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Catching Hipo's

Maarten C.W. Janssen

Tinbergen Institute
The Tinbergen Institute is the institute for economic research of the Erasmus Universiteit Rotterdam, Universiteit van Amsterdam and Vrije Universiteit Amsterdam.

Tinbergen Institute Amsterdam
Keizersgracht 482
1017 EG Amsterdam
The Netherlands
Tel.: +31.(0)20.5513500
Fax: +31.(0)20.5513555

Tinbergen Institute Rotterdam
Burg. Oudlaan 50
3062 PA Rotterdam
The Netherlands
Tel.: +31.(0)10.4088900
Fax: +31.(0)10.4089031

CATCHING HIPO'S:
SCREENING, WAGES AND UNEMPLOYMENT

Maarten C.W. Janssen *)

Abstract. In this paper, I study the wage a firm sets to attract high ability workers (hipo's) in situations of unemployment. I show that the higher unemployment, the larger a firm's incentives to sort high and low ability workers. Moreover, workers will signal their (high) ability in situations of (high) unemployment only if a job offers a high enough wage. The main result, therefore, says that a firm sets higher wages, the higher unemployment. As the model is applicable to the upper segment of the labour market, the result is in line with the empirical fact that income inequality increases when more people are unemployed.

Key words: Monopsony Power, Labor Market, Screening

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Correspondence address**:**
Prof. Maarten Janssen
Dept. of Economics-micro
Erasmus University
P.O. Box 1738
3000 DR Rotterdam
The Netherlands
e-mail: janssen@few.eur.nl
fax 31-10-4089149

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1.Introduction

Since the pioneering work of Spence (1973) many economists have investigated the consequences of asymmetric information in the labor market. Although Spence studied the consequences of signaling in a competitive market, a large part of the subsequent literature is game theoretic in nature.[1] In the strategic literature the typical model has two firms competing for one worker whose ability is unknown. The reason that a worker may signal his ability is due to the fact that firms are willing to offer higher wages to more able workers (who have signaled their ability). In this type of models there is no role for unemployment.

It is quite plausible that signaling is more observed in periods of unemployment than in times of full employment. The main reason workers (students) may signal their (high) ability is that they want to increase their chances of getting a (well-paid) job. In order to study the impact of unemployment on the signaling activity of workers I look at a situation in which N workers compete for one job in one firm.[2] The ability of each worker is modeled as an independent draw from a common pool of abilities. Each individual worker knows his own ability, but does not know the abilities of the other workers. The firm only knows the characteristics of the common pool from which abilities are drawn. In the model, the firm sets wages *before* the workers signal and firms are committed to pay the wages they announced.[3] Once the firm has observed the signals, it will choose one of the workers.

The model is intended to describe certain segments of the labor market, especially the market for hipo's, i.e., high potential (hipo) students who just graduated and apply for "big boys in the city jobs", including jobs in investment banking, consultancy and law

[1] See, e.g., Cho and Kreps (1987) for the first complete game theoretic analysis of the Spence model, and Fudenberg and Tirole (1991) and Rasmusen (1989) for textbook presentations.
[2] For a survey of the way monopsony models have been used in studies of the labor market, see Boal and Ransom (1997).
[3] Hence, our model falls in the category of screening models (see Weiss, 1995). The reason for the assumption is that in a signaling model in which workers signal before the firm sets its wages, the signaling costs of the worker are sunk and the firm does not have an incentive to set a wage above the reservation wage of the worker.

firms. Firms in these market segments have a reputation for offering high wages and students in universities and MBA programs know this.[4] The commitment to paying high wages that we assume is made credible through this reputation mechanism. Students compete to get jobs for these highly paid jobs by trying to get high grades, doing many extra curricular activities, and so on. Accordingly, the signals that are modeled here are not just education, but activities students employ during or besides their studies (cv-building). As long as these signals are positively correlated with ability, firms are willing to offer higher wages, because it increases the chance of attracting high ability workers.[5]

The main result of the model says that there for a wide range of parameter values there is a *positive* relation between the size of unemployment, measured by N, and the relative wage rate, i.e., the monopsonist firm sets higher relative wages, the larger the number of workers looking for a job.[6] The intuition for the result can be explained in two steps. First, if the firm wants high ability workers to signal their ability it should set higher wages, the higher unemployment. As the firm is a monopsonist in the labor market, it will set the lowest wage possible such that high ability workers will signal their ability. High ability workers will only signal their ability if the expected returns of doing so are larger than the signaling cost. As the chance of getting a job in case of signaling decreases with the size of unemployment, the expected returns of signaling are decreasing in N. Therefore, the higher the unemployment rate, the higher the wage the firm has to set in order to induce the high ability workers to signal. Second, the incentives for firms to make workers signal their ability are stronger, the larger the level of unemployment. If no worker signals, the firm has to choose one of the workers at random. However, if the number of applicants becomes larger relative to the number of vacancies, the chances of getting really good people becomes larger. Thus, it may be the case that the firm does not

[4] It can be argued that these firms commit themselves to setting high wages by organizing information gatherings for the students in which they inform them about their career perspectives.

