Information and unionization in a simulated labor market: a computational model for the evolution of workers and firms

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Abstract

In free markets workers and firms exchange work for salaries and they have both competing and mutual interests. Workers need to work to get a salary but they are interested in getting as high a salary as possible. Firms need to hire workers but they are interested in paying them as low a salary as possible.

We used a genetic algorithm in an agent-based model to evolve the bargaining behavior of workers and firms by encoding in the genotype of firms the maximum salary a firm is ready to pay to workers and in the genotype of workers the minimum salary a worker is ready to accept in exchange for his/her work. We studied the total production of the system, the wealth differences between the two categories, the effects of unionization among workers, and the effects of different social network structures connecting workers.

Two kinds of scenarios are simulated. In the first scenario, only workers evolve while firms cannot vary the salary they offer. We found that in this scenario total production is below the level of carrying capacity. In the second scenario both workers and firms do evolve. The results show that total production is higher than the carrying capacity and that salaries paid by firms to workers tend to be the minimum salaries that are compatible with the survival of workers. However, if a sufficient fraction of workers unionize and decide to collectively ask for higher salaries, then firms are forced to pay these higher salaries not only to unionized workers but also to all workers.

Our model allows us to analyze the role of social interaction among workers when they are looking for a new job. A worker's genotype includes a value that indicates how many job offers are evaluated by the worker before deciding which job offer to accept. Because the evaluation of each job offer has a fixed cost, the evolution of this value indicates the value of information on job offers for workers. We found that this value is higher in the second scenario than in the first. Finally, when workers are connected in social networks we found that this value increases with the degree of globalization of the network.

Keywords

Labor markets, agent-based models, genetic algorithms, social network structures

1. Introduction

Neoclassical microeconomics formalizes the labor market as any other good market. Workers represent the supply of labor and firms represent the demand. Workers are assumed to have perfect knowledge about wages and marginal rate of substitution between leisure and income so that they can decide how to allocate their hours: work in order to increase their income and leisure in order to rest. Firms know the level of wages, the prices on the market, and the marginal product of labor (the increase in production resulting from the increase of one unit of labor) so that they can compute the quantity of labor hours they need. At the macro level, workers' supplies and firms' demands are aggregated and they intersect in the equilibrium point determining the level of wage and the level of employment. The neoclassical formalization of the labor market is the point of departure of many other analyses of labor markets (Ehrenberg and Smith 1997; Bresnahan 1989). However, the micro foundation of neoclassical economics is a strong simplification of reality and it does not take in consideration many other important factors like fairness (Rees 1993; Fehr and Schmidt 1999), bargaining power (Holt 1995), and information matching and social contacts (Rees and Shultz 1966; Montgomery 1991; Granovetter 1995). In order to include these phenomena in the analysis of labor markets, neoclassical assumptions need to be changed or at least relaxed and extended.

Another problem with neoclassical economics is that it provides a static explanation of the equilibrium in which macro variables should be if workers and firms were always rational and information were always completely available. In the last three decades alternative approaches have been proposed such as evolutionary economics (Nelson and Winter 1982; Dosi and Nelson 1994; Arthur et al. 1997) and agent-based computational economics (Epstein and Axtell 1996; Tesfatsion 2002a). Both approaches have in common the idea that economic agents only have bounded rationality. Evolutionary economics focuses on the fitness of the agents' behavior in a given environment and how these behaviors adapt and evolve under the pressure of selective reproduction rules. Agent-based approaches use computational models to simulate the behavior of economic agents and to show how macro-regularities of the economy emerge from the micro-rules of the interactions of economic agents. These approaches have been applied also to the study of labor markets and many researches have appeared that aim at explaining crucial stylized facts like job concentration (Tesfatsion 2001), Beveridge curve, Phillips curve vs Wage curve and Okun's curve (Fagiolo et al. 2004), and equality and segregation (Tassier and Menczer 2002).

In this paper we describe an agent-based model in order to study (a) the evolution of different labor markets, (b) the effects of unions on the labor market, and (c) the effects of social network structures on the value of information for workers.

First, labor markets differ according to the constraints firms have when hiring new workers. Either employers are completely free to have a one-to-one bargaining process with the worker or they have to respect existing regulations concerning minimum wage and wage indexation scales and bargaining norms such as fairness. In this paper we present a comparison between two scenarios that represent the two extremes of this continuum. In the first scenario firms are completely constrained and they cannot change and adjust their behavior. In the second scenario firms are free to change, evolve, enter and leave the market according to their performance. With the help of our model we describe the effects of these different scenarios on total production, level of salaries, firms' profits, and the value of information about jobs.

Second, in labor markets labor unions tend to increase the workers' bargaining power. Unions limit competition among workers and they defend the interests of unionized workers by means of collective bargaining. The positive influence on worker's salaries extends to non-unionized workers because unions strongly influence the evolution of firms' strategies. The model allows us to introduce collective bargaining where a fraction of worker agents is unionized and it shows how unionization affects the average level of salaries.

