INTERNATIONAL ECONOMIC REVIEW
Vol. 35, No. 3, August 1994

THE EFFECT OF JOB HETEROGENEITY ON RESERVATION WAGES*

BY BRIAN P. MCCALL[1]

This paper develops a model of job search in which jobs differ in the amount of inspection and experience uncertainty. Under these circumstances, reservation wages may not remain constant or decrease over an unemployment spell. Even if job offer rates are constant over an unemployment spell, negative duration dependence of the reemployment hazard can occur when individuals search amongst a variety of jobs. Since this duration dependence is a result of *time-varying* unobserved heterogeneity, conventional methods for controlling for unobserved heterogeneity in reduced form hazard models are inappropriate.

1. INTRODUCTION

This paper develops a model of job search with heterogeneous job opportunities. It builds on previous research by Johnson (1978), Miller (1984), Salop (1973), Viscusi (1980) and Weitzman (1979), who model job heterogeneity but concentrate explicitly on its consequences for either job search or job matching and also on the research of Jovanovic (1984), Lippman and McCall (1981), and Wilde (1979), who recognize that the job search and job matching are interdependent processes but model all jobs as being indistinguishable, ex ante.[2]

When an individual begins searching for a job, whether he/she is a new entrant to the labor force or has just left previous employment, the information accumulated over his/her lifetime (either purposely or incidentally) will lead him/her to distinguish between jobs. The costs of inspecting (searching) different jobs may vary and an individual may expect different outcomes at different jobs. In addition, jobs may differ not only in the *amount* of uncertainty which surrounds them but also in the *process* by which that uncertainty is resolved. Here, Nelson's (1970) distinction between inspection (search) attributes and experience attributes is useful. While most uncertainty may be resolved upon inspection in some jobs, it may primarily be resolved only through actual work experience in others.

Section 2 of the paper shows that risk neutral individuals, all else equal, will inspect jobs with more experience match (EM) uncertainty and that such jobs will be characterized by a lower reservation wage. This result is intuitive when one thinks in terms of options. When an individual accepts a job, they are, in a sense,

* Manuscript received June 1992.

[1] I am grateful to John Budd, David Card and two anonymous referees for helpful comments and the Industrial Relations Section of Princeton University for financial support.

[2] An exception is McCall and McCall (1981). However, their analysis was preliminary. This paper is a significant elaboration of their model.

also purchasing a call option.[3] Since this option is more valuable in jobs with large EM uncertainty, she/he is willing to accept a lower starting wage (utility).

This suggests that if only the amount of EM uncertainty differed across jobs, reservation wages would tend to rise over an unemployment spell. Propositions 4 and 5 of Section 2 set out conditions under which this suggestion is correct. It is also shown that, ceteris paribus, an individual will first inspect jobs with lower inspection costs, jobs with better expected prospects, and jobs with more inspection match (IM) uncertainty. These types of job heterogeneity cause reservation wages to fall over an unemployment spell. Hence, if there is considerable heterogeneity across jobs reservation wages need not be constant or fall throughout an unemployment spell.

Many recent empirical studies of unemployment durations have taken a hazard function approach (see Devine and Kiefer 1991). The reemployment hazard is approximately equal to the probability that reemployment occurs in the next "small" interval of time given that unemployment is ongoing. The hazard function is said to exhibit duration dependence if this conditional probability changes as the unemployment spell lengthens. The reemployment hazard is said to exhibit negative (positive) duration dependence if this conditional probability decreases (increases) as the unemployment spell lengthens.

Several of these studies have found evidence of negative duration dependence in reemployment hazards. Identifying the source of such duration dependence is important for both theoretical and policy reasons. When the arrival rate of job offers is constant over the unemployment spell, most standard models of job search predict that reemployment hazards are either constant or increasing over the unemployment spell (see Lippman and McCall 1976). Thus, empirical findings of negative duration dependence have been used as support for the theories of declining job offer rates such as the discouraged worker effect and the stigma effect (see Vishwanath 1989). Omitting a time-constant regressor which affects the reemployment hazard, however, biases the estimates towards a finding of negative duration dependence (Heckman and Singer 1984). Although many studies control for this type of unobserved heterogeneity (see Devine and Kiefer 1991), Lynch (1989) continued to find evidence of negative duration dependence in the reemployment hazards of youth when applying such controls.