[5] Alternatively, it makes the selection costs of the firms lower, because part of the selection is done in the form of self-selection on the part of the students.

[6] For simplicity, we keep the reservation wage constant in our model. The wage rate that appears in the model should be interpreted as a level of wages relative to the reservation wage. To the extent that the reservation wage depends on N, our result basically says that the gap between the "haves" and the "have nots" increases with the level of unemployment. In this way, we explain the empirical fact alluded to above.

induce the workers to signal their ability for low levels of unemployment, but that it does induce them to signal at larger unemployment levels. This explains that at certain levels of unemployment the wage rate may jump upwards.

If we interpret the main result as saying that the wage rate of higher income groups goes up relative to some average wage, then we can interpret our model as a simple explanation of the well-known empirical fact that the difference between low and high income groups becomes larger if unemployment increases. Blinder and Esaki (1978: 607), for example, find that "each one percent point rise in the unemployment rate takes about 0.26%-0.30% of the national income away from the lowest 40% of the income distribution and gives it to the richest 20%." Especially, high income groups apparently benefit from high levels of unemployment. Similar results are also found in other studies, see e.g., Gramlich (1974). Despite the fact that the empirical finding is quite robust, no good theoretical explanation has been offered. This paper attempts to fill this gap by offering an explanation based on asymmetric information and screening.

Information asymmetries have been used in many different ways in studies of the labor market; see Weiss (1995) for a survey. Traditionally, the focus was on asymmetric information between a worker and a firm about the worker's ability level. More recently, a number of papers have shifted attention to an employer's private information (vis-à-vis the market) about an employee's ability (see, e.g., Waldman, 1984 and Gibbons and Katz, 1991). In contrast, I stay within the framework set out by Spence (1973). Dynamic issues concerning signaling and education have been studied in Nöldeke and van Damme (1990).

In the efficiency wage literature (see Weiss, 1990 for a survey) a firm chooses to set relatively high wages as this yields higher labor productivity. Two mechanisms are distinguished, a selection effect and an incentive effect. Our paper can be considered as giving an alternative explanation for the selection mechanism based on asymmetric information. At low wages, firms have to select a worker at random, whereas at higher wages, workers selects themselves out through signaling and the firm can select from a smaller pool of high quality workers.

Another related paper is that of Lazear and Rosen (1981). They show that it may be optimal for a firm to set wages based on rank, and to pay high salaries to executives, as this provides incentives for all other individuals in the firm to work hard in order to "win" one of the executive positions in the future. Our model shows that the idea of competitive lotteries can also be applied in the labor market, a well-paid job being the "prize" and fellow students being the competitors.

The paper is organized as follows. Section 2 describes the model. In section 3 I analyze the model and characterize the equilibrium properties and depend on the parameters. Section 4 concludes.

2. The Model

The model has N workers and one firm with one job vacancy.[7,8] In stage 0, Nature decides about the type of each worker. Workers can be of different abilities; the ability of agent I is denoted by q_i. Abilities are uniformly distributed on the interval [0,1]. The ability level is private information to the worker, i.e., neither the firm nor the other workers know the ability of a worker. In stage 1 the firm offers wage contracts. It sets two wages, $w(1)$ and $w(0)$, where $w(1)$ denotes the wage for a worker who signals and $w(0)$ denotes the wage for a worker who does not signal. As it is optimal for the firm to set $w(0)=0$, we will concentrate on $w(1)$ and when there is no room for confusion, we drop the dependence of the wage rate on the signal. In stage 2 knowing the wages that are offered, workers decide whether or not to signal. For simplicity, I assume that the signal s can take on two values, 0 (no signal) or 1 (signal). Finally, in the last stage of the game the firm selects one worker possibly based on the signal it observes. If none of the workers signals or if they all signal, the firm randomly selects a worker. If some workers signal and the others do no, it may choose randomly among the workers that signaled or among those that did not.

[7] In other words, the marginal productivity of labor of a second worker is very low.
[8] In a discrete version of the model (see, Janssen, Makansi and Morrison, 1997) we analyze a duopsony extension with two firms hiring workers. The analysis is quite messy, but for some parameter values the equilibrium exhibits similar properties as the equilibrium of the present model.

