DISCUSSION PAPER SERIES

IZA DP No. 583

On the Efficiency of Job Search with Social Networks

Pierre Cahuc
François Fontaine

September 2002

Forschungsinstitut
zur Zukunft der Arbeit
Institute for the Study
of Labor

On the Efficiency of Job Search with Social Networks

Pierre Cahuc
Université Paris 1-EUREQua, CREST, CEPR and IZA Bonn

François Fontaine
Université Paris 1-EUREQua

Discussion Paper No. 583
September 2002

IZA

P.O. Box 7240
D-53072 Bonn
Germany

Tel.: +49-228-3894-0
Fax: +49-228-3894-210
Email: iza@iza.org

IZA Discussion Paper No. 583
September 2002

ABSTRACT

On the Efficiency of Job Search with Social Networks

This paper provides a simple matching model in which unemployed workers and employers can be matched together through social networks and through more efficient, but also more costly, methods. In this framework, decentralized decisions to utilize social networks in the job search process can be inefficient and give rise to multiple equilibria for some parameters values. More precisely, in a decentralized equilibrium, social networks can be over-utilized, with respect to an efficient allocation, in some circumstances and under-utilized in others. Moreover, the existence of different job search methods can give rise to a higher job search intensity than the efficient one. This is in sharp contrast with the standard result, derived in matching models, according to which search intensity is always too low if not efficient. Eventually, in the presence of different job search methods, conditional unemployment benefits hikes can improve welfare when individuals are risk neutral.

JEL Classification: E24, J64, J68

Keywords: social networks, unemployment, job search

Corresponding author:

Pierre Cahuc
Université Paris 1- EUREQua
Panthéon-Sorbonne
106-112 Boulevard de l'Hôpital
75013 Paris
France
E-mail: cahuc@univ-paris1.fr

1 Introduction

To a large extent, economic analysis spreads the idea that search intensity of unemployed workers is too low. The design of unemployment insurance system is indeed deeply influenced by the existence of moral hazard, which implies that unemployed workers lower their search intensity if they are not strongly urged to find a job. One strand of literature has focused on the design of optimal unemployment systems in partial equilibrium models, in which unemployed workers face job arrival rates that depend on their search intensity (Shavell and Weiss, 1979, Hopenhayn and Nicolini, 1997). It shows that optimal systems involve a replacement ratio that decreases throughout the unemployment spell and a wage tax after reemployment that increases with the unemployment spell. Another strand is more focused on equilibrium models of the labor market in which matches between job seekers and job vacancies are explicitly taken into account (Pissarides, 2000). In such a framework, externalities yielded by the decisions of participants of both sides of the market are taken into account. This strand of literature also contributes to fuel the idea that job search intensity is too low. In his synthesis, Pissarides (2000, p. 194) concludes that job search intensity is efficient only if surpluses provided by job-worker matches are shared according to the Hosios-Pissarides rule[1] (Hosios, 1990, Pissarides, 2000). Otherwise, search intensity is too low. It should be noticed that some contributions have tried to stress that unemployment insurance may raise efficiency by improving the average productivity of job-worker matches (Diamond, 1981, Acemoglu and Shimer, 1999, 2000, Marimon and Zilibotti, 1999). In this context, unemployment insurance allows workers to bear long unemployment spell in order to find good matches, with high productivity. However, even if the increase in matches quality may improve efficiency, job search intensity is always too low if not efficient.

In this paper, we argue that the result according to which job search intensity is too low relies on a very restrictive conception of job search activity. Indeed, the efficiency of job search intensity has been analyzed in a framework in which search effort is treated as unidimensional. However, in the real life, unemployed workers can use a large range of methods to find a job. They can send direct applications, but they can also use friends and relatives, newspapers, private agencies and State agencies. It is now well known that a large proportion of people (about 50% on average) hear about or get their job through friends and relatives (see: Granovetter, 1995, Holzer, 1988, Montgomery, 1991, Topa, 2000, for the U.S., Gregg and Wadsworth, 1996, for the U.K. and Addison and Portugal, 2001, for Portugal). Moreover, to a large extent, employers also use social networks. For example, Holzer (1987) reports that 36 percent of firms interviewed

[1] The Hosios-Pissarides condition states that the decentralized equilibrium of a standard matching model with risk neutral agents is efficient if and only if the share of jobs surplus that accrues to the workers is equal to the elasticity of the matching function with respect to unemployment.

filled their last opening with referred applicants. Campbell and Marsden (1990) find that about the half of a sample 52 Indiana establishments make a regular use of referred applicants.

The aim of our paper is to analyze the job-worker matching process when workers and firms have access to different search methods. Given the importance of social networks in the actual job search process, it will be assumed that workers and firms can be matched together through social networks and through such alternative methods as private agencies and ads in newspapers, which can be more efficient, but also more expensive as a counterpart. In his 1995's Afterword, Granovetter, who has written a seminal book on the role of social networks in the job search process, argued that "a full understanding of matching requires also an assessment of when formal procedures have an advantage [over social networks], and when we may expect to find them. This is an important subject about which we know very little. [...]. It is unclear whether these contrasting systems differ dramatically in efficiency". Our contribution is aiming at shedding some light on this issue. Our paper indeed shows that analyzing job search and job advertising in a context in which there are several search methods sheds some new lights on the consequences and the efficiency of search activities in the labor market.

More precisely, the main contributions of our paper are the followings. First, we provide a very simple matching model of the labor market, inspired from Diamond (1981), Pissarides (2000), and Calvo-Armengol and Zenou (2001), with an endogenous arrival rate of job offers driven by free-entry. In this simple model, unemployed workers and jobs can be matched together through social networks and through more efficient, but also more costly, methods. Second, the choice of search methods is endogenous. This allows us to show that the decentralized choices of search methods can give rise to a multiplicity of equilibria: For some parameters values, both the use of networks and of costly search methods can be Nash equilibria. Moreover, it appears that the decentralized decisions to utilize social networks can be inefficient: With respect to an efficient allocation, in a decentralized equilibrium, social networks can be over-utilized in some circumstances, and under-utilized in others. As search costs with formal methods are higher, individuals over-invest in search activities if networks are under-utilized. Hence, the existence of different job search methods can give rise to a larger job search intensity than the efficient one. This is in sharp contrast with the standard result, that has been recalled above, according to which search intensity is too low in matching models. This case can occur if individuals use costly methods, whereas efficiency requires to use social networks. Third, in our framework, a rise in unemployment benefits can induce a welfare improvement even if workers are risk neutral.

The idea that social networks play a large and unusual role on the labor market has been explored for a long time by sociologists[2]. In economics, some contributions have underscored that

[2] See Granovetter (1995) and the references therein.

transmission of job information through contact networks influences the job-worker matching process. To our knowledge, Boorman (1975) was the first to provide a formal network model to describe the information structure of job finding. In Boorman's model, networks are endogenous: contacts are developed by individuals who maximize their probability of getting some new job in the event that they lose their present job. Boorman focused on the supply-side of the labor market only, whereas we rather study search strategies on both sides of the market. Accordingly, for the sake of simplicity, we assume that the network structure is exogeneous. Calvó-Armengol and Zenou (2001) use Boorman's framework to provide a matching model in discrete time with contact networks and an endogenous arrival rate of job offers driven by free-entry. Our own model, which is set in continuous time, is simpler and allows us to explicitly derive equilibria with several matching strategies and endogenous bargained wages. This last point is important, since it is well-known that networks have large effects on wages (see Petersen *et al.*, 2000). Calvó-Armengol and Jackson (2002) take into account this fact, but in a different context in which the job arrival rate is exogenous.

In the economic literature dealing with contact networks and labor market, few attempts have be done to provide a model in which individuals (workers or employers) can explicitly choose between alternative search methods. Holzer (1987) provides such a model together with an instructive empirical work. Holzer considers a "partial" job search model where individuals face exogenously determined offer probabilities and wage offer functions that reflect the demand side of the market. Then, he assumes that search cost, offer probabilities and wage offer functions hinge on search methods. Montgomery (1991) examines the choice between alternatives methods in an adverse selection model. He assumes that the offers transmitted through networks are taken in a better wage distribution without analyzing the way individuals could transmit job offers. Therefore, in the contributions of Holzer (1987) and Montgomery (1991), the hiring mechanism was largely "black boxed". Our model, focused on the matching process with an endogenous job arrival rate, allows us to consider explicitly the interactions between employers and workers search strategies.

The model is presented in section 2. Section 3 and 4 are respectively devoted to the analysis of the decentralized equilibria and the efficient allocation. Section 5 provides some insights on the economic policy implications of the multidimensionality of search activities.

