Firm’s institutional behavior and industry dynamics. An evolutionary modeling proposal

Sandra Tavares Silva\textsuperscript{a}, Mário Rui Silva\textsuperscript{b} and Aurora A. C. Teixeira\textsuperscript{a, *}

\textsuperscript{a} CEMPRE, Faculdade de Economia, Universidade do Porto, Portugal
\textsuperscript{b} CEDRES, Faculdade de Economia, Universidade do Porto, Portugal

Abstract

Understanding economies' growth patterns is a fundamental objective of economic growth theorizing. However, the micro constructions are linked to growth and cannot be neglected in such process. Therefore, there is a problem in the relation between macroeconomic behaviors and microfoundations. Our main research goal concerns with such problem, seeking for a formal mechanism to establish the bridge between macro regularities and micro evolutionary behavior, based in a bottom-up perspective.

Building a computer simulation model, focussed on firms' choices about their 'institutional settings' on labour, allowed us to draw important implications. The results show that firm's ability to change its 'institutional setting' is crucial for survival. Firms with bad performance (profitability and market share) engage in search for a new configuration of its workers' mix. In a model without a learning mechanism the results seem irregular and unstable. In a model with learning the outcome is stable. The probability of survival depends on firms' hiring capacity and ability to react to environmental changes.

Results also seem to support the idea that firms' ability to change its 'institutional set' determines industry's composition and dynamics. The institutional features of the industry shape the behavior of the firms' population.

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\* Tel. +351225571214; fax: +351225505050.
E-mail addresses: sandras@fep.up.pt (S. Silva); mrui@fep.up.pt (Mário Rui Silva); ateixeira@fep.up.pt (A. Teixeira).
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 'regularity of behavior' or 'rules' or 'routines' or 'institutional settings', which evolve over time building the firms' own 'culture' or '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.

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 focussed on the labour market.

We propose a model to explore the implications of firms’ behavior in the respective industry. Although the simulation exercise is still very 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 selected 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 focussed on the relations between the population of firms¹ 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 may be 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 argumentations. 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

¹For 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.

Having identified our major theoretical references, we would like 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 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 super-
ficial 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 re-
search 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 focussed
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 will 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 micro-economic work on organizational learning and adaptation to evolutionary macro-economic 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 want to stress in particular the firms as heterogenous organizations, with distinct ’regularity of behavior’ or ’rules’ or ’routines’ or ’institutional settings’, which evolve over time building the firms’ own ’culture’ or ’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. 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-policied 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 labour 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 labour market is not merely 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 firm’s institutional settings. The specificity of labour amongst the firm’s inputs is clear as it carries imprinted relations and constitutes the core of firm’s routines.

3 Basic model - microeconomic foundations

3.1 Some initial considerations

We consider that each firm in a certain industry is associated with one specific institutional setting (’culture’) or ’social capital’ that can be or not relatively close to the industry’s institutional frame.\footnote{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.} 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). 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:

\[ \Pr(\text{firm}'s \ survival) = \varphi(\text{firm}'s \ hiring \ efficiency, \ firm)'s \ reactions \ to \ environment). \]

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 'satisfacing' 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

\(^3\)For example, changes in the technological paradigm may result in a situation whereas firms which were not well-fitted can outperform well-fitted firms.
only by information processing capabilities but also by the environment (Simon (1956)). As Simon himself focusses: '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 will assume that firms take decisions based on adaptive expectations, with decisions being revised periodically since their strategies are likely to be inconsistent.

In the labour market we have L workers \( j \in L \), of two distinct types. We have the ’routine-workers’, \( L^R = \{1, ..., L^R\} \), 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’, \( L^{NR} = \{1, ..., L^{NR}\} \) and \( L = L^R + L^{NR} \). These last agents have attributes that make them ’fit’ into activities where the reaction to change and learning-by-thinking is crucial.

