without entry, for the Learn set.

3.2.2 Baseline model with entry of firms

Entry (like exit) is a very common phenomenon in industries (for example, Mata, 1993; Geroski, 1995). However, in our model the problematic action is not the entry but rather the ability to survive once the firm is in the market. Important regularities in this context are precisely the very high probability that exit follows entry and the evidence that a few

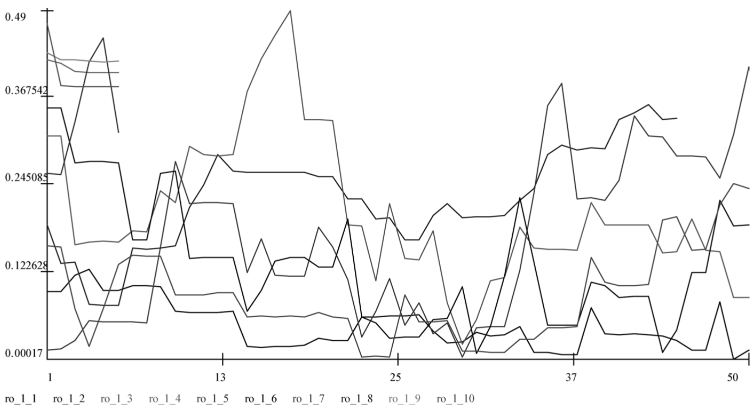

Fig. 4. Evolution of Firm's "Institutional Fitness" NoLearn Model (T=50).

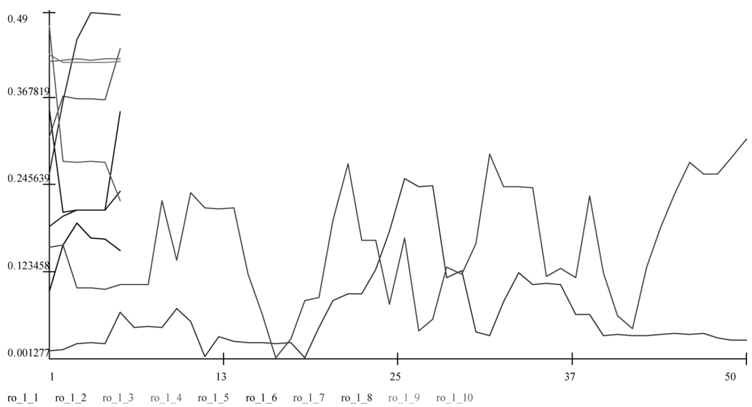

Fig. 5. Evolution of Firm's "Institutional Fitness" Learn Model (T=50).

successful entries require years to catch up with the competitive level of the incumbent firms (Jovanovic, 1982; Geroski, 1995). For example, Jovanovic (1982) argues that there is a selection process in industries with imperfect information, based on the fact that firms have different efficiency levels, and that, as they operate in a certain industry, they learn how to improve those levels. The author argues that the whole entry process in the market is a learning process, through which new firms study its productive efficiency and the adjustment of products to consumers' preferences. Several studies, for example Mata and Portugal (1994), in an analysis of the Portuguese manufacturing industry for the period 1983–1987, conclude that the hazard function exhibits a negative duration dependence, that is, the firm's probability to fail decreases with age. In this subsection we detail a similar, though more realistic version, of that defined in the previous section, considering now the possibility of the entry of firms in the industry. The entry process is considered in the model as an automatic process that allows us to maintain a constant number of firms in the industry.[25)]

The number of firms operating in the industry in each period of time t, N_t, is constant since we assume that the firms that exit the market are automatically replaced by firms with characteristics that correspond to the average of the attributes of the surviving firms in that period. This assumption is coherent with population ecology arguments, namely the dynamic version of Hawley (1968)'s principle of isomorphism, which states that, in equilibrium, "units subjected to the same environmental conditions (. . .) acquire a similar form of organization" (Hawley, 1968, p. 334, quoted from Hannan and Freeman, 1989, p. 13). The dynamic version of this principle stresses the interdependence between organizations, meaning that the success of any strategy for dealing with an environmental feature is likely to depend on the strategies adopted by the other organizations in the system (Freeman, 1982).

A detailed analysis of exit and entry processes falls outside the scope of this paper. However, since both processes are central in discussing the evolution of industrial structures, they are introduced in the baseline model in association with simple assumptions. Therefore, firms leave the market as the result of a selection mechanism based on profitability and market shares. In an evolutionary frame, such a mechanism induces changes in the fitness of the population. The less fit elements die or mutate into new configurations. However, according to the population ecology perspective, there are also inertia phenomena in the population behaviour (for example, Hannan and Freeman, 1977; Hannan and Freeman, 1984). Therefore, the selection process may actually cause the death of the fittest. In addition, the fittest in the short term may be inferior in the long run. The environment is crucial to the global outcome.

