

## An evolutionary model of firms institutional behavior focusing on labor decisions

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# **An evolutionary model of firms' institutional behavior focusing on labor decisions**

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## **Abstract**

The understanding of the economy's aggregate growth patterns is a fundamental objective of economic growth theorizing. However, the micro constructions are strongly linked to economic growth and so cannot be neglected in such process. This paper is concerned with this problem, proposing a formal mechanism to establish the bridge between macro regularities and micro evolutionary behavior.

Within a micro to macro or bottom-up perspective, the adopted approach is focused in the influence of firms' 'institutional settings' on economic growth and in the industry dynamics that lies behind more aggregate behaviors. The analysis associates such settings to firms' labor choices in terms of hiring/firing policies and to their screening capabilities.

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

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were able to draw some important implications. The results show that firm's ability to change its 'institutional setting' is crucial for its survival. In a model without a learning mechanism the results show significant turbulence in terms of exit and entry of firms and no significant connection with firm's initial 'institutional set'. In the Learn Model the outcome is much more stable, with the initial firms surviving for long periods of time. Results also suggest that the presence of a learning mechanism is particularly striking in what concerns firm's behavior and industry's dynamics. The probability of survival depends on firm's hiring efficiency and on firm's ability to react to environmental changes. Since firm's hiring efficiency and its learning rate depend on its accumulated non-routine workers, the results seem to imply some 'lock-in' paths. Firms with initial low values of relative non-routine workers have lower chances of survival. However, firms with initial high values of relative non-routine workers will survive if and only if they rapidly improve their hiring efficiency.

Keywords: evolutionary, industrial dynamics, learning, labor decisions

JEL-Codes: D21, D8, L2, J2

## 1 Introduction

Neoclassical economic growth theory has been mainly concerned with aggregate models. Conversely, non-orthodox theoretical streams, such as evolutionary economics, have been strongly concerned with micro behavior, rejecting the notion of representative agents and building on diversity and selection.

It is clear that the understanding of the economy's aggregate growth patterns is a fundamental objective of economic growth theorizing. However, the micro constructions are strongly linked to economic growth and so cannot be neglected in such process. Therefore, there is a fundamental problem here concerned with the relation between the observed macroeconomic behaviors and the microfoundations.

Our main research goal concerns the above fundamental problem, seeking for a

formal mechanism to establish the bridge between macro regularities and micro evolutionary behavior. This research goal is also pointed out in Carlaw and Lipsey (2004). However, their approach is a macro to micro one and ours is the inverse, a micro to macro or bottom-up perspective.

Our investigation involves in a first stage the analysis of the co-evolution of firms' performances and of their respective industry. In a later stage, we intend to study such co-evolution considering the aggregate economy. We want to stress in particular the firms as heterogenous organizations, with distinct 'institutional settings', which evolve over time building the firms' 'social capital', in a context where structural dynamics is at the core of analysis. Therefore, our research is particularly concerned with institutional choices at the firm level and with how such choices interact with the evolving industrial process. More particularly, the model presented below associates such settings to firms' labor choices in terms of hiring/firing policies and to their screening capacities.

To achieve such purpose we develop a model which deals explicitly with the nature and evolution of the knowledge that guides firms' efforts to improve their institutional settings. As Nelson (2004) emphasizes, even the evolutionary economic literature has mainly neglected the evolution of organizational forms, and institutions more generally. These variables, labeled in Nelson (2004) as 'social technologies' are a crucial part of the economic growth process since 'economic growth needs to be understood as a process driven by the coevolution of physical and social technologies' (Nelson (2004), p. 15). The formal analysis of firms' choices in terms of their institutional settings is focused on the labor market.

We propose a model to explore the implications of firms' behavior in the respective industry. Although the simulation exercise is still preliminary, at this stage of our investigation we want to answer the following research questions:

1. How the variety of organizational forms interacts with the apparent relative regularity of institutional environment?
2. How firm's ability to change its institutional settings influences its survival and shapes industry's dynamics and composition?

3. How do the industry's characteristics in institutional terms influence the behavior of the firms' population?

The paper is structured as follows. After this introductory part, Section 2 critically reviews the pertinent literature and systematizes the gaps to be explored. In the following section we detail the basic model and the microfoundations at the firm and industry level. Subsequently (Section 4), the simulation exercise is detailed and the results discussed. In Conclusions we present the key results of the investigation.

## **2 A critical review of the literature. Gaps to be explored**

Neoclassical economic growth theory has been mainly concerned with aggregate models. Conversely, non orthodox theoretical streams such as evolutionary economics have been strongly concerned with micro behavior, rejecting the notion of representative agents and building on diversity and selection (Nelson (2004), Carlaw and Lipsey (2004)).

Our commitment towards the understanding of economic growth as based on assumptions that are not too far from what the empirical evidence shows about individual behavior and the microeconomics guided our choice in terms of the theoretical paradigm relevant for the analysis. We select the evolutionary economic theory as our reference theoretical matrix. Therefore, in our analysis the economy is conceived as a complex and evolving system; agents are bounded rational and heterogeneous in almost 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 such theoretical frame, there are no constraints imposed by equilibrium concerns and it is allowed endogenous structural change.

Nonetheless, one strand of literature born within the sociological theory - The Population Ecology of Organizations (Hannan and Freeman (1977), Hannan and Freeman

(1984), Hannan and Freeman (1989)) - is also relevant to our investigation. Particularly important to the consideration of this theoretical approach was the awareness that it provides macro-level explanations for changing rates of organizational populations, being focused on the relations between the population of firms<sup>1</sup> 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 appears mostly pertinent when understandings about industry evolution and economic growth are in investigation.

In Tavares Silva *et al.* (2004) we explore the existence of several convergent points between evolutionary theory and population ecology of organizations, for example in terms of the cognitive capacity of economic actors and of the importance of path-dependency in strategic action. It is interesting to stress here that both the evolutionary approach and the population ecology theory put selection, with heterogeneity and variation as the premises for selection, at the core of their arguments. As Durand (2001) points out: 'The ecological perspective focuses on the way in which *various strategies* fit in with an environment that selects for or against these strategies by encouraging foundings and discouraging failures' (Freeman (1995), p. 222 quoted from Durand (2001), p. 395). Evolutionary economics 'place major emphasis on the *heterogeneity* of the population of business firms and on the sources of that heterogeneity in the idiosyncratic internal features of individual firms' (Winter (1995), p. 147).

Having identified our major theoretical references, it is important to sustain our investigation approach. It is clear that the understanding of the economy's aggregate growth patterns is a fundamental objective of economic growth theorizing. However, the micro constructions are strongly linked to economic growth and so cannot be neglected in such process. Therefore, there is a fundamental problem here concerned with the relation between the observed macroeconomic behaviors and the microfoundations.

In the present research we seek for a formal mechanism to establish the bridge between macro regularities and micro evolutionary behavior. We think that such quest

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<sup>1</sup>For Hannan and Freeman (1984), a population of firms is a group of organizations sharing a common dependency on their material and social environment and on the resources they can attain.

is important even if it ends just as a satisfactory reflection on economic growth and development theorizing. As a matter of fact, although an approach based on appreciative theorizing in the sense proposed by Nelson and Winter (1982) is important for exploring a new area since it helps establishing an agenda for empirical and theoretical research, its wide flexibility allows a great number of ways of reducing complex phenomenon. Therefore, formal theoretical efforts are important to the building of a common language that helps communication between researchers in the area and offers a standard interface towards researchers, economists in general and policy makers (Andersen (1998)).

With a complementary line of research, Carlaw and Lipsey (2004)'s macro to micro approach tried 'to build a macro model of GPT-driven growth and then *amend it incrementally to incorporate an increasing number of evolutionary characteristics*' (Carlaw and Lipsey (2004) (p. 3)). We consider that these attempts are particularly motivating since, as highlighted by these authors, 'when something new is being attempted, there is value in having many different attacks on the same problem' and such distinct approaches may be understood as 'complementary and not as competitive'(Carlaw and Lipsey (2004) (p. 3)).