2 The model

The basic environment borrows from Pissarides (2000) matching model of the labor market. An endogenously sized continuum of competitive firms produce a numeraire output, using labor as sole input. There is a large labor force which size is denoted by L. Time is continuous, individuals are infinitely lived, risk neutral and discount the future at rate $r > 0$.

Hiring a worker and searching for a job are costly activities. Vacant jobs and unemployed workers — the only job seekers, by assumption — are brought together in pairs through an imperfect matching process. Vacancies send job offers at a given rate a. Accordingly, if there are V vacancies, our assumptions imply that the arrival rate of job offers amounts to Va, and that the probability that more than one offer is sent by the finite set of V vacancies in a small interval of time $dt \to 0$ goes to zero (see Appendix 1). In other words, the probability that an individual gets more than one job offer in a small interval of time, $dt \to 0$, goes to zero.

Our matching function is based on an urn-ball process, in which each worker has an urn and each job offer is a ball that is sent into urns. Each individual has access to two different search strategies. The first one is a high cost search method whereas the second one allows individuals to search at low cost.

Let us first look at the high cost search method. A worker i can "switch his urn on", at cost $s_i = \bar{s}$ per unit of time, to signal that he is looking for a job. Similarly, an employer j can pay a cost $c_j = \bar{c}$, in order to check, in the *entire* population, if some urns are switched on. Such strategies represent formal methods of search, since firms and workers are engaged in costly search activities, that make easier job-worker matches.

The alternative method relies on social networks. In this case, workers search cost is assumed to amount to zero: $s_i = 0$. With formal methods, individuals have to put ads in newspapers, send direct application, register in private or public agencies, whereas networks lead generally to a lower cost (Granovetter, 1995) since worker do not actively search[3]. An employer, who does not pay to check which urns are switched on, can send his offer at random in the urns at a low cost $c < \bar{c}$. Accordingly, his offer can reach an unemployed worker but also an employee who forwards this offer through his network of acquaintances. Nevertheless, there exists a positive probability that the employee has no unemployed friend. In this case, the offer is lost. It is worth noticing that a large part of the empirical literature on networks bear the assumption that $c < \bar{c}$. For instance, Fernandez and al. (2000) find that using networks (in form of a referral bonus) leads to an important reduction in recruiting costs.

A social network links every worker with ℓ other workers, and it is assumed that information about job offers can be transmitted at no cost between two individuals who are linked. It is also

[3]For instance, Hanson and Pratt (1991) claim that the "fixation of the traditional job search model on the cost of acquiring information [...] seems misplaced, as for the majority of cases in our sample, the information leading to new job came through existing social networks at no cost to the worker at all". Even if this assertion does not take into account the cost of maintaining a network of friends and relatives, such studies give some empirical basis to our assumption.

assumed that information is transmitted only to the direct links. In other words, if i and i' are linked, and i'' is linked to i', but not to i, the information gotten by i' can be transmitted to i and i'', however, the information gotten by i is transmitted to i', but not to i''.

The matching function

The matching function defines the rate at which job offers meet job demands as a function of the number of vacant jobs, V, the unemployment rate u, and the search methods chosen by workers and employers. In order to define the matching function between unemployed workers and vacancies, it is useful to define the indicator functions $x(c_j)$ and $p(s_i)$ as follows, for all unemployed worker i and vacancy j:

$$x(c_j) = \begin{cases} 1 \text{ if } c_j = \bar{c} \\ 0 \text{ if } c_j = c \end{cases} \text{ and } p(s_i) = \begin{cases} 1 \text{ if } s_i = \bar{s} \\ 0 \text{ if } s_i = 0 \end{cases}.$$

Accordingly, $x(c_j) = 1$ means that the firm j uses formal methods to fill its vacant job. Then $\sum_j x(c_j)$ amounts to the number of firms which use this search method. Likewise, $p(s_i) = 1$ implies that the worker i signals that he is looking for a job (he "switches his urn on").

Since all vacant jobs face the same probability to send a job offer per unit of time, each job offer is sent through the formal search method with probability $\sum_j x(c_j)/V$. A job offer sent through the formal method if filled with probability one if there is at least one urn switched on. Thus, the probability that an offer is filled thanks to formal methods is $\left(\sum_j x(c_j)/V\right)\left[\underset{i}{\text{Max}}\ p(s_i)\right]$. If no urn is switched on, it is assumed that job offers are sent at random.

Therefore, with a probability $\left[1 - \left(\sum_j x(c_j)/V\right)\left[\underset{i}{\text{Max}}\ p(s_i)\right]\right]$ the offer is sent at random and reaches each worker has a probability $(1/L)$. If the job offer reaches an unemployed worker, an event that occurs with probability u, the job is immediately filled. If the job offer reaches an employee, an event that occurs with probability $(1-u)$, the employee forwards it towards the unemployed workers that belong to his network. If there is more than one unemployed worker in the network, they all get the same probability to obtain the forwarded job offer. As any individual of any network is employed with probability[4] $(1-u)$, the probability that all the ℓ links of any individual are employed amounts to $(1-u)^\ell$, which implies that the probability that an employee with ℓ links knows zero unemployed individual is $(1-u)^\ell$. Accordingly, the

[4]It should be noticed that this result holds only if each individual is re-matched at random with ℓ links just after every job arrival. Otherwise, there would be a distribution of unemployment rates across networks. Taking into account such a phenomenon is beyond the scope of this paper. We adopt the standard (and often implicit) assumption that each individual is re-matched at random with ℓ links just after every job arrival (Diamond, 1981, Calvo-Armengol and Zenou, 2001).

probability that a job offer sent at random in the L urns reaches an unemployed worker is:

$$\underbrace{u}_{\substack{\text{Probability to}\\ \text{reach an}\\ \text{an unemployed}\\ \text{worker}}} + \underbrace{(1-u)}_{\substack{\text{Probability to}\\ \text{reach}\\ \text{an employee}}} \cdot \underbrace{\left[1-(1-u)^{\ell}\right]}_{\substack{\text{Probability that an}\\ \text{employee gets at least}\\ \text{an unemployed}\\ \text{worker in his network}}} = \left[1-(1-u)^{\ell+1}\right] \tag{1}$$

Eventually, given that job offers arrive at rate Va, job offers meet job demands at rate:

$$M\left(u, V, \{s_i\}, \{c_j\}\right) = Va\left\{\frac{\sum_j x(c_j)}{V}\left[\operatorname*{Max}_i\ p(s_i)\right] + \left(1-\frac{\sum_j x(c_j)}{V}\left[\operatorname*{Max}_i\ p(s_i)\right]\right)\left[1-(1-u)^{\ell+1}\right]\right\} \tag{2}$$

It can be seen that the matching rate merely amounts to Va (for any unemployment rate $u > 0$) if all employers and workers pay the high search costs $\bar{c}$ and $\bar{s}$. In the opposite case, where matching only relies on low cost search methods, the matching rate amounts to $Va\left[1-(1-u)^{\ell+1}\right]$. It is increasing with the unemployment rate and the size of networks, because the larger the networks, the smaller the probability that an employee has no unemployed worker within his network.

Flow equilibrium

Assuming that filled jobs are destroyed at rate q, the flow equilibrium reads:

$$Lq(1-u) = M\left(u, V, \{s_i\}, \{c_j\}\right) \tag{3}$$

Expected utilities and profits

For the sake of simplicity, it is assumed that individuals do not know whether the members of their network are employed. Therefore, every individual, who knows the unemployment rate, expects each member of his network to be employed with a probability $(1-u)$. This assumption implies that the expected gains of the workers do not hinge on the actual composition of their network. Moreover, we shall begin to focus on cases in which all workers choose the same search method. This will allow us to define symmetric equilibria. The analysis of deviations from these equilibria will be analyzed latter on. In this context, the expected exit rate from unemployment amounts to M/Lu, where M denotes the function $M(\cdot)$ defined equation (2). An unemployed workers benefits from an income flow z, and faces search costs, denoted by s_i, that amounts either to $\bar{s}$ or to zero. The value function of an unemployed worker, denoted by V_u, satisfies:

$$rV_u = z - s_i + \frac{M}{uL}(V_e - V_u) \tag{4}$$

where V_e denotes the value function of an employee, that reads:

$$rV_e = w + q(V_u - V_e) \tag{5}$$

We begin to focus on cases in which all employers adopt the same search method. Thus, vacant jobs are filled at rate M/V and one has either $c_j = c$ or $c_j = \bar{c}$ for every vacancy j. A filled job produces $y > z$ units of output per unit of time and pays a wage w. The values of a vacant job and a filled job, denoted by Π_v and Π_e respectively, satisfy the following equations:

$$r\Pi_v = -c_j + \frac{M}{V}(\Pi_e - \Pi_v) \tag{6}$$

$$r\Pi_e = y - w + q\left(\Pi_v - \Pi_e\right) \tag{7}$$

It is assumed that all profit opportunities from new jobs are exploited. Accordingly, jobs are created until the expected value of vacancies goes to zero. From equation (6), the free-entry condition, $\Pi_v = 0$, entails:

$$\Pi_e = \frac{Vc_j}{M} \tag{8}$$

Wage bargaining

Wages are bargained by firms and workers after they meet. The surplus of each match is shared according to the Nash solution to the bargaining problem. Let us denote by $\beta \in [0,1]$ the share that accrues to the worker. The Nash solution reads $(1-\beta)\left(V_e - V_u\right) = \beta\left(\Pi_e - \Pi_v\right)$, which implies, together with the free-entry condition $\Pi_v = 0$, equations (4), (5) and (8), that:

$$\frac{Vc_j}{M} = \frac{(1-\beta)(y - z + s_i)}{r + q + \beta\frac{M}{Lu}} \tag{9}$$