The wage adjustment is rigid and 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.\(^4\)

\(^4\)In a later stage we will introduce uncertainty about the worker quality and training efficiency in the model. In such a scenario, since the type of worker may be unknown, hiring decisions may be subject to adverse selection problems.
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 \( t, F = \{1, 2, ..., N_t\} \). Firms are assumed to produce the same homogeneous good, with two production factors, capital and labour, 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 \( t = 0, 1, 2, ... \)

Industry_1 is characterized by an exogenous institutional environment represented by the variable \( II nd_1 \). 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 \( |I_i - II nd_{1t}| \).

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

\[
Firm_{it}(K_t, L_{it}^R, L_{it}^{NR}, \Delta \alpha_{it})
\]  

(1)

where

\( K_t \) is the physical capital stock of the firm and assumed equal for all firms in the industry;

\( L_{it}^R \) 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 importance of non-routine workers. The firm decides on changes in that ratio, \( \Delta \alpha_{it} \), in each period of time.
The firm’s output level is a function of physical capital, $K$ and of its workers, $L_i^R$ and $L_i^{NR}$:

$$X_i = f(A, K, L_i^R, L_i^{NR})$$

(2)

We start by assuming a Cobb-Douglas production function,\(^5\) with constant returns to scale (CRS)\(^6\) associated to capital, routine labour and non routine labour:

$$X_{it} = A_t K^{1-(\beta_1+\beta_2)} (L_{it}^R)^{\beta_1} (L_{it}^{NR})^{\beta_2}$$

(3)

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

$$\frac{X_{it}}{L_{it}^R} = A_t K^{1-(\beta_1+\beta_2)} (L_{it}^R)^{\beta_1} (L_{it}^{NR})^{\beta_2}$$

(4)

$$x_{it} = A_t k_{it}^{1-(\beta_1+\beta_2)} (L_{it}^{NR} / L_{it}^R)^{\beta_2}$$

$$x_{it} = A_t k_{it}^{1-(\beta_1+\beta_2)} (L_{it}^{NR} / L_{it}^R)^{\beta_2}$$

$$x_{it} = A_t k_{it}^{1-(\beta_1+\beta_2)} (\frac{\alpha_{it}}{1-\alpha_{it}})^{\beta_2}$$

where $k_{it}$ represents the stock of physical capital per unit of routine labour.

In this framework we include the assumption that each firm aims to increase its survival probability by narrowing the ‘institutional gap’, adopting an ‘institutional

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\(^5\)We consider it is realistic to assume the existence of an imperfect degree of substitutibility 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, $\alpha_i \in [0, 1]$.

\(^6\)The replication argument of CRS is usually a reasonable assumption to make about technologies (Varian (1992), p. 15).
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 of its workers.

We consider that each firm learns-by-doing in the procedures related to the screening of its workers.\(^7\) We have distinct rates of learning-by-doing in screening growth rates for the firms, represented as \(\zeta_j\). By simplification we assume only two rates of learning-by-doing, \(\zeta_1\) and \(\zeta_2\), with \(\zeta_1 < \zeta_2\). Firms with a relative higher proportion of routine workers \((L_i^R)\) learn slower (rate \(\zeta_1\)) while firms with a relative higher proportion of non-routine workers \((L_i^{NR})\) learn faster (rate \(\zeta_2\)) thus the ability to react to changes in labour 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 \(\zeta_j\) represent the firm’s rate. We have:

\[
\begin{align*}
\zeta_1 & \text{ if } \alpha_i \leq 0.5 \\
\zeta_2 & \text{ if } \alpha_i > 0.5
\end{align*}
\]

A crucial idea within our framework is that to work within the firm’s ‘culture’, workers must have certain specific attributes. To acquire such attributes, the employer (the firm) screens the labour 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 \(\zeta_j\) 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 labour 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 labour market and of its needs. The measure of the ‘institutional gap’, \(|I_t - IInd_1|\), should therefore be connected with this learning effect.

More specifically, we consider that firms have distinct degrees of efficiency in the

\(^7\)Arrow (1962) states ‘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).
activities of screening and hiring labour (for example in the detection of adverse selection and moral hazard problems), which we represent as \( p_{it}^{s} \). 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-by-doing 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:

\[
p_{it}^{s} = (1 - \Delta |I_{i} - II nd_{i}|) . e^{-\frac{1}{\gamma_{it}}} \tag{5}
\]

and \( p_{it}^{s} \in ]0, 1[\).

