Computational Economics (2006) 27: 35–62
DOI: 10.1007/s10614-005-9015-1

Knowledge-Based Jobs and the Boundaries of Firms Agent-based Simulation of Firms Learning and Workforce Skill Set Dynamics

EDOARDO MOLLONA and DAVID HALES
Department of Computer Science, University of Bologna, Italy; E-mail: emollona@cs.unibo.it

Abstract. The article explores emergence and survival of human resource management strategies and organisational types in a knowledge-based job market. The analysis considers a dynamic environment in which skill requirements change rapidly. We built an agent-based model to simulate a market where firms post job offers to fill vacancies and decide how to select and reward employees; employees, bearing skills, select firms comparing job offers. Taking an evolutionary approach, we explore how hiring strategies, which guarantee survival, emerge from interconnected variation, selection and retention processes. The simulation experiments suggest that, as the rate of change of the environment increases, long-term employment and firm-specific knowledge building emerge as the survival strategy.

1. Introduction: Organisational Issues in a Knowledge-Based Economy

A prevalent claim is that we are in a *knowledge economy*. In this work, we take the view that what characterises a knowledge economy is the growing importance of human capital in productive processes (Foss, 2005: 8) and the increasing knowledge intensity of jobs (Hodgson, 1999: 183). In addition, an increasingly influential argument is that the division of labour is becoming complex and firms can be viewed as networks of knowledge nodes (Foss, 2005: 9), that is, sets of interacting individuals with key skills and competencies. Such networks crystallises firm-specific knowledge and provide ground upon which firms build their heterogeneity. The fact that the knowledge content of jobs increases raises questions concerning emerging organisational forms.

Hodgson (1999), for example, suggests that the lack of managerial control on knowledge-based jobs, especially when knowledge is tacit and cannot be codified, impairs and bounds the appliance of traditional employment contracts (1999: 193). Hodgson proposes that the nature of contracts evolves along with the evolution of the distribution of bargaining power. As a matter of fact, employers maintain a *de iure* ownership of produced goods or services and of the physical means of production but these latter have a decreasing impact in a firm's value-creation processes (1999: 194). On the other hand, employees have got ownership on knowledge-based means of production and have and increasing control on production processes (1999: 208).

Yet, firms maintain ownership on the mechanisms of knowledge accreditation, which increases rents extracted from knowledge-based jobs. For example, the brand Microsoft allows to extract rents from the jobs of many computer scientists and IBM brand allows extracting rents from the jobs of information system experts and consultants. Along similar lines, Liebeskind (1996) advises that firms have institutional capabilities that protect knowledge from expropriation and imitation thereby creating unique knowledge assets (1996: 104).

Firm-specificity is a further characteristic of knowledge-based jobs that contributes to influence the evolution of employment relations. Learning processes are largely grounded upon exchange of tacit knowledge (Polany, 1962; Nelson and Winter, 1982) in groups of actors working together (Aoki, 1990; Teece and Pisano, 1994). Thus, knowledge-based jobs require workers to invest in firm-specific learning; in exchange, workers might want security and long-term employment (Hodgson, 1999: 248). On the other hand, if by learning-by-doing processes, workers develop unique ways to perform tasks, the emergence of idiosyncratic jobs makes *internal labour markets* an efficient organisational mode (Williamson, Watcher and Harris, 1975).

Capitalising on the resource-based view of the firm (Penrose, 1995; Wernerfelt, 1984; Barney, 1986, 1989; Reed and DeFilippi, 1990; Conner, 1991; Mahoney and Pandian, 1992), we assume that firms have incentives in integrating firm-specific, unique networks of scarce skills which fit the requirements of the competitive environments they are embedded into. We also assume that workers select jobs on the base of wage and security. That is, workers, aware of the idiosyncratic nature of their knowledge-jobs, prefer long-term contracts rather than short-term employment agreements.

We address how the evolving nature of jobs, namely the knowledge content of jobs, produces ambiguous and partially counterbalancing effects on hiring policies and emerging organisational forms. To explore the issue, we are inspired by scholars who have addressed how strategic resources management affects competence exploitation (Ulrich and Lake, 1990; Lado and Wilson, 1994) and by Harrison and Carroll's advise (1991) that the dynamics of competence adaptation are strictly connected with the processes, for example, hiring or rewarding, that influence organisational demography.

The study presents results from experiments with an agent-based model, the FirmWorld model, which contains three kinds of agents: The Environment, Firms and Employees. The model captures the dynamic of employee skill sets, firm performance and organisational policies adaptation through the process of selective hiring, firing, firm creation and bankruptcy.

We specify a very simplified artificial dynamic "economic environment" in which firms potentially compete for employees in order to recruit a high quality skill set. Each firm has an internal model concerning what an optimal workforce should be. However, these internal models may or may not be correct. Additionally, what constitutes an optimal skill set may change over time dynamically. In this environment firms modify their work force based on hiring and firing policies making offers based on a pay policy.

2. Firms Incentives in a Resource-Based Theory of Rent Generation

According to the Resource-based View of the firm (Penrose, 1995), the essence of a firm's characteristics is the bundle of resources that constitutes it and the main aim of firms is to acquire inputs to which rents may accrue (Conner, 1991). Among the most widely quoted, Barney (1986, 1991) and Wernerfelt (1984) provided theoretical arguments explaining the link between resource heterogeneity and rents. Generally, this view sees firms diversity and rents as generated by exchanges of heterogeneous resources in imperfect factor markets. These markets, generating information asymmetries, allow differences in resource positions among firms to be created and sustained. Rents are results of first-mover advantages: skilled managers reckon the value of resources and acquire them before competitors thereby building resource position barriers. Barney (1986, 1991) proposed that necessary conditions for inter-firm heterogeneity to be maintained in equilibrium include differences in *luck* or *foresight* among agents, *imperfect factors markets*, and *imperfect imitability* and *substitutability*. Resources are heterogeneous: some are more valuable than others; and imperfect factor markets ensure that agents maintain asymmetric information and different expectations concerning the values of the resources. Lucky managers, or managers with more accurate expectations, acquire before their competitors, valuable resources at a price that does not reflect yet their true value, thereby creating a rent. The latter can be sustained if the valuable resource is offered in limited quantity and/or if complexity and causal ambiguity (Reed and DeFilippi, 1990) prevent competitors from recognising how to create value from the deployment of a particular resource. In both cases, either acquiring a valuable resource, or acquiring exclusive know-how concerning a particular process of value creation, the firm generates a rent.

More specifically, necessary conditions for rent creation are fourfold (Peteraf, 1993). First, resources must be heterogeneous; this is a necessary condition for Ricardian and monopoly rents to accrue.

Second, imperfect factor markets must create *ex-ante* conditions for the rents not to be offset by the costs of resource acquisition. Information concerning value of resources should be asymmetric among agents to limit competition for resource acquisition. To create a rent, it is necessary that one agent, for reasons of luck or because he has more information than the others, hires the capable applicant at the same salary the other firms pay for their less productive resources.

Third, *ex-post* conditions, such as imperfect imitability and substitutability, allow resource heterogeneity to be sustained. Imperfect substitutability prevents substitute products from decreasing rents via increases in demand elasticity (Peteraf, 1993). Imperfect imitability derives from limitations in input or from cognitive and organisational difficulties in replicating a valuable resource.

Fourth, *imperfect mobility* ensures that valuable resources remain inside the firm. Indeed, the specificity of resources to the firm's asset base links valuable productive factors to the firm. If a resource was identically valuable for many firms, this could be sold in the market. Specific resources, on the other hand, are not tradable because they have a market price that is significantly less than their value for the firm employing it (Conner, 1991; Peteraf, 1993). The difference between the value for the owner and the market price of the resource defines a Paretian rent. This type of rent is also defined as *quasi-rent* (Mahoney & Pandian, 1992) because the firm employing the valuable productive factor shares the rent with the productive factor itself (Peteraf, 1993).