[25)] There is an important stream of literature concerning the modeling of entry and exit. In evolutionary economics, there are two broad groups of simulation models. One corresponds to agent-based computational economics, based on the cellular automata approach. The other corresponds to neo-Schumpeterian models, in the line of Nelson and Winter's contributions. Within the second group, the one where our model fits, we have contributions such as Bottazzi *et al.* (2001) where exit is modeled as a simple selection mechanism based on the firm's size, and entry is stochastically modeled as a Poisson distribution where the mean is equal to the number of incumbent firms in the industry. Klepper (1996) introduces entry modeled according to expectations. In Dosi *et al.* (1995), entry depends on the number of incumbent firms, on a parameter that governs the strength of barriers to entry and on random events modeled as a uniform random distribution.

We analyze exits in the common way, examining the characteristics of the surviving firms. In our model, since we consider that the firms' start-up size and technology set[26] are equal, we analyze their "institutional fitness" as a distinctive feature.

Entry vs. No Entry of firms in the Learn configuration

Assuming that learning is taking place, we have less instability in the model with entry than in the model without entry. The industry observes a strong shakeout phase in the NoEntry set, while the initial firms survive much longer in the set with entry. At 50 time steps we have three initial firms, firm 1, firm 2 and firm 5. Moreover, a firm that entered in an early stage ($T=8$, firm 12) is the dominant firm until 458 time steps (Table 5). As the empirical literature shows (for example, Jovanovic, 1982; Mata, 1993; Geroski, 1995), only a few of the entrant firms survive and those successful entries require a long period of time to catch up with the competitive level of the incumbent firms. Therefore, the model with learning and entry seems to fit reality better since the initial firms stay for many time step runs and the surviving ones correspond to those with the highest learning capacity, as the evolution of the ScreenHire computational variable shows (Table 6).

Table 5. Learn Model With and Without Entry of Firms.

Time steps	Number of initial firms in the market		AlphaFirmof the dominant firmat entrant date and at final T		Inverse of the Herfindal Index (8.9 at $T=0$)		Final average 'institutional gap'in industry (0.30455773 at $T=0$)	
	No Entry	Entry	No Entry	Entry	No Entry	Entry	No Entry	Entry
$T=10$	2	7	Firm7 ($\alpha_{0/7}=0.659$ and $\alpha_{T/7}=0.734$)	Firm6 ($\alpha_{0/6}=0.853$ and $\alpha_{T/6}=0.850$)	1.9996	11.0511	0.106119	0.158724
$T=50$	2	3	Firm5 ($\alpha_{0/5}=0.513$ and $\alpha_{T/5}=0.528$)	Firm2 ($\alpha_{0/2}=0.312$ and $\alpha_{T/2}=0.592$) Firm12 ($\alpha_{8/12}=0.681$ and $\alpha_{T/12}=0.656$)	1.8615	9.6598	0.169722	0.202459
$T=100$	2	2	Firm5 ($\alpha_{0/5}=0.513$ and $\alpha_{T/5}=0.824$)	Firm2 ($\alpha_{0/2}=0.312$ and $\alpha_{T/2}=0.675$)	1.9339	9.4504	0.329301	0.204047
$T=500$	1	0	Firm5 ($\alpha_{0/5}=0.513$ and $\alpha_{T/5}=0.076$)	Firm33 ($\alpha_{247/33}=0.404$ and $\alpha_{T/33}=0.398$)	1	9.8409	0.412041	0.127712

26) Mata and Portugal (1994) identify some crucial factors influencing firms' survival rate: the start-up size, the number of establishments by firm, industry specific characteristics such as the growth rate.

Table 6. Time Descriptive Statistics ScreenHire With Entry.

50 Cases	Average	Variance	Min	Max
ScreenHire 1_1 (50)	0.8142	0.029217	0.122388	0.9630
ScreenHire 1_2 (50)	0.7523	0.024937	0.109849	0.9634
ScreenHire 1_3 (41)	0.6477	0.016144	0.352087	0.9072
ScreenHire 1_4 (5)	0.2508	0.010065	0.078192	0.3589
ScreenHire 1_5 (50)	0.6639	0.002875	0.506966	0.8619
ScreenHire 1_6 (10)	0.5285	0.008339	0.331844	0.6331
ScreenHire 1_7 (9)	0.5462	0.006526	0.431942	0.6495
ScreenHire 1_8 (15)	0.5916	0.008023	0.379161	0.7086
ScreenHire 1_9 (5)	0.2674	0.012719	0.076899	0.3928
ScreenHire 1_10 (20)	0.6135	0.017534	0.270862	0.7854
ScreenHire 1_11 (24)	0.6955	0.044916	0.000000	0.9111
ScreenHire 1_12 (46)	0.7878	0.024224	0.000000	0.9384
ScreenHire 1_13 (42)	0.7255	0.023005	0.000000	0.8988
ScreenHire 1_14 (38)	0.6796	0.024791	0.000000	0.8774
ScreenHire 1_15 (36)	0.7924	0.024769	0.000000	0.9324
ScreenHire 1_16 (31)	0.7848	0.026777	0.000000	0.8945
ScreenHire 1_17 (23)	0.7102	0.041717	0.000000	0.8999
ScreenHire 1_18 (10)	0.5644	0.041547	0.000000	0.7078
ScreenHire 1_19 (4)	0.4812	0.084641	0.000000	0.7193