Section 3 of this paper demonstrates that negative duration dependence of the (re)employment hazard can arise even when job offer rates are constant, if an individual searches for different types of jobs during the unemployment spell and the type of job they are seeking at any particular moment is not observed. Since the duration dependence in this circumstance results from time-varying unobserved heterogeneity, statistical methods which are designed to control for time-constant unobserved heterogeneity (see Lancaster 1979 and Heckman and Singer 1984) are inadequate. This is illustrated by two examples where estimation using a mixture model leads to incorrect inferences about the behavior of reservation wages over an unemployment spell.

The examples contained in Section 3 also suggest that new entrants or youths are

[3] They exercise this call option by remaining at the job after EM uncertainty is resolved.

more likely than individuals with substantial work experience to search amongst a variety of job types. Thus, this explanation for duration dependence is more pertinent for youths. In addition, the effects of risk aversion are studied in Section 3. In the examples considered, the search behavior of risk averse individuals does not differ from risk neutral individuals as long as they are not too risk averse.

Finally, a summary and some concluding remarks are contained in Section 4.

2. A MODEL OF JOB SEARCH WITH HETEROGENEOUS OPPORTUNITIES

Suppose that an individual has N different job prospects, $i = 1, 2, \dots, N$, each of which is characterized by an inspection cost c_i and two random variables $\tilde{w}_i$ and $\tilde{\alpha}_i$ with joint cumulative distribution function (c.d.f.) $G_i(w, \alpha)$. Assume that for all $i \neq j$, $(\tilde{w}_i, \tilde{\alpha}_i)$ is independent of $(\tilde{w}_j, \tilde{\alpha}_j)$. Also assume that one job is sampled (i.e., inspected or worked) per period, that jobs not currently being sampled remain in the same state, and that recall is possible.

After an initial inspection of job i, $\tilde{w}_i$ is revealed. The random variable $\tilde{w}_i$ thus characterizes the amount of IM uncertainty. At this point, the individual must decide whether to accept the job or sample another job. If the job is accepted, the individual receives a return of $\tilde{w}_i$ in his/her first period of work. More generally, $\tilde{w}_i$ can be considered the annuity equivalent of the expected return from working at job i permanently, given inspection information. This expected return calculation would incorporate the starting wage, expected wage growth, and the monetary equivalent of the nonpecuniary benefits derived from the job.

For convenience, assume that after one period of employment, all EM uncertainty is resolved.[4] This uncertainty is characterized by the random variable $\tilde{\alpha}_i$. Consequently, if an individual remains at job i beyond the first period, they will remain permanently with a net compensation of $\tilde{w}_i + \tilde{\alpha}_i$ (per period). Finally, assume that the time horizon is infinite and that individuals maximize expected discounted returns where β is the discount factor, $0 < \beta < 1$.

In the statistics literature, the sequential decision problem facing the individual here is termed a multi-armed bandit (MAB) problem. The attractive feature about MAB problems is that the optimal decision policy reduces to an index policy.[5] An index policy is a decision policy which at time t calculates an index for each alternative (or, in this case, job) under consideration and then chooses the alternative with the highest index.[6] The index for each alternative depends solely on its own characteristics and not on the characteristics of any other alternative. Indices are revised over time as information is revealed.

Formally, suppose there are N alternatives and let $x_i(t)$, $i = 1, 2, \dots, N$ be the

[4] More complicated job matching processes could be incorporated into the model. However, since the primary focus of the paper is on the effect of EM uncertainty on reservation wages and unemployment durations, this simple matching process suffices.

[5] For formal derivations of the optimality of the index policy, see Gittins and Jones (1974) and Whittle (1980).