Moreover, whilst the contribution made in Carlaw and Lipsey (2004) stresses the role of General Purpose Technologies (GPT) on economic growth, our approach intends to deal mainly with the influence of institutional settings on such process, particularly within the firm, and with the industry dynamics that lies behind more aggregate behaviors.

It is widely recognized that firms are mainly treated as a black-box in neoclassical theory even if this literature recognizes the essential role that firms have 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 such 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 intrafirm 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 supports the objectives of the firm's members are mostly ignored (Martimort and Verdier (2003)).

As it is obvious, the neoclassical mainstream is not insensitive to the above questions. As Martimort and Verdier (2003) clearly stresses, microeconomics, and they mean here the mainstream micro, has recently made several efforts 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 analysis. This theory is particularly interested in the discussion of how agency problems influence the firm's profit, focusing on the consequences of several informational problems within the firm on its global performances.

It is not surprising that, within the neoclassical equilibrium mainstream perspective, 'a natural research program then is to embed the insights of agency theory into the general equilibrium environment of growth theory' (Martimort and Verdier (2003), p. 622).

As an example of the above research program we have the approach developed in Martimort and Verdier (2003) that consists in an attempt to deal with intrafirms incentives and growth. They pick the endogenous growth model proposed by Aghion and Howitt (1992) to illustrate such interactions. The later work presents a two-way interaction between the growth process and the internal organization of the firm. Acemoglu *et al.* (2003) also deals with the internal organization of firms and economic growth within neoclassical endogenous growth theory. The paper explores the differences in the organization of firms between technological advanced societies and those that are technologically relatively backward. This study is built on the trade-off associated to firms' options of outsourcing and vertical integration, following previous contributions on this theme such as Aghion and Tirole (1997) and Grossman and Hart (1986).

The above mentioned 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, they still ignore or treat in superficial terms economic structural dynamics. We consider this omission as a major



in economic growth studies. As Nelson (2004) 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' (Nelson (2004), p. 4). Of course, a central part 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 perspective adopted must be different from the one that has been characterizing general equilibrium theory since the basic research questions and the mechanisms of microeconomics must treat 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, we rely mostly on the evolutionary paradigm to our research since one of the most important advantages of such theoretical frame is that it is focused on economic dynamics. Nelson clearly states the relevance of such paradigm to the study of economic growth: 'the central reason I am an evolutionary economist is that evolutionary theory does have long run economic growth at the center of the stage. Evolutionary theory is, at its core, a theory of economic growth' (Nelson (2004), p. 4).

Given that our main research goal involves the quest for a formal mechanism to establish the bridge between macro regularities and micro evolutionary behavior, we have in mind the framework proposed in Dopfer *et al.* (2004), which is based on a distinct conceptualization of evolutionary economic analysis that sets three analytical domains - micro-meso-macro instead of the traditional micro-macro division. As it is highlighted in the cited paper 'The most immediate benefit of this new framework is its capacity to synthesize disparate parts of evolutionary economics into a unified framework, enabling us, for example, 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. 6).

The concept of a meso trajectory is outlined as the fundamental unit of economic evolution and 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), p. 5). This perspective of economics involves dealing with connections between elements that exist both within and beyond the economic system.

On 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. 'When we observe change in the meso, by which we mean a change in generic rules, i.e. in the knowledge base, and/or in their respective populations, we can then analytically focus on both the micro and macro aspects of this process' (Dopfer *et al.* (2004), p. 5). In other words, micro corresponds to a change in the composition of rule-carriers and how they interact, while macro involves a change in the coordination structure between meso units.

As it is stressed in Dopfer *et al.* (2004), this micro-meso-macro frame is not a new perspective since what is here proposed - 'a meso is a thing (a rule and its population) that is made of complex other things (micro) and is an element in higher order things (macro)', then used in the 'specific sense of identifying and conceptualizing the dynamical building blocks of an economic system' - was already adopted in studies on industrial districts, regional knowledge clusters, learning regions, inter-firm industrial organization, national innovation systems, amongst others (Dopfer *et al.* (2004), p. 6, footnote 13).

Another potential research avenue to explore emerges from the awareness that both neoclassical mainstream literature and evolutionary economic theory ignore or mainly neglect the importance of the evolution of 'social technologies' on 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), whereas 'social technologies' is the concept proposed by Nelson to label business practices, organizational forms and institutions in general.

We intent to contribute to reduce the above gap, by choosing a conceptualization of the firm that recognizes the importance of both physical technologies and social

technologies to its performance, and so to industry dynamics and economic growth process. 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’.

The goal of our investigation involves in a first stage the analysis of the co-evolution of firms’ performances and of their respective industry. We develop here an evolutionary model relating the micro and meso levels of analysis. We stress in particular the firms as heterogenous organizations, with distinct ‘institutional settings’, which evolve over time building the firms’ own ‘social capital’,<sup>2</sup> in a context where structural dynamics is at the core of analysis. Therefore, our research is particularly concerned with institutional choices at the firm level and with how such choices interact with the evolving industrial process. In our research context we adopt the definition of ‘institution’ as “a regularity of behavior or a rule that is generally accepted by members of a social group, that specifies behavior in specific situation, 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, the rules apply only internally. Organizations have constitutions, are collective actors and are also subject to social rules” (Rutherford (1994), p. 182).

To achieve such purpose we work with a computer simulation model which deals explicitly with the nature and evolution of the knowledge that guides firms’ efforts to improve their institutional settings. The formal analysis of firms’ choices in terms of their institutional settings is focused on the labor market. As it seems clear, a formal attempt to work with such complex system could not deal with all the universe of firms’ decisions. Our option for the decisions concerning the labor market is not merely arbitrary. In fact, the structure of labor 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

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<sup>2</sup>Despite the huge amount of research associated to the term ‘social capital’, its definition remains vague (Durlauf and Fafchamps (2004)). We use here the concept of ‘social capital’ with a broad interpretation as the relations that influence personal interaction - in our case, within the firm as an organization.

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 labor involve the permanent interaction between distinct human actors, they appear as the main component of firm's institutional settings. The specificity of labor amongst the firm's inputs is clear as it carries imprinted relations and constitutes the core of firm's routines.

Moreover, few models within evolutionary economic literature deal with labor issues. Few exceptions are Fagiolo *et al.* (2004) and Tesfatsion (2001). Even if some evolutionary studies deal with distinct types of human capital (for example, Carreira (2004)) they do not introduce labor market dynamics.

### 3 Basic model - microeconomic foundations

#### 3.1 Some initial considerations

The simple model proposed in this paper intends to be a first step for the representation of the macro phenomenon of economic growth by using a micro-meso-macro approach.

We consider that each firm in a certain industry is associated with one specific 'institutional setting' that can be or not relatively close to the industry's institutional frame.<sup>3</sup> The survival likelihood for each firm  $i$  depends on its ability to hire the suitable workers for its institutional set and on its ability to react to environmental change (which are connected with the transparency of the institutional environment).<sup>4</sup> 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:

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<sup>3</sup>The modelling effort at the micro level here developed was inspired by the model of organizational culture presented in Carrillo and Gromb (2002). The cited paper intends to show that an organization is more productive if its agents 'fit' in its culture and that organizations choose agents who are 'good fits' but do so in an imperfect way and over time.