This equation shows that, in equilibrium, the expected cost of a vacancy, represented by the left-hand side, equates the expected profit of a filled job, represented by the right-hand side.

The equilibrium unemployment rate depends on the search and hiring strategies chosen by workers and firms that are analyzed in the next section.

3 Decentralized equilibrium

In this section, we first define the two types of equilibria that are considered in the paper. Namely, on one hand, the equilibrium where matches hinge on social networks, in which firms and workers decide not to use costly search methods, and on the other hand, the equilibrium in which costly search methods are used. Then, we shall determine the conditions under which the utilization of each search and hiring method is a Nash equilibrium.

The decentralized equilibrium with social networks

When social networks are utilized, search costs are low: $s_i = 0$ and $c_j = c > 0$. Therefore, equations (2), (3) and (9) imply that the equilibrium unemployment rate, denoted by u_ℓ, satisfies the following condition:

$$\frac{c}{a\left[1-(1-u_\ell)^{\ell+1}\right]} = \frac{(1-\beta)(y-z)}{r+q+\beta q\frac{(1-u_\ell)}{u_\ell}} \tag{10}$$

It can easily be checked that this equation defines a unique equilibrium value of the unemployment rate in the interval $]0,1]$. The left-hand side, which represents the expected cost of a vacant job, denoted by EV in Figure 1, is decreasing with respect to u, goes to $+\infty$ as $u \rightarrow 0$, and amounts to c/a for $u = 1$. The right-hand side, which represents the expected profit of a filled job, denoted by EP in Figure 1, increases with respect to u, goes to 0 as $u \rightarrow 0$, and amounts to $(1-\beta)(y-z)/(r+q)$ for $u_\ell = 1$. Accordingly, $u_\ell \in]0,1[$ if $c/a < (1-\beta)(y-z)/(r+q)$ and $u_\ell = 1$ if $c/a \geq (1-\beta)(y-z)/(r+q)$.

It is also worth noting that the unemployment rate decreases with the network size. Large networks are favorable to employment because they entail low expected hiring costs, as it is shown by the left-hand side of equation (10), that decreases with ℓ.

The decentralized equilibrium with costly search methods

When high search costs are paid ($s_i = \bar{s} > 0$ and $c_i = \bar{c} > c$) social network are not used to transmit information about job offers. Therefore, equations (3) and (9) imply that the equilibrium unemployment rate, denoted by $\bar{u}$, satisfies the following condition:

$$\frac{\bar{c}}{a} = \frac{(1-\beta)(y-z+\bar{s})}{r+q+\beta q\frac{(1-\bar{u})}{\bar{u}}} \tag{11}$$

This equation defines a unique value of $\bar{u} \in]0,1[$ if $\bar{c}/a < (1-\beta)(y-z+\bar{s})/(r+q)$. One gets $\bar{u} = 1$ if $\bar{c}/a \geq (1-\beta)(y-z+\bar{s})/(r+q)$. The equilibrium is displayed on Figure 2, in which the

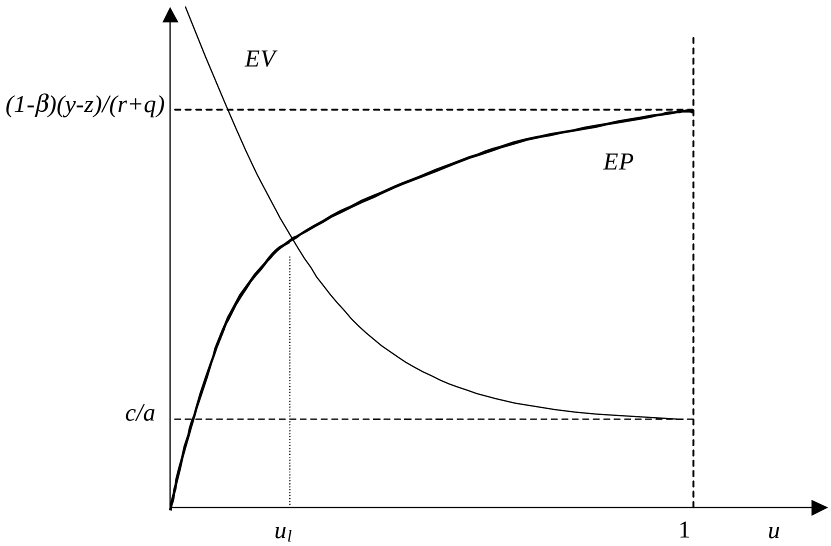

Figure 1: An equilibrium with social networks

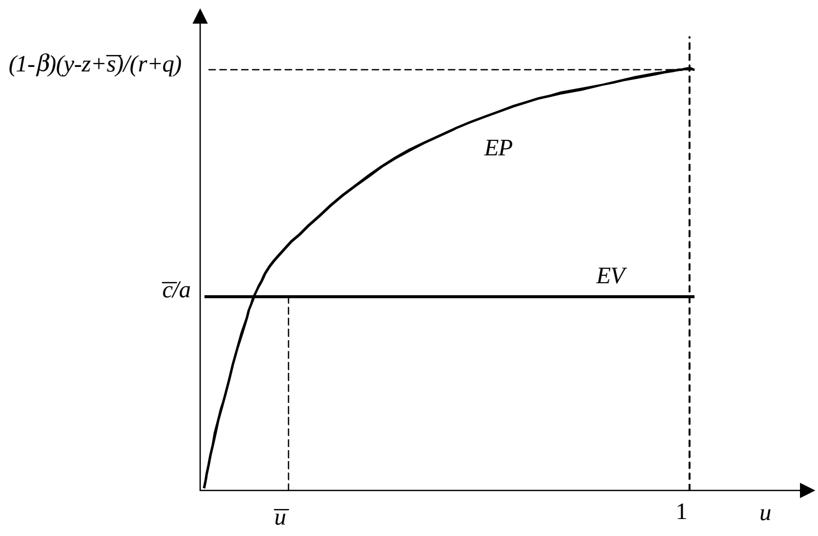

Figure 2: The equilibrium without social network

expected cost of a vacant job, $\bar{c}/a$, is represented by the EV schedule and the expected profit of a filled job is represented by the EP schedule.

The decision to use social networks

Using social networks to find a match is a Nash equilibrium only if each worker and employer prefers to use social networks rather than trying to get a match thanks to the alternative method. In case of deviation from an equilibrium with networks, an employer can decide to use a costly search method, instead of relying only on the information transmitted by the employees. However, in our simple model, it is never worth paying high search costs to check whether there are some urns switched on by unemployed workers as all urns are off when nobody pays high search cost. Therefore, employers never deviate from an equilibrium with low search costs. The same reasoning implies that unemployed workers have no incentive to deviate from a Nash equilibrium in which nobody pays high search cost, because it is not worth bearing the cost to switch one's urn on if nobody pays the cost to check whether some urns are on. Accordingly, the case in which social networks are used to transmit information about job offers is always a Nash equilibrium.

The decision to use costly search and hiring methods

It is also worth looking at the condition under which the utilization of formal costly job search methods is a Nash equilibrium.

Any employer has always the possibility to decide to rely on the networks of the employees to find a worker. In order to look at the deviation from a Nash equilibrium in which costly search methods are utilized, let us begin to write the value of a vacant job in the Nash equilibrium with high search costs, denoted by $\bar{\Pi}_v(t)$, as follows

$$\bar{\Pi}_v(t) = \frac{1}{1+rdt}\left[-\bar{c}dt + \frac{M}{V}dt\bar{\Pi}_e(t+dt) + \left[1 - \frac{M}{V}dt\right] \text{Max}\left\{\bar{\Pi}_v(t+dt), \bar{\Pi}_v^d(t+dt)\right\}\right],$$

where $\bar{\Pi}_e$ denotes the value of a filled job in the Nash equilibrium without social networks.