[6] Sometimes these indices are referred to as dynamic allocation indices or Gittins' indices in honor of J. C. Gittins who first devised a solution to the MAB problem. Since only one alternative can be pursued each period, one can think of the problem in terms of allocating one's own effort over time.

state of alternative i at time t. Denote the index associated with alternative i at time t by $Z_i(x_i(t))$. The optimal decision policy, then, is one which pursues alternative j at time t when

$$Z_j(x_j(t)) = \max_i \{Z_i(x_i(t))\}. \tag{1}$$

Consider the decision problem with only two alternatives: i and a simple alternative which, if chosen, pays m per period. Let $M = m(1-\beta)^{-1}$. Denote by $V_i(x, M)$ the optimal value function associated with this decision problem.[7,8] Whittle (1980) has shown that the index associated with alternative i, $Z_i(x)$, satisfies the recursive equation

$$Z_i(x) = V_i(x, Z_i(x)). \tag{2}$$

Intuitively, $Z_i(x)$ is the value of M which renders an individual indifferent between alternative i and the simple alternative, when alternative i is in state x.

To simplify matters further (and to ensure the existence of a reservation wage), assume that, for all i, match uncertainty is of the form $\alpha_i \tilde{y}_i$ where α_i is a constant and $\tilde{y}_i$ is a random variable, independent of $\tilde{w}_i$, which takes either the value $+1$ or the value -1 with equal probability. Also, suppose that the random variable $\tilde{w}_i$ can be characterized by the absolutely continuous c.d.f. F_i, which admits a probability density function (p.d.f.) $f_i(w)$ with total support on $[\underline{w}, \bar{w}]$, where $\bar{w} > \underline{w} > 0$. The state space of job i, X_i, is defined by the union of (0, 0) with the cross product $[\underline{w}, \bar{w}] \times \{-1, 0, 1\}$. When $x_i = (0, 0)$, the job has yet to be inspected. The state space of job i moves from (0, 0) to $(w, 0)$ if an inspection of job i produces a wage offer of w. After the ith job is experienced for one period, the state space moves from $(w, 0)$ to $(w, -1)$ or $(w, 1)$ depending on whether $\tilde{y}_i = -1$ or $\tilde{y}_i = +1$, respectively. Under these assumptions, it is not difficult to show that $V_i((0, 0), M)$ satisfies

$$V_i((0,0), M) = \max_{w_i^1, w_i^2} ER(w_i^1, w_i^2, \alpha_i, f_i, c_i, M) \tag{3}$$

$$\text{subject to} \quad \underline{w} \leq w_i^1 \leq w_i^2 \leq \bar{w}$$

where

$$\begin{aligned} &ER(w_i^1, w_i^2, \alpha_i, f_i, c_i, M) \\ &= -c_i + \beta(1-\beta)^{-1}\left[\int_{w_i^2}^{\bar{w}} w f_i(w)\, dw + (1 - .5\beta)\int_{w_i^1}^{w_i^2} w f_i(w)\, dw\right] \\ &\quad + .5\beta^2(1-\beta)^{-1}[F(w_i^2) - F(w_i^1)]\alpha_i + \beta[F(w_i^1) + .5\beta\{F(w_i^2) - F(w_i^1)\}]M. \end{aligned} \tag{4}$$

In equations (3) and (4), the value w_i^1 denotes the minimal wage offer necessary to induce the individual to work job i for at least one period and the value w_i^2 denotes

[7] Since no uncertainty surrounds the simple alternative, if the simple alternative is first chosen at time s, it will then be chosen for all $t > s$.