<sup>4</sup>For example, changes in the technological paradigm may result in a situation whereas firms which were not well-fitted can outperform well-fitted firms.

$$\Pr(\textit{firm}'_i \textit{s survival}) = \varphi(\textit{firm}'_i \textit{s hiring efficiency}, \textit{firm}'_i \textit{s reactions to environment}).$$

It is important to clarify that, in our framework, firms cannot fully understand the complexity of the economic system. Information is incomplete, in particular with respect to the future economic development (imperfect foresight). We will base our study on the concept of bounded rationality (Simon (1955), Simon (1956), March and Simon (1958)), which appears in opposition to the neoclassical traditional assumption of fully rational agents. Herbert Simon proposed a bounded rationality programme that meant to incorporate all the constraints on human knowledge and human computation, which are responsible for distinct behaviors of real actors comparing to the predictions made by the neoclassical economic theory. Since the actors face uncertainty when assessing the effects of alternative strategies, Simon sustained the idea that the mind can only elaborate approximate solutions to the problems (Sent (1998)). Therefore, Simon proposed the substitution of the neoclassical unrealistic assumption of perfect information and unlimited computational capacity with a more consistent assumption with 'the access of information and the computational capacities that are actually possessed by organisms, including man, in the kinds of environment in which such organisms exist' (Simon (1955)). Therefore, Simon proposes that agents' decisions are consistent and intended rational but limited by cognitive constraints. The agent does not have all the information and does not have the computational capacities usually imputed to her by models of rational choice. Therefore, he sustains that the decision makers must simplify the decision actions, suggesting the 'satisficing' concept as one possibility (Simon (1955)). A decision maker will maintain 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).

Additionally, the author introduces the idea that decision making is influenced not only by information processing capabilities but also by the environment (Simon (1956)). As Simon himself focuses: 'The paper showed how relatively simple choice mechanisms could enable an organism, searching through its life's maze, to survive in an uncertain environment' (Simon (1996), p. 166).

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 of the economic system are workers, which also represent households, and firms. They are held together by two markets: an output market and a labor market.

A single good is produced in the industry. Therefore, there are no difference between the output of the firms in quality terms. 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. Households (workers) spend part of their income in this market.

In the labor market we have  $\mathbf{L}$  workers ( $j \in \mathbf{L}$ ), of two distinct types. We have the 'routine-workers',  $L^R = \{1, \dots, \mathbf{L}^R\}$ , that correspond to agents that do not have capacity to deal with activities involving innovator procedures since they lack the minimum attributes to deal with unexpected change. Their learning capacity is a learning-by-doing type. We will assume that such workers have attributes that make them 'fit' into activities featured by routine or standard procedures. Additionally, we have the 'non-routine workers',  $L^{NR} = \{1, \dots, \mathbf{L}^{NR}\}$  and  $\mathbf{L} = \mathbf{L}^R + \mathbf{L}^{NR}$ . These last agents have attributes that make them 'fit' into activities where the reaction to change and learning-by-thinking is crucial.

Firms employ labor in 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  $w_{NR}$ , with  $w_{NR} > w_R$ . Therefore, on one hand we have workers that earn less, representing lower costs to firms, but are incapable of adjusting themselves and so a firm with a high proportion of such workers is much more likely to die when facing an unexpected and significant environmental change than those with higher proportion of  $L^{NR}$  workers. On the other hand, the other group of workers receive a higher wage, meaning a higher cost for the firm, but are flexible and able to quickly adjust to changes. They are crucial for the firm to react to such changes, avoiding

bankruptcy or even allowing firm's growth.<sup>5</sup>

## 3.2 Model setup

### 3.2.1 Firm level

Let's consider an industry -  $Ind_1$ - composed by a certain number of firms in each period of time  $t$ ,  $F = \{1, 2, \dots, N_t\}$ . Firms are assumed to produce the same homogeneous good, with one production factor, labor, with two distinct types of workers. In each period, a firm  $i \in F$  produces  $X_{it}$  units of the homogeneous good, whose price is  $p_t > 0$ . We assume discrete time periods  $t$ , with  $t = 0, 1, 2, \dots$

Industry<sub>1</sub> is characterized by an exogenous institutional environment represented by the variable  $IInd_1$ . Each firm  $i$  in the industry is featured by a specific 'institutional frame' represented by the variable  $I_i$ . The 'institutional fitness' of the firm is measured by  $|I_{it} - IInd_{1t}|$ .

The firm decides on a certain set of variables in each period of time:

$$Firm_{it}(L_{it}^R, L_{it}^{NR}, \Delta\alpha_{it}) \quad (1)$$

where

$L_{it}^R$  corresponds to the number of workers associated with routine activities - learning-by-doing - employed by the firm;

$L_{it}^{NR}$  corresponds to number of workers associated with non-routine activities - learning-by-thinking - employed by the firm.

The variable  $\alpha_{it}$  corresponds to the ratio  $\frac{L_{it}^{NR}}{L_{it}}$ , that is, corresponds to the relative

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<sup>5</sup>Introducing uncertainty about the worker quality and training efficiency in the model, hiring decisions are subject to adverse selection problems.

importance of non-routine workers. The firm decides on changes in that ratio,  $\Delta\alpha_i$ , in each period of time.

The firm's output level is a function of technological progress,  $A_i$  and of its workers,  $L_{it}^R$  and  $L_{it}^{NR}$  :

$$X_i = f(A_i, L_i^R, L_i^{NR}) \quad (2)$$

We start by assuming a Cobb-Douglas production function,<sup>6</sup> with constant returns to scale (CRS)<sup>7</sup> associated to routine labor and non routine labor:

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

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

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

where  $l_{it}$  represents the stock of routine workers per unit of total labor.

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<sup>6</sup>We consider it is realistic to assume the existence of an imperfect degree of substitutability between inputs. We assume that each firm has at least one worker of each type, adopting a certain proportion of  $L_i^R$  and  $L_i^{NR}$ , with  $\alpha_i = \frac{L_i^{NR}}{L_i}$ . Therefore,  $\alpha_i \in ]0, 1[$ .

<sup>7</sup>The replication argument of CRS is usually a reasonable assumption to make about technologies (Varian (1992), p. 15).



In this framework we include the assumption that each firm aims to increase its survival probability by narrowing the 'institutional gap', adopting an 'institutional frame' suitable with the institutional environment (the one that characterizes the industry where they belong). The adjustment is systematic indicating that the firm learns with time how to reduce such gap, for example, implementing a more efficient screening<sup>8</sup> of its workers.

We consider that each firm learns in the procedures related to the screening of its workers.<sup>9</sup> We have distinct rates of learning in screening growth rates for the firms, represented as  $\varsigma_j$ . By simplification we assume only two rates of learning,  $\varsigma_1$  and  $\varsigma_2$ , with  $\varsigma_1 < \varsigma_2$ . Firms with a relative higher proportion of routine workers ( $L_i^R$ ) learn slower (rate  $\varsigma_1$ ) while firms with a relative higher proportion of non-routine workers ( $L_i^{NR}$ ) learn faster (rate  $\varsigma_2$ ) thus the ability to react to changes in labor market is relatively higher in such firms. It is important to clarify that the speed at which workers and firms learn are distinct and that  $\varsigma_j$  represent the firm's rate. We have:

$$\begin{cases} \varsigma_1 & \text{if } \alpha_i \preceq 0.5 \\ \varsigma_2 & \text{if } \alpha_i > 0.5 \end{cases}$$

A crucial idea within our framework is that to work within the firm's 'social capital', workers must have certain specific attributes. To acquire such attributes, the employer (the firm) screens the labor market for the suitable workers and, additionally, provides and pays for enhancing such attributes among its workers by hiring the adequate workers in the market. The parameter  $\varsigma_j$  defined above 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 labor it is reasonable to assume that it will learn during such activity. It will analyze its previous experiences to change its own perception of the labor market and of its needs. The measure of the 'institutional gap',  $|I_i - IInd_1|$ , should therefore be

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<sup>8</sup>Screening corresponds here to firms testing in order to hiring the suitable workers and firing those that do not reach the desired features.