Third, many studies have showed that informal hiring methods like employee referrals and direct applications are relevant when workers are looking for a new job (Rees and Schultz 1970; Granovetter 1995). Friends and social contacts are important sources of information about employment information and level of salaries. Montgomery (1991) has analyzed four databases on alternative job-finding methods and has found that approximately a half of all employed workers find a job through social contacts like friends and relatives. How much effort do workers spend for getting a job? How many offers do they consider before deciding which job offer to accept? How important is information about other job offers for workers? And how the value of this information changes with different labor market conditions? Many studies have analyzed how workers try to find a job using referral networks (Granovetter 1973; Tassier and Menczer 2002) but all these studies focus on the importance of friends and relatives in finding a job and they assume the labor demand of firms to be fixed and given. On the other hand, one can suppose that finding a job may depend on the general conditions of the labor market. For example, during recession periods finding a job is much more difficult than during periods of economic growth. We have connected the worker agents of our multi-agent model in different network structures and we have studied the effects of such structures on the value of information about jobs for workers looking for a job.

2. The model

Workers and firms are in a relation of mutualism and co-evolution (Epstein 1997). Workers need firms in order to get a salary and firms need workers to produce and sell goods. On one hand, in any given market, if workers were to disappear, firms also would disappear, and vice versa. On the other hand, if firms increase in number because of more resources of the environment, also workers would increase in number in order to use those resources. Assuming infinite resources in the environment, workers' and firms' populations would increase exponentially but if we assume limited available resources (carrying capacity), the process is blocked and at a certain point workers and firms will stop increasing in number. However, although their mutual relationship induces both workers and firms to collaborate in order to increase in number, the two categories compete with each other in that they have opposite interests: workers aim at getting higher salaries from firms and firms aim at paying lower salaries to workers because this enables them to compete more successfully with other firms on the market. Workers want many firms offering high salaries and firms want many workers accepting low salaries.

We have reproduced such a situation in an agent-based simulation where worker agents (W agents) and entrepreneur agents (E agents) are two separated categories that live together in an environment with a given carrying capacity. The simulation proceeds by discrete time steps (cycles). A local selection algorithm (Menczer and Belew 1996) is used to evolve the behavior of W agents and E agents. Both W agents and E agents are born, live, reproduce, and die. At birth each agent is endowed with a certain energy of which a constant quantity is consumed at each cycle in order for the agent to remain alive. If an agent's energy goes to zero, the agent dies. To survive the agent must procure other energy to re-integrate the consumed energy. As long as an agent succeeds in remaining alive, the agent periodically (every K_1 cycles of the simulation) generates an offspring, i.e., a new agent of the same category that inherits the genotype of its single parent with the addition of some random noise. All agents die at a certain maximum age (K_2 cycles of the simulation). The agents that are better able to procure energy live longer and have more offspring. Therefore, the two populations of agents vary in number during the simulation according to the behavior of the agents and those agents that adopt the best strategies are more likely to leave offspring and to invade with their behavior the population.

At each time step an agent's energy is reduced because of consumption and it increases because W agents gain new energy getting salaries and E agents getting profits. Equations 1 and 2 describe the evolution of energy respectively for worker and entrepreneur agents:

$$ew_{i,t} = ew_{i,t-1} - C_p - h_i * C_r + s_{i,t} \quad (1)$$

$$ee_{j,t} = ee_{j,t-1} - C_p + \pi_{j,t} \qquad (2)$$

where $ew_{i,t}$ indicates the energy of W agent i at time t, C_p are fixed costs for individual consumption in order to survive, $h_i C_r$ are fixed costs for job search (h_i indicates the number of offers evaluated by the worker agent i and C_r indicates fixed costs for each offer), $s_{i,t}$ indicates the salary the W agent i gets for its job, $ee_{j,t}$ indicates the energy of E agent j at time t, and $\pi_{j,t}$ indicates its profits at time t. Equation 3 describes profits of E agent j:

$$\pi_{j,t} = P * y_{i,t} - C_f - \sum_q s_{q,t} \qquad (3)$$

Profits of E agents are equal to total revenue $P*y_{j,t}$ (where P is the fixed price, and $y_{j,t}$ is the quantity produced) minus fixed costs of the E agent's firm C_f and minus salaries paid to the employed W agents.

The genetic algorithm permits the evolution of both W and E agents' behaviors. Each agent, both W and E, possesses a different "genotype" that determines its behavior. For W agents, the genotype specifies the minimum salary (minS) that the agent is ready to accept from an E agent and the number of different E agents (h) that the W agent will contact when, being unemployed, it is looking for a job. For E agents, the genotype only specifies the maximum salary (maxS) that the E agent is ready to pay to a W agent if the W agent hires it. When a W agent is jobless, it contacts h E agents and it takes into consideration only the highest offer. The W agent's genotype ($minS_i$) and the E agent's genotype ($maxS_j$) are compared and the E agent I starts working for the E agent j only if $maxS_j$ is equal to or higher than $minS_i$. When a contract is concluded, the salary of the W agent is set to the mean of $maxS_j$ and $minS_i$ as indicated in equation (4).

$$s_{i,t} = \min S_i + \left(\frac{1}{2} \left(\max S_j - \min S_i \right) \right) \qquad (4)$$

All working contracts have the same length (K_3 cycles of the simulation) and, when a contract expires, the W agent becomes jobless and it looks again for a new job. For both W agents and E agents it is convenient that maxS and minS evolve towards stable values in order to increase the chances of contracts to start. At the same time, for W agents it is not convenient to have a very low minS because that means a low salary and for E agents it is not convenient to have a high maxS because that means high costs and less profits. The evolution of $\overline{\min S}$ and $\overline{\max S}$ (respectively average of W agents and average of E agents) indicates how the relation between W agents and E agents change during the course of the simulation. Finally, the second part of a worker's genotype measures how important for the agent is information about possible jobs when the agent becomes jobless. The higher h_i, the higher the chances to find a better paid job. However, also h_i has its costs (C_r) so that the evolution of $\bar{h}$ (average of W agents) indicates how much W agents are ready to pay to have more information about job offers.