[8] When no confusion arises, $x_i(t)$ is written simply as x.

the minimal wage offer which induces the individual to remain at job i after receiving unfavorable information $(-\alpha_i)$. Choosing w_i^1 and w_i^2 to maximize expected discounted returns and denoting these optimal values by w_i^{1*} and w_i^{2*}, respectively, equations (2), (3) and (4), imply that the index for job i in state (0, 0), $Z_i(0, 0)$, satisfies

$$\begin{aligned} Z_i(0,0) = {} & -c_i + \beta(1-\beta)^{-1} \\ & \times \left[\int_{w_i^{2*}}^{\bar{w}} w f_i(w)\,dw + (1-.5\beta) \int_{w_i^{1*}}^{w_i^{2*}} w f_i(w)\,dw \right] \\ & + .5\beta^2(1-\beta)^{-1}[F(w_i^{2*}) - F(w_i^{1*})]\alpha_i \\ & + \beta[F(w_i^{1*}) + .5\beta\{F(w_i^{2*}) - F(w_i^{2*})\}]Z_i(0,0). \end{aligned} \tag{5}$$

It can be shown that when job i is in state $(w, 0)$, its index is

$$Z_i(w, 0) = (1-\beta)^{-1}w + \beta[(1-\beta)(2-\beta)]^{-1}\alpha_i. \tag{6}$$

Once all information about job i has been revealed, the index is $(w + \alpha_i)(1-\beta)^{-1}$ or $(w - \alpha_i)(1-\beta)^{-1}$, depending on whether the information revealed after one period of work is favorable or unfavorable, respectively.

Suppose that job j currently possesses the largest index. Define Z_j^* or simply Z^* to be the value of the index of the next best alternative. Thus, $Z^* = \max_{i \neq j}\{Z_i(x)\}$.

The next two lemmas characterize the dependence of $Z_i(0, 0)$ on α_i. (All proofs are relegated to the Appendix.)

LEMMA 1. *$Z_i(0, 0)$ is increasing in α_i and strictly increasing in α_i if $w_i^{2*} > w_i^{1*}$.*

LEMMA 2. *$Z_i(0, 0)$ is convex in α_i.*

For the remainder of this section assume, for simplicity, that $\underline{w} < w_i^{1*} < w_i^{2*} < \bar{w}$, for all i. The next lemma shows that the optimal job acceptance policy is characterized by a reservation wage that decreases as α_j is increased.

LEMMA 3. *If job j is searched, then a wage offer of w will be accepted (temporarily) if and only if $w \geq \xi_j$, where ξ_j satisfies:*[9]

$$\xi_j = Z^*(1-\beta) - \beta(2-\beta)^{-1}\alpha_j. \tag{7}$$

As a first step toward analyzing the behavior of reservation wages over an unemployment spell, assume that only α_j differs across jobs. Label jobs from the largest to the smallest α_j and assume that all jobs are initially in state (0, 0). Hence, from Lemma 1, job 1 will be searched first, then job 2 (if the wage offer from job 1 is below ξ_1), and so on. From Lemma 3 it is clear that if Z^* is held constant ξ_j increases as α_j decreases. However, with recall, Z^* is a random variable which

[9] This result was reported in McCall and McCall (1981). If all job opportunities are the same so $Z^* = Z_i(0, 0)$, then this result reduces to equation (8) of Lippman and McCall (1981) with $p = 1$.

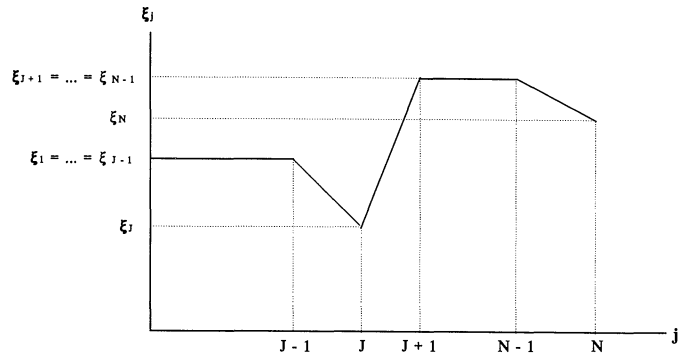

FIGURE 1

BEHAVIOR OF RESERVATION WAGES OVER AN UNEMPLOYMENT SPELL TWO JOB TYPES

decreases, almost surely, as the unemployment spell lengthens ($P(Z_i^* \geq Z_j^*) = 1$ for $j > i$).