The pay-off to the firm depends on the worker it hires and the wages it offers. The pay-off to the worker if he is hired depends on the wages that are offered and the signaling cost. Denote the ability (or labor productivity) of individual i by θ_i and the signaling cost of individual i by $c(\theta_i)$. I assume that the signaling cost of an individual with ability level θ to be given by $c(\theta) = k/\theta$, i.e., it is more costly to signal for a low ability worker than for a high ability one. In order to have non-trivial solutions, I assume $k<½$. The pay-off to the firm when hiring worker i with signal s is then given by $\pi_f = \theta_i - w(s)$ and the pay-off to the worker who is hired *by* $\pi_i = w(s) - c(\theta_i)$. The workers that signaled and are not hired get a negative pay-off equal to their signaling cost.[9] Both the firm and the workers are assumed to be risk neutral and maximize their pay-offs given the strategies of the others.

3. Equilibrium Properties

In this section I will analyze the equilibrium properties of the model. From the set-up described in the previous section, it is clear that the firm can set $w(1)$ and $w(0)$ in such a way that workers with ability levels larger than some critical level θ^* will signal and workers with an ability level lower than θ^* do not signal. What the firm is in fact doing is dichotomizing the continuous type space. A worker with ability θ^* or above will signal if the wage multiplied by the probability of getting the job is at least equal to his cost of signaling. The probability of getting the job depends, in turn, on the number of people who have an ability level larger than θ^*. It can be shown that the probability of getting the job is given by[10]

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[9] Hence, we assume that the worker's reservation wage is zero.

[10] Using: the fact that $\binom{N-1}{k} = \frac{N-k}{N}\binom{N}{k}$, the L.H.S of (1) can be written as $\frac{1}{N}\sum_{k=0}^{N-1}\binom{N}{k}(1-\theta^*)^{N-1-k}(\theta^*)^k$. Taking out θ^* and moving the summation up to N and correcting by subtracting the N^{th} term one gets: $\frac{1}{N(1-\theta^*)}(\sum_{k=0}^{N}\binom{N}{k}(1-\theta^*)^{N-k}(\theta^*)^k - (\theta^*)^N)$. The binomial term in the left of the brackets is equal to 1, so that the whole expression equals $\frac{1}{N(1-\theta^*)}(1-(\theta^*)^N)$.

$$\sum_{k=0}^{N-1}\binom{N-1}{k}(1-q^*)^{N-k-1}(q^*)^k\frac{1}{N-k}=\frac{(1-(q^*)^N)}{N(1-q^*)} \tag{1}$$

Hence, in the N worker case, workers with ability level larger than or equal to q^* will signal if the wage is at least:

$$w(1)=\frac{N(1-q^*)c(q^*)}{(1-q^{*N})} \tag{2}$$

Workers with ability levels smaller than q^* will not signal at this wage rate. By using (2) the maximization problem of the firm can be written as if the firm chooses q^*:

$$\max \qquad p_f=(1-q^{*N})\left(\int_{q^*}^{1}qf(q)dq-w(q^*)\right)+q^{*N}\left(\int_{0}^{q^*}qf(q)dq\right) \tag{3}$$

Substituting the signaling cost function, and the separating wage given in (2) in (3) I get:

$$p_f=(1-q^{*N})\left(\tfrac{1}{2}(1+q^*)-\frac{kN(1-q^*)}{q^*(1-q^{*N})}\right)+\tfrac{1}{2}(q^*)^{N+1}\ , \tag{4}$$

which reduces to

$$p_f=\frac{1}{2}(1-q^{*N})+\frac{1}{2}q^*-\frac{kN(1-q^*)}{q^*}\,. \tag{5}$$

Maximizing this expression with respect to ability yields an optimal q^*. This is the demarcation ability level chosen by the firm in the separating equilibrium. The optimal q^* is implicitly defined by