E agents continue hiring W agents till the marginal revenue (the increase in production caused by hiring one more W agent) is higher than or equal to the marginal cost (the salary paid to the new W agent). We assume that the production curve is convex, that is, that the marginal product of labor is declining: the more W agents are assumed by the E agent, the less production will increase by hiring a new W agent. Equation 5 describes the production curve of the firm of E agent j:

$$y_j = \alpha N^z \tag{5}$$

where y_j is the production of the firm of E agent j, N is the number of W agents employed by j, α is a constant indicating how much production an additional W agent guaranties, and $0<z<=1$ is a constant value that represents the decreasing contribution to production of the additional W agent hired by E agent j. Total production is simply the sum of productions of the firms of the E agents and, when total production reaches the level of the carrying capacity, the market is divided and assigned to the E agents according to their relative contribution to total production. Fig. 1 presents a graphical representation of the cycle of the simulation run.

In order to analyze the effects of globalization of communication networks we connect W agents in different network structures and let information travel through these networks. The nodes of the networks are W agents and the arcs of the networks are the contacts among W agents. If a contact exists between two W agents, they are friends and exchange information about their jobs. When a W agent looks for a new job, it uses its friends, obtaining information about the E agents for which they work and evaluating the offers of those E agents. We consider different network structures: regular networks, small-world networks, and random networks (Watts and Strogatz 1999). In a regular network, all nodes have contacts only with their neighbors so that if a W agent i is a friend of W agent j and W agent j is a friend of worker agent k, it is very likely that also W agents i and k are friends. Such networks are very clustered and information travels very slowly through it. It can represent a highly segregated world where workers have just local information coming from their neighbors. If we take a regular network and we rewire each arc of the network with a probability p=1, then we obtain a random network where W agents are connected completely randomly among themselves. Such network is not clustered at all and information goes very fast through it. This structure can represent a global world where all contacts among W agents have the same probability to exist. If we rewire each arc of the regular network with a probability p such that $0<p<1$, then we obtain a small-world network where W agents are still very clustered but information travels very fast through the network and it easily reaches all agents. Such structure can represent a global world where the influence of local information is still very high. Fig. 2 shows a graphical representation of such networks for a low number of nodes (20) and arcs (40).

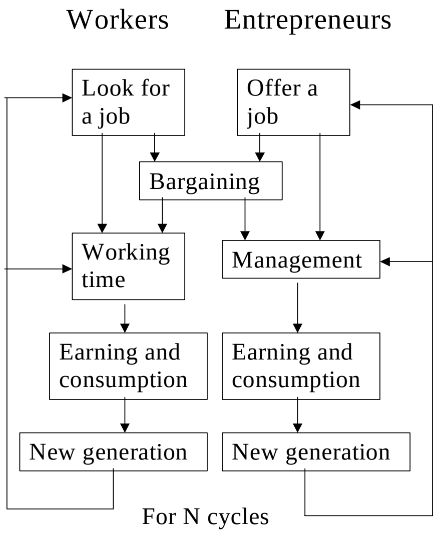

Fig. 1. A graphical representation of the genetic algorithm for the N cycles of the simulation.

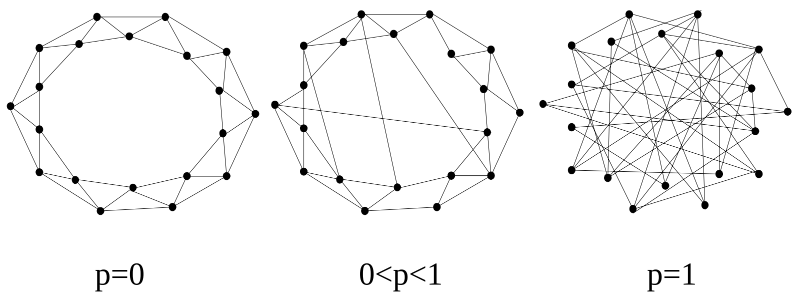

Fig. 2. Different network structures for 20 nodes and 40 links. Regular network (p=0), small-world network (0<p<1) and random network (p=1).

3. The experimental design

We have simulated two different scenarios. In the first scenario E agents are fixed in number and their genotypes do not evolve. This assumption represents a closed market where firms cannot freely decide about job offers. These markets have to respect many constraints created by laws like job protection, minimum salaries, etc. In the second scenario E agents are free to evolve and the best E agents determine the level of job offers. They evolve according to the efficiency of their strategies and those E agents who earn more, have more chances to reproduce. In this case, markets are assumed to be totally free for firms.

First, we compare the levels of production of the two scenarios at steady state in order to analyze the efficiency of different markets at a global level. For similar amounts of resources (the same carrying capacity), more production means more efficiency of the system. Moreover we study also how the average level of energy changes in the two different markets and how W agents' and E agents' genotypes evolve. This allows us to analyze the efficiency of the system at the level of the individual agents. The higher the average level of energy in the two populations, the better conditions are available to the agents. The higher the value of $\overline{\min S}$ and $\overline{\max S}$, the higher the chances for W agents to get a better paid job.

Second, we study the effects of W agents' unionization on the level of salaries. We let a fraction of W agents (coop) to be unionized and to bargain collectively with E agents. These W agents do not accept any salary which is inferior to a minimum collectively established salary (min_sal). Our goal is to determine whether unionization can affect E agents' bargaining behavior, i.e., the value of $\overline{\max S}$ in E agents' genotypes. The higher the value of $\overline{\max S}$ at steady state , the stronger the effect of unionization.