Now, equation (7) implies for $j > i$,

$$P(\xi_j \geq \xi_i) = P\left(Z_i^* - Z_j^* \leq \frac{\alpha_i - \alpha_j}{\beta(2-\beta)(1-\beta)}\right). \tag{8}$$

The next two propositions give sufficient conditions for $P(\xi_j \geq \xi_i) = 1$ for most $j > i$.

PROPOSITION 1. *Assume that* $c_i = c$ *and* $F_i(w) = F(w)$ *for* $i = 1, 2, \dots, N$. *Furthermore, assume that* $\alpha_1 = \alpha_2 = \cdots = \alpha_J = \alpha' > \alpha_{J+1} = \alpha_{J+2} = \cdots = \alpha_N = \alpha''$, $J \geq 2$ *and* $N - J \geq 2$. *Then,*

$$\xi_J < \xi_1 = \cdots = \xi_{J-1} < \xi_{J+1} = \cdots = \xi_{N-1}$$

and

$$\xi_N < \xi_{J+1} = \cdots = \xi_{N-1}$$

with probability 1.

Reservation wages decrease only when the last job of each type is inspected, otherwise they remain constant or increase over an unemployment spell (see Figure 1).[10] Now, an individual may recall a past job offer before inspecting any job with lower EM uncertainty (i.e., a job with $\alpha_i = \alpha''$). However, if a job with lower EM

[10] Although in Figure 1 $\xi_N > \xi_1 > \xi_J$, this relation is not always true in general. For example, from equation (7) it can be shown that $\xi_N > \xi_1$ only if

$$\frac{\alpha_1 - \alpha_N}{Z_1^* - Z_N^*} > \beta(2-\beta)(1-\beta)$$

where the subscript associated with Z^* denote its (random) value when job 1 and N are inspected.

uncertainty is inspected, then the reservation wage corresponding to it is larger than the reservation wages of *all* previously inspected jobs.

Proposition 1 can be extended to situations where there are more than two types of jobs as long as there are at least two jobs of every type.

PROPOSITION 2. *Assume that* $c_i = c$ *and* $F_i(w) = F(w)$, $i = 1, \dots, N$. *Furthermore, assume that there are K different types of jobs. Let* N_k *represent the number of jobs of type k and assume* $N_k \geq 2$, $k = 1, \dots, K$. *Finally, assume that*

$$\alpha_1 = \cdots = \alpha_{N_1} > \alpha_{N_1+1} = \cdots = \alpha_{N_1+N_2} > \cdots > \alpha_{N_1+\cdots+N_{K-1}+1} = \cdots = \alpha_N$$

where

$$N = \sum_{k=1}^{K} N_k .$$

Then,

$$\xi_{N_1} < \xi_1 = \cdots = \xi_{N_1-1} < \xi_{N_1+1} = \cdots = \xi_{N_1+N_2-1},$$

$$\xi_{N_1+N_2} < \xi_{N_1+1} = \cdots = \xi_{N_1+N_2-1} < \xi_{N_1+N_2+1} = \cdots = \xi_{N_1+N_2+N_3-1},$$

$$\vdots$$

$$\xi_{N_1+\cdots+N_{K-1}} < \xi_{N_1+\cdots+N_{K-2}+1} = \cdots = \xi_{N_1+\cdots+N_{k-1}-1}$$
$$< \xi_{N_1+\cdots+N_{k-1}+1} = \cdots = \xi_{N_1+\cdots+N_K-1},$$

and

$$\xi_{N_1+\cdots+N_k} < \xi_{N_1+\cdots+N_{k-1}+1} = \cdots = \xi_{N_1+\cdots+N_K-1}$$

with probability 1.