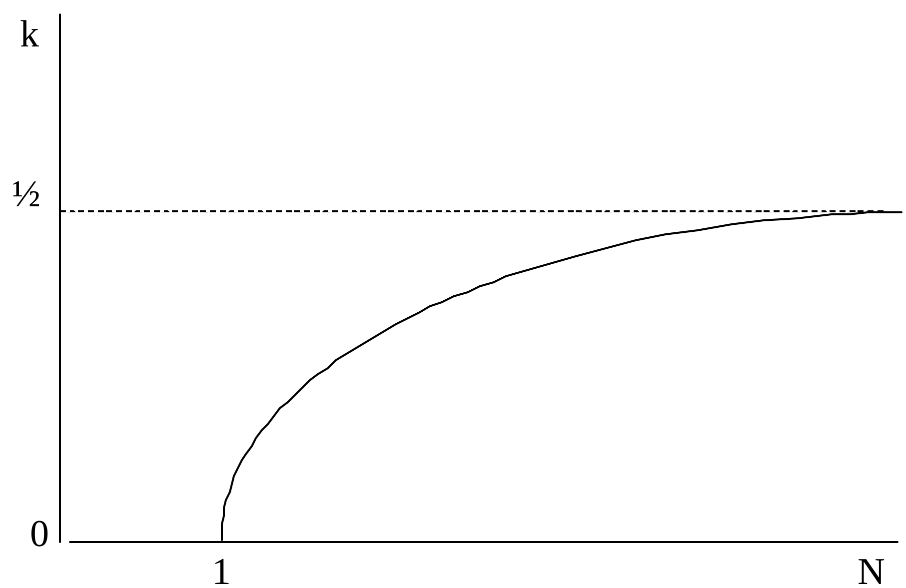
$$-\frac{N}{2}q^{*N-1}+\frac{1}{2}+\frac{kN}{q^{*2}}=0\,. \tag{6}$$

From the q^* that solves equation (6) the wage $w(q^*)$ that the firm offers follows by virtue of (2). In order to emphasize the fact that the optimal wage rate and the demarcation value of q depend on the exogenous parameters N and k, we also write $w_N(k)$ and $q_N(k)$, respectively. The rest of the section is devoted to investigate how $w_N(k)$ and $q_N(k)$ depend on N and k.

First, note that the second-order derivative of the profit function with respect to q is strictly negative and that the first-order derivative at q =0 is strictly positive. This implies that for each value of N and k there is a unique optimal value of θ* in [0,1], possibly 1 itself. In order to have an interior solution the first-order derivative at q =1 must be strictly negative. This is the case if

$$(k - \tfrac{1}{2})N + \tfrac{1}{2} < 0\,.$$

When this condition is violated, it is optimal for the firm to set wages in such a way that no agent signals his ability and the firm randomly selects one of the agents. I will define the corresponding wage rate to be equal to 0. Figure 1 indicates the region of N and k where the firm chooses to induce agents to signal. From the figure it is clear that for a given value of k unemployment must be larger than a certain critical value to make it worthwhile for the firm to induce workers to signal. Basically, the idea here is that if the number of applicants is large relative to the number of vacancies, the chances of getting really good people becomes larger and it pays to have them self-select. The firm has to offer a strictly positive wage to induce signaling. Hence, when the unemployment level irises above a critical value, the optimal wage rate jumps from zero upwards. This is the second effect mentioned in the Introduction.



Figuur 1: For a given level of k the unemployment level has to be high enough to have the firm induce agents to signal their ability

In case of an interior solution, we can also ask the question how the optimal wage rate $w_N(k)$ depends on the unemployment level, measured by N. it turns out that the dependence is unambiguously positive: the larger N, the larger $w_N(k)$. The result is formally stated in Proposition 1.

Proposition 1. If $(k-\frac{1}{2})N+\frac{1}{2}<0$, then $w_N(k)$ is positively related to N.

The proof is given in the appendix. The standard way of proving a result like the one of Proposition 1 is to use the envelope theorem. Unfortunately, as we cannot explicitly write q as a function of w, it is difficult to assess $\partial^2 p_f / \partial w \partial N$. Instead, the proof compares the optimal value of $q_{N+1}(k)$ with a demarcation value of q in case the firm would keep its wage rate at the level of $w_N(k)$. It is shown that the optimal value of $q_{N+1}(k)$ is smaller and that therefore the firm has to adjust its wage rate upward. The main economic intuition is that as unemployment increases, the chance of getting a job in case of signaling decreases and so is the expected returns of signaling. Therefore, the higher the unemployment rate, the higher the wage the firm has to set in order to induce the high ability workers to signal.

The impact of N on $q_N(k)$ is less clear. When the cost of signaling is very low, i.e., k is close to 0, it follows from (6) that $q_N(k)$ is approximately equal to $\sqrt[N-1]{1/N}$. This expression is increasing in N. If, on the other hand, k is such that for a certain N $q_N(k)$ is close to 1, then it follows from (6) that $q_{N+1}(k)<q_N(k)$. There are two opposing forces at work. A lower value of $q_N(k)$ increases the chances of having at least one individual signal. This is beneficial to the firm as it can select a high ability worker. On the other hand, firms have to pay higher wages if it wants to induce more signaling. N When $q_N(k)$ is close to 1, the first effect is important as the probability of any individual signaling is small, while second effect is negligible as the probability is small that there is another agent with an ability level close to 1. Hence, $q_{N+1}(k)<q_N(k)$ when $q_N(k)$ is close to 1. The reverse holds true when $q_N(k)$ is approximately equal to $\sqrt[N-1]{1/N}$.