Third, to determine the value of information when W agents look for a job we observe the evolution of $\overline{h}$ in the two scenarios. The value of h_i indicates how many offers the worker agent i evaluates when looking for a job. The higher the value of $\overline{h}$, the higher the value of job information for W agents.

Finally, we connect W agents in different network structures (regular network, small-world network, and random network) and we observe the influence of such structures on the value of $\overline{h}$. Table 1 summarizes the experimental design by indicating the assumptions and the independent and dependent variables of the simulation experiments.

Table 1. Experimantal design

Given values and assumptions	Independent variables	Dependent variables
C = [0, 3000]	C_p = {30, 35, 40, 45, 50, 55, 60, 65, 70, 75, 80, 85}	Y
P = 100	C_r = {0, 1, 2, 5, 10}	$\overline{ew}$
K_1 = 20 cycles	z = {0.95, 1}	$\overline{ee}$
K_2=100 cycles	p = {0, 0.1, 0.2, 0.3, 0.4, 0.5, 0.6, 0.7, 0.8, 0.9, 1.0}	$\overline{\max S}$
K_3 = 10 cycles	min_sal ={30, 40, 50, 60, 70, 80, 90, 100}	$\overline{\min S}$

Table 1. (cont.)

$\alpha = 1$	coop = {0, 0.1, 0.2, 0.3, 0.4, 0.5, 0.6, 0.7, 0.8, 0.9, 1.0}	$\overline{h}$
RangeMutationMinS = [-2, 2]		
RangeMutationMaxS = [-2, 2]		
RangeMutationH=[-0.2, 0.2]		
$ew_{i,0}$ = [0,100]		
$ee_{i,0}$ = [100, 1000]		
$\#W_0$ = 1000		
$\#E_0$ = 200		
CC = 10^5		
C_f = 50		

where c is the cycle of simulations, P is the price; K_1 is the number of simulation cycle after which each agent reproduces; K_2 is the maximum number of cycle an agent lives; K_3 is the number of cycles a worker agent works for an entrepreneur agent every time it finds a job; α is the additional contribution of a new worker to the production; z represents the decreasing contribution to production of a new worker, RangeMutationMinS, RangeMutationMaxS and RangeMutationH indicate how much $minS_i$ and $maxS_j$ and h_i can change when agents reproduce, $ee_{i,0}$ and $ew_{i,0}$ are the amounts of energy entrepreneur and worker agents have at cycle 0; $\#W_0$ and $\#E_0$ are the numbers of worker and entrepreneur agents at the beginning of the simulation run; CC is the carrying capacity; C_f stays for the fixed costs for each entrepreneur agent's firm at each cycle, C_p stays for the individual consumption at each cycle, C_r stays for the cost a worker has to pay for each evaluation of a job offer; p represent the degree of globalization the worker agents' network; min_sal is the minimum salary worker agents want when they bargain collectively; coop is the portion of worker agents that belong to the union; Y is the total production; $\overline{ew}$ and $\overline{ee}$ are the averages of worker agents' and entrepreneur agents' energies; $\overline{\max S}$ is the average value of $maxS_j$; $\overline{\min S}_c$ is the average value of $minS_i$; $\overline{h}$ is the average value of h_i.

4. Results

In this section we describe how our system evolves in the two different labor market environments, i.e., in a scenario with fixed labor demand (Scenario 1) and in a scenario with an evolving and free labor demand (Scenario 2). Section 4.1 presents the results concerning level of production, level of contracts, and level of wealth of W and E agents. Section 4.2 describes the effects of unionization among workers. Section 4.3 reports how W agents spend different efforts and resources in order to find a job in the two scenarios. Section 4.4 describes the differences in the value of information for W agents when they are connected through different network structures.

4.1. A comparison between a fixed labor demand and an evolving labor demand

Fig. 3 presents the level of production in the two scenarios for similar conditions: C_p=30, C_r=10. In Scenario 1 W agents reproduce selectively and evolve but entrepreneur agents do not. Therefore, only $minS_i$ evolves but $maxS_j$ = [0, 100] is fixed for each E agent. In Scenario 2 both W agents and E agents reproduce selectively and both $minS_i$ and $maxS_j$ can evolve. When E agents reproduce and evolve but E agents do not (Scenario 1), the production does not even reach the level of carrying capacity. In a very high bureaucratic and closed market where new firms are not allowed to enter the market and old firms cannot change their strategies, the system cannot move to a better state unless there is exogenous change such as the introduction of new technologies. This result represents a lock-in situation where both W and E agents are satisfied of what they have and they have no interest in using more of the available resources of the environment. In contrast, when new E agents are allowed to enter the market and to evolve their strategies (Scenario 2), all the resources of the environment are used and production goes well beyond the carrying capacity. The level of production is much higher then the carrying capacity of the system because in our model the only form of competition among E agents is the level of production. The more E agents produce, the larger their chances of increasing their share of the market. Because in Scenario 2 evolution rewards the best competitive E agents, production is pushed at the maximum level, even beyond the carrying capacity of the system.