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, \( \nu_{it} \).

More exactly, in each period of time \( t \), this variable results from the stock of organizational 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 screening of the labour market, hiring and firing decisions) represented by \( \Delta \alpha_{it} \), and from an unobservable random variable, \( \nu_{it} \). Formally we have:

\[
\alpha_{it} = \Delta \alpha_{it} + \alpha_{it-1} + \nu_{it} \tag{6}
\]
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 culture 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'?

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

\[
\pi_{it} = X_{it}p_t - c_{it}
\]

(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 \((w_R \text{ and } w_{NR})\) and on the 'mix' of workers \((\alpha_{it})\), and on the cost of physical capital \((r)\). They also depend on a 'transaction cost' associated to the workers competencies which is defined as \( \tau_{it} = \mathcal{S}(|I_i - I_{ind}|) \). If the firm has a proportion of labour competencies close to the one that features its environment this means a lower 'transaction cost'. If not, such cost rise 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 'culture'. 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:

18
\[ c_{it} = c(w_R, w_{NR}, \alpha_{it}, r, K, \tau_{it}) \]  

We start with a constant unit capital cost, that is, constant over distinct production techniques and over time, represented by \( r \). The wages for both types of workers are defined by worker and we assume that each worker supplies only one unit of labour. 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:

\[ c_{it} = (1 + \tau_{it})(\frac{w_R \cdot L_{it}^R + w_{NR} \cdot L_{it}^{NR}}{p_{it}}) + r.X_{it} \]  

\[ \text{3.2.2 Industry level} \]

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:

\[ X_t = \sum_{i=1}^{N_i} X_{it} \]  

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):

\[ p_t = \frac{D_t}{(X_t^D)^{1/\eta}} \]
where $\eta$ is the price elasticity demand and $D_t > 0$, $p_t$ is the market price and $X_t^D$ denotes the market demand at time $t$, with $\lim_{X_t^D \to 0} p_t \to \infty$ and $\lim_{Q_t^D \to \infty} p_t = 0$. In each period $t$, the market price is determined by the equilibrium of the product market, that is,

$$p_t = \frac{D_t}{(X_t)^{1/\eta}}$$

The number of firms operating in the industry in each period of time $t$, $N_t$, 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 $t$:

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

In figure 1 it is represented a structural scheme of the proposed model.\(^8\)

\(^8\)Inspired in Andersen (2001) and in its useful schemes about the Nelson-Winter models.
Our main goal with the above modelling frame is to explore the implications of firms’ behavior in their respective industry and answer to the research questions 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 work, which is still in a preliminary stage.

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)).

The simulation exercise is still in a preliminary stage. In a first approach, we have the following stages of implementation:

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 defined that firms that accumulate negative or nil profits during the last five time steps leave the market. There is no entry.

In a later stage we will consider that the environment may change and that firms have certain expectations about that. Therefore, we will 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 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 argumentations since we consider bounded rational agents. We may have a simple rule to guide the firm’s expectations about the environment’s evolution.

The main goal with this first experimentation is to analyze the industry’s evolution in terms of the features of the population of firms, particularly the surviving firms.

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9Lsd is written in C++ and every Lsd model is C++ compiled code.

10Alternatively we may define that in the end of the five runs the firms that leave the market are automatically replaced by firms with features that correspond to the average of firm’s attributes in that period.
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:

\[
Firm_i(L^R_i, L^{NR}_i, \Delta \alpha)
\]

and we decide on the firms’ learning-by-doing rate \((\zeta_{ij})\) and on the initial values for the parameters. Our calibration work is still crude and we guided our choices 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.
At this preliminary stage, the structure of our simulation model corresponds to one industry, composed by 10 firms. The industry is characterized by its institutional set, $\alpha_i$, 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, $\alpha_i = \alpha$. 

Figure 2 - Simple Simulation Model
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, $\alpha_{i0}$, were drawn from an uniform distribution in the $[0, 1]$ interval. We also set initial values for the common capital stock and the common technology (see appendix) to implement the model.