<sup>9</sup>Arrow (1962) states that 'the concept of knowledge which underlies the production function at any moment needs analysis' since 'knowledge has to be acquired'. He uses the term 'learning' to refer to the acquisition of knowledge, invoking a clear empirical generalization to describe it - 'learning is the product of experience'. As he stresses, 'learning can only take place through the attempt to solve a problem and therefore only takes place during activity' (Arrow (1962), p. 155).

connected with this learning effect.

More specifically, we consider that firms have distinct degrees of efficiency in the activities of screening and hiring labor (for example in the detection of adverse selection and moral hazard problems), which we represent as  $p_{it}^\epsilon$ . 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 measure of efficiency depends on the firm's 'institutional gap'. We assume that, for a certain moment in time, the higher this gap the smaller this efficiency. In formal terms we have:

$$p_{it}^\epsilon = (1 - \Delta|I_i - Ind_1|) . e^{-\frac{1}{\varsigma_{ij} \cdot T}} \quad (5)$$

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

Note that  $I_i$  - the 'institutional set' of firm  $i$  that corresponds to some kind of social capital - is a function of the proportion of types of workers ( $L_i^R$  and  $L_i^{NR}$ ) and of other factors that may also determine this set but are not explicitly considered in our analysis.

Since our goal is to conduct the analysis in formal terms we consider a simple framework in which the institutional set of each firm is represented by  $\alpha_{it}$ , that is, by each firm's relative importance of non-routine workers, and by an ex-ante unobservable variable that sums up factors able to determine such set but are not controlled by the firm,  $\psi_{it}$ .

More exactly, in each period of time  $t$ , this variable results from the stock of 'social capital' measured as the value of the variable in time  $t - 1$ , the investment made in time  $t$  by the firm to improve its own 'fitness' in the institutional environment (the rearrangement of the proportion of workers through hiring and firing decisions<sup>10</sup> associated with a screening process which appears only in ex post terms) represented by  $\Delta\alpha_{it}$ , and from an unobservable random variable  $\psi_{it}$ . Formally we have:

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<sup>10</sup>We are already working in a model that deals explicitly with the interaction between firms and workers through a matching and bargaining process.

$$\alpha_{it} = \Delta\alpha_{it} + \alpha_{it-1} + \psi_{it} \quad (6)$$

The firm adopts an 'institutional set' that may reflect a set of bureaucratic and rigid norms and procedures (rigid 'institutional set') or a more flexible one featured by a flexible and innovator environment. In the first case the firm will choose to have more  $L_i^R$  workers than  $L_i^{NR}$ . In the second case the  $L_i^{NR}$  workers are crucial. The parameter  $\alpha_i$  will represent the firm's institutional options. It is necessary to state that the firm have some clues but does not know perfectly the institutional setting of the industry since we adopt a concept of bounded rationality (e.g. Simon (1955)) for the agents in our model.

Each firm faces a trade-off: it must choose the 'better' proportion of workers, knowing that a very low  $\alpha$  means low wage costs but low possibilities to adjust, and that a very high  $\alpha$  corresponds to high possibilities to adjust but also to high wage costs that may be not be compensated by the adjustment benefit. The decision is then: what's the 'best'  $\alpha$  for the firm, given the industry's 'institutional set'?

At this stage the analysis considers firms' hiring/ firing decisions and their screening efficiencies. It is important to focus that the model deals with firms' different screening efficiencies in an ex-post perspective. Therefore, we do not deal in particular with the asymmetries that might have conducted 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.

Each firm  $i$  has a short-run profit function,  $\pi_{it}$ :

$$\pi_{it} = X_{it} \cdot p_t - c_{it} \quad (7)$$

where  $X_{it}$  is the firm's output in period  $t$ ,  $p_t$  is the market price 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 ( $\alpha_{it}$ ). They also depend on a 'transaction cost' associated to the workers competencies which is defined as  $\tau_{it} = \mathfrak{S}(|I_i - Ind_1|)$ . If the firm has a proportion of labor competencies close to the one that features its environment this means a lower 'transaction cost'. If not, such cost rises since the firm will have, for example, to subcontract thinking workers able to react to certain unexpected situations or deal with innovator procedures in industries featured by flexible 'institutional sets'. On the other hand, a firm within an industry characterized by a rigid 'institutional set' 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 as costs of constant search for new possibilities in a very inert environment. Formally, the cost function,  $c_{it}$ , is defined as:

$$c_{it} = c(w_R, w_{NR}, \alpha_{it}, \tau_{it}) \quad (8)$$

The wages for both types of workers are defined by worker and we assume that each worker supplies only one unit of labor. In a first stage we will assume that  $A_{it} = A \forall i, t$ . This means that total factor productivity does not distinguish firms. Therefore, it will be irrelevant in the cost function at the firm's level. However, in a latter stage, we will consider that firms have distinct productivity levels in part because productivity changes over time. This later study of the co-evolution of firms and industries towards the aggregate economy will follow a 'micro-meso-macro' framework as proposed in Dopfer *et al.* (2004). For now, total cost of firm  $i$ , at time  $t$  is given by:

$$c_{it} = (1 + \tau_{it}) \cdot \left( \frac{w_R \cdot L_{it}^R + w_{NR} \cdot L_{it}^{NR}}{p_{it}^\epsilon} \right) \quad (9)$$

### 3.2.2 Industry level

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

$$\mathbf{X}_t = \sum_{i=1}^{N_t} X_{it} \quad (10)$$

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

$$p_t = \frac{\mathbf{D}_t}{(\mathbf{X}_t^D)^{1/\eta}} \quad (11)$$

where  $\eta$  is the price elasticity demand and  $\mathbf{D}_t > 0$ ,  $p_t$  is the market price and  $\mathbf{X}_t^D$  denotes the market demand at time  $t$ , with  $\lim_{\mathbf{X}_t^D \rightarrow 0} p_t < \infty$  and  $\lim_{Q_t^D \rightarrow \infty} p_t = 0$ . In each period  $t$ , the market price is determined by the equilibrium of the product market, that is,

$$p_t = \frac{\mathbf{D}_t}{(\mathbf{X}_t)^{1/\eta}} \quad (12)$$

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 leave the market are automatically replaced by firms with characteristics that correspond to the average of the attributes of the surviving firms in that period.<sup>11</sup> A deep analysis of exit and entry processes is out of the scope of the present paper. However, since both processes are central in discussing the evolution of industrial structures, they are introduced in the 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 mechanism induces changes in the fitness of the population. The less fit elements die or mutate into new configurations. However, according to

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<sup>11</sup>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. xiii). 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 (Teixeira (2004)).

the population ecology perspective, there is also inertia phenomena in the population behavior (for example, Hannan and Freeman (1977), Hannan and Freeman (1984)). Therefore, the selection process may actually cause the death of the fittest. In addition, fittest in the short term may be inferior in the long run. The environment is crucial for the global outcome.

We analyze exits in the common way, asking about the characteristics of the surviving firms. In our model, since we consider that firms' start-up size and the technology set<sup>12</sup> are equal, we analyze as distinctive feature their 'institutional gap'.

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. Without the intention to discuss the literature concerning entry regularities, it is important to briefly mention that the introduction of an entry modelling mechanism is coherent with the recognition that entry (as exit) is a very common phenomenon in industries (for example Mata (1993), Geroski (1995)). The problematic action is not the entry but rather the ability to survive once the firm is in the market. Important regularities are precisely the very high probability that exit follows entry and the evidence that few successful entries need years to catch the competitive level of the incumbent firms (Jovanovic (1982), Geroski (1995)).<sup>13</sup>

In figure 1 it is represented a structural scheme of the proposed model.<sup>14</sup>

Our main goal with the above modelling frame is to explore the implications of firms' behavior in their respective industry and answering to the research questions

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<sup>12</sup>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.