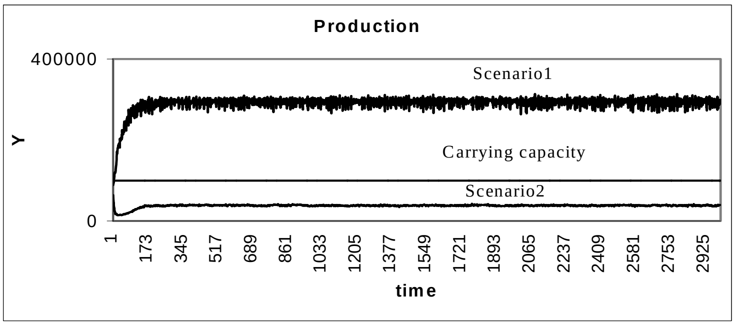

Fig. 3. The evolution of total production (Y) in the two scenarios.

Fig. 4 and Fig. 5 describe the evolution of $\overline{\min S}$ and $\overline{\max S}$ respectively in the two scenarios with the same conditions as before. In both scenarios a steady state is reached but $\overline{\min S}$ and $\overline{\max S}$ are much higher in Scenario 1 than in Scenario 2. In Scenario 1 W agents can ask for higher salaries because labor demand varies more than in Scenario 2. While in Scenario 1 there are always E agents that offer high salaries because they do not compete with other E agents and cannot evolve, in Scenario 2 E agents compete with each other and with W agents, and the salaries that they offer become lower and more similar. This means that there are better conditions for W agents in Scenario 1 because in Scenario 1 they have the opportunity to obtain higher salaries. Surprisingly this does not mean lower profits for E agents. Fig. 6 and Fig. 7 compare the average amount of energy of the two categories of agents, $\overline{ew}$ and $\overline{ee}$ respectively, across time. It can be seen that both categories have a higher amount of energy in Scenario 1 than in Scenario 2. The initial period is very favorable for both categories: $\overline{ew}$ reaches about 500 in Scenario 1 and 300 in Scenario 2; $\overline{ee}$ is more than 1200 in Scenario 1 and almost 600 in Scenario 2. After the initial boom, when the system reaches a steady state, $\overline{ee}$ stays always higher than $\overline{ew}$ and the difference between $\overline{ee}$ and $\overline{ew}$ is much less in Scenario 1 than in Scenario 2.

Why do both W and E agents have less energy in Scenario 2 than in Scenario 1 if the level of production is much higher in Scenario 2 than in Scenario 1? The reason seems to be that the number of agents is much lower in Scenario 1 than in Scenario 2. Therefore, although there is less production in Scenario 1 than in Scenario 2, all agents have more per capita energy in Scenario 1 than in Scenario 2. Moreover, it can be observed that in Scenario 2 the level of salary is just above the minimum threshold that W agents need to survive. We have varied the value of C_p in 13 simulation runs (C_p = {30, 35, 40, 45, 50, 55, 60, 65, 70, 75, 80, 85, 90}) and, after the system has reached a steady state, we collect values of $\overline{\min S}$ and $\overline{\max S}$ after 3000 cycles. Fig. 8 describes how the level of $\overline{\min S}$ and $\overline{\max S}$ depends on the fixed consumption C_p in Scenario 2. For values C_p >= 85, both populations become extinct. Selection pushes W agents to the minimum level of salary. Those W agents that are ready to earn just what they consume are those that reproduce. Asking for a higher salary can mean less chances to find a job because almost all E agents offer lower salaries. Asking for a lower salary can mean not to have enough to survive.

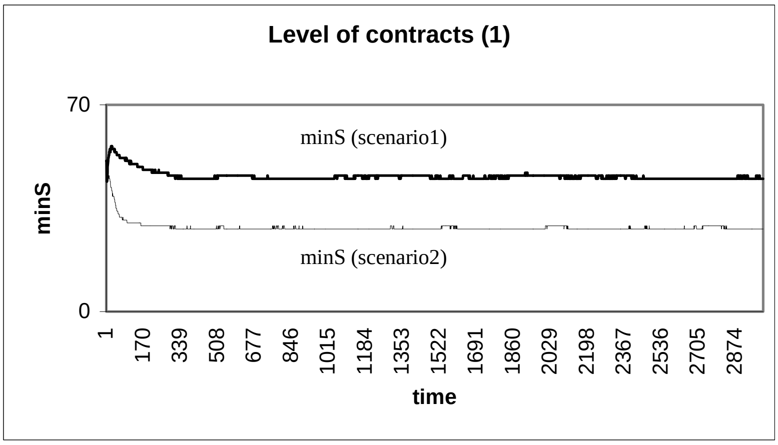

Fig. 4. The evolution of $\overline{\min S}$ in the two scenarios.

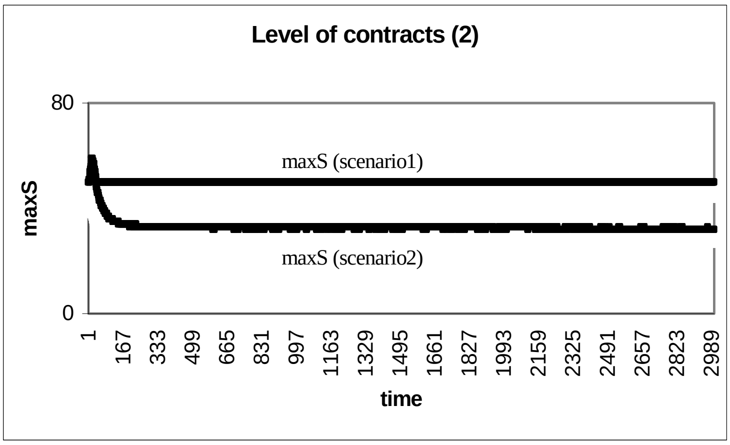

Fig. 5. The evolution of $\overline{\max S}$ in the two scenarios.