In case of deviation from the Nash equilibrium with high search costs, the probability to reach an unemployed worker when a job offer is sent amounts to $\left[1-(1-\bar{u})^{\ell+1}\right]$, which implies that the value of a vacant job, denoted by $\bar{\Pi}_v^d(t)$, satisfies:

$$\begin{aligned}\bar{\Pi}_v^d(t) &= \frac{1}{1+rdt}[-cdt + a\left[1-(1-\bar{u})^{\ell+1}\right]dt\bar{\Pi}_e(t+dt) + \\ &\quad \left\{1 - a\left[1-(1-\bar{u})^{\ell+1}\right]dt\right\}\text{Max}\left\{\bar{\Pi}_v(t+dt), \bar{\Pi}_v^d(t+dt)\right\}].\end{aligned}$$

Using the free-entry condition, one gets $\bar{\Pi}_v(t+dt)=0$ and $\bar{\Pi}_e(t+dt)=c/a$, which implies that a deviation from the equilibrium with high search costs is not profitable if $\bar{\Pi}_v(t) \geq \bar{\Pi}_v^d(t)$, which is equivalent to:

$$\frac{c}{[1-(1-\bar{u})^{\ell+1}]} - \bar{c} \geq 0. \tag{12}$$

Condition (12) shows that the use of a costly search and hiring method can be a Nash equilibrium only if the relative cost of this method is low, and if the size of the networks is sufficiently small. Let us remark that for large values of $\bar{u}$ the deviation becomes more profitable since the probability an employee has no unemployed friends is low. Accordingly, this condition hinges on the parameters that influence the equilibrium unemployment rate $\bar{u}$: firms are more likely to deviate from this equilibrium if the workers' search cost, $\bar{s}$, is small, if the income of unemployed workers, z, and the bargaining power of employees, β, are large.

Let us now look at the strategies of unemployed workers. If $\bar{V}_u(t)$ stands for the expected utility of an unemployed worker in an equilibrium where costly search methods are used and $\bar{V}_u^d(t)$ stands for the expected utility of an unemployed worker who deviates from such an equilibrium, one gets:

$$\begin{aligned}
\bar{V}_u(t) &= \frac{1}{1+rdt}\left[(z-\bar{s})dt + \frac{M}{\bar{u}L}dt\bar{V}_e(t+dt) + \left[1-\frac{M}{\bar{u}l}dt\right]\text{Max}\left\{\bar{V}_u(t+dt), \bar{V}_u^d(t+dt)\right\}\right] \\
\bar{V}_u^d(t) &= \frac{1}{1+rdt}\left[zdt + \text{Max}\left\{\bar{V}_u(t+dt), \bar{V}_u^d(t+dt)\right\}\right]
\end{aligned}$$

where $V_e(t)$ is the expected utility of an employee at date t in the equilibrium with costly search methods.

Then, deviation from the Nash equilibrium with formal search methods is not profitable to the unemployed workers if $\bar{V}_u(t) \geq \bar{V}_u^d(t)$. In steady state equilibrium, this condition is equivalent to:

$$\bar{s} \leq \frac{M}{\bar{u}L}\left(\bar{V}_e - \bar{V}_u\right) \tag{13}$$

Noticing that $M = Va = q(1-\bar{u})L$ (from equations (2) and (3)), and that the sharing rule together with the free entry condition (8) implies that $\bar{V}_e - \bar{V}_u = \beta\bar{c}/(1-\beta)a$, using the definition (11) of $\bar{u}$, equation (13) can be written as:

$$\frac{(1-\beta)a(y-z)}{r+q} - \bar{c} \geq 0 \tag{14}$$

This last condition, that defines the set of parameters values that ensure that workers do not deviate from an equilibrium in which costly search methods are used, deserves at least two comments.

First, it appears that an increase in workers' bargaining power incites workers to deviate from the equilibrium with costly search methods. At first glance, this might seem surprising, since one could think that unemployed workers search harder if they get larger rents when they find a job. Actually, in equilibrium, the returns of formal methods decrease with the bargaining power of workers. Indeed, from (4), (8), (11) and the sharing rule, one gets $r\bar{V}_u = y - \frac{r+q}{a(1-\beta)}\bar{c}$, which decreases with β. An increase in the workers' bargaining power implies a rise in $\bar{u}$ and, consequently, a decrease in the exit rate from unemployment. Therefore, unemployed workers deviate from the equilibrium with costly search methods when the bargaining power of employees is important.

Second, condition (14) does not depend on the cost of formal search methods for the unemployed workers, denoted by $\bar{s}$. This comes from the fact that $\bar{V}_u$ does not depend on $\bar{s}$ at equilibrium. When $\bar{s}$ increases, unemployed workers bear larger search costs, then wages decrease through the bargaining process, which induces firms to create more vacant jobs that exactly compensate the impact of the variation in $\bar{s}$ on $\bar{V}_u$.

The multiplicity of Nash equilibria

Firstly, let us recall that firms and workers have no incentive to deviate from a Nash equilibrium with social networks. Hence, an equilibrium with low search costs is sustainable for any set of parameters value satisfying $\bar{s} > s = 0$ and $\bar{c} > c$. The utilization of costly search methods can be sustained as a Nash equilibrium if and only if conditions (12) and (14) are fulfilled. Thus, a multiplicity of equilibria can occur, as the utilization of social networks and the utilization of alternative methods can be Nash equilibria for a given set of parameters value. The multiplicity of equilibria is displayed in the $(\bar{s}, \beta)$ plane on Figure 3. In the area N, the situation in which social networks are used is a Nash equilibrium. In the area F, where (12) and (14) are fulfilled the situation in which costly search methods are used is a Nash equilibrium. In the area where multiple Nash equilibria exist, the unemployment rate is always larger if individuals use social networks rather than costly search methods (see equations (10), (11) and (12)). Figure 3 shows that the utilization of costly search methods can be a Nash equilibrium if the bargaining power of workers, β, is small enough and if the search cost of workers, $\bar{s}$, is large enough. That costly search methods can be sustained as a Nash equilibrium for large values of the search cost of workers only might seem counter-intuitive. Actually, the explanation relies on the fact that the condition (14), which ensures that workers do not deviate from the equilibrium with costly search methods, does not hinge on $\bar{s}$. Accordingly, large values of $\bar{s}$, that contribute to lower the unemployment rate $\bar{u}$, also diminish the returns of networks as a recruitment channel, and eventually incite firms to prefer costly search methods rather than networks to hire workers.

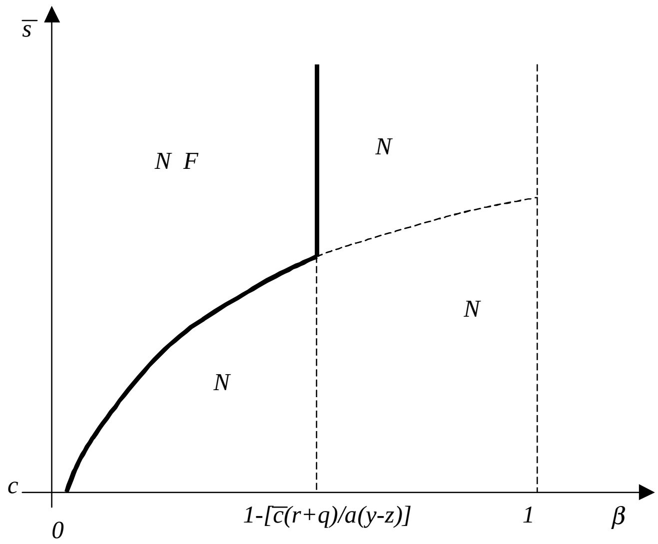

Figure 3: The multiplicity of equilibria.
N is the area where using social networks is a Nash equilibrium.
F denotes the area where using formal matching methods is a Nash equilibrium.

The multiplicity of equilibria relies on strategic complementarities. For a given set of parameters value, the relatively low unemployment rate associated with the utilization of formal methods, which are more efficient than low search costs methods to create matches, increases the expected cost of a vacancy filled thanks to social networks, $c/a\left[1-(1-u)^{\ell+1}\right]$, and induces every employer to use costly search methods as long as the other employers do so. Besides, neither the firms nor the workers can individually deviate from an equilibrium with networks: it is not worth bearing the cost to switch one's urn on (respectively to check whether some urns are on) if no firm pay the cost to monitor the urns (respectively if no workers switches his urn on).