We set a common fixed amount of labour input for the firms. Therefore, firms differ not in the amount of employed labour but in the relative composition of this input, hiring non-routine and routine workers in distinct fractions (labour market is exogenous at this stage). As it was already mentioned above, each firm decides to change its mix of workers through time when facing bad performances. In the computational model the variable $\text{AlphaFirm}$ 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 have focussed 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 Poisson process, with a certain arrival rate $\lambda$. The firm does not know when it will draw a new, valid, configuration for its institutional set. However, it can improve the probability of getting such draw by investing in flexible, non-routine, more expensive, workers. We assume that the draws arrive randomly with a Poisson arrival rate $\alpha_i \lambda$, where $\lambda$ is the parameter that indicates the success of search.

We have considered 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 labour, that is we omit the variable $p_{il}$ from the model.

In the second case, we have a learning mechanism associated with $p_{il}$. 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. In addition, each firm’s ‘institutional gap’ also influences this efficiency measure.

The search procedure in the scenario with learning is influenced by each firm’s learning rate, $\zeta_{ij}$, since we consider that the probability of success in the search is equal to each firm’s learning rate ($\lambda = \zeta_{ij}$). 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 the configuration without learning we assume two scenarios, one for each value of the learning rate.

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 even for 10000 time steps.

4.2 Preliminary results

As it would be reasonable to expect, industry’s dynamics is quite different in the two main defined configurations: the NoLearn set and the Learn set.

In the first situation we have much more irregularity in firms’ behavior and in the evolution of the industry as a whole. The simulation exercise shows different results as we consider distinct time steps in the simulation runs. Differently, the Learn set shows more regular patterns: most firms leave market and we end with a stable duopoly just after 6 time step run. After less than 50 time steps we have a monopoly. In tables 1, 2 and 3 we have a sum up of the three configurations: the model without learning and $\lambda = 0.5$ (NoLearn Model Lambda=0.5); the model without learning
and $\lambda = 1.5$ (NoLearn Model Lambda=1.5) and the model with learning and $\lambda = \zeta_{ij}$ (Learn Model Lambda= FirmLearnRate).

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.

<table>
<thead>
<tr>
<th>Time steps</th>
<th>Number of the firms in the market</th>
<th>AlphaFirm of the survival firms at T=0 and at final T</th>
<th>Final average “institutional gap” in industry (0.30455773 at T=0)</th>
</tr>
</thead>
<tbody>
<tr>
<td>T=25</td>
<td>6</td>
<td>Firm 1 ($\alpha_{t0}=0.404$ and $\alpha_{t7}=0.999$); Firm 4 ($\alpha_{t0}=0.08$ and $\alpha_{t7}=0.999$); Firm 5 ($\alpha_{t0}=0.513$ and $\alpha_{t7}=0.395$); Firm 7 ($\alpha_{t0}=0.659$ and $\alpha_{t7}=0.623$); Firm 8 ($\alpha_{t0}=0.659$ and $\alpha_{t7}=0.999$); Firm 10 ($\alpha_{t0}=0.972$ and $\alpha_{t7}=0.727$)</td>
<td>0.152189</td>
</tr>
<tr>
<td>T=50</td>
<td>5</td>
<td>Firm 1 ($\alpha_{t0}=0.404$ and $\alpha_{t7}=0.999$); Firm 4 ($\alpha_{t0}=0.08$ and $\alpha_{t7}=0.999$); Firm 7 ($\alpha_{t0}=0.659$ and $\alpha_{t7}=0.765$); Firm 8 ($\alpha_{t0}=0.659$ and $\alpha_{t7}=0.868$); Firm 10 ($\alpha_{t0}=0.972$ and $\alpha_{t7}=0.999$)</td>
<td>0.124067</td>
</tr>
<tr>
<td>T=100</td>
<td>4</td>
<td>Firm 1 ($\alpha_{t0}=0.404$ and $\alpha_{t7}=0.999$); Firm 4 ($\alpha_{t0}=0.08$ and $\alpha_{t7}=0.664$); Firm 7 ($\alpha_{t0}=0.659$ and $\alpha_{t7}=0.238$); Firm 10 ($\alpha_{t0}=0.972$ and $\alpha_{t7}=0.999$)</td>
<td>0.216372</td>
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<tr>
<td>T=1000</td>
<td>2</td>
<td>Firm 1 ($\alpha_{t0}=0.404$ and $\alpha_{t7}=0.999$); Firm 10 ($\alpha_{t0}=0.972$ and $\alpha_{t7}=0.999$)</td>
<td>0.136567</td>
</tr>
<tr>
<td>T=10000</td>
<td>2</td>
<td>Firm 1 ($\alpha_{t0}=0.404$ and $\alpha_{t7}=0.999$); Firm 10 ($\alpha_{t0}=0.972$ and $\alpha_{t7}=0.276$)</td>
<td>0.380032</td>
</tr>
</tbody>
</table>