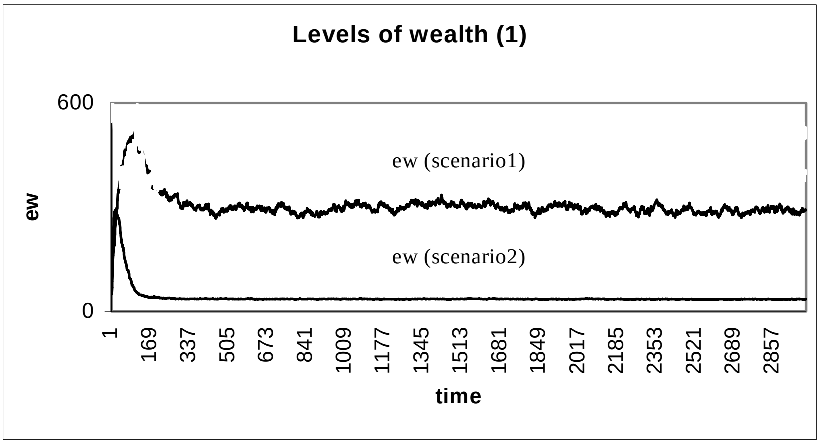

Fig. 6. The evolution of $\overline{ew}$ in the two scenarios.

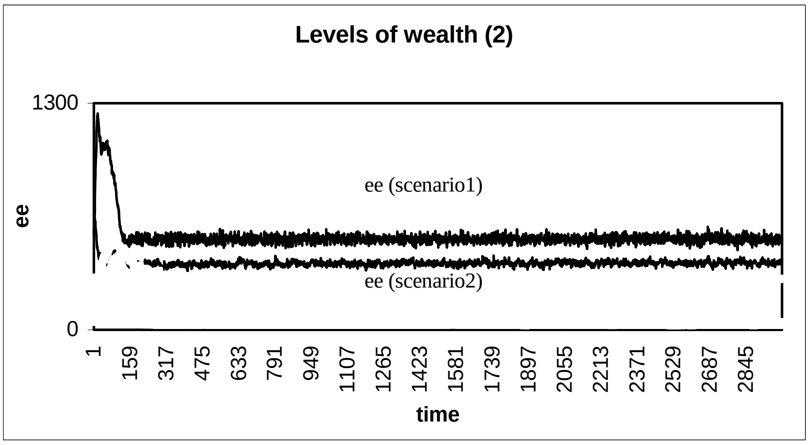

Fig. 7. The evolution of $\overline{ee}$ in the two scenarios.

4.2. The effects of unionization

As described in Fig. 8, in Scenario 2 E agents are able to push W agents to the limit of their individual consumption. Salaries stabilize just at the level of C_p. In this situation W agents earn just enough to remain alive and, if the economy of the system grows, either E agents earn more or the number of W and E agents increases so that also production can increase. But what would happen if W agents unionize in order to obtain higher salaries? What would happen if they set up a union that collectively bargains with E agents? We simulate such a situation by introducing two more independent variables in the basic set up of the simulation: the percentage W agents that are unionized (coop) and the minimum salary that W agents that belong to the union decide to ask (min_sal). Thus, if a W agent belongs to the union and is unemployed, it uses min_sal instead of minS in bargaining with E agents. That is, unionized W agents do not accept any salary that is lower than min_sal. Finally, coop indicates the fraction of the W agent population that belongs to the union.

We set the model in Scenario 2 with parameters' values C_p = 30 and C_r = 10, and we determine the value of $\overline{\max S}$ at steady state for different values of min_sal and coop (min_sal = {30, 40, 50, 60, 70, 80, 90, 100} and coop = {0, 0.1, 0.2, 0.3, 0.4, 0.5, 0.6, 0.7, 0.8, 0.9, 1.0}). Fig. 9 shows the results. Whatever the minimum salary asked by those W agents that cooperate in the union, they manage to get better conditions if the percentage of W agents that belong to the union is higher than 50%. We might have expected that the higher the minimum salary they ask, the higher the percentage of unionization that it is needed. But our results indicate that the system has a threshold mechanism: if the unionization involves less than a half of the worker population, E agents can resist and they do not change the way they bargain. In this case, they just hire those W agents that do not belong to the union because there are enough non-unionized W agents to hire. On the contrary, if more than a half of the W agent population decides to adhere to the union, then E agents have to adapt and accept the W agents' requests. The value of $\overline{\max S}$ increases linearly with the value of coop and the slope of the curve is determined by min_sal. It is important to notice that the evolution of the system is bounded between two limits: min_sal cannot be lower than C_p (=30) because that is the minimum W agents need to survive and it cannot be higher than P (=100) because in this case E agents would have no profits. In our simulation we found that both W and E agents become extinct when coop>=0.5 and min_sal>=92.

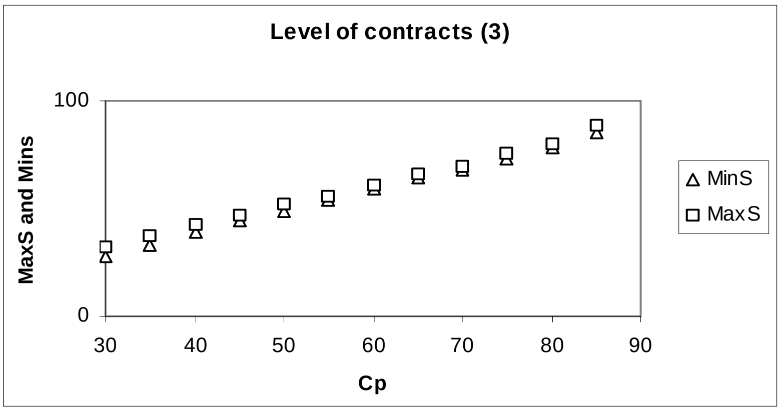

Fig. 8. The influence of individual consumption (C_p) on the level of salaries in scenario2.