<sup>13</sup>There is an important literature concerning the modelling of entry and exit. In evolutionary economics, there are two broad groups of simulation models. One corresponds to agent-based computational economics, being based in the cellular automata approach. The other corresponds to neo-Schumpeterian models, in the line of Nelson and Winter contributions. Within the second group, the one where our model fits, we have contributions such as Bottazzi *et al.* (2001) where exit is modelled as a simple selection mechanism based on the firm's size and entry is stochastically modelled as a Poisson distribution with mean equal to the number of incumbent firms in the industry. Klepper (1996) introduces entry modelled according to expectations. In Dosi *et al.* (1995) entry depends on the number of incumbent firms, on a parameter that governs the strenght of barriers to entry and on random events modelled as an uniform random distribution.

<sup>14</sup>Inspired in Andersen (2001) and in its useful schemes about the Nelson-Winter models.

proposed in section 1. To achieve such purpose the next stage of our investigation corresponds to the construction of our model in computational terms. In section 4 we offer some details on such exercise, which is still in a working stage.

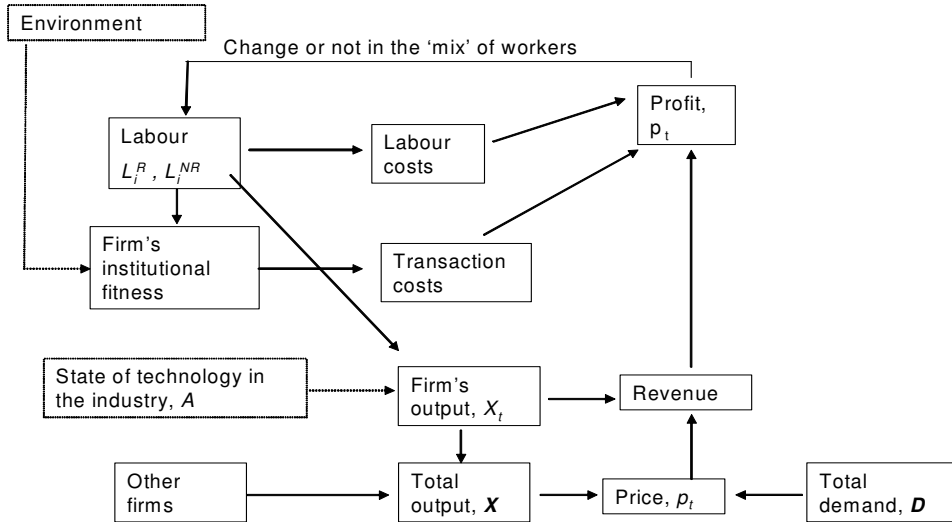


Figure 1 - Structural Diagram of the Model

## 4 Simulation exercise

### 4.1 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 (sd)).<sup>15</sup>

In a first approach, we have the following stages of implementation 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 set of firms and the institutional environment in the industry at  $t = 0$ .
2. Following an evolutionary framework, firms decide to maintain or to change its institutional set in the next period, according to the evolution of their profits and their market shares. This decision is materialized in the mix of its 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. If not 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 leave the market. The firms that leave the market are automatically replaced by firms with features that correspond to the average of survival firms' attributes in that period.

In a later stage we consider that the environment may change and that firms have certain expectations about that. Therefore, we have a decision based on the profit the firm attains in  $t$  and its expected profit in period  $t + 1$ . To compute this expected profit we must define the expected profit both when the firm thinks that the environment is going to change and when it believes the institutional environment will be stable. Our theoretical frame is not suitable for rational expectations arguments since we consider bounded rational agents. We may have a simple rule to guide the firm's expectations about the environment's evolution.

In figure 2 we present a simple schema of the simulation process at the firm level. Each firm  $i$  decides on a set of variables:

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<sup>15</sup>Lsd is written in C++ and every Lsd model is C++ compiled code.



$$Firm_i(L_i^R, L_i^{NR}, \Delta\alpha)$$

and we decide on the firms' learning rate ( $\varsigma_{ij}$ ) and on the initial values for the parameters. Our calibration work is guided by some available literature, for example Andersen (1996) and Andersen (2004). In appendix we present a synthesis of the assumed initial values and possible combinations defined for some relevant parameters.

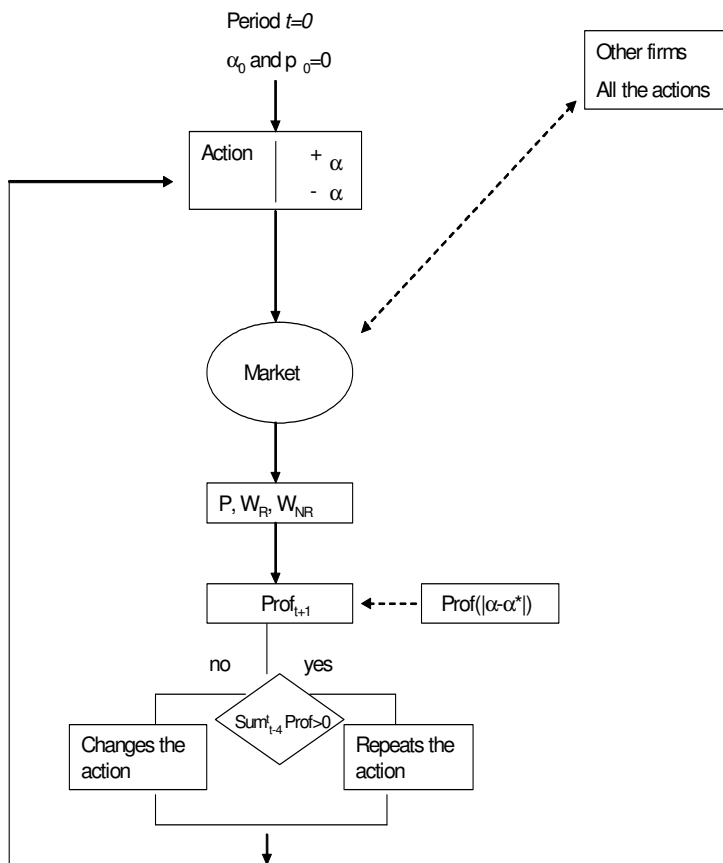


Figure 2 - Simple Simulation Model

At this stage, the structure of our simulation model corresponds to one industry, composed by a constant number 10 of firms. The industry is characterized by its

institutional set,  $\alpha_t$ , which is for now an exogenous variable, only partially observable by the firms. Note that we have not yet considered the effect of changes in the environment (represented as a change in industry's main institutional feature). Therefore,  $\alpha_t = \alpha$ .

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

We set a common fixed amount of labor input for the firms. Therefore, firms differ not in the amount of employed labor but in the relative composition of this input, hiring non-routine and routine workers in distinct fractions (labor market is exogenous at this stage). As mentioned above, 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, at each time step. Therefore, it assumes 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 set but are not controlled by the firm.

As we focused above, each firm decides, according to a certain rule, to change or not the proportion of its workers. The firm's main goal is to increase its 'institutional fit' so to increase its survival probability. If the decision corresponds to change the action the firm engages on search procedures to invest in its 'institutional set'. Such investment requires the presence of non-routine workers since these correspond to the degree of flexibility of the firm.

In our simulation exercises we considered that the investment made by firms to improve their 'institutional fit' is governed by a uniform distribution around the relative value of non-routine workers of each firm. Therefore, the amplitude or sensitivity of the changes depend on the relative importance of the flexible, non-routine, more expensive, workers.

We consider two main settings in the simulation exercise: a model without learning and a model with learning. In the first situation, firms engage in searching for new institutional settings when they observe bad performances. However, there is no learning mechanism and we ignore that firms have distinct degrees of efficiency in the activities of screening and hiring labor, that is we omit the variable  $p_{it}^\epsilon$  from the model.