Table 1 - No learn and low probability of successful search model (NoLearn Lambda=0.5)
<table>
<thead>
<tr>
<th>Time steps</th>
<th>Number of the firms in the market</th>
<th>AlphaFirm of the survival firms at T=0 and at final T</th>
<th>Final average “institutional gap” in industry (0.30455773 at T=0)</th>
</tr>
</thead>
<tbody>
<tr>
<td>T=25</td>
<td>9</td>
<td>Firm 1 (α₁₀=0.404 and α₁₀=0.752); Firm 2 (α₂₀=0.312 and α₂₀=0.990); Firm 3 (α₃₀=0.08 and α₃₀=0.990); Firm 4 (α₄₀=0.513 and α₄₀=0.990); Firm 5 (α₅₀=0.659 and α₅₀=0.990); Firm 6 (α₆₀=0.854 and α₆₀=0.661); Firm 7 (α₇₀=0.920 and α₇₀=0.990); Firm 8 (α₈₀=0.659 and α₈₀=0.784); Firm 9 (α₉₀=0.068 and α₉₀=0.990); Firm 10 (α₁₀₀=0.972 and α₁₀₀=0.798)</td>
<td>0.124128</td>
</tr>
<tr>
<td>T=50</td>
<td>8</td>
<td>Firm 2 (α₁₀=0.312 and α₁₀=0.532); Firm 4 (α₄₀=0.08 and α₄₀=0.990); Firm 5 (α₅₀=0.513 and α₅₀=0.852); Firm 6 (α₆₀=0.854 and α₆₀=0.990); Firm 7 (α₇₀=0.659 and α₇₀=0.664); Firm 8 (α₈₀=0.659 and α₈₀=0.01); Firm 10 (α₁₀₀=0.972 and α₁₀₀=0.782)</td>
<td>0.193067</td>
</tr>
<tr>
<td>T=100</td>
<td>6</td>
<td>Firm 4 (α₄₀=0.08 and α₄₀=0.990); Firm 5 (α₅₀=0.513 and α₅₀=0.990); Firm 6 (α₆₀=0.854 and α₆₀=0.528); Firm 7 (α₇₀=0.659 and α₇₀=0.527); Firm 8 (α₈₀=0.068 and α₈₀=0.339); Firm 10 (α₁₀₀=0.972 and α₁₀₀=0.990)</td>
<td>0.195000</td>
</tr>
<tr>
<td>T=1000</td>
<td>3</td>
<td>Firm 5 (α₅₀=0.513 and α₅₀=0.990); Firm 9 (α₉₀=0.068 and α₉₀=0.990); Firm 10 (α₁₀₀=0.972 and α₁₀₀=0.990)</td>
<td>0.124068</td>
</tr>
<tr>
<td>T=10000</td>
<td>2</td>
<td>Firm 5 (α₅₀=0.513 and α₅₀=0.418); Firm 10 (α₁₀₀=0.972 and α₁₀₀=0.434)</td>
<td>0.191835</td>
</tr>
</tbody>
</table>