The comparison of the efficiency of multiple equilibria relies on the analysis of the sign of the externalities induced by the search decisions of workers and firms. This analysis is far from being trivial in a framework in which the decisions of each individual exert an influence on both sides of the market. Accordingly, it is worth looking in some details at the efficiency issue to shed light on this problem.

4 Efficiency

This section is devoted to the analysis of the efficient allocation and its comparison with the decentralized equilibrium. For the sake of simplicity, we limit the analysis to symmetric allocations in which all unemployed workers and all employers choose the same search strategies. We begin by defining the efficient allocation, first in the economy with social networks, and second in the economy in which social networks are not used as a channel to match workers and jobs. Eventually, we determine the values of the parameters such that it is efficient to use networks in the job search process.

The social planner chooses the vacancy rate at each date t, denoted by $v(t)$, that maximizes the discounted value of the stream of production of the numeraire output per individual, which amounts to: $y\left[1-u(t)\right]+u(t)z-v(t)c$.

The efficient outcome with social networks

The value function of the social planner, denoted by $W\left[u(t)\right]$, satisfies:

$$\begin{aligned} W\left[u(t)\right] &= \underset{v(t)\geq 0}{\mathrm{Max}}\left(\frac{1}{1+rdt}\right)\left\{\left[y\left[1-u(t)\right]+u(t)z-v(t)c\right]dt+W\left[u(t+dt)\right]\right\} \\ \text{subject to} &: \quad u(t+dt)=u(t)+\left[1-u(t)\right]qdt-Mdt. \end{aligned}$$

Let us denote by $M_i, i=v,u$, the partial derivatives of the matching function with respect to v and u respectively. The first-order and the envelope conditions read respectively:

$$\begin{aligned} -c-M_v W'\left[u(t+dt)\right] &= 0 \\ (z-y)dt+W'\left[u(t)\right] &= W'\left[u(t+dt)\right]\left\{1-qdt-M_u dt\right\}. \end{aligned}$$

In a steady state, these two conditions imply, together with the law of motion of $u(t)$ and the definition (2) of M, that the equilibrium value of the efficient unemployment rate with social networks, denoted by u_ℓ^*, satisfies:

$$\frac{c}{a\left[1-(1-u_\ell^*)^{\ell+1}\right]}=\frac{(y-z)}{r+q+q\frac{(\ell+1)(1-u_\ell^*)^{\ell+1}}{\left[1-(1-u_\ell^*)^{\ell}\right]}} \tag{15}$$

The comparison of the decentralized equilibrium value of the unemployment rate with social networks, u_ℓ, defined equation (10), with the efficient solution, u_ℓ^*, defined equation (15), shows that the decentralized equilibrium if efficient if and only if

$$\beta = \beta^* \equiv \frac{M_u}{r + q + \frac{M}{u_\ell^*}(1 + \eta(u_\ell^*))} \in]0, 1[\,, \text{ where } \eta(u_\ell^*) = u_\ell^* \frac{M_u}{M} \tag{16}$$

This condition looks like the Hosios-Pissarides condition (Hosios, 1990, Pissarides, 2000) which states that the decentralized equilibrium of a search and matching models is efficient if and only if the share of the surplus of the jobs that accrues to the workers, β, is equal to the elasticity of the matching function with respect to the unemployment rate in a context in which the matching function is homogeneous of degree one with respect to u and v. In our framework with social networks, the matching function is not homogeneous with respect to u and v. But there exists a value of β which makes the decentralized equilibrium efficient.

The efficient outcome with costly search methods

When costly search methods are used, the efficient outcome can be found very easily. The expected cost of a vacant job amounts to $\bar{c}/a$, and the expected gain from a filled job is $(y - z + s)/(r + q)$. Both values hinge neither on the unemployment nor on the number of vacancies. Accordingly, it is worth creating vacancies only if $\bar{c}/a \leq (y - z + \bar{s})/(r + q)$. If this condition is not fulfilled the efficient unemployment rate is equal to one. If this condition is satisfied, it is optimal to create vacancies until the unemployment rate goes to zero, which implies, from equations (2) and (3), that the efficient vacancy rates, V/L, worth q/a. In other words, the efficient unemployment rate without social networks, denoted by $\bar{u}^*$, satisfies:

$$\bar{u}^* = \begin{cases} 0 \text{ if } \bar{c}/a \leq (y - z + \bar{s})/(r + q) \\ 1 \text{ otherwise} \end{cases} \tag{17}$$

The comparison of the efficient unemployment rate, $\bar{u}^*$, with the unemployment rate obtained in the decentralized equilibrium, $\bar{u}$ (see equation (11)), shows that the decentralized equilibrium is efficient if and only if $\beta = 0$ in the non degenerate case, $\bar{c}/a \leq (y - z + \bar{s})/(r + q)$, which is compatible with positive employment.

The efficient use of social networks

Let us denote by $\bar{W}(u)$ the value function of the social planner when costly search methods are utilized. Assuming that the condition to get $\bar{u}^* = 0$ is fulfilled (see equation (17)), the value function of the social planner amounts to $\bar{W}(0) = [y - (\bar{c}q/a)]\,/r$ at the optimum. The optimal value of the objective of the social planner when the social networks are used amounts to

$W(u_\ell^*) = [y(1-u_\ell^*) + u_\ell^* z - cv_\ell^*]/r$. It is efficient to use costly search methods if $W(u_\ell^*) \leq \bar{W}(0)$, which is equivalent to:

$$\frac{c}{\left[1-(1-u_\ell^*)^{\ell+1}\right]} - \bar{c} + au_\ell^* \left[\frac{(y-z)}{q} - \frac{c}{a\left[1-(1-u_\ell^*)^{\ell+1}\right]}\right] \geq 0 \qquad (18)$$

Equations (12), (14) and (18) show that the decentralized decisions do not generally yield an efficient use of social networks.

This issue can be enlightened by comparing the decentralized equilibrium with the efficient allocation for different values of the bargaining power of employees. If β is sufficiently large, one knows, according to Figure 3, that networks are necessarily utilized in the decentralized equilibrium. As condition (18) does not hinge on β, this implies that costly search methods can be under-utilized in the decentralized equilibrium for some parameters values when workers have an important bargaining power. In the opposite situation, in which the bargaining power of workers is low, that is social networks which can be under-utilized if individuals are coordinated on a Nash equilibrium with costly search methods.

It is worth noticing that if the coordination failure leads to an under-utilization of social networks, both unemployed workers and firms devote too much resources to the search activity. Accordingly, we are in a situation in which job search intensity is too high. This is in sharp contrast with the standard result usually obtained in search and matching models, according to which the labor market frictions and the inefficiency of the decentralized equilibrium induce workers to adopt a too low search intensity (Mortensen, 1982, Pissarides, 2000).

In our framework, that takes account of the existence of different search strategies, workers and firms can be badly coordinated on expensive search strategies that lead them to choose an inefficiently high search intensity. Obviously, it can also be the case that networks are over-utilized. Such a coordination failure leads to a high level of unemployment. This case might illustrate some features of European Mediterranean countries in which networks provide an important source of insurance against unemployment thanks to transfers between agents that do not involve only standard economic assets, but also jobs (see Bentolila and Ichino, 2000). It could be the case that the high unemployment rates in these countries result from an over-utilization of networks at the expense of more efficient matching methods.

5 Economic Policy

In the preceding sections we saw that equilibrium unemployment can be inefficient because individuals choose wrong search methods. In this section, we ask whether some policy tools could reduce this inefficiency. In this perspective, two issues are discussed. First, it appears that unemployment benefits, through their influence on the search strategies of firms and workers, have non standard effects on welfare. Namely, an increase in unemployment benefits can improve efficiency by inciting individuals to coordinate on efficient search methods. Second, and more important, we consider unemployment benefits and job offers subsidies *conditional on the search method*. Such conditional search subsidies allow the policy maker to force firms and workers to deviate from an inefficient equilibrium. More precisely, we have seen that one cannot deviate from an equilibrium with job search relying social networks, even if this method in inefficient. From this point of view, it can be useful to utilize coordination devices in order to create incentives to adopt costly methods. Our framework allows us to show that conditional unemployment benefits and search subsidies for the firms can play an important role in this realm.