In the second case, we have a learning mechanism associated with  $p_{it}^\epsilon$ . As it is represented in (5), each firm's efficiency in screening and hiring activities improves as time goes by. The pace of improvement of such efficiency depends on each firm's learning rate. This last rate assumes a higher or a 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 gap' also influences this efficiency measure.

In order to generate the dynamic properties of the model and study the robustness of our model we have run several simulations of distinct time steps. The model shows robustness<sup>16</sup> for distinct settings of time step runs and for several seed values<sup>17</sup> and for different set-ups of the parameters and the initial values.

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<sup>16</sup>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 emerges by chance or simply by the nature of the parametric set-up imposed to the model. This kind of test corresponds to a robustness test, which gives information to the researcher about how the model varies according with input values such as initial conditions, parametric values and random events (Reichstein (2003)).

<sup>17</sup>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 allows the recreation of (pseudo) random events. Running the simulation for different seed values allows the researcher to analyse 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 has being random event un-robust (Valente (sd)). For more considerations about the processes and techniques associated to the validation and verification of simulation models see Sargent (1999).

## 4.2 Simulation results

As it would be reasonable to expect, the dynamics of the industry structure is different in the two main defined configurations, the NoLearn set and the Learn set.

In the first situation we have much more turbulence in the economy, with all the initial firms leaving the market at 50 time steps. In the Learn set we have less instability. The number of exit and entry firms is much lower and the initial firms survive much longer. At 50 time steps we have three initial firms, firm 1, firm 2 and firm 5. Moreover, one firm that entered in an early stage (T=8, firm 12) is the dominant firm until 458 time steps. As the empirical literature shows (for example, Jovanovic (1982), Mata (1993), Geroski (1995)), only few of the entrant firms survive and those successful entries need a long period of time to catch the competitive level of the incumbent firms. Therefore, our model with learning seems to fit the reality since the initial firms stay for many time steps run and the survival ones correspond to those with the highest learning capacity as the evolution of the ScreenHire computational variable shows.

At this stage, although we are unable to provide an account of learning mechanisms characterizing real industries, we tend to observe that more concentrated industries seem to be characterized by more stable patterns. In the No Learn set the inverse of the Herfindal Index shows a more or less stable value, whilst in the Learn set the same index shows a reduction of the concentration for an initial run of 10 time steps but observes then a small increase of concentration in the industry.

As the tables below show, in the model with entry and exit, the 'institutional gap' of the industry, in average, substantially decreases, reaching a much lower value than the one that initially featured the population of firms.<sup>18</sup> Therefore, the selection mechanism strongly contributes to improve the institutional fitness of the population in both simulation sets for this model.

The global result of the simulation sets without entry, as the market converges to a duopoly or a monopoly, reaches a higher 'institutional gap' for the survival firms than

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<sup>18</sup>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.

the one that characterizes the initial population. This pattern is coherent with the literature that considers the entry threat as an important pressure for the incumbent firms. As Eliasson (1996), Eliasson (1997) and Eliasson and Taymaz (2000) state 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 in technological terms, or to close activity and leave the market.

Time steps	Number of initial firms in the market		Alpha Firm of the dominant firm at entrant date and at final T		Inverse of the Herfindal Index (89 at T=0)		Final average 'institutional gap' in industry (0.30455773 at T=0)	
	Nb Entry	Entry	Nb Entry	Entry	Nb Entry	Entry	Nb Entry	Entry
T=10	6	5	Firm3 ( $\alpha_{63}=0.814$ and $\alpha_{73}=0.799$ )	Firm8 ( $\alpha_{68}=0.761$ and $\alpha_{78}=0.704$ )	5.9431	10.9601	0.177996	0.122968
T=50	5	0	Firm7 ( $\alpha_{67}=0.659$ and $\alpha_{77}=0.740$ )	Firm26 ( $\alpha_{626}=0.573$ and $\alpha_{726}=0.733$ )	4.9703	9.9659	0.188290	0.108278
T=100	4	0	Firm1 ( $\alpha_{61}=0.404$ and $\alpha_{71}=0.623$ )	Firm32 ( $\alpha_{632}=0.490$ and $\alpha_{732}=0.680$ )	3.8602	9.8815	0.166193	0.120783
T=500	3	0	Firm1 ( $\alpha_{61}=0.404$ and $\alpha_{71}=0.300$ )	Firm83 ( $\alpha_{683}=0.391$ and $\alpha_{783}=0.709$ )	2.4525	9.8890	0.353796	0.107110

Table 1 - No Learn Model (seed=1)

Time steps	Number of initial firms in the market		AlphaFirm of the dominant firm at 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
<b>T=10</b>	2	7	Firm 7 ( $\alpha_{07}=0.659$ and $\alpha_{17}=0.734$ )	Firm 6 ( $\alpha_{06}=0.853$ and $\alpha_{16}=0.850$ )	1.9996	11.0511	0.106119	0.158724
<b>T=50</b>	2	3	Firm 5 ( $\alpha_{05}=0.513$ and $\alpha_{15}=0.528$ )	Firm 2 ( $\alpha_{02}=0.312$ and $\alpha_{12}=0.592$ ) Firm 12 ( $\alpha_{012}=0.681$ and $\alpha_{112}=0.656$ )	1.8615	9.6598	0.169722	0.202459
<b>T=100</b>	2	2	Firm 5 ( $\alpha_{05}=0.513$ and $\alpha_{15}=0.824$ )	Firm 2 ( $\alpha_{02}=0.312$ and $\alpha_{12}=0.675$ )	1.9339	9.4504	0.329301	0.204047
<b>T=500</b>	1	0	Firm 5 ( $\alpha_{05}=0.513$ and $\alpha_{15}=0.076$ )	Firm 33 ( $\alpha_{033}=0.404$ and $\alpha_{133}=0.398$ )	1	9.8409	0.412041	0.127712

Table 2 - Learn Model (seed=1)

In the scenario without entry the few survival firms adopt an inert strategy, represented by hiring a very small relative number of non routine workers (flexible but more expensive), in a completely stable environment, in consistency with the reasonings postulated by population ecology theory, which argues that firms are featured by structural inertia (for example, Hannan and Freeman (1989)).<sup>19</sup>

The global outcomes show that firm's ability to change its 'institutional setting' is crucial for its survival. This ability is represented as a simple action in the computational model. Firms with bad performance in terms of profitability and market share engage in search for a new configuration of its workers' mix. As stressed, such ability is (for now) simulated as a random event governed by an uniform distribution, set around the relative value of non-routine workers of each firm. In a model without a learning mechanism the results seem much more irregular, unstable and with no strong connection with firm's initial 'institutional set'. To

<sup>19</sup>It is important to note that structural inertia does not means that organizations never change. Instead, it means that organizations react slowly to the environment's challenges. As Hannan and Freeman (1984) stresses, organizations have structures featured by high inertia when the speed of reorganization is significantly lower than the rate at which the environment changes.

explain such results we must recall that when a firm decides to change its workers' mix, it engages into a random search. Therefore, even if firm's past investments in non-routine workers influence the current choices, there is still scope for each firm to successfully change its 'institutional set'.

These results suggest that the presence of a learning mechanism is particularly striking in what concerns firm's behavior and industry's dynamics. As it was focused in our model's description, the probability of survival depends on firm's hiring efficiency, which is represented in our model by  $p_{it}^e$ , and on firm's ability to react to environmental changes. At this stage of our work we keep environment stable. Therefore, the simulation results only offer some clues about the impact of firm's learning and hiring efficiency on the probability of survival. A detailed analysis of the simulation iterations on  $p_{it}^e$  (ScreenHire) shows that, in the model with entry and exit, the initial survival firms, 1, 2 and 5, were the most efficient among the initial population of firms. Table 3 show this for the run with 50 time steps.