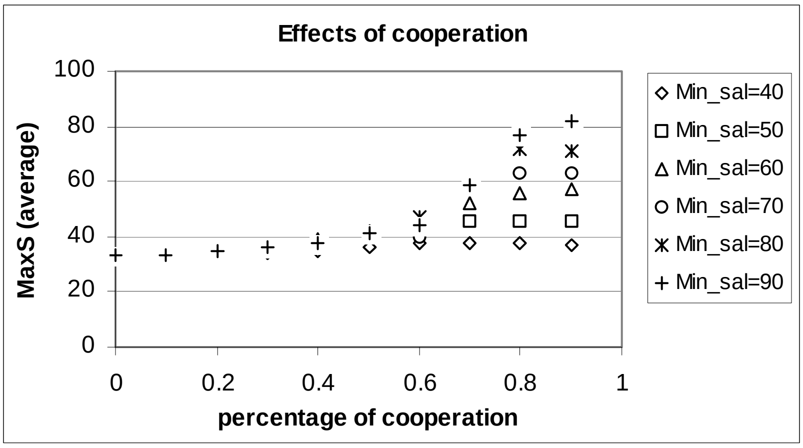

Fig. 9. Effects of unionization in scenario2.

4.3. The value of information

In Fig. 10 we present the evolution of $\bar{h}$ in the two scenarios for different costs of information (C_r = 1, C_p = 30) and in Fig. 11 we show how $\bar{h}$ varies at steady state for a larger parameters' space (C_r = {0, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10}, C_p = 30). The value of $\bar{h}$ at steady state is higher in Scenario 1 than in Scenario2. W agents are ready to pay more for information when E compete with each other and evolve. This result may be surprising because it means that information becomes more important when W agents have lower salaries. When E agents compete with each other and evolve, they tend to offer similar and lower salaries to W agents. Why do W agents give more value to information when salaries are lower and the chances to find a better job smaller? And furthermore W agents earn just the amount of salary/energy that allows them to survive? Why, then, in these circumstances, does evolution select those W agents that decide to look for more job offers?

The value of information explains this apparently surprising result. In Scenario 1 W agents live better than in Scenario 2 because they earn more and they easily find good jobs. They have no pressure to find a better job. On the contrary, in Scenario 2 W agents are pushed to their survival limits so that, if a single W agent is able to find a better job, it obtains a considerable advantage in comparison with other W agents and therefore selection rewards W agents with a high h value.

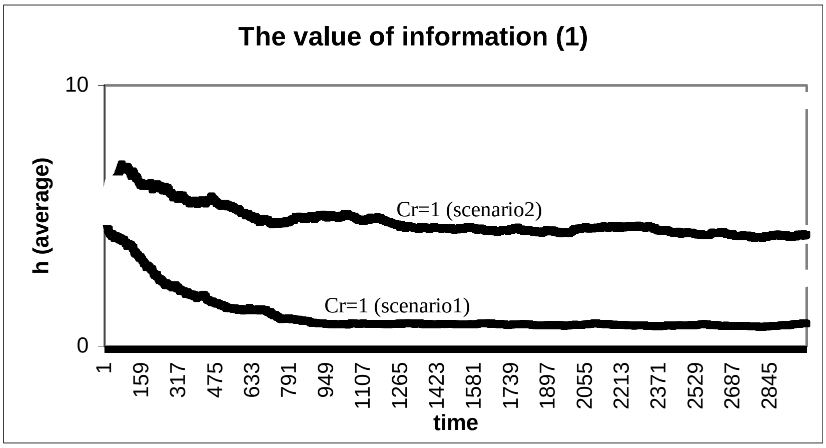

Fig. 10. The evolution of $\bar{h}$ in the two scenarios for different costs of the information (C_r).

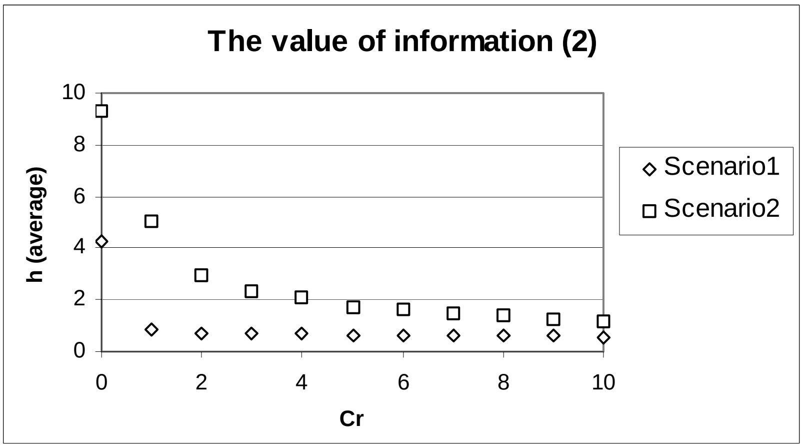

Fig. 11. The value of $\bar{h}$ at the steady states for different costs of the information in the two scenarios.