5.1 The consequences of unemployment benefits

Let us assume that unemployed workers get unemployment benefits, denoted by b, that are financed by lump-sum taxes. Simple replication of the reasonings made previously implies that equations (10) and (11), that define the decentralized equilibrium unemployment rate, can be rewritten as follows:

$$\begin{cases} \frac{c}{a\left[1-(1-u_\ell)^{\ell+1}\right]} = \frac{(1-\beta)(y-z-b)}{r+q+\beta q\frac{(1-u_\ell)}{u_\ell}} & \text{if networks are used} \\ \frac{\bar{c}}{a} = \frac{(1-\beta)(y-z-b+\bar{s})}{r+q+\beta q\frac{(1-\bar{u})}{\bar{u}}} & \text{if formal methods are used} \end{cases} \tag{19}$$

Equation (19) shows that rises in b always lead to increases in the unemployment rate, through a wage pressure rise. Nevertheless, unemployment benefits hikes can have a positive impact on efficiency if they force individuals to give up coordination on an inefficient equilibrium in which costly search methods are used. In order to illustrate this point, let us begin to remark that conditions (12) and (14) that define the range of parameters values for which the costly search methods can be sustained as a Nash equilibrium still hold when unemployment benefits are introduced. It appears that the condition (14) that ensures that workers do not deviate does not hinge on b. However, according to condition (12), firms are more likely to deviate from an equilibrium with costly search methods if b is increased, since $\bar{u}$ increases with b. Then, looking at Figure 4, it can be seen that an economy at point E, where costly search methods can be sustained as a Nash equilibrium, that faces an unemployment benefit rise, can switch to a situation in which costly search methods cannot be used any more in a decentralized equilibrium. As costly search methods can be over-utilized in the decentralized equilibrium — for instance if the bargaining power of employees is small —, it can be the case that unemployment benefit

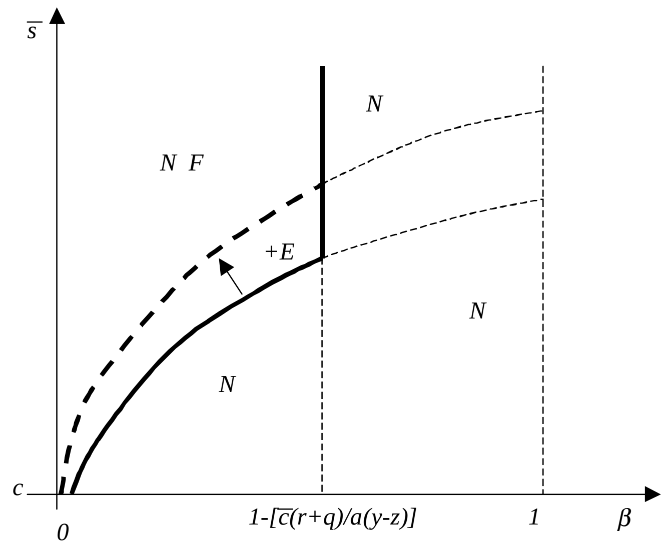

Figure 4: The consequences of an unemployment benefit rise.
N is the area where using social networks is a Nash equilibrium.
F denotes the area where using formal matching methods is a Nash equilibrium.

hikes force individuals to switch from a “bad” equilibrium, in which to much resources are devoted to search, to a “good” equilibrium, in which job-worker matches rely on networks.

This case is illustrated by Figure 5, that displays the relation between unemployment benefits, the unemployment rate and welfare. There is a discontinuity in the unemployment rate and welfare schedules around the point $b = 0.1$, where the economy goes from an equilibrium in which formal methods are used to an equilibrium in which employers recruit through social networks. The increase in the unemployment rate is large. However, welfare rises simultaneously. Obviously, this example is only illustrative. Nevertheless, it stresses that changes in multidimensional search strategies may strongly influence the relation between unemployment benefits and welfare.

5.2 Conditional unemployment benefits and job offers subsidies

Let us now assume that unemployed workers receive an unemployment benefit flow, denoted by b, that is added to their income flow z, *on the condition that* they use costly search methods. For instance, in order to receive unemployment benefits, an unemployed worker must go regularly to a public employment agency, accept interview and so on. Similarly, when firms are looking for filling a vacant job, they receive a subsidy, h, per unit of time, *on the condition that* they use formal search methods. In the real world, this subsidy could be conditional to the fact that

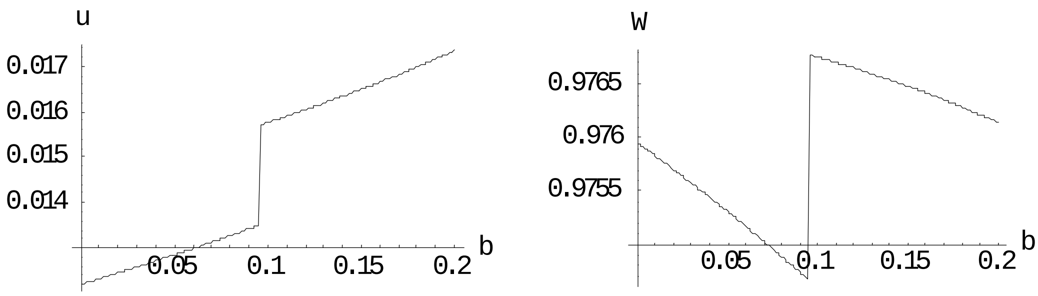

Figure 5: Unemployment benefits, the unemployment rate and welfare. Parameters value are: $c = 0.2, \bar{c} = 0.4, q = 0.3, r = 0.05, y = 1, z = 0.2, a = 10, s = 0.2, \beta = 0.5, \ell = 50$.

firms send their offers to public employment agencies.

These transfers are assumed to be financed through lump sum taxes. Accordingly, taxes modify neither surpluses nor the surplus sharing rule. Thus, simple replication of the reasonings made previously implies that equations (10) and (11), that defines the decentralized equilibrium unemployment rate, can be rewritten as follows:

$$\begin{cases} \frac{c}{a\left[1-(1-u_\ell)^{\ell+1}\right]} = \frac{(1-\beta)(y-z)}{r+q+\beta q\frac{(1-u_\ell)}{u_\ell}} \text{ if networks are used} \\ \frac{\bar{c}-h}{a} = \frac{(1-\beta)(y-z-b+\bar{s})}{r+q+\beta q\frac{(1-\bar{u})}{\bar{u}}} \text{ if formal methods are used} \end{cases}. \quad (20)$$

Can public employment agency make Nash equilibria no longer sustainable when they are inefficient?

It can be shown that it is possible to incite individuals to abandon networks thanks to conditional search subsidies on both sides of the market. First, it is straightforward to see that equation (4) implies that if the agency gives a conditional unemployment benefits b to the unemployed workers, with $b > \bar{s}$, workers always choose costly search methods. In this situation, unemployment benefits are sufficiently high to cover additional search expenses for any given job offers arrival rate. In a similar way, firms always prefer to use costly search methods if the agency gives a conditional subsidy h, with $h > \bar{c} - c$ (see equation (6)). Therefore, the use of costly search methods is the only Nash equilibrium if $b > \bar{s}$ and $h > \bar{c} - c$.

This line of reasoning shows that a public agency which “buys” the job demands and offers at prices $b > \bar{s}$ and $h > \bar{c} - c$ respectively can incite individuals to coordinate on an equilibrium with a low unemployment rate, as costly search methods entail a lower unemployment rate than the utilization of social networks. From this point of view, conditional unemployment benefits together with job offers subsidies allow individuals to adopt more efficient search method, and lead to decrease the unemployment rate.

It is worth using conditional search subsidies only if the costly search method is more efficient than the utilization of social networks. This case arises if condition (18) is fulfilled. In this situation, we have seen that, if $\bar{c}/a \leq (y - z + \bar{s})/(r + q)$, the social planner post vacancies until $\bar{u}^* = 0$. It is easy to define the economic policy that allows us to implement social efficiency in this case. Equation (20) defines the unemployment rate when formal methods of search are used. One can verify that, when $b = \bar{s}$ and $h = \bar{c}$, one gets $\bar{u} = 0$. As $h = \bar{c}$, the instantaneous cost of vacancies amounts to zero, which implies that the number of vacancies created by firms can go to infinite. Such a situation is obviously inefficient. Accordingly, the public agency should limit the number of job offers that benefit from subsidies. The flow equilibrium (3) implies that this number has to be equal to q/a in order to entail zero unemployment.