50 Cases	Average	Variance	Min	Max	Sigma
ScreenHire 1_1 (50)	0.814234	0.029217	0.122388	0.963015	0.172664
ScreenHire 1_2 (50)	0.752253	0.024937	0.109849	0.963422	0.159519
ScreenHire 1_3 (41)	0.647702	0.016144	0.352087	0.907252	0.128637
ScreenHire 1_4 (5)	0.250849	0.010065	0.078192	0.358880	0.112153
ScreenHire 1_5 (50)	0.663860	0.002875	0.506966	0.861923	0.054166
ScreenHire 1_6 (10)	0.528518	0.008339	0.331844	0.633126	0.096259
ScreenHire 1_7 (9)	0.546231	0.006526	0.431942	0.649525	0.085685
ScreenHire 1_8 (15)	0.591566	0.008023	0.379161	0.708630	0.092717
ScreenHire 1_9 (5)	0.267396	0.012719	0.076899	0.392759	0.126090
ScreenHire 1_10 (20)	0.613489	0.017534	0.270862	0.785366	0.135858
ScreenHire 1_11 (24)	0.695452	0.044916	0.000000	0.911071	0.216491
ScreenHire 1_12 (46)	0.787821	0.024224	0.000000	0.938415	0.157359
ScreenHire 1_13 (42)	0.725491	0.023005	0.000000	0.898835	0.153511
ScreenHire 1_14 (38)	0.679554	0.024791	0.000000	0.877384	0.159566
ScreenHire 1_15 (36)	0.792423	0.024769	0.000000	0.932428	0.159614
ScreenHire 1_16 (31)	0.784787	0.026777	0.000000	0.894495	0.166342
ScreenHire 1_17 (23)	0.710283	0.041717	0.000000	0.899485	0.208838
ScreenHire 1_18 (10)	0.564384	0.041547	0.000000	0.707806	0.214855
ScreenHire 1_19 (4)	0.481991	0.084641	0.000000	0.719258	0.335939

Table 3 - Time descriptive statistics ScreenHire (T=50)

Since 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 shows the fact that two of the winning firm in the learning scenario are firm 5 and firm 1. Firm's with initial low values of  $\alpha$  have lower chances of survival. However, firms with initial high values of  $\alpha$  will survive if and only if they rapidly improve their hiring efficiency. We must not forget that we also have random disturbances affecting firms' behavior. In the scenario without learning, chance is definitively more important in running results than in the learning set as the high turbulence of the industry shows.

At this point we have results that support the idea that firms' ability to change its 'institutional set' is crucial for their survival chances. Therefore, such ability determines the composition and the dynamics of the industry structure. Additionally, the main feature in institutional terms of our industry (for now we have chosen an exogenous value  $\alpha$  to represent industry's institutional setting, which corresponds to the relative importance of non-routine workers in such industry) shapes the behavior of the firms' population. Indeed, firms' actions depend on their profitability that is influenced by the distance of the firm relatively to the industry in what concerns institutional features. Moreover, firms' reactions involves changes in such features.

In what concerns economic growth rates, as it was expected since technological progress is constant and exogenous in the model, in both sets the values in the long run ( $T=500$ ) are very low and steady.

In the next figures we have some information concerning the behavior and survival paths of firms in the three scenarios, measured in terms of their profitability and of their 'institutional gap', for  $T=50$  time steps.



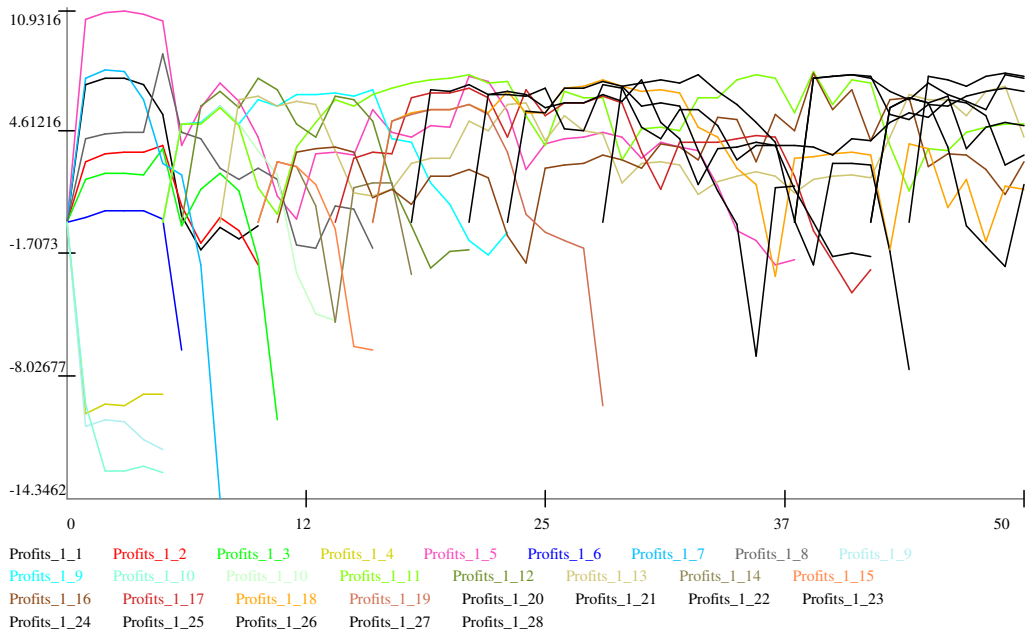


Figure 3 - Evolution of firm's profits No Learn Model (T=50 and seed=1)

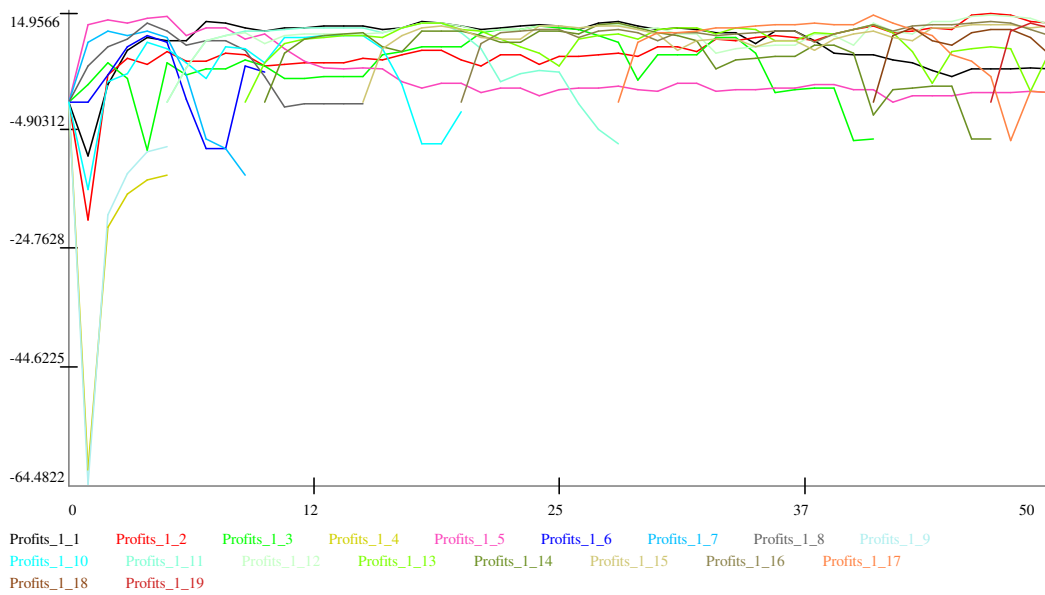


Figure 4 - Evolution of firm's profits Learn Model (T=50 and seed=1)