In the model with entry, the "institutional fitness" of the industry, on average, substantially decreases, reaching a much lower value than the one that initially featured the population of firms.[27)] Therefore, the selection mechanism strongly contributes to improving the "institutional fitness" of the population in this set. In contrast, the simulation results for the set without entry, as the market converges to a duopoly or a monopoly, show a higher "institutional fitness" for the survival firms than the one that characterizes the initial population (see Table 5). This pattern is coherent with the literature that considers the entry threat as an important pressure on the incumbent firms. As Eliasson states, the entrance of new firms has immediate effects in terms of the competitive levels of the economy since it forces the firms in activity to reorganize, that is, to innovate in organizational and technological terms, or to foreclose and leave the market (Eliasson, 1996, 1997; Eliasson and Taymaz, 2000).

In the scenario without entry the few surviving firms adopt an inert strategy, represented by hiring a very small relative number of non-routine workers (flexible but

27) Recall that the institutional feature of the industry, represented by the Alpha variable, is exogenous and constant in the model. Therefore, it is not influenced by the entry and exit processes.

more expensive), in a completely stable environment, in consistency with the reasonings postulated by population ecology theory, which argues that firms are marked by structural inertia (for example, Hannan and Freeman, 1989).

The global outcomes show that in both entry scenarios, as we have already observed for the NoEntry set in Subsection 3.2.1, the ability of firms to change their "institutional settings" is determinant for their survival. This capacity is connected to the learning process that characterizes the firms' internal organization. Similarly to the procedure employed in the scenario without entry, we report the simulation iterations in p_{it}^{ε} (ScreenHire), which show that, in the model with entry, the initial surviving firms, 1, 2 and 5, were the most efficient among the initial population of firms. Table 6 shows this for the run with 50 time steps (ScreenHire 1_*i* reports the value of the variable for each firm i, in the first simulation, and the numbers in brackets correspond to the time step at which the firm leaves the market).

Economic growth rates (calculated as the growth rates of the real total output per worker) have very low and steady average, long-run values, as expected since technological progress does not exist and the technical level is exogenous in the model. The simulated aggregate output series reveals a very low self-sustained growth characterized by wide and persistent fluctuations. We may define this result, in an inert environment, as a stable evolutionary pattern.

The following figures depict some information concerning the behaviour and survival paths of firms in the scenario with entry, measured in terms of their profitability and their "institutional fitness," for $T=50$ time steps. Comparing Fig. 6 with Fig. 3 above

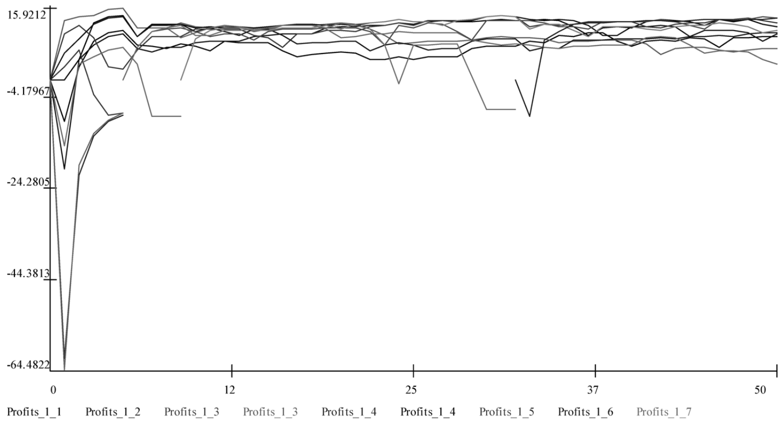

Fig. 6. Evolution of Firm's Profits Learn Model With Entry (*T*=50).