Eventually, it appears that these results shed some new light on the role of employment agencies. First, in a context where individuals have access to different search methods, employment agencies are an instrument of coordination and, therefore, can contribute to eliminate inefficient outcomes of a decentralized labor market. This is an important difference with the usual approach on the design of the unemployment insurance, according to which the unemployment agency is considered as a principal that tries to provide the appropriate incentives in order to rise the agent's search intensity (see for instance: Boone and van Ours, 2000). In our model, subsidies are considered as a device to coordinate on the efficient method of search. It should be noticed the choice of search methods can be easily monitored. Moreover, formal search methods mostly give rise to observable actions. Indeed, since the firms must send their offers to a public employment agency if they want to get subsidies, the agency observes immediately their search effort. In the same way, workers are urged to make an observable effort (for example to post their C.V and accept the interviews provided by the agency) to receive unemployment benefits. Besides, we have shown that it is necessary to give conditional subsidies *to both sides* of the market. Conditional unemployment benefits can reduce the unemployment rate and increase welfare, if firms also get search subsidies. From this perspective, our contribution shows that it can be fruitful to take into account the interactions between different policy tools to achieve labor market efficiency.

6 Conclusion

Recent literature shows a growing interest in social interactions and argues that they can explain a wide range of phenomena that was previously omitted in economics. We have attempted to provide a simple framework to study some effects of social networks on labor market equilibrium.

We have developed a simple matching model in which unemployed workers and employers can be matched together either through social networks or through more efficient, but also more costly, methods. In this framework, the use of social networks is an endogenous choice and we show that the decentralized choices of search strategies can give rise to multiple equilibria for some parameters values.

It is also shown that decentralized decisions can be inefficient. The existence of different job search methods can give rise to a job search intensity which is larger than the efficient one. This is in sharp contrast with the standard result according to which search intensity is always too low if not efficient. Besides, these results give a theoretical answer to Granovetter (1995) when he enquires into the efficiency of different job search methods. Then, we ask whether some policy rules could reduce the inefficiency of the decentralized equilibrium with multidimensional search strategies. We consider two instruments: unemployment compensation and search subsidies for firms conditional to the method used. Both methods can lead to a more efficient coordination of firms. More surprisingly, for some parameters values, a rise in the unemployment compensation induces a decrease in the unemployment rate. If the decentralized equilibrium is characterized by an inefficient utilization of social networks, this rise can force workers to coordinate on a more efficient method, which induces a lower unemployment rate. Besides, our analysis sheds some new light on the role of public employment agencies. They are an instrument of coordination between workers and employers and can steer the economy away from inefficient equilibrium.

Our results have been obtained with a very simple model. Some extensions could lead to a better understanding of the consequences of social networks on the labor market. First, the networks size is exogenous. It would be more appropriate to suppose that workers can adjust the size of their networks in order to respond to changes in the labor market tightness. An endogenous choice of search strategies by the workers could induce some interesting labor supply effects that our framework omits. Moreover, we have assumed that networks are continuously recomposed and that workers do not know whether the members of their network are employed. This implies that the expected gains of the workers do not hinge on the actual composition of their network. By assuming more rigid network structures, we would get a situation in which workers embedded in networks with few employees have a smaller probability to move into employment than workers belonging to networks with many employees. To some extent, these mechanisms may contribute to influence the wage distribution and inequalities. They could yield some theoretical foundations to one of the main results of Granovetter's analysis (1995): "[...] routine social mechanisms which are quite rational at the micro-level have the macro-level result of institutionalizing social inequality [...]"(p.100). This issue is on our research agenda.

References

Acemoglu, D. and Shimer, R. (1999), "Efficient Unemployment Insurance", *Journal of Political Economy,* vol 107, pp. 893-928.

Acemoglu, D. and Shimer, R. (2000), "Productivity Gains from Unemployment Insurance", *European Economic Review,* 44, pp. 1115-1125.

Addison, J. and Portugal, P. (2001), "Job Search Methods and Outcomes", IZA working paper, N° 349. www.iza.org.

Bala, V. and Goyal, S. (2000), "A Noncooperative Model of Network Formation", *Econometrica,* 68, pp. 1181-1230.

Bentolila, S. and Ichino, A. (2000), "Unemployment and Consumption: Are Job Losses Less Painful Near the Mediteranean?", CEPR Discussion Paper n°2539. www.cepr.org.

Boorman, S.A. (1975), "A Combinatorial Optimization Model for Transmission of Job Information Through Contact Networks", *Bell Journal of Economics*, 6, pp. 216-249.

Boone, J. and van Ours, J. C., "Modeling Financial Incentives to Get Unemployed Back to Work", IZA Discussion Paper, N°108, www.iza.org.

Calvo-Armengol, A. and Jackson, M. (2002), "Social Networks and Resulting Patterns and Dynamics of Employment and Wages", mimeo, Universidad Carlos 3.

Calvo-Armengol, A. and Zenou, Y. (2001), "Job-Matching, Social Network and Word-of-Mouth Communication", CEPR working paper, N° 2797. www.cepr.org.

Campbell, K. and Mardsen P. (1990), "Recruitment and Selection Processes: The Organizational Side of Job Searches", in Breiger, R. (ed.), *Social Mobility and Social Structure*, New York: Cambridge University Press, pp. 59-79.

Granoveter, M. (1995), *Getting a Job: A Study of Contacts and Careers,* 2^{nd} edition, Harvard University Press, Cambridge.

Gregg, P. and Wadsworth, J. (1996), "How Effective Are State Employment Agencies? Jobcentre Use and Job Matching in Britain", *Oxford Bulletin of Economics and Statistics*, 58, pp. 43-67.

Hansen, S. and Pratt, G. (1991), "Job Search and the Occupational Segregation of Women", Annals of the Association of American Geographers, 81 (2), pp. 229-253.

Holzer, H. (1987), "Hiring Procedures in the Firm: Their Economics Determinants and Outcomes", NBER Working Paper n°2185, www.nber.org.

Holzer, H. (1988), "Search Methods Use by Unemployed Youth", *Journal of Labor Economics*, 6, pp. 1-21.

Hopenhayn, H. and Nicolini, J. (1997), "Optimal Unemployment Insurance", *Journal of Political Economy,* 105, pp. 412-438.

Hosios, D. (1990), "On the Efficiency of Matching and Related Models of Search and Unemployment", *Review of Economic Studies*, 57, pp. 279-298.

Marimon, R, and Zilibotti, F. (1999), "Unemployment vs. Mismatch of Talents: Reconsidering Unemployment Benefits", *Economic Journal,* 109, pp. 266-291.

Montgomery, D. (1991), "Social Networks and Labor Market Outcomes: Toward an Economic Analysis", *American Economic Review,* 81, pp. 1408-1418.

Mortensen, D. (1982), "Property rights and efficiency in mating, racing and relatied games", *American Economic Review,* 72, pp. 968-979.

Petersen, T., Saporta, I., and Seidel, M-D. (2000), "Offering a Job: Meritocracy and Social Networks", *American Journal of Sociology*, 106, pp.763-816.

Petrongolo, B. and Pissarides, C (2001), "Looking into the blackbox: a survey of the matching function", *Journal of Economic Literature*, 39, pp. 390-431.

Pissarides, C. (2000), *Equilibrium unemployment theory*, 2nd edition, Cambridge, MIT Press.

Ross, S. (1985), *Introduction to Probability Models,* Academic Press, Harcourt Brace Jovanovich Publishers.

Shavell, S. and Weiss, L. (1979), "The Optimal Payment of Unemployment Benefits over Time", *Journal of Political Economy,* 87, pp. 1347-1362.

Topa, G. (2000), "Social Interactions, Local Spillovers and Unemployment", *Review of Economic Studies,* 68, pp. 261-295.

A Appendix

A.1 Appendix 1. The arrival rate of job offers

This appendix presents standard results about the properties of the arrival rate of job offers (see Ross, 1985, for instance). They are given for the sake of clarity.

Let us assume that there are V vacancies. Every vacancy *sends* job offers according to a Poisson process with arrival rate $a > 0$. Let us denote by $N(dt)$ the number of job offers sent by a given vacancy in the time interval dt. According to the definition of a Poisson process, this implies that the probability that this vacancy send n offers in dt is

$$\Pr\left[N(dt) = n\right] = e^{-adt}\frac{(adt)^n}{n!} \tag{21}$$

Let us use the following:

Definition 1:

The function $f(x)$ is said to be $o(x)$ ($f(x) = o(x)$) if $\underset{x\to 0}{\text{Lim}}\frac{f(x)}{x} = 0$.