Figures 2 and 3 illustrate how for different values of k the optimal value of q* and $w(q^*)$ varies with N. For small values of k, the firm induces agents to signal for all values of N>1. Figure 2 shows for k=0.2 that q^* is first decreasing and then increasing in N and that it approaches 1 for large N. Hence, as unemployment increases beyond a critical value firms become more and more selective. Substituting q^* into equation (2) yields the relation between the optimal wage w and N also depicted in figure 2. One can see that wages are smoothly increasing in N that they increase by around 40% from N=2 to N=10 and that the increase smoothens out when N increases further.

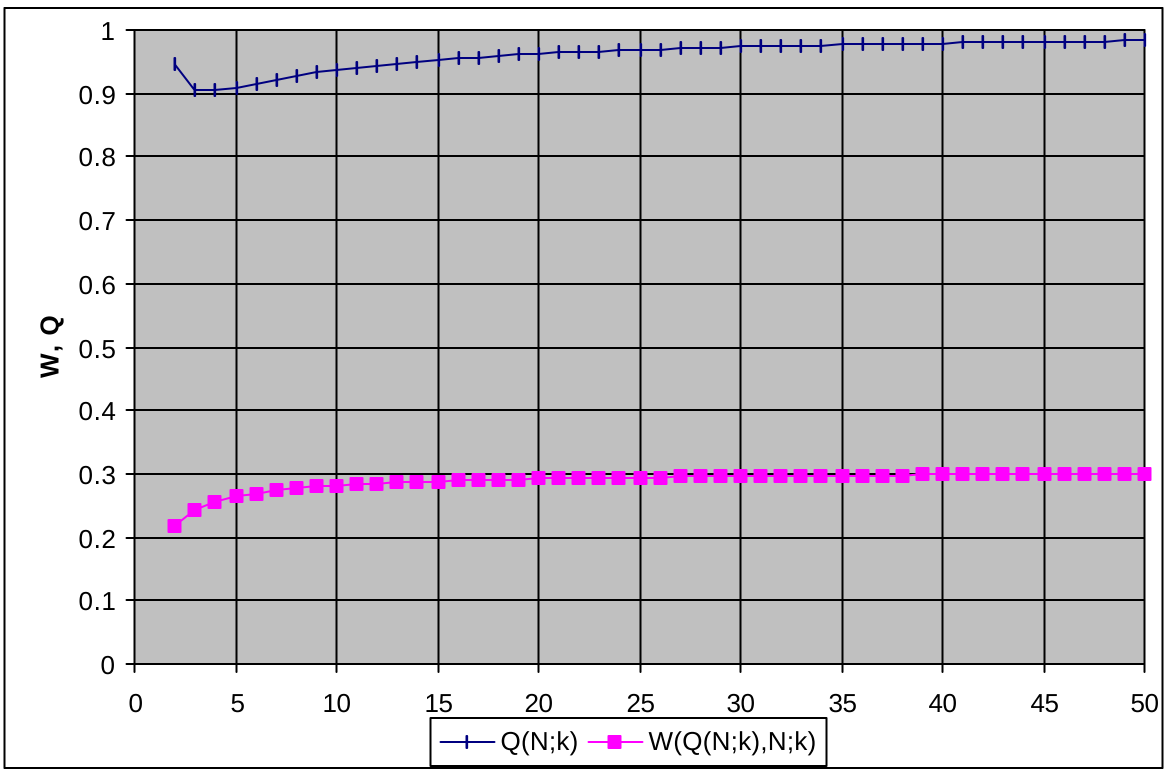


Figure 2. q* and $w(q^*)$ as a function of N for k=0.2.

When k is larger, the firm does not induce the agents to signal for small values of N. This is depicted in Figure 3 for k=0.4. the figure shows that wages jump upwards at k=5 and increase smoothly from that moment onwards. The corresponding values of q* are very close 1 and show a similar pattern as in figure 2.