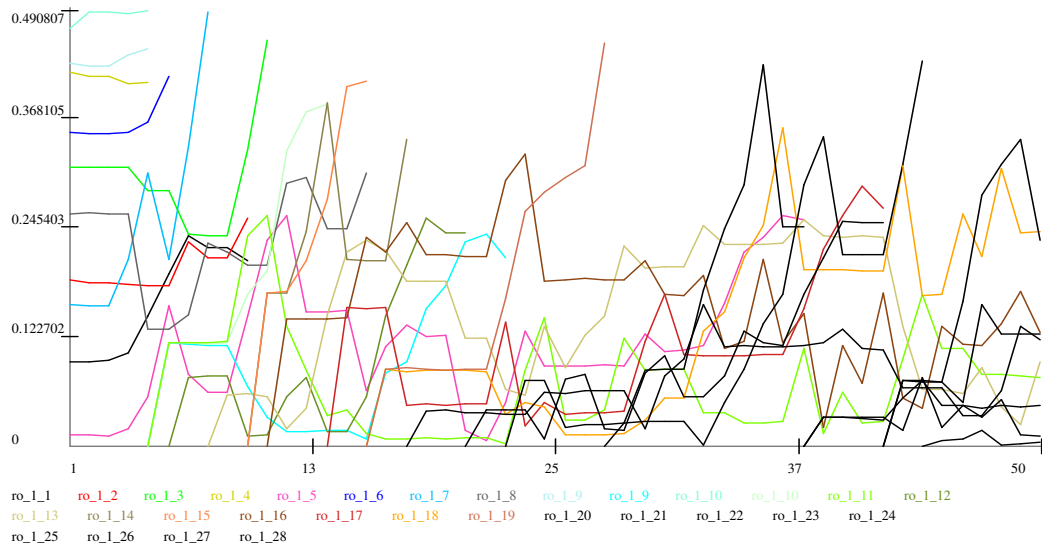


Figure 5 - Evolution of firm's 'institutional gap' No Learn Model (T=50 and seed=1)

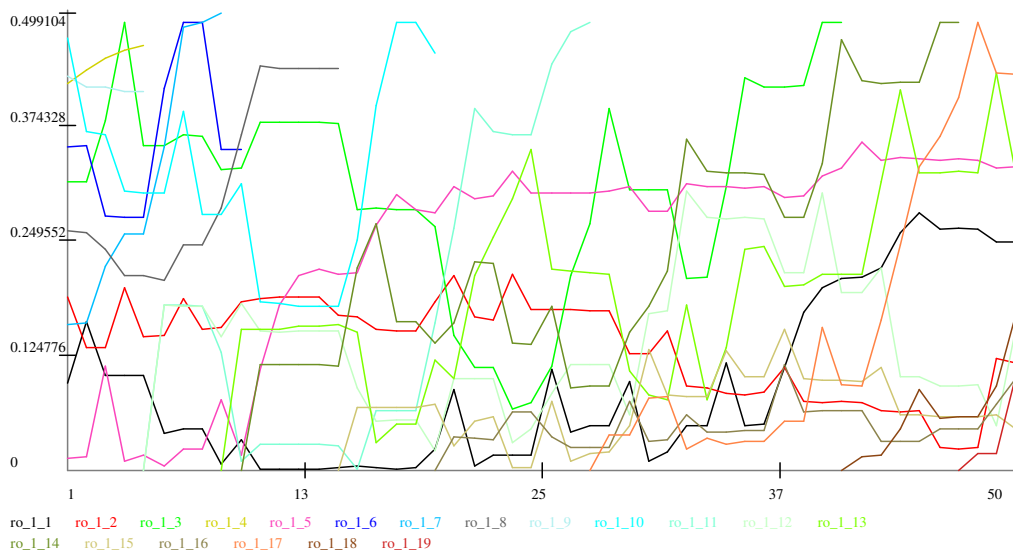


Figure 6 - Evolution of firm's 'institutional gap' Learn Model (T=50 and seed=1)

The main conclusions of this ongoing work and the main steps for future research are pointed out in next section.

## 5 Conclusion

The simulation exercise focusing on firms' choices in terms of their institutional settings on the labor market permitted to draw some important implications:

1. The results show that firm's ability to change its 'institutional setting' is crucial for its survival. Firms with bad performance in terms of profitability and market share engage in search for a new configuration of its workers' mix. In a model without a learning mechanism the results show significant turbulence in terms of exit and entry of firms and no significant connection with firm's initial 'institutional set'. In the Learn Model the outcome is much more stable, with the initial firms surviving for long periods of time.
2. Results suggest that the presence of a learning mechanism is particularly striking in what concerns firm's behavior and industry's dynamics. The probability of survival depends on firm's hiring efficiency and on firm's ability to react to environmental changes. At this stage of our work we keep environment stable. Therefore, the simulation results only offer some clues about the impact of firm's learning and hiring efficiency on the probability of survival.
3. Since 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 a matter of fact, firm's with initial low values of relative non-routine workers have lower chances of survival. However, firms with initial high values of relative non-routine workers will survive if and only if they rapidly improve their hiring efficiency.
4. Results also seem to support the idea that firms' ability to change its 'institutional set' determines the composition and the dynamics of the industry structure. The main feature in institutional terms of our industry, which corresponds to the relative importance of non-routine workers in such industry (for now exogenous), shapes the behavior of the firms' population. In fact, firms' actions depend on their profitability that is influenced by the distance of the firm relatively to the industry in what concerns institutional features. In addition, firms' reactions involves changes in such features.

In brief, and returning to our departing questions, the results suggest that firm's ability to change its institutional settings strongly influences its survival probability and shapes industry's structure dynamics and composition. Although we have not yet fully explored how the industry's characteristics in institutional terms influence the behavior of the firms' population, at this stage we might speculate that if we change some industry's related parameters we would obtain quite different results.

Regarding to future research, our model may be extended in several directions. At the firm-industry level, we might explore other options in terms of learning processes, for example in what concerns each firm's learning rate. This rate may be defined in a more realistic way if we assume the presence of decreasing returns to scale. Another topic that we intend to study at this level concerns the introduction of an endogenous labor market in our evolutionary frame, allowing the analysis of issues such as job search, job queues, labor matching and bargaining processes. Moreover, still at the firm-industry level, we intend to study the impact of major environmental change.

In a later stage, bridging to macro level, we aim at analyzing the dynamics concerning the co-evolution of physical and social technologies.

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# Appendix

## Initial Values

## Object Structure

Root->Industry->Firm

**Object Industry Total instances = 1**

<b>Label</b>	<b>InitialValues</b>
<i>Dem_Coeff(P)</i>	150
<i>Dem_Elast(P)</i>	1.0
<i>Alpha(P)</i>	0.5

**Object Firm Total instances = 10**

<b>Label</b>	<b>InitialValues</b>										
<i>ProfitsLag(1)</i>	0	0	0	0	0	0	0	0	0	0	0
<i>ProfitsLag(2)</i>	0	0	0	0	0	0	0	0	0	0	0
<i>ProfitsLag(3)</i>	0	0	0	0	0	0	0	0	0	0	0
<i>ProfitsLag(4)</i>	0	0	0	0	0	0	0	0	0	0	0
<i>beta1(P)</i>	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
<i>beta2(P)</i>	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7
<i>WR(P)</i>	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
<i>WNR(P)</i>	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
<i>A(P)</i>	0.368	0.368	0.368	0.368	0.368	0.368	0.368	0.368	0.368	0.368	0.368
<i>AlphaFirmLag(1)</i>	0.404334	0.311681	0.814229	0.0777613	0.512565	0.853656	0.658692	0.761495	0.0682124	0.972433	
<i>LT Lag(1)</i>	50	50	50	50	50	50	50	50	50	50	50
<i>MShareLag(1)</i>	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1

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