Then let us state the following:

Proposition:

(i) *In a small interval of time $dt \to 0$, the probability that one job offer is sent by the finite set of the V vacancies amounts to $Vadt$.*

(ii) *In a small interval of time $dt \to 0$, the probability that more than one job offer is sent by the finite set of the V vacancies goes to zero.*

Proof:

From (21) one gets, using the facts that $e^{-ax} \underset{0}{\sim} 1 - ax$ and that ax^2 is $o(x)$ according to definition 1:

$$\underset{dt\to 0}{\text{Lim}} \Pr\left[N(dt) = 1\right] = \underset{dt\to 0}{\text{Lim}}\, e^{-adt}adt = \underset{dt\to 0}{\text{Lim}}\left[adt - (adt)^2\right] = \underset{dt\to 0}{\text{Lim}}\left[1 - \frac{o(adt)}{adt}\right] adt = \underset{dt\to 0}{\text{Lim}}\, adt \tag{22}$$

Using the same reasoning, one gets

$$\underset{dt\to 0}{\text{Lim}} \Pr\left[N(dt) = 2\right] = \underset{dt\to 0}{\text{Lim}}\left[e^{-adt}\frac{(adt)^2}{2!}\right] = \underset{dt\to 0}{\text{Lim}}\frac{1}{2}\left[(adt)^2 - (adt)^3\right] = \underset{dt\to 0}{\text{Lim}}\left[\frac{o(adt)}{adt}\right]\frac{adt}{2} = 0 \tag{23}$$

and, more generally, for any $n \geq 2$

$$\underset{dt\to 0}{\mathrm{Lim}}\Pr\left[N(dt)=n\right]=\underset{dt\to 0}{\mathrm{Lim}}\left[e^{-adt}\frac{(adt)^n}{n!}\right]=\underset{dt\to 0}{\mathrm{Lim}}\frac{1}{n!}\left[(adt)^n-(adt)^{n+1}\right]=\underset{dt\to 0}{\mathrm{Lim}}\left[\frac{o(adt)}{(adt)}\right]\frac{adt}{n!}=0 \tag{24}$$

This shows that the probability that any vacancy sends more than one offer in a small interval of time dt goes to zero.

Let us show that this result also holds for the finite set of V vacancies. Let us denote by $N_V(dt)$ the number of job offers sent by the V vacancies in the interval of time dt. Assuming that vacancies send offers according to independent Poisson processes with parameter a, equation (21) implies that

$$\Pr\left[N_V(dt)=1\right]=V\left\{\Pr\left[N(dt)=0\right]\right\}^{(V-1)}\Pr\left[N(dt)=1\right]=Ve^{-(V-1)adt}e^{-adt}adt=Ve^{-Vadt}adt$$

accordingly, using $e^{-ax}\underset{0}{\sim}1-ax$, one gets:

$$\begin{aligned}\underset{dt\to 0}{\mathrm{Lim}}\Pr\left[N_V(dt)=1\right] &= V\underset{dt\to 0}{\mathrm{Lim}}(1-Vadt)adt= \\ V\underset{dt\to 0}{\mathrm{Lim}}\left[adt-V(adt)^2\right] &= V\underset{dt\to 0}{\mathrm{Lim}}\left[1-V\frac{o(adt)}{adt}\right]adt=\underset{dt\to 0}{\mathrm{Lim}}\,Vadt\end{aligned}$$

this equation proves the first part of the proposition.

For any n such that $2\leq n\leq V$, noticing that $\underset{dt\to 0}{\mathrm{Lim}}\Pr\left[N(dt)=n\right]=0$, one can write:

$$\begin{aligned}\underset{dt\to 0}{\mathrm{Lim}}\Pr\left[N_V(dt)=n\right]=C_V^n\left\{\underset{dt\to 0}{\mathrm{Lim}}\left\{\Pr\left[N(dt)=0\right]\right\}^{(V-n)}\underset{dt\to 0}{\mathrm{Lim}}\left\{\Pr\left[N(dt)=1\right]\right\}^n\right\}= \\ C_V^n\underset{dt\to 0}{\mathrm{Lim}}e^{-(V-n)adt}e^{-nadt}(adt)^n=C_V^n\underset{dt\to 0}{\mathrm{Lim}}e^{-Vadt}(adt)^n\end{aligned}$$

(where $C_V^n=\frac{V!}{(V-n)!n!}$),which implies that

$$\begin{aligned}\underset{dt\to 0}{\mathrm{Lim}}\Pr\left[N_V(dt)=n\right] &= C_V^n\left\{\underset{dt\to 0}{\mathrm{Lim}}(1-Vadt)(adt)^n\right\}= \\ C_V^n\left\{\underset{dt\to 0}{\mathrm{Lim}}(adt)^n-V(adt)^{n+1}\right\} &= C_V^n\left\{\underset{dt\to 0}{\mathrm{Lim}}\left[\frac{o(adt)}{adt}\right]adt\right\}=0\end{aligned} \tag{QED}$$

A.2 Appendix 2: The probability to get a job through social networks

Let us assume that an employee of the network of an unemployed individual gets a job offer. The probability π that this unemployed worker gets the job offer is (i) the probability that none of the other $\ell - 1$ workers belonging to the network of the employee need the job, plus (ii) the probability that the unemployed worker gets the job if a set $S \neq \emptyset$ of the other workers belonging to the network of the employee need the job. Thus, one gets formally:

$$\pi = (1-u)^{\ell-1} + \sum_{k=1}^{\ell-1} (1-u)^{\ell-k-1} u^k \left[\frac{(\ell-1)!}{\ell!\,(\ell-k-1)!} \right] \left(\frac{1}{k+1} \right) = \frac{1-(1-u)^\ell}{\ell u}$$

Each unemployed worker has ℓ links, each of whom has a probability $(1-u)$ to be employed. Job offers arrival rate on the labor market is Va, and each employee gets an arriving job offer with probability $1/L$, since this offer can reach an employee but also a unemployed worker. Moreover, this worker can also get a job offer directly through formal methods. Thus, the arrival rate of job offers for the unemployed workers with ℓ links is:

$$\underbrace{\frac{Va}{L}}_{\substack{\text{Job offers arrival} \\ \text{to an employee}}} \cdot \underbrace{\pi}_{\substack{\text{Probability to get a job} \\ \text{offer from an employee} \\ \text{who gets a job offer}}} \cdot \underbrace{\ell(1-u)}_{\substack{\text{Expected number} \\ \text{of employed links}}} + \underbrace{\frac{Va}{L}}_{\substack{\text{Job offers arrival} \\ \text{to the unemployed} \\ \text{worker}}} = va \left\{ \frac{\left[(1-u) - (1-u)^{\ell+1}\right]}{u} + 1 \right\}$$

IZA Discussion Papers

No.	Author(s)	Title	Area	Date
568	H. O. Duleep D. J. Dowhan	Revisiting the Family Investment Model with Longitudinal Data: The Earnings Growth of Immigrant and U.S.-Born Women	1	09/02
569	J. Haltiwanger M. Vodopivec	Worker Flows, Job Flows and Firm Wage Policies: An Analysis of Slovenia	4	09/02
570	T. K. Bauer S. Bender	Technological Change, Organizational Change, and Job Turnover	1	09/02
571	O. Ashenfelter M. Greenstone	Using Mandated Speed Limits to Measure the Value of a Statistical Life	5	09/02
572	C. Y. Co I. N. Gang M.-S. Yun	Self-Employment and Wage Earning: Hungary During Transition	4	09/02
573	R. T. Riphahn O. Serfling	Item Non-Response on Income and Wealth Questions	6	09/02
574	R. Kuhn S. Stillman	Understanding Interhousehold Transfers in a Transition Economy: Evidence from Russia	4	09/02
575	H. Antecol D. A. Cobb-Clark S. J. Trejo	Human Capital and Earnings of Female Immigrants to Australia, Canada, and the United States	5	09/02
576	M. Fertig C. M. Schmidt H. Schneider	Active Labor Market Policy in Germany – Is There a Successful Policy Strategy?	6	09/02
577	K. Ariga G. Brunello	Are the More Educated Receiving More Training? Evidence from Thailand	2	09/02
578	I. N. Gang F. L. Rivera-Batiz M.-S. Yun	Economic Strain, Ethnic Concentration and Attitudes Towards Foreigners in the European Union	1	09/02
579	I. N. Gang M.-S. Yun	Decomposing Inequality Change in East Germany During Transition	4	09/02
580	I. N. Gang J. Landon-Lane M.-S. Yun	Gender Differences in German Upward Income Mobility	1	09/02
581	P. Cahuc F. Malherbet	Unemployment Compensation Finance and Labor Market Rigidity	5	09/02
582	P. Cahuc C. Gianella D. Goux A. Zylberberg	Equalizing Wage Differences and Bargaining Power: Evidence from a Panel of French Firms	6	09/02
583	P. Cahuc F. Fontaine	On the Efficiency of Job Search with Social Networks	5	09/02

An updated list of IZA Discussion Papers is available on the center's homepage www.iza.org.