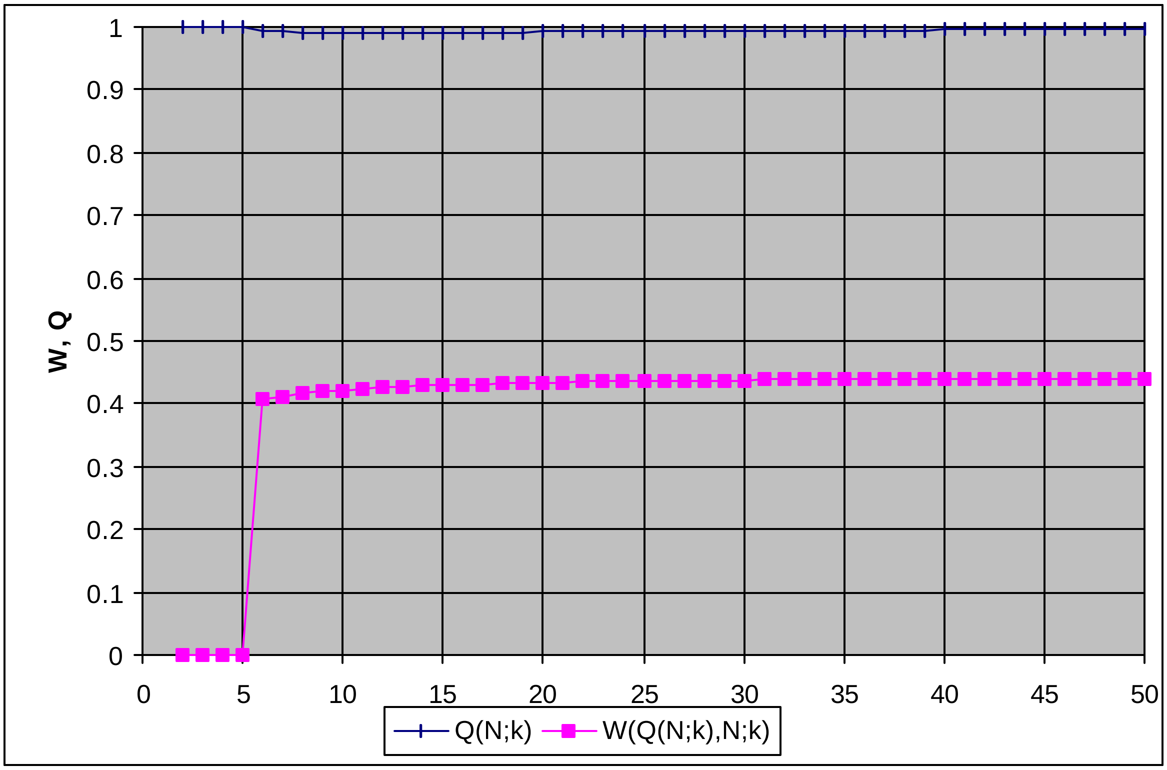


Figure 2. q^* and $w(q^*)$ as a function of N for k=0.2.

Finally, I briefly discuss the impact of the cost of signaling measured by k on $w_N(k)$ and $q_N(k)$. From equation (6) it is clear that the impact on $q_N(k)$ is positive as long as there is an interior solution, i.e., the higher the cost of signaling the higher the demarcation value chosen by the firm. Also, the impact of a higher k on $w_N(k)$ is, as is to be expected, positive. If the firm would not adjust $q_N(k)$ the wage the firm has to set increases quite sharply in k. The firm partially off-sets this pressure on the wages it has to pay to induce agents to signal by increasing the demarcation value $q_N(k)$. In this way, there is a smaller chance that someone has an ability larger than the demarcation value, and accordingly, a person with a high ability level has to be compensated to a lesser extent.

4. Conclusion

In this paper, I have analyzed the consequences of unemployment on the relative wage that is set by firms to sort out workers (students) with different ability levels. It has been shown that in a variety of settings this relation is positive, i.e., the higher unemployment, the higher the (relative) wage set by the firm(s). This indicates that the gap between the rich and the poor, i.e., between those that have a well-paid job and those that have not, may become larger in situations where the model applies. I think that this is the case in "big boys in the city jobs" in the sphere of investment banking, consultancy and law firms.

Appendix 1. (Proof of Proposition 1)

We will prove that for any k, $w(N) < w(N+1)$. The proof is in several steps. We first look for a fixed N at the first order condition for profit maximization. From (7) it follows that the optimal q^* has to satisfy:

$$-\frac{N}{2}q_N^{N-1} + \tfrac{1}{2} + \frac{kN}{q_N^2} = 0, \qquad \text{(A.1)}$$

where q_N is the optimal value of q for a given N. Note that for a fixed value of N, q_N is increasing in k. This in turn implies that the smallest value of q_N is given by $\sqrt[N-1]{1/N}$, which is larger than ½From (A.1) it follows that for any k,

$$q_N^{N+1} - \frac{q_N^2}{N} = q_{N+1}^{N+2} - \frac{q_{N+1}^2}{N+1}. \qquad \text{(A.2)}$$