Given the framework proposed above, a number of scholars stressed how firms' competitive advantages hinge upon the ability to build and maintain knowledge-based assets by integrating different skills within an organisation. Prahalad and Hamel (1990), for example, focused on the concept of *core competence* as the "... *collective learning in the organization...*" advocating that firms ought to "... *to co-ordinate diverse production skills and integrate multiple streams of technologies...*" (1990; p: 82). More recently, Conner and Prahalad (1996) set the premises to build a theory of why firms exist based on the capability of these latter to integrate knowledge of different actors. Grant (1996) puts forward that the strategically most important resource of a firm is knowledge and that the essence of organisational capability is the integration of individual knowledge. Spender (1996) proposes to establish on knowledge a dynamic theory of the firm (1996) and Kogut and Zander (1996) recommend that firms, by the creation of an identity, facilitates internal processes of learning, knowledge communication and coordination. Finally, Adler (2001) explains how trust has unique effective properties for the coordination of knowledge and suggests that community, rather than hierarchy or market, might be an efficient organisational form to integrate knowledge-based jobs.

3. Schumpeterian Rents, Evolutionary Approach and Inter-Firm Heterogeneity

Some scholars (Goshal and Moran, 1996) claim that the resource-based approach to inter-firm heterogeneity is associated with the concept of *appropriation* and competition is reduced to a race for first-mover advantage thereby overlooking intra-organisational processes leading to creation and adaptation of firm-idiosyncratic resource endowments. Indeed, the resource-based view of inter-firm heterogeneity apparently emphasises Ricardian rents and overlooks Schumpeterian rents.

The emphasis on long-lived and durable rents and on an equilibrium analysis explains the lack of interest in Schumpeterian rents. Schumpeterian rents generate dynamic inter-firm differences. In a Schumpeterian framework, a firm builds a rent by finding a new, more profitable, combination of productive factors. This position lasts until competitors are able to imitate it. However, the firm that introduced the innovation can use its advantage to conceive of another, new combination of inputs that puts this firm ahead again in the competition. On the other hand, the imitator, in his imitative attempt, might introduce a different, more advantageous, combination of productive factors. The situation described is not one in which a favourable competitive position exists, protected by imitation, but one where competitive positions evolve dynamically.

In this line of thinking, competitive advantage is the result of the ability to create and update a *situational fit* between combination of resources and environmental demand, playing an ever-changing, *dynamic puzzle game* (Boggiest, Martens, and Van Cauwenberg, 1994). Firms build up *flexible-response capabilities* (Grant, 1996) or *dynamic capabilities* (Teece, Pisano and Shuen, 1997, 2000; Pisano, 1997, 2000) in order to respond to dynamic environment by recombining their skill endowments.

As Levinthal (1995) suggests, the analysis of Schumpeterian rents dynamics requires an evolutionary approach; firms do not pursue an optimising decision-making behaviour, rather they learn by searching for new, more efficient routines of resource management. Decision makers are *procedurally* rational (Simon, 1955, 1964), they use heuristics to decrease the average number of searches and have different sets of choices because of their different histories (Nelson and Winter, 1982).

4. Method and Approach

4.1. MODELLING AND SIMULATION

Modelling and simulation constitute a fundamental element of the research design.[1] Simulation helps rigorously to deduce consequences from modelled assumptions when complexity of modelling makes difficult to obtain closed-form solutions. In addition, simulation allows looking at unfolding organisational and social processes, capturing the behavioural characteristics in transitory states. In this work, we use a computer simulation model as a theoretical laboratory to analyse the circumstances in which different hiring and reward strategies, firms' heterogeneity and rent distribution patterns emerge. Alternative hypothetical, though dormant, trajectories will be activated by modifying the underlying modelled assumptions. This approach has the advantage of creating an appropriate setting to conduct controlled experiments. History can be re-run, showing how small, *ab-initio* modifications in parameter values can be amplified over time, to yield firms with distinct characteristics. Simulation is a unique methodology to perform this journey in history. This kind of method is a form of computational "thought experiment" in which we ask "what if" questions in an artificial world. However, the ultimate aim is to allow us to develop hypotheses and theories that can then applied to real world phenomena and data. We use the computer model at this stage to help us to generate and test, in a rigorous and deductive way, candidate ideas.

4.2. MULTI-AGENT BASED SIMULATION

We used an agent-based model to simulate interaction among employees and firms. Axtell (1999), for example, presents a model in which employees spontaneously form firms and then make rational calculations on when and if to leave or stay. In that model firms are not modelled directly and agents act rationally to maximise their own payoffs. In our model firms are represented directly as an agent with internal models of the economy and our employees are far from rational – they greedily and locally attempt to increase their salary without any model of the economy or of the firms.

The use of computer simulation models (Axelrod, 1997) is an emerging paradigm within the social sciences. Increasingly social scientists are using the techniques of multi-agent based simulation (MABS) to explore complex dynamics in artificial social systems (Hales et al., 2003).

The FirmWorld model should be viewed as an “artificial society” type model (i.e. similar to the SugarScape model (Epstein and Axtell, 1996)). It is not an attempt to capture a specific target such as some real labour market based on a real industry informed by quantitative empirical data. Rather, the FirmWorld model allows use to express formally (computationally) a number of hypotheses about potential processes that may occur in real labour markets but in a stylised and executable manner such that experiments can be performed to deduce the consequences of those hypotheses when they are combined in complex, adaptive systems (CAS). We therefore purposefully present a simplified model in which we hope to capture the kinds of complex dynamics in which we are interested. The FirmWorld can be contrasted with previous more simplified tag-based skill models (Hales, 2000) in which only a single level agent is modelled and organisations (or groups) emerge from simple interactions. In the FirmWorld, firm agents directly recruit and coordinate their employee agents based on their evolving policies (see next section).

5. The FirmWorld Agent-Based Model

The model contains three kinds of agents: The Environment, Firms and Employees. They are related into a non-strict container hierarchy. The environment contains all other agents. Firms contain employees. However, firms may have no employees and agents may be outside all firms when unemployed.

There is a single environment agent; it stores an economic model that represents the actual economy in which the firms and employees reside – we call this the “master model”. This model is not directly visible to other agents. Only indirectly, via the receipt of earnings over time, do firms receive information from this model.

Firms consist of a hiring policy, a pay policy, an internal economic model (called a “firm model”), capital and a (possibly empty) set of individual employee agents. A firm with negative capital is considered bankrupt and is closed – making all employees unemployed. We describe the firm agents in more detail below.

Each employee possesses a single skill type from a set. Currently these are fixed and endogenously specified (so employees do not change skills). Each employee has an employment policy – a decision process that allows it to decide if to accept an offer from a firm. Currently, unemployed agents accept any offer but employed agents only accept offers that are higher than their current salary (incorporating a "security bonus" see below) – to this extent, employees can be seen as greedy maximisers. Employees currently have no internal economic model of their own so they cannot calculate their own worth and, hence, rents potentially accruing to employers. In the current implementation of the model, skills are represented by single cardinal values (though they have no ordinal significance). We describe employee agents in more detail below.

Figure 1 gives a schematic of the entire FirmWorld – indicating the major objects and their relationships.