4.4. Globalization and segregation: the effects of different social network structures

The preceding section has shown that the value of information on prospective jobs depends on the conditions in which W agents live when they look for a job. Another variable that affects the value that W agents give to information about jobs is the network of communication among W agents. We set the model to $C_r = 1$, $C_p = 50$ and z = 0.95 and we investigate the parameter space of p from 0 to 1 for 11 conditions (p = {0, 0.1, 0.2, 0.3, 0.4, 0.5, 0.6, 0.7, 0.8, 0.9, 1.0}). Compared to the preceding simulation runs, the value of z has been lowered in order to avoid lock-in situations where one single E agents can hire all W agents. Each W agent i has 10 friends; therefore h_i indicates how many of its friends the W agent i consults when it is looking for a job. Thus h_i can vary from 1 to 10. We collected results at steady state after 3000 cycles and Fig. 12 shows the results. The value of $\bar{h}$ is greater than 5 also when the network is completely clustered. This is due to the low cost of information (C_r = 1) compared with individual consumption (C_p = 50). From Fig. 12 it is clear that W agents are more interested in job information when the network is less clustered because information is less redundant. When W agents are connected in a regular network, they are very segregated because their sources of information about jobs are just local neighbors. In this case information traveling in their local network will be highly redundant; the more friends a W agent asks for job information, the higher the chances to obtain new information but in general these chances are small. On the contrary, when the network becomes less clustered, the chances to have useful news about well-remunerated jobs are higher. Thus the value of $\bar{h}$ becomes higher for higher values of p. However, when p approaches 0.6, the value of $\bar{h}$ stabilizes around 9. For such value, the network is already very randomized and information about good jobs is already well spread among W agents. Any increase in randomization of the network does not affect the value of $\bar{h}$.

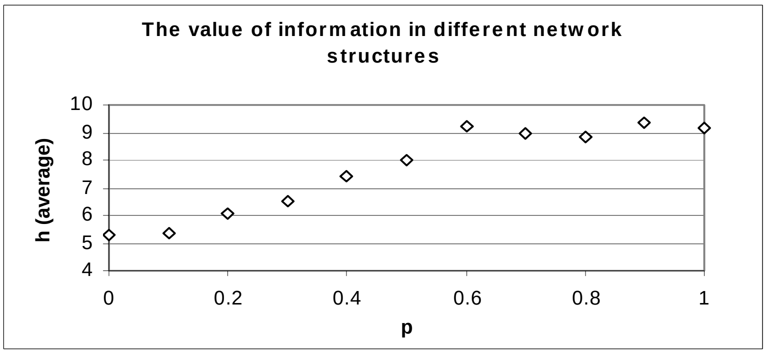

Fig. 12. The effects of network structures on the value of information for worker agents.

5. Conclusions

In this paper we have described an agent-based model that simulates the evolution of workers' and firms' behavior in the labor market. A sharp distinction is created between completely free labor markets and completely constrained labor markets. When workers and firms individually bargain for the salary, the free labor market is globally more efficient because the level of production is much higher than the carrying capacity and locally less efficient because the level of wealth is lower for both workers and firms. This seems to support the idea that privatization, deregulation, and liberalization tend to be related to growth and higher efficiency of the global market. However - and this is the other side of the same coin - in many markets such policies can create lower levels of individual wealth in workers because of lower salaries. Our simple evolutionary model is able to simulate these two sides of the coin and it allows us to study more detailed phenomena of labor markets like unionization and the value of information.

According to our results, in a completely free market individual bargaining (one worker vs one firm) leads to minimum levels of salaries. The rules of the genetic algorithm adopted in our model impose a greater pressure on workers than on firms. However, unionization can reduce this pressure and it can substantially influence the evolution of firms' behavior. When we allow the workers in our model to unionize and to bargain collectively with firms, our results show the critical variable is the specific fraction of workers that belong to the unions. It is this specific fraction that can have a crucial influence on the evolution of the system. If less than half of the workers belong to the union, then firms "win" and salaries stay at the level of survival for workers. But if more than a half of the workers unionize, then workers "win" and they obtain an increase in the level of salaries. After this threshold is reached, the higher the fraction of unionized worker agents, the higher the salaries that workers can obtain. However, if workers' requests become too high (capturing all the profits of the firms), then firms simply abandon the market and the entire system collapses.

The last part of the paper focuses on the analysis of the value of information for workers in the labor market. Our model explains how the value of social contacts changes according to the conditions of the market. We found that in a completely free labor market, where salaries stabilize to the level of individual consumption, the value of information is systematically higher than in a constrained labor market. This phenomenon is today very evident in labor markets. Higher flexibility is accompanied by higher competition even for part-time and badly paid jobs. In large firms, competition at the low levels of the organization is also very high and workers struggle for increments in their work position. On the contrary, in more bureaucratic systems including public organizations workers seem to pay little attention to the chances of promotion they have. In this case there is little competition in order to obtain a better position and usually no effort is paid by workers in order to obtain a better job.

Finally, we have used our model to study the effects of globalization and segregation in a labor market and we have found that the value workers give to information about jobs increases with the degree of globalization. The less clustered the network structure connecting workers, the higher the value of the information. Nowadays people search for better jobs much more than before. Especially in the last few decades, looking for a job has become a very important activity and it has been extended to the entire working life of workers. Globalization and the great advances in communication technologies make it possible to obtain more non-local information and, thus, increase the chances of getting better jobs.

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