From equation (2), we can also derive a relation between different values of q in case the firm does not adjust w when N increases. I denote by $\tilde{q}_{N+1}$ the value of the demarcation value of q_{N+1} when the firm does not adjust the wage rate from its optimal value in case of N unemployed agents. for each value of q_N. It follows that

$$(N+1)(q_N + ... + q_N^N) = N(\tilde{q}_{N+1} + ... + \tilde{q}_{N+1}^N). \qquad \text{(A.3)}$$

From equation 2 it easily follows that for a fixed N, w is decreasing in q for all q<1. The proof concentrates on the relation between q_{N+1} and $\tilde{q}_{N+1}$ and we show that $q_{N+1} < \tilde{q}_{N+1}$. This implies that the optimal value of q is smaller than the value in case the firm does not adjust w. This together with the fact that w is decreasing in q implies that if N increases, the firm should adjust its wage upwards.

From (A.3) it follows that $q_N < \tilde{q}_{N+1}$. On the other hand, from (A.1) it does not follow that $q_N < q_{N+1}$. In case $q_{N+1} < q_N$, it follows trivially that $q_{N+1} < \tilde{q}_{N+1}$. Hence, in the rest of the proof we concentrate on the case where $q_N < q_{N+1}$.

For notational simplicity, we will use in the rest of the proof x and y instead of q_N and q_{N+1}, respectively. Using this notation, we rewrite (A.2) as

$$x^{N+1} - \frac{x^2}{N} = y^{N+2} - \frac{y^2}{N+1}.$$

For each x let us define y_1 as the solution to $x^{N-1} - \frac{1}{N} = y_1^N - \frac{1}{N+1}$. For all x such that $x \le y$ we know that $y \le y_1$. We can rewrite the equation defining y_1 as

$$x = \sqrt[N-1]{y_1^N + \frac{1}{N(N+1)}}. \tag{A.4}$$

Next, let us rewrite (A.3) as $(N+1)(x + ... + x^N) = N(\tilde{y} + ... + \tilde{y}^{N+1})$. For each x let us define y_2 implicitly as the solution to $(N+1)x = Ny_2 + y_2{}^2$. I will argue that $y_2 \le \tilde{y}$. The proof consists of two steps. The first step argues that if $(N+1)x = Ny_2 + y_2^2$, then $(N+1)x^k \ge (N+1-k)y_2^k + ky_2^{k+1}$ for all k. Details of this first step are given below. The second step argues that if for all k $(N+1)x^k \ge (N+1-k)y_2^k + ky_2^{k+1}$, then it follows by simple summation that $(N+1)\sum_{j=1}^{N} x^j \ge N\sum_{j=1}^{N+1} y_2^j$. As $\tilde{y}$ is implicitly defined by $(N+1)\sum_{j=1}^{N} x^j = N\sum_{j=1}^{N+1} \tilde{y}^j$, it follows that $y_2 \le \tilde{y}$.

The proof of the first part is by induction on k. It is clear that the statement holds for k=1. So, suppose then that the statement holds true up to a certain k, 2 $\le k < N$, i.e., if $(N+1)y_2 = Ny_2 + y_2^2$, then $(N+1)x^k \ge (N+1-k)y_2^k + ky_2^{k+1}$. We will then show that also if $(\mathrm{N}+1)\mathrm{x} = \mathrm{Ny}_2 + \mathrm{y}_2^2$, then $(N+1)x^{k+1} \ge (N-k)y_2^{k+1} + (k+1)y_2^{k+2}$. This is the case if (using expressions for x and x^{k+1})

$$\frac{(Ny_2 + y_2^2)[(N+1-k)y_2^k + ky_2^{k+1}]}{(N+1)} \ge (N-k)y_2^{K+1} + (k+1)y_2^{K+2}$$

$$\Leftrightarrow (N + y_2)[N+1-k+ky_2] \ge (N-k)(N+1) + (N+1)(k+1)y_2$$

$$\Leftrightarrow k - 2ky_2 + y_2^2 \ge 0$$

$$\Leftrightarrow k(1-y_2)^2 \ge 0.$$

Hence, if $(N+1)x = Ny_2 + y_2^2$ then $(N+1)x^k \ge (N+1-k)y_2^k + ky_2^{k+1}$ for all $2 \le k \le N$.