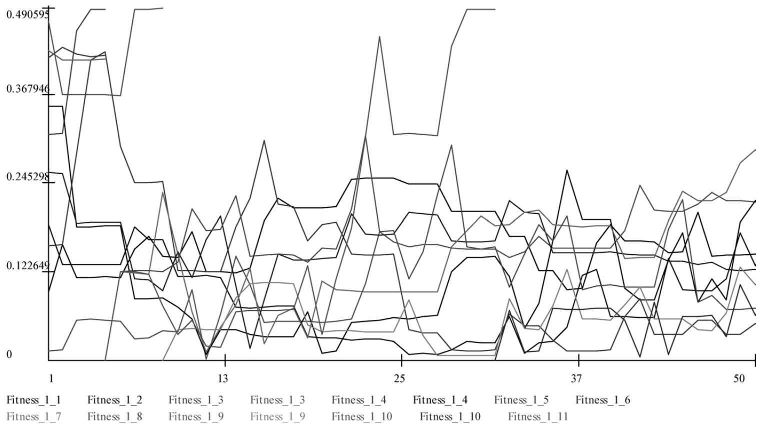

Fig. 7. Evolution of Firm's Profits "Institutional Fitness" Learn Model With Entry (*T*=50).

(Subsection 3.2.1), we can confirm that profit levels are lower in the scenario with entry than in the set without entry. Furthermore, by matching Fig. 7 with Fig. 5 (Subsection 3.2.1), we verify that the surviving firms have closer "institutional settings" in the situation with entry than in the no entry configuration, reaching a relatively lower final average "institutional fitness".

4. Conclusion

Within evolutionary economics, we cannot talk about a definite and exclusive microfoundation for aggregate processes. Instead, we must understand the importance of interactions, of upward and downward causation, between multiple levels that build the economic system. The ecology population of organizations appears as a relevant and complementary theoretical branch for our research since it offers macro explanations for the interactions between the population of organizations and their related environment. In order to account for this conception of changes in an economic system as associated with multi-level dynamics of connections, we followed the micro–meso–macro frame proposed by Dopfer *et al.* (2004). Within this frame, we proposed a model that allowed us to draw important implications. The results showed that firms' ability to change their "institutional setting" is crucial for survival. In a model without a learning mechanism the results showed significant turbulence in terms of exit and entry of firms, and no significant connection with the firms' initial "institutional settings". In the model with learning, the outcome was more stable, with the initial firms surviving for longer periods of time. Hence, the results seem to suggest that the presence of a learning mechanism is particularly striking with regard to the firms' behaviour and industrial dynamics. The probability of survival depends on the firms' hiring capacity and ability to react to environmental changes. Since the firms' hiring efficiency and their learning rates depend on their accumulated non-routine workers, the results seem to suggest some "lock-in" paths. The choices in terms of the "institutional setting" made by firms in the model have to do with hiring and firing decisions and the firms' screening capacities. The accumulation of each firm's social capital, a firm-idiosyncratic knowledge, is embodied in workers, and is highly influenced by the decisions of the firms in terms of job creation and destruction. The way firms organize their workers, choosing to have more non-routine or more routine workers, by changing their profitability and market shares, influences the aggregate performance of the industry. At the same time, the environment in which the population of firms is integrated influences the firms' choices. The agenda for future research certainly includes the challenging search to match with real world information in order to study labour and social change in terms of occupational structures and the dynamics of firms. This certainly demands a deeper reflection on human behaviour and the categorization of workers and occupations.

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Appendix

Object Structure

Root → Industry → Firm

Object Industry (total instances=10): parameters and initial values

Table 7.

Object Firm (total instances=10): parameters and initial values

Table 8.

Table 7. Object Industry Initial Values.

Label	Initial Values
Dem_Coeff (P)	150
Dem_Elast (P)	1.0
Alpha (P)	0.5

Note: In Tables 7 and 8 the letter "P" in brackets means that the respective label corresponds to a parameter in the model. The labels that correspond to variables have in parentheses an integer that denotes the lagged time associated with each of the variables.

Table 8. Object Firm Initial Values.

Label	Firm1	Firm2	Firm3	Firm4	Firm5	Firm6	Firm7	Firm8	Firm9	Firm10
Profits (1)	0	0	0	0	0	0	0	0	0	0
Profits (2)	0	0	0	0	0	0	0	0	0	0
Profits (3)	0	0	0	0	0	0	0	0	0	0
Profits (4)	0	0	0	0	0	0	0	0	0	0
Beta1 (P)	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
Beta2 (P)	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7
WR (P)	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
WNR (P)	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
A (P)	0.368	0.368	0.368	0.368	0.368	0.368	0.368	0.368	0.368	0.368
AlphaFirm (1)	0.404334	0.311681	0.814229	0.0777613	0.512565	0.853656	0.658692	0.761495	0.0682124	0.972433
LT (1)	50	50	50	50	50	50	50	50	50	50
MShare (1)	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1

Note: In Tables 7 and 8 the letter "P" in brackets means that the respective label corresponds to a parameter in the model. The labels that correspond to variables have in parentheses an integer that denotes the lagged time associated with each of the variables.