6. A Month in the FirmWorld

The model is executed by running it for a fixed number of "cycles". We designate a cycle as a notional month. For all the experiments presented here we run the model for 120 months. At the start of each month, each company considers its internal economic model of the economy and its current employee skill set. If the

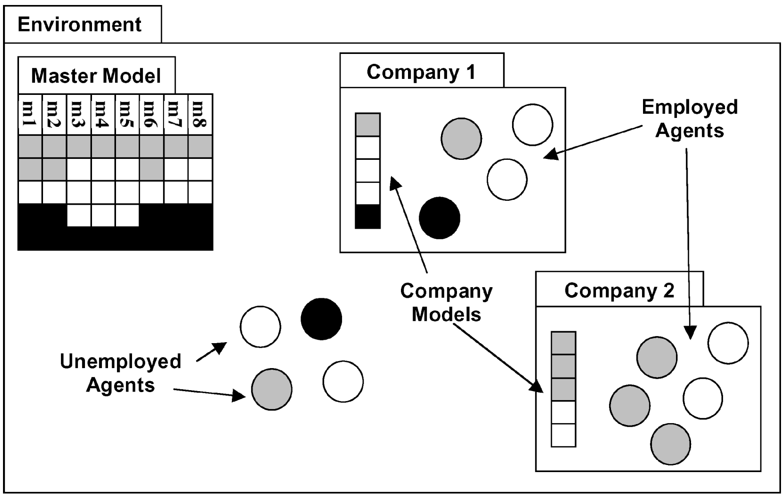


Figure 1. A schematic diagram of the main entities in the system. The environment contains a "master model" giving the optimal set of employee skills for each cycle (here we only see eight cycles ml..m8 we use shades to indicate three skill types). Each firm contains a company model and some employee agents. Each firm attempts to make its workforce match its model by hiring and firing. In this case firm 2 has managed to archive this (it has 3 grey agents and two white agents) but firm 1 is one white agent short. The calculate earnings the workforce is compared to the master model for the given cycle and the distance calculated (see text for details).

company detects a shortfall in any given skill, it "advertises" publicly for employees with that skill. All unemployed agents, and some randomly selected proportion of employed agents, approach a randomly selected subset of firms advertising for their skill. The firms respond with salary offers based on their internal economic model, hiring policy and pay policy. This works in the following way: selected employee agent *i* approaches a set of firms F that have advertised for their skill. Agent *i* approaches each company *k* in F and *k* makes a job offer. A job offer consists of a salary amount plus a job status: either permanent or non-permanent. Those taking permanent positions cannot be fired at a future date; this is not the case for non-permanent jobs.

When making a salary offer, a firm uses its economic model to determine how much it believes its earnings would increase if it hires the employee agent and then makes a salary offer determined by its pay policy. The job status type offered (permanent or non-permanent) is determined based on the perceived scarcity of the skill in the market.

After the employee agent *i* has visited each company in F it takes the best offer proposed and revisits each company in F, communicates this highest offer, asking for a further offer. The company may then make a higher second offer or make no further offer.

If *i* is currently unemployed, it accepts the best offer and it becomes an employee of the relevant company. If *i* is already employed it compares the best offer with its current job and moves if a better offer has been made. No employed employee moves without consulting its current employer in the round of offers (this allows a current employer to retain an employee by making the best offer).

After the hiring process firms have their bank balance reduced by their total monthly costs (which equal total salary costs plus other fixed costs). The environment then allocates, for each firm, earnings for the month based on the composition of the workforce in the firm and the economic "master model". That is, we assume that the composition of the workforce (number of employees with each skill) determines the earnings for each firm. Hence, two firms with identical workforces will receive identical earnings.

Currently, the economic "master model" stored by the environment is an exogenously defined optimal employee set (number and skill set) for each month. In our experiments we have modelled both static (never changing) and dynamic (constantly changing) "master models".

The workforce of each firm is compared to the current "master model". For each useful employee (an employee with a required skill) a marginal contribution to the firm's total sales is calculated using both a marginal decreasing return function and a specificity function that adjust marginal productivity by assessing how specific the employee is for a company (see below). The more specific the employee is for a company, the higher his value will be for the company.

After companies have received their income from the economy, they pay their outgoings (salary and fixed costs). Those companies that run-out of capital go bankrupt – they close and all their employees become unemployed. Since our model imposes a fixed number of companies, when a company goes bankrupt, a new one is immediately formed to take its place. The new company copies the characteristics of a successful company (such as internal company model and pay policy) and then changes this slightly with a low probability. This is a kind of "replication" and "mutation". New companies start with some initial capital and zero employees.

Below is an outline algorithm of FirmWorld. In the following sections we describe in a little more detail the behaviour of Employee agents and Company Agents to cover each of the processes described in the sequence.

FirmWorld Outline Algorithm

```
Initialise firms
Initialise employees
Loop for 120 cycles
       Firms fire non-permanent employees they do not want to keep
       Firms advertise job vacancies
       All Unemployed agents approach some companies for offers
       Sample of employed agents approach some companies for offers
       Companies are awarded income and pay costs and salaries
       Bankrupt companies dissolved - employees become unemployed
       New companies formed - copy "gene" of more successful
         companies
End Loop
```

7. Employee Agents

Employee agents are relatively simple (see Figure 2). They are marked by a single skill, a number fixed for the career of the agent. In the experiments for this paper, in

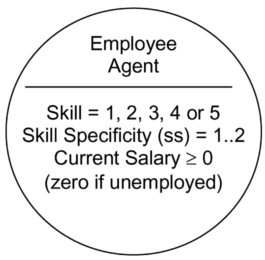


Figure 2. Shows the composition of Employee agents – they store a fixed skill, skill specificity and a current salary.

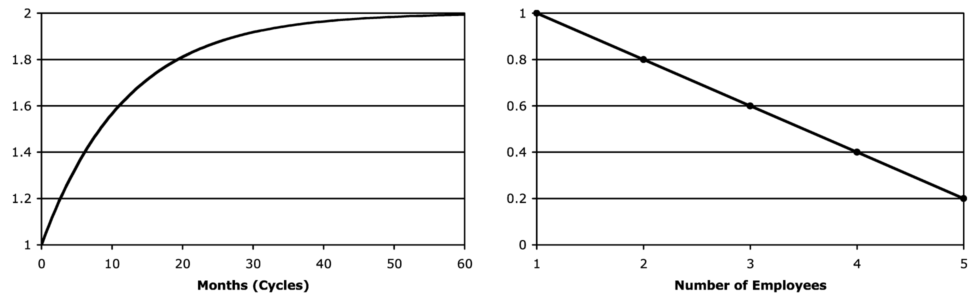
all cases, there are 5 skills represented by the cardinal numbers [1 . . . 5]. Associated with an agent's skill is a second value called the skill "specificity factor" (*sf*). This is a real number ($1 < sf < 2$) representing how specialised the skill is to a particular employer. A high value means the skill is of high value to the current employer but of low value to another employer. This value is not fixed but changes during the career of the employee.

7.1. SPECIFICITY OF SKILLS

The specificity factors of all agents start at $sf = 1$. They increase non-linearly (following a convex, learning, curve function) over each month an agent is employed in a given company such that after 4 notional years (48 months) the *sf* value goes from 1 to 2. The *sf* value is not allowed to become greater than 2. However, the value is reduced back to 1 if an agent leaves its current employer. This captures the notion that skills produce value when embedded within a firm-specific network and training is a socialisation process that takes place when a new employee is embedded within a group of incumbent workers (Doeringer and Piore, 1971; Piore, 1973; Williamson, Watcher and Harris, 1975). In Equation (1), *sf* is a function of *x*, that is, the number of months that an employee *i* stays within the same organisation *k*. Workers become specialised within a company, build firm specific knowledge and this latter is not transferable to other firms (see Figure 3a).

$$sf = 2 - e^{\frac{x_{i,k}}{12}} \tag{1}$$

The specificity potentially adds value to the company. If an employee possesses a required skill then the marginal return generated by the employee is multiplied by



(a) (b)

Figure 3. (a) Shows a graph of the specificity function ($y = 2 - e^{-x/12}$) where y is the specificity value and x is the number of months with the same employer – this represents a kind of simplified "learning curve". (b) Shows a graph of the simple linear marginal return function ($y = 1 - ((x - 1)/n)$) – here shown where the number of required employees of skill i is $n = 5$ and the number of employees already in the organisation holding skill i is x. A company uses its internal company model to choose the n value and the environment uses the master model.

the *sf* value. When firms consider employing an agent they consider the specificity value to be 1 even if it is higher for a current employer – since the value is reset to 1 if the employee decides to move.