Table 2 - No learn and high probability of successful search (NoLearn Model and Lambda=1.5)
<table>
<thead>
<tr>
<th>Time steps</th>
<th>Number of the firms in the market</th>
<th>AlphaFirm of the survival firms at T=0 and at final T</th>
<th>Final average ‘institutional gap’ in industry (0.30455773 at T=0)</th>
</tr>
</thead>
<tbody>
<tr>
<td>T=10</td>
<td>2</td>
<td>Firm 3 (α_{0}=0.814 and α_{T3}=0.350); Firm 10 (α_{0}=0.972 and α_{T3}=0.990);</td>
<td>0.168531</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>T=25</td>
<td>2</td>
<td>Firm 3 (α_{0}=0.814 and α_{T3}=0.382); Firm 10 (α_{0}=0.972 and α_{T3}=0.990);</td>
<td>0.181583</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>T=50</td>
<td>1</td>
<td>Firm 3 (α_{0}=0.814 and α_{T3}=0.910); Firm 10 (α_{0}=0.972 and α_{T3}=0.990);</td>
<td>0.190000</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>T=100</td>
<td>1</td>
<td>Firm 3 (α_{0}=0.814 and α_{T3}=0.990); Firm 10 (α_{0}=0.972 and α_{T3}=0.990);</td>
<td>0.190000</td>
</tr>
<tr>
<td>T=1000</td>
<td>1</td>
<td>Firm 3 (α_{0}=0.814 and α_{T3}=0.990); Firm 10 (α_{0}=0.972 and α_{T3}=0.990);</td>
<td>0.190000</td>
</tr>
<tr>
<td>T=10000</td>
<td>1</td>
<td>Firm 3 (α_{0}=0.814 and α_{T3}=0.990); Firm 10 (α_{0}=0.972 and α_{T3}=0.990);</td>
<td>0.190000</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 3 - Learning with the probability of successful search equal to each firm’s learning rate (Learn Model Lambda=FirmLearnRate)

As the tables above show, the number of firms in the industry (with no entry) depends critically on the learning mechanism. In the scenario with no learning the exit is slow. The industry ends with two firms only after almost a 250 time steps run for a low probability of successful search (λ = 0.5) and after 2500 time steps for a high probability of successful search (λ = 1.5). In the first case (λ = 0.5) the survival firms are firm 1 and firm 10, with an ‘institutional gap’ at T=0 of respectively 0.396 (higher than average) and 0.172 (lower than average). In the second case (λ = 1.5) the survival firms are firm 5 (initial ‘institutional gap’ of 0.287, lower than average) and firm 10.

Table 1 shows that, in average, the ‘institutional gap’ of the industry has an irregular behavior for the scenario NoLearn (Lambda=0.5), ending with 0.38 at T=10000. Table 2 depicts a smoother behavior for this variable in scenario NoLearn (Lambda=1.5): it assumes the value 0.30 at T=0 and ends as 0.19 at T=10000.

The results 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 we have already pointed out, such ability is (for now) simulated as a random event governed by a Poisson distribution. In a model without a learning mechanism the results seem irregular, unstable and with no significant connection with firm’s initial ‘institutional
set’. To 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 arrival rate of events, there is still scope for each firm to successfully change its ‘institutional set’. Additionally, we have non observable, random disturbances with influence on firm’s ‘institutional characteristics.

Simulation results are very different for our third scenario (Learn Model). In Table 3 we may observe that only two firms stay in the market for a 10 time steps run: firm 3 (initial ‘institutional gap’ of 0.199) and firm 10 (initial ‘institutional gap’ of 0.300). For 25 time steps run the two same firms survive. For a run with 50 time steps the industry is featured by a monopoly. The survival firm is firm 3, with a final ‘institutional gap’ of 0.190. As Table 3 shows this outcome is stable.