We can rewrite the equation defining y_2 as $x = \dfrac{Ny_2 + y_2^2}{(N+1)}$. (A.5)

Finally, we prove that $y_1 < y_2$. Using (A.4) and (A.5) and the fact that in both equations x is a monotonically increasing function of y_1 and y_2, respectively, it suffices to show that for the some arbitrary value of $y_1 = y_2 = z$:

$$\frac{Nz+z^2}{N+1} < \sqrt[N-1]{z^N + \frac{1}{N(N+1)}}$$

$$\Leftrightarrow z^N + \frac{1}{N(N+1)} > \frac{z^{N-1}(N+z)^{N-1}}{(N+1)^{N-1}}$$

$$\Leftrightarrow (N+1)^{N-1} z^N + \frac{(N+1)^{N-2}}{N} > z^{N-1}(N+z)^{N-1} \qquad \text{(A.6)}$$

We first consider $N=3$. In this case (A.6) reduces to $16z^3 + \frac{4}{3} > z^2(3+z)^2$, or $z^4 - 10z^3 + 9z^2 - \dfrac{4}{3} < 0$. Straightforward calculations show that the maximum value of the L.H.S. of this inequality is negative (approx. –0.09). Hence, (A.6) holds for $N=3$. I next consider $N>3$. To this end, define a function

$$f(z;N) = z^{N-1}(N+z)^{N-1} - (N+1)^{N-1} z^N - \frac{(N+1)^{N-2}}{N} \quad .$$

I will show that for every fixed *y* this function is decreasing in *N*.

$$\begin{aligned}\frac{\partial f}{\partial N} &= (N+z)^{N-1} z^{N-1} \log z + (N-1)(N+z)^{N-2} + (N+z)^{N-1} \log(N+z) \\ &\qquad - (N+1)^{N-1} z^N \log z - (N-1)(N+1)^{N-2} - (N+1)^{N-1} \log(N+1) \\ &= (N-1)[(N+z)^{N-2} - (N+1)^{N-2}] + \\ &\qquad + (N+z)^{N-1} \log(N+z) - (N+1)^{N-1} \log(N+1) \qquad \text{(A.7)} \\ &\qquad\qquad + z^{N-1} \log z[(N+z)^{N-1} - (N+1)^{N-1} z] .\end{aligned}$$

It is clear that the first two terms of (A.7) are negative for all $z<1$. The third and last term is also negative if $(N+z)^{N-1} - (N+1)^{N-1} z \geq 0$ for all $0 \leq z \leq 1$. To see that this is the case note the expression equals 0 at z=1 and that the first order derivative with respect to y equals

$$(N-1)(N+z)^{N-2}-(N+1)^{N-1} \leq (N+1)^{N-2}(N-1-N-1),$$

which is negative. Hence, (A.6) holds for all $N \geq 3$. Finally, for $N=2$, (A.6) reduces to $(N+1)z^2+\frac{1}{2}>(N+z)y$, or, $2z^2-2z+\frac{1}{2}>0$. It is easy to see that this holds if $z>\frac{1}{2}$, which is true given the discussion just below (A.1).

References

Blinder, A. and H. Esaki. 1978. Macroeconomic Activity and Income Distribution in the Postwar United States. *The Review of Economics and Statistics* 604-609.

Cho, I.-K. and D. Kreps. 1987. Signalling and Stable equilibria. *Quarterly Journal of Economics* **102**:179-221.

Fudenberg, D. and J. Tirole.1991. *Game Theory*. Harvard (Mass.): MIT Press.

Gibbons, R. and L. Katz. 1991. Layoffs and Lemons. *Journal of Labor Economics* **9**: 351-80.

Gramlich, E. 1974. The Distributional Effects of Higher Unemployment. *Brookings Papers on Economic Activity* **2:** 293-342.

Janssen, M.C.W and E. Rasmusen. 1997. Uncertain Bertrand Competition, mimeo.

Lazear, E. and S. Rosen. 1981. Rank-Order Tournaments as Optimum Labor Contracts. *Journal of Political Economy* **89**: 841-864.

Nöldeke, G. and E. van Damme. 1990. Signalling in a Dynamic Labour Market. *Review of Economic Studies* **57**: 1-23.

Rasmusen, E. 1989. *Games and Information*. Oxford: Basil Blackwell.

Spence, A.M. 1973. Job Market Signalling. *Quarterly Journal of Economics* **90**: 225-43.

Waldman, M. 1984. Job Assignments, Signalling and Efficiency. *Rand Journal of Economics* **15**: 255-67.

Weiss, A. 1990. *Efficiency Wage Models of Unemployment, Layoffs, and Wage Dispersion*: Princeton University Press, Princeton. New Jersey.

Weiss, A. 1995. Human Capital vs. Signalling Explanations of Wages. *Journal of Economic Perspectives*: 133-153.