7.2. THE EMPLOYEE CAREER HISTORY

All agents start out as unemployed but may become employees of a firm through a hiring process as described previously. Through bankruptcy or firing, they may become unemployed again during periods of their career, employees may also move among firms comparing different salaries offered in this way agents may make several career moves during a simulation run (which simulates a notional 10 years).

Agents do not exercise complex decision processes or maintain internal models of the environment, firms or other agents, they simply choose the best jobs offered to them and move to the associated firm.

Over the course of a career (the entire length of a simulation run) their skill never changes but the specificity may change several times. If an agent joins a firm and stays there for many months then its specificity will eventually become 2; in this condition the employee is potentially worth twice the maximum of what it could be worth in any other firm (graph in Figure 3a describes employees' specificity curve).

7.3. MARGINAL PRODUCTIVITY OF EMPLOYEES

Productivity of each worker marginally decreases as the number of employees hired with the same skill increases. Therefore, we define *max mp* as the maximum marginal productivity that a worker contributes when hired in a firm. If the economy requires more than one worker with the same skill, each new worker hired with that skill will contribute $mp < \max\ mp$. In Equation 2, we model marginal productivity as a function of the number of employees hired in a firm *k* with skill j ($e_{j,k}$) and the total number of employees holding skill *j* that an organisation *k* desires to employees according to its company model ($\bar{e}_{j,k}$) (see graph in Figure 3b).

$$mp = 1 - \left(\frac{e_{j,k} - 1}{\bar{e}_{j,k}}\right) \tag{2}$$

7.4. MARGINAL CONTRIBUTION OF EMPLOYEES TO FIRMS' SALES

In our model, the marginal contribution that each worker gives to a firm's total sales depends both on his marginal productivity, as specified in Equation (2), and the specificity (*sf*) of a worker in an organisation. Thus, specificity is the second element that influences a worker's contribution to a firm's sales. In the model, to obtain a worker's contribution to sales (*mc*), then, we multiply his marginal productivity, as calculated in Equation 2, by the specificity factor (*sf*) which captures his embeddedness within the organisational network. Thus, each hired worker contributes zero if his skill is not required by the economy or if the firm has already the amount of workers required with that skill. If the worker hired bears a skill required by the economy, he contributes with:

$$mc = mp \cdot sf \tag{3}$$

8. Company Agents

Company (or Firm) agents store a model of their believed optimal skill set called the "company model". This model is a vector giving the number of each kind of skill believed to be optimal and represented by a believed optimal workforce skill set – that is what the firm *believes* would produce optimal results. This may or may not match the *actual* optimal skill set contained in the master model for a given quarter. It is important to realise that firms are not rewarded based on the similarity of their economic model but on their *actual* workforce, which although informed by the model will often not be identical to it since this depends on the hiring process and other policies. However, the firm uses its actions to attempt to minimize the gap between its economic model and the actual workforce composition. The firm tries to recruit employees that match the required skills. Hence if the company model indicated a company needed two employees with skill 3 and 1 employee with skill 5 then the company would "advertise" vacancies for those skills if it did not have enough employees with those skills.

So to summarize we have the interplay of three factors that determine the earnings of a company, its internal economic model (the firm model), its actual workforce composition and the master model (representing the actual optimal workforce composition determined by the economic environment).

8.1. HIRING EMPLOYEES

A company model may or may not match the master model. If it does then the firm will tend to make "economically rational" decisions when hiring and firing. Obviously, if it bears no relationship to the master model a firm may hire employees that add no value and do not increase their earnings in reality.

In addition to the company model, firms store three real values that potentially affect hiring, firing and salary offers (*ne, oe* and *st*). When a salary offer is made to a potential employee i, the firm uses its company model and the prospective employee's skill to calculate the value the firm believes the new employee would add (*mc*) excluding any company costs. The offer made is not this full amount mc rather it is $mc \cdot ne$. So for $ne < 1$ the offer is less than the believed value and if $ne = 1$ it is identical. The *oe* value is used in a similar way but for "firing" calculations (see later). The *st* value gives a "scarcity threshold" above which a skill is considered "scarce". New employees with scarce skills are offered permanent contracts (see below).

Essentially, then, the company model, combined with *ne, oe* and *st*, defines the hiring and firing behaviour of a company; one can think of these three items combined as a kind of "company gene", which, if copied to another company, brings over much of the behaviour.

8.2. SCARCITY OF SKILLS AND PERMANENT CONTRACT OFFERS

When companies make a job offer they make a salary offer and a status offer (permanent or non-permanent). They decide on this latter aspect by assessing whether a skill is "scarce". If it is, then they make a permanent offer.

A firm calculates the binary function of scarcity for a given skill in the following way: a proportion is calculated as the number of companies still advertising for employees with the given skill *after* the recruitment phase, i.e. the proportion of companies still requiring the skill. If this value is *larger* than the internally stored scarcity threshold (*st*) then the company offers a permanent contract.

Hence, companies with low *st* values are characterized by a propensity to offer permanent contracts as they will offer permanent contracts at lower scarcity than those with high *st* values. As stated previously, the *st* value forms part of the company "gene" and is copied by new companies from the more successful companies (based on profit).

Employees on permanent contracts cannot be fired; however, they are more loyal than temporary workers and are much less likely to look for new jobs (probabilistically 75% less likely). The assumption is justified by the fact the employment contract may contain clauses and agreement that disincentives employees from leaving a firm. For example, employment contracts may contain *non-compete* clause, which forbids employees from working for competitors for a given period of time after leaving the firm (Liebeskind, 1996). In addition, importantly, when employees decide on the "best" job offer they weight a permanent offer by notionally increasing the salary offer by a "security bonus" (currently set to 100% for all employees). This means that a permanent offer is "as good as" a temporary offer of double the salary.

8.3. FIRM FINANCIALS, BANKRUPT AND EVOLUTIONARY LEARNING

Firms maintain a bank balance (which is initialised to some positive value for new firms) from which payments are made (fixed costs and salaries) and sales are paid into. Firms' sales are given by the sum of marginal contributions of skills of the workers employed in the firm. Thus, sales of firm k are:

$$S_k = \sum_{i=1}^{n} mc_i \tag{4}$$

Firms total costs (tc) are the sum of fixed costs ($\bar{c}$) and salaries, which are variable costs (c) depending on the number of employees hired. We did not consider any economies of scale.

$$tc = \bar{c} + c \cdot n$$

If the balance goes below zero then the company is considered bankrupt. When a firm becomes bankrupt, all employees are made unemployed and a new company is formed to take its place. The new company is not initialised randomly but sets its "gene" (i.e. company model and *ne, oe* and *st* values) by sampling a subset of the population of firms and copying the "gene" of the firm with highest, last cycle, profit. Also with some small probability the "gene" is "mutated" by applying small random changes to the company model and the *ne, oe* and *st* values. This creates a weak evolutionary learning in which profit in the last cycle can be seen as a measure of fitness. The process is weak in the sense that we assume that inertia prevents firms' adaptation. Thus, learning is determined by firms' selection. In this respect, we assume that both company model and hiring policies are elements of core features that firms cannot easily adapt (Hannan and Freeman, 1977, 1984, 1989).

The number of firms is kept constant for the purposes of simplicity of analysis and modelling. We wait for a firm to "die" before reproducing a successful one. However, a similar evolutionary process would emerge if high profit firms spontaneously generated copies.