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 focussed in our model’s description, the probability of survival depends on firm’s hiring efficiency, which is represented in our model by $p_{lt}$, 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 $p_{lt}$ (ScreenHire) shows that the survival firms, 3 and 10, were the most efficient, in average and in absolute terms, for the run with 10 (or with 25) time steps (Table 4 and Table 5).
<table>
<thead>
<tr>
<th></th>
<th>Average</th>
<th>Var.</th>
<th>Min</th>
<th>Max</th>
<th>Sigma</th>
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<tbody>
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<td>ScreenHire 1_1 (6)</td>
<td>0.140717</td>
<td>0.002321</td>
<td>0.081788</td>
<td>0.236089</td>
<td>0.052772</td>
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<td>ScreenHire 1_2 (6)</td>
<td>0.579184</td>
<td>0.054413</td>
<td>0.069249</td>
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<td>0.255529</td>
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<td>ScreenHire 1_3 (10)</td>
<td>0.738297</td>
<td>0.015376</td>
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<td>0.905334</td>
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<td>ScreenHire 1_4 (6)</td>
<td>0.173474</td>
<td>0.009397</td>
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<td>ScreenHire 1_5 (6)</td>
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<td>ScreenHire 1_7 (6)</td>
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<td>ScreenHire 1_8 (6)</td>
<td>0.639217</td>
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<tr>
<td>ScreenHire 1_9 (6)</td>
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<tr>
<td>ScreenHire 1_10 (10)</td>
<td>0.714984</td>
<td>0.015464</td>
<td>0.424887</td>
<td>0.863670</td>
<td>0.131080</td>
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Table 4 - Time descriptive statistics ScreenHire (T=10)

<table>
<thead>
<tr>
<th>ScreenHire 1_1</th>
<th>ScreenHire 1_2</th>
<th>ScreenHire 1_3</th>
<th>ScreenHire 1_4</th>
<th>ScreenHire 1_5</th>
<th>ScreenHire 1_6</th>
<th>ScreenHire 1_7</th>
<th>ScreenHire 1_8</th>
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Table 5 - ScreenHire iterations values (T=10)

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 α have lower chances of survival. However, firms with initial high values of α 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.

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. 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. In addition, firms’ reactions involves changes in such features.

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 NoLearn Model (T=50 and $\lambda = 0.5$)**
Figure 4 - Evolution of firm’s ‘institutional gap’ NoLearn Model (T=50 and \( \lambda = 0.5 \))

Figure 5 - Evolution of firm’s profits (T=50 and \( \lambda = 1.5 \))
Figure 6 - Evolution of firm’s ‘institutional set’ \( (T=50 \text{ and } \lambda = 1.5) \)

Figure 7 - Evolution of firm’s profits Learn Model \( (T=50) \)
Figure 8 - Evolution of firm’s ’institutional set’ Learn Model (T=50)

The graphical analysis shows that in the set with learning the average ’institutional gap’ decreases in a consistent way, while the no learn setups show a more irregular evolution. As expected, but regardless the learning hypothesis, the profitability of incumbent firms increases.

In the next section we reinforce the main conclusions of this preliminary work and point out the main steps for our future research.

5 Conclusion

The simulation exercise focusing on firms’ choices in terms of their institutional settings on the labour market permitted to draw some important implications:
1. In a setup with no entry, the number of firms in the industry depends critically on the learning mechanism. In the configuration without learning, the probability of successful search does not seem to impact on the industry’s market structure, whilst in the alternative set (admitting learning) the outcome is to reach in a relatively early stage to highly concentrated market structures.

2. 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 seem irregular, unstable and with no significant connection with firm’s initial ‘institutional set’. In the Learn Model the outcome is stable.

3. 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.

4. 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.

5. Results also seem to support the idea that firms’ ability to change its ‘institutional set’ determines the composition and the dynamics of the industry. 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.
Summing up, and returning to our departing questions, results obtained suggest that the variety of organizational forms does interact with the relative regularity of institutional environment since firms with initial distinct ’institutional sets’ tend to converge to the industry’s main institutional feature. Additionally, results clearly evidence that firm’s ability to change its institutional settings strongly influences its survival probability and shapes industry’s 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 intend to explore the presence of uncertainty about the worker quality and training efficiency in the model. Additionally, we seek to analyze other options in terms of learning processes, for example in what concerns each firm’s learning-by-doing rate. This rate may be defined in a more realistic way if we assume the presence of decreasing returns to scale. Another topic to explore at this level concerns the consideration of an endogenous labour market. 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.

References


**Appendix**

**Initial Values**

**Object Structure**

Root->Industry->Firm
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Object Firm Total instances = 10

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