8.4. FIRING EMPLOYEES

Firms periodically reassess the value of their current employees on *non-permanent* contracts using a similar method as for hiring new employees. The only difference is that the calculated value of the employee (*mc*) based on the company model and specificity (as previously described) is multiplied by *oe* instead of *ne*. If $mc \cdot oe <$ current salary then the employee is fired. Firing is only allowed for employees on non-permanent contracts. Hence a company with a high *oe* value is more likely to keep its non-permanent employees than one with a low value.

9. Simulation Experiments

In our initial experiments we made runs for 4 scenarios based on the different combinations of two binary dimensions:

1. Scarce labour (SL = 1) v. abundant labour (SL = 0)
2. Static economy (FE = 1) v. dynamic economy (FE = 0)

For 1, scarce labour meant 200 employees, abundant labour 400. For 2, in the static market case the master model was never changed, in the dynamic case the master model was changed slightly with some probability each month.

For all experiments, we fixed the number of firms at 50 and the number of different skill types to 5. Each experiment was run to 120 cycles (notional months). The master model was set to one for each skill type (i.e. the optimal firm would contain 5 employees, one with each skill). Company model vectors were initialised randomly with each skill being set to a uniform randomly drawn integer [0...5]. The *ne* and *oe* real values were drawn from the range [0...1]. New companies were initialised with a bank balance of 50,000 units, maximum marginal productivity of a skill is 1000 and fixed costs of 5000 units per month.

Given these values, the maximum value of sales for a firm would be $2000 \times 5 = 10000$ units, if it had the perfect skill set, highest specificities and if economy required one worker for each of the skills. Maximum profit would be $10000 -$ (costs of) $5000 = 5000$ units. This is true in the fixed economy case (FE = 1). Where the economy was dynamic (FE = 0) then the possible maximum income values will changed randomly over time because the number of employee agents required for each skill in the master model follows a random walk.

Employees were initialised with a randomly selected skill [1...5] and a skill specificity (*sf*) of 1.5. This means that at the start of each simulation run, skills are, probabilistically, distributed evenly over the population.

For each of the 4 scenarios we ran 100 independent runs with different pseudo-random number seeds.

10. Findings

The conducted experiments explore how firms manage with different policies their skill endowments. In the following, we focus on how management policies emerge as we move from a stable to a dynamic scenario, with labour scarcity. The aim of the experiments is to understand what kind of organisations survive in a dynamic economic environment where firms need both to nurture firm-specific skills and accommodate competitive pressures that evolve rapidly and generates ambiguous signals concerning strategic values of different skills.

10.1. STABLE ECONOMY

In the stable economy, firms' perceptions regarding scarcity and strategic value of different skills converge toward the economy model through a process of imitation. Thus, firms are able to aggregate workers in different categories depending on the value of their skills.

As explained in Figure 4, permanent contract includes two clusters of workers. A first cluster, in the upper right corner of the graph, includes valuable scarce skills which have been hired with long-term contracts and receive high wages. A second cluster includes skills which are scarce but produce less value. For this reason, these skills have lower salaries given similar level of specificity.

Figure 5 describes clusters of workers holding a temporary contract in the fixed economy. Here again we can recognise two clusters of workers. We can recognise, in the top right corner of the graph, a cluster of workers enjoying high salaries, they are not scarce but their skills are strategic. On the top left corner, we can notice the cluster of workers whose skills are neither strategic nor scarce. As we can see,

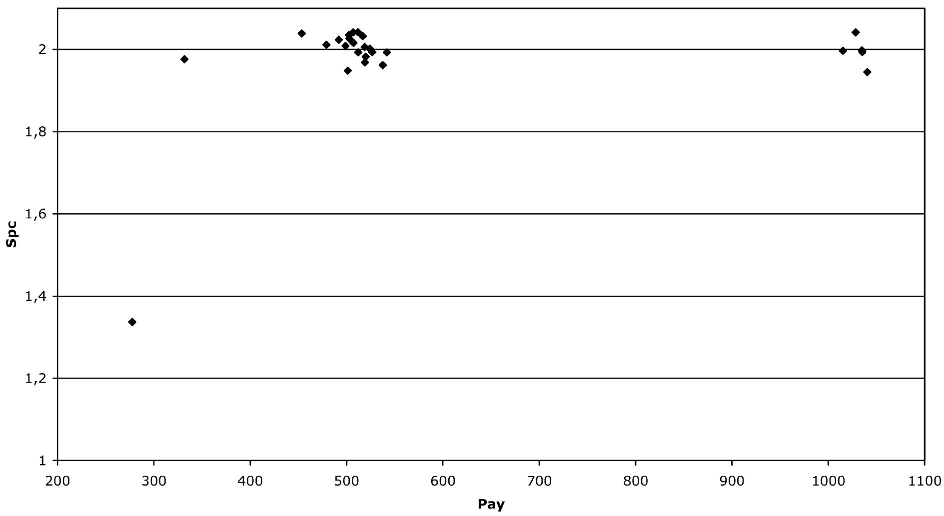


Figure 4. Permanent employment in stable economy.

there is a vertical line of workers below this cluster; along the vertical line are distributed workers that have different level of specificity but the same low salary. This phenomenon is generated by the fact that the workers, holding a temporary contracts, move from one firm to the other, thus, their specificity level is different. However, since their skills are not required by the environment, their wages remain equally low notwithstanding the different level of specificity. These workers are similar to commodities; they move among organisations, these latter are able to lower salaries putting workers in competition.

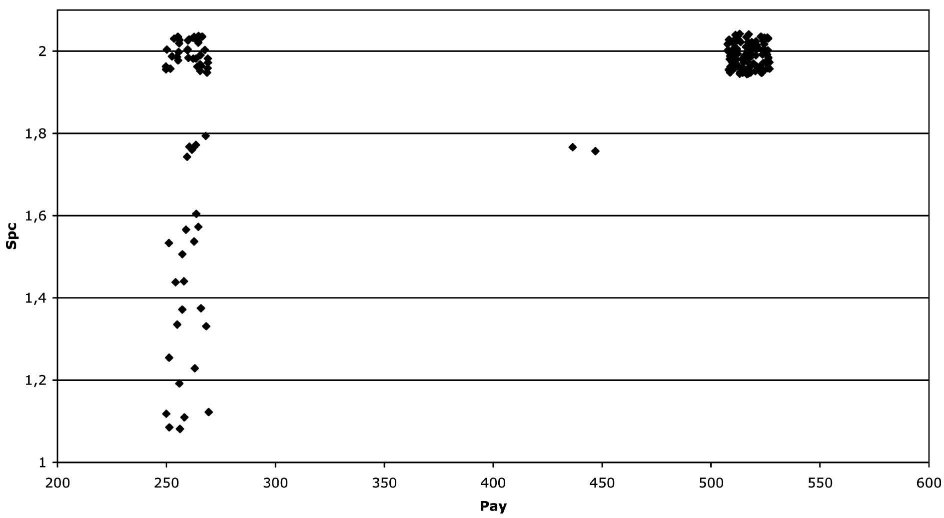


Figure 5. Temporary employment in stable economy.

Simulation experiments suggest, that, in general, with stable economies, firms have a clear idea of which skills they need to hire long term and which skills can be managed with temporary arrangements. Thus, the proportion of permanent contracts is low compared to temporary jobs. Temporary workers move among firms as commodities, scarce strategic skills are locked within firms and produce value by building firm-specific knowledge. Firms, in general, maintain high bargaining power that allows them to appropriate large part of value produced by labour.

10.2. DYNAMIC ECONOMY

In the dynamic economy, strategic value of skills changes rapidly thereby producing ambiguous signals to firm that adapt their skill endowments. Ex ante, we expected that firms would have preferred to select temporary contracts. The expectation was grounded on two hypotheses.

First, assuming ambiguous information on skill strategic values, we expected a repertoire of very different models among firms, indicating different priorities in term of skills hiring. Different models would lead to different hiring policies; thus, we expected that firms directed their attention to different skills thereby decreasing perceived scarcity of each skill. We expected that lower perceived scarcity favoured temporary rather than long term contracts.

Second, the emergence of a large proportion of temporary contracts was suggested by the evolutionary mechanism built in the model. We expected that those firms, which were initially assigned a high propensity to hire long term, would have been selected out in a simulated environment in which firms need to be more flexible and continuously adapt their skill endowments to evolving competitive environments.

Simulation experiments proved that our expectations were faulted: as described by Figure 6, in a dynamic environment the proportion of long term contracts is, on average, significantly higher than in stable economies.

The simulation experiments articulate a counterintuitive lesson that suggests two plausible causes of observed behaviours.

A first mechanism deals with the interaction among individual perceptions and aggregate decision-making. Firms have different perceptions concerning skills' strategic value this leads them to use, at least some, long term contracts. As environments change, skills' value changes as well. Firms cannot lay off their employees so the employees already hired with long term contracts will remain within the firm. In addition, the firm will hire with long term contracts those skills whose strategic value has increased due to change in the status of the economy. As the process continues, firms rush to hire long term workers endogenously generating labour scarcity and perceiving an increasing need for long term contracts.

A second explanation of the spread of long term contracts in the dynamic economy is the evolutionary selection of such a hiring policy in the simulated economy.

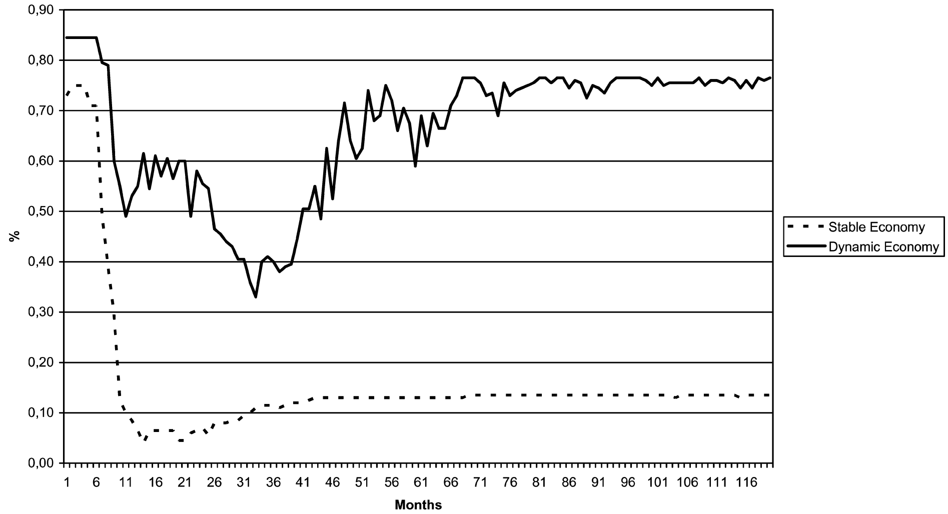


Figure 6. Share of permanent contracts.

If hiring temporary workers was the optimal strategy in a dynamic economic environment, why new firms created did not copy such a strategy? Why the attitude to hire long term is positively selected in the evolutionary process? The reason is that firms hiring long term have superior performances and, thus, are copied by firms newly created. As described in Figure 7, as the simulation unfolds, firms

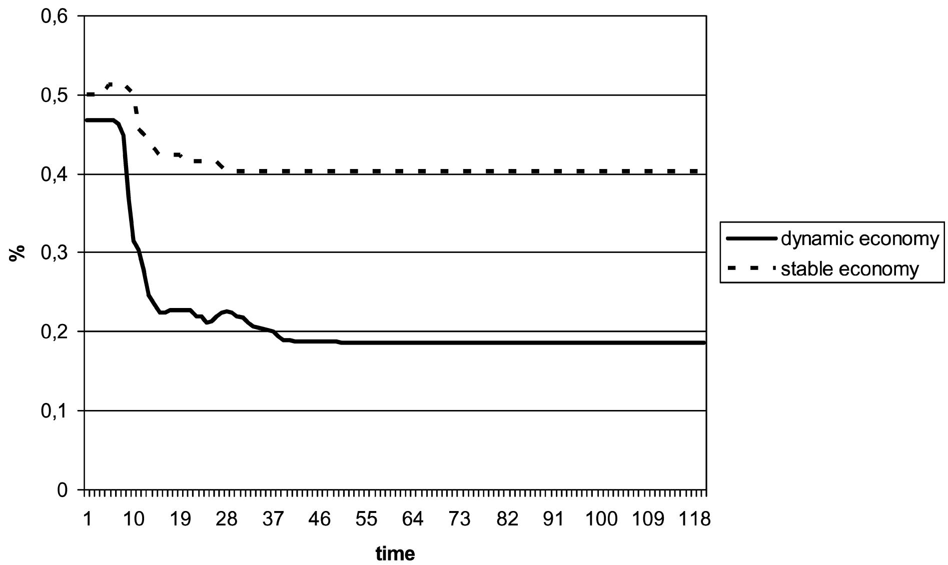


Figure 7. Scarcity thresholds.

operating in a dynamic economy decrease their 'scarcity threshold' compared to firms operating in stable economies. That is, in what we defined as a dynamic economy, surviving firms tend to use permanent contracts more frequently that those firm operating in a stable economy.

In other words, in our simulation, firms have a biased model of which skill is really valuable. Such a perception is honed through the process of going bankruptcy and recreating a firm that copies strategies of best performers. This adjustment delay is long and by the time a company has reshaped its strategy, the environment might have changed again making useless any previous adaptation. In this context, temporary contracts do not generate a sustainable competitive advantage.

On the other hand, by hiring long term skills as they emerge as scarce, firms build a very rich skill endowment, composed of skills whose value change as the simulation unfolds. The key issue is that these skills, by remaining within a firm, build firm-specific knowledge. Had the value of a particular skill, included in a firm's skill endowment, to increase, the demand for that skill will increase in the labour market. Yet, high specificity of the skill decreases its transferability and the firm will be able to maintain the skill in the organisation paying a lower salary compared to the salary the firm would have paid if the skill had been fully transferable to other organisations. This is because, full mobility leads to bargaining processes that increase salaries and decreases rents appropriated by firms. In this respect, lack of specificity and transferability increases the portion of rent appropriated by labour (Peteraf, 1993). Figure 8 can help us in explaining this mechanism. By looking at Figures 4 and 8 together, we can compare emerging clusters of workers holding permanent contracts in both fixed and dynamic economies. In dynamic economies, it is much harder to define well defined clusters. If we look at the left side of

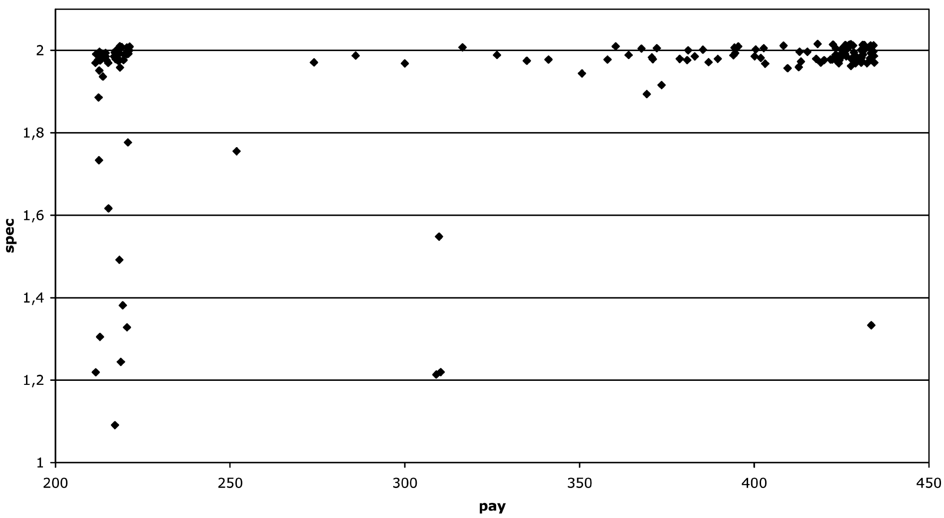


Figure 8. Permanent employment in dynamic economy.

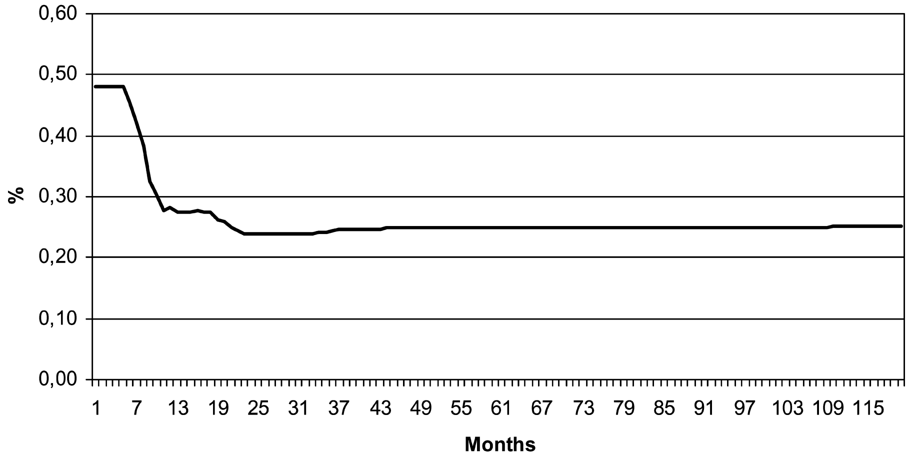


Figure 9. Salary/Value in a dynamic economy.

the graph, we recognise a vertical line of workers with low wage and increasing specificity, which is not present in graph 4. If we look in the upper part of the graph, we can see a horizontal line of workers with fixed specificity and high wage, which, again, is not present in graph 4. The vertical line of workers on the left is explained by the fact that, differently from the stable economy, firms' lifetime is shorter, new firms rapidly substitute for failing old firms. In this environment, new entrant firms hire scarce skills in different point in time, this explaining why we can observe different levels of specificity.

The horizontal line in the upper part of the graph has another interesting explanation. As we can see, differently from graph 4, in graph 8, strategic values of skills may change as the simulation unfolds. Thus, firms hire workers bearing skills whose value change along the simulation. As a consequence, firms pay different salaries to workers with the same levels of specificity depending on the strategic value of the skills they bear. Yet, given the high level of specificity and, consequently, low transferability of skills among different firms, job market does not erode firms' rents and the wages paid are much lower value created as described in Figure 9.

11. Discussion: Learning without Earning

The simulation experiments in our work suggest that mobility favours firms when estimation of expected marginal productivity of workers is not ambiguous. In such a context, where employers are able to discriminate between strategic and non-strategic skills, it is possible to use temporary jobs to increase mobility for non-strategic skills. On the other hand, the use of temporary jobs and mobility may lead to counterintuitive results when estimated expected marginal productivity of workers is ambiguous in highly dynamic environment. When competitive environmental dynamics continuously change the strategic value of different skills, the attempt to continuously adapt to environmental requirements, adopting hiring policies based on temporary contracts, may be suboptimal for two reasons.

First, firms may find themselves hiring skills when the expected marginal productivity of these latter is high and, thus, the market salary is increasing.

Second, a firm, once has paid high wage to hire the worker, might have to discover that competitive environment has changed and the expected marginal productivity of the skill is decreasing.

The results of our work support the idea that in a dynamic environment firms have higher survival performances when they use long-term contracts to build and maintain a repertoire of different firm-specific skills. These skills provide the organisations with the flexibility and adaptability needed to take advantage of emergent opportunities and neutralise threats (Miner, 1987).

In the environment that we describe in our model, firms are fairly inertial and observed organizational change result more from organizational selection than from voluntary adaptation (Hannan and Freeman, 1977, 1984, 1989). The rate of change in the environment is faster than the speed of learning mechanisms, that is, the rate at which firms are able to hire new skills and extract rents by exploiting accumulation of firm-specific knowledge. Thus, firms are better of when, rather than trying to follow environmental change, maintain a repertoire of skills to face different competitive settings. The situation that our experiments depict calls to mind Hannan and Freeman's hypothesis of structural inertia, according to which *attempts at reorganization increase death rates* (1984: 159).

On the other hand, our study suggests that, despite their inertial features, organizations may adapt to evolving environments by exploiting the network-specific nature of organizational learning. In our model, employed workers, when embedded within an organisation, start to learn. If their skill is not strategic, given the competitive context, they accumulate network-specific knowledge but not necessarily their salaries increase. As the environment evolves and their skills become strategic, the specificity of their know-how makes the skills not perfectly tradable in the job market. As a consequence, the emerging idiosyncratic nature of the skills push downward the wage that other firms are ready to offer thereby decreasing the wage that the original employer needs to pay to retain the worker. Employers are thus able to retain portion of quasi-rents because they are not paying the full value of extra output of their firm-specific human capital (Milgrom and Roberts, 1992: 333).

Thus, our study tease out two mechanisms – protection of quasi-rents and speed of organisational learning – that explain why trading off flexibility in hiring policies with adaptability, this latter deriving from reallocating a large repertoire of firm-specific skills, may result in a successful strategy. Advantages accrue to firms not only because they are able to fit changing needs of environment with their skill portfolio but also because they are able to protect quasi-rents produced by firm-specific human capital. Thus, while in some authors, for example, Williamson, Watcher and Harris (1975), idiosyncratic jobs create a small number bargaining situation in which incumbents workers with idiosyncratic know-how opportunistically display a perfunctory cooperation and destroy portions of idiosyncratic efficiencies gains, we stress how job idiosyncrasies may define a 'bilateral monopoly' in which, once relationship is established, both parties lose if it is terminated (Weaklien, 1989). Indeed, we focus on the small number situation on the demand side created by idiosyncratic know-how which cannot entirely be transferred to other organisations. In our model, employers' opportunistic behaviour facilitates the acquisition of scarce skills at a salary that allows large rents to be extracted.

Another issue concerns the relations between our findings and results from empirical studies.

In some respect, our argument has a connection with the countercyclical hiring posited by Greer and Ireland as these latter found that firms having high financial performances adopt a countercyclical hiring; that is they hire in downturns when salaries are lower (Greer and Hireland, 1992).

On the other hand, a number of studies found a positive correlation between variability in employment levels required by economic cycles and use of temporary workers (Davis-Blake and Uzzi, 1993). Our simulation experiments suggest that the empirical relationships between variability in demand of jobs and the hiring of temporary workers may be mediated by the relationship between workers' marginal productivity and their embeddedness within firm-specific networks of skills. Indeed, Davis-Blake and Uzzi (1993) also found a negative correlation between jobs requiring firm-specific training and use of temporary workers.

A further issue concerns the relationship between size and the use of temporary workers. Davis-Blake and Uzzi (1993), for example, found that large firms are less likely to use temporary workers. They observed a negative relation between size and use of temporary workers thereby advocating the hypothesis that large firms can reallocate employers within the organisation. Observable behaviours in our simulations are coherent with these findings. In addition, simulation experiments help to articulate hypotheses concerning causal relationships among firms' size, use of temporary workers and adaptability. The mentioned empirical study ex-post captures a relationship between organizational size and hiring of temporary workers: because firms are large, they can adapt by reallocating workers. In our experiments, we design firms of the same size and give them the choice to growth and build large repertoires of skills or remain small and adapt by hiring temporary workers as environment requires different skills. The observed emerging pattern is that firms that decide, in turbulent times, to use permanent, rather than temporary, workers get larger and are more successful than firms that decide to remain small and hire temporary workers. The issue is explored in the graphs in Figures 10–12. The graphs describe the relationships among age, size and use of permanent contracts in a typical simulation run, in a dynamic economy. In Figure 10, the firms that survive longer, approximately 6–7 years, are those that use large proportions

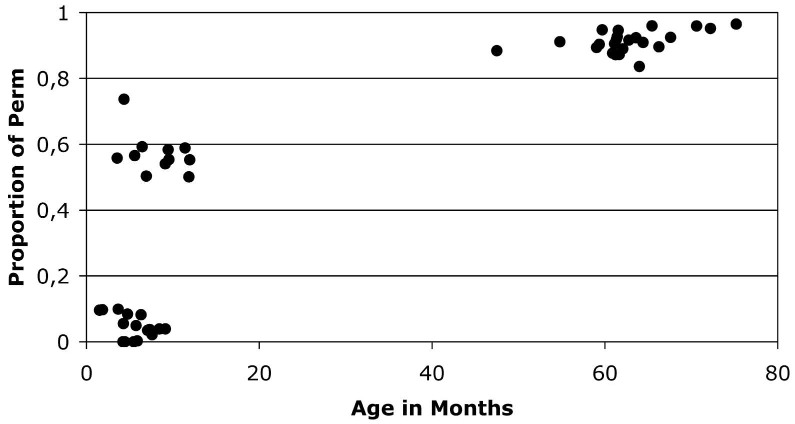


Figure 10. Company age and labour permanence.

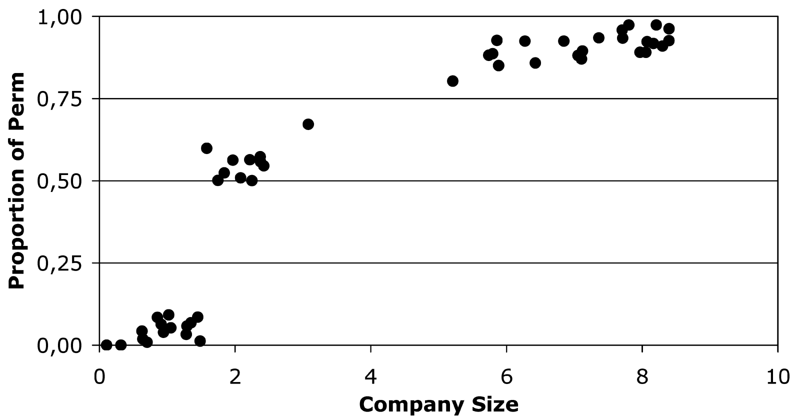


Figure 11. Company size and labour permanence.

of permanent contracts. These firms, as described in Figure 11, are the larger ones, approximately ten employees. Figures 10 and 12 suggest that it is unlikely to observe firms that survive longer than 1 year by adopting a small proportion of permanent contracts (around 20%) and maintaining a small size.

Last issue concerns what kind of organization is likely to emerge in a knowledge economy. If we assume that in a knowledge economy an increasing number of technological disciplines are required and organizations increasingly need to rely on a large number of knowledge specialists interconnected within firm-specific networks (Foss: 9–10, 2005), then it is interesting to speculate on how organizations ought to manage the employment relationship with these specialists.

Davis-Blake and Uzzi, for example, in the mentioned empirical study, found that large firms are more likely to hire independent contractors to have temporary access

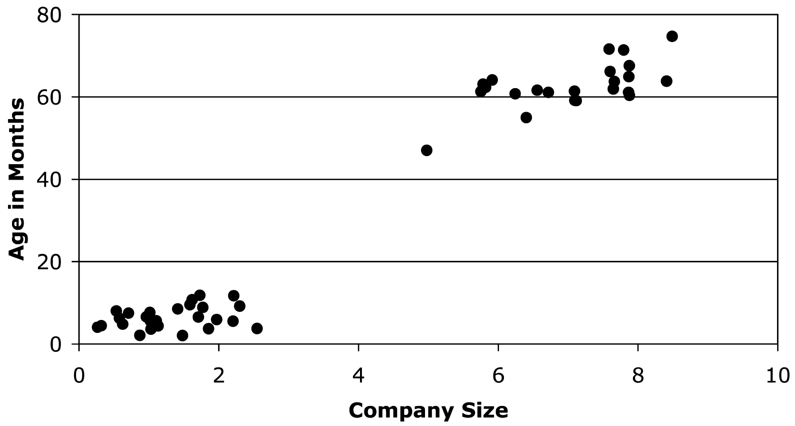


Figure 12. Company size and age.

to specialised skills and services. Again, we suspect that the problem is to assess the extent to which the specialised skills are firm-specific and firm-specificity impacts on marginal productivity. Our study suggests that hiring independent contractors in turbulent environments may work if specialised skills do not need network-specific learning and proposes, instead, the hypotheses that firms in the knowledge economy may have an incentive to have an increasing number of specialists of technological disciplines in-house (Brusoni, Prencipe and Pavitt, 2001). Thus, the simulation experiments support the argument that, in turbulent environments, firms, which rely on in-house availability of diverse specialists, better face change because specific skills provide access to cutting-edge knowledge and novel solutions to organizational problems (Moch and Morse, 1977; Haveman, 1993).

Concluding, in most western countries, even in those in which employment is growing, the proportion of jobs that qualifies as temporary or part-time is dramatically increasing. Interest in this pattern is motivated by the concern of a decreasing quality of the job stock. Indeed, temporary jobs suffer from reduction in real wages, increased inequality in wages, reduced job protection and insurance benefits (Farber, 1999). A number of studies addressed the welfare implications of temporary employment. Jenkins and Chun-Yan Kuo (1978), for example, addressed the social opportunity costs of temporary employment. The angle that we take in our study deals with firm-level strategies and suggests that, in dynamic environments, the use of temporary jobs might results in decreasing survival performances at organisational level.

A line of further work that is worth considering concerns the representation of actors-employees reaction to firms' policies. In particular, in the present model, employees do not control the rate and direction of learning. In a further work, we intend to model with more accuracy workers' decision-making.

On the one hand, we have in mind to assign workers the decision on whether or not to invest in firm-specific know-how. To take the decision, we assume that employees consider long-term job security (Hodgson, 1999: 248) and that, in general, high turnover rates discourage firm-specific learning (Jovanovic, 1979).

On the other hand, we want to model workers' capability to develop particular skills, evaluating, both by imitating other workers and by interpreting environmental scenario, which skill it is desirable to build up.

Acknowledgements

This work is partially supported by the EU within the 6th Framework Programme under contract 001907 (DELIS). We acknowledge the helpful comments received by Dr. Ferdinando Monte and an anonymous referee, errors and omissions remain our responsibility.

Note

[1] Simulation studies have a long tradition in organisational research, dating back to the seminal works in the area of the behavioural theory of the firm and organisational decision theory (Cyert, Feigenbaum and March, 1950) some of the most important theoretical pieces in the theory of the firm and organisational theory are based on simulations studies. This is true, for example, for the "Garbage Can" model (Cohen, March and Olsen, 1972) and for the work leading to the development of "The Behavioral Theory of the Firm" (Cyert and March, 1963). More recently, simulations have characterised studies in organisational evolution and dynamics, and, in particular, inter-organisational evolution (Lomborg, 1996), intra-organisational evolution (Burgelman and Mittman, 1994) and organisational change (Mezias and Glynn, 1993; Lant and Mezias, 1992; Sastry, 1997).

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