So far we have assumed that jobs can differ only in the amount of EM uncertainty. Jobs, however, may also differ in search costs and the amount of IM uncertainty. Applying equation (5) shows that $Z_i(0, 0)$ decreases as inspection costs increase, and $Z_i(0, 0)$ increases as the expected value and/or riskiness of $\tilde{w}_i$ increases.[11] Differences only in c_i and F_i across jobs would cause ξ to fall over an unemployment spell.

One implication of this analysis is that reservation wages may not behave in a monotonic fashion over an unemployment spell. Nevertheless, $\max_i \{Z_i(x_i(t))\}$

[11] Formally, suppose that there are two jobs, labeled 1 and 2, such that $c_1 = c_2$ and $\alpha_1 = \alpha_2$. If $F_1(w) \leq F_2(w)$ for all $w \in [\underline{w}, \bar{w}]$, $Z_1(0, 0) \geq Z_2(0, 0)$. Alternatively, if

$$D(w) = \int_0^w (F_1(s) - F_2(s))\, ds \leq 0$$

for all $w \in [\underline{w}, \bar{w}]$ and $D(\bar{w}) = 0$, then $Z_1(0, 0) \geq Z_2(0, 0)$.

does decline monotonically over an unemployment spell. Since lingering uncertainty after a job inspection is an important determinant of the reservation wage, empirical studies of reservation wages which ignore it may be flawed.

3. TWO ILLUSTRATIVE EXAMPLES

The index attached to jobs of the same type (i.e., jobs with identical parameterizations) will be the same. Thus, given the assumption that information is independent across jobs of the same type, individuals will inspect every job of the "best" type before inspecting any job of the "next best" type.[12] If there is an infinite number of jobs of each type, then reservation wages would be constant over an unemployment spell.[13]

However, if one associates different job types with different occupations or industries, then it seems reasonable to assume that information obtained by inspecting a job may be useful for predicting the outcome of inspecting another job of the same type.[14,15] In this case, an individual might not inspect all jobs of the best type before inspecting a job from the next best type. Thus, reservation wages may not be constant or fall over an unemployment spell under these circumstances.

This is illustrated by the following examples. The first example (Example 1) supposes that there are an infinite number of two types of jobs, labeled 1 and 2, available for inspection. The prior distribution of wages is assumed to be identical for each job type, but some learning occurs with respect to the wage distribution for type 1 jobs.

Specifically, it is assumed that for type 1 jobs, an individual believes that he/she is sampling from one of two possible wage distributions, f_1^H and f_1^L, where f_1^H first order stochastically dominates f_1^L. Furthermore, it is assumed that the individual initially believes that it is equally likely that he/she is sampling from f_1^H or f_1^L ($f_1 = 1/2\, f_1^H + 1/2\, f_1^L$). Table 1 describes the particular distributions used in Example 1. For these distributions, learning takes on a particularly simple form. A wage offer of either w_5 or w_6 (w_1 or w_2) results in the posterior probability distribution $f_1 = f_1^H$ ($f_1 = f_1^L$) and a wage offer of either w_3 or w_4 results in no revision of the prior distribution ($f_1 = 1/2\, f_1^H + 1/2\, f_1^L$).

The wage opportunities for type 2 jobs are also summarized in Table 1 by two wage distributions, f_2^H and f_2^L. However, no learning occurs in type 2 jobs since $f_2^H = f_2^L$. Matching information is assumed to arrive after one period of job experience, but only in type 1 jobs ($\alpha_1 = 200$ and $\alpha_2 = 0$). Finally, it is assumed that the individual's cost of search is the same across both type of jobs ($c_1 = c_2 =$

[12] See Miller (1984) for a similar result.

[13] Even if there were a finite but large number of jobs of each type, reservation wages would, for all practical purposes, be constant over an unemployment spell.

[14] Formally, suppose that, for jobs of the same type, the independence assumption is replaced with the weaker assumption of exchangeability (see de Finetti 1974).

[15] McCall (1990a) presents empirical evidence that such an assumption is reasonable for jobs within the same occupation.

TABLE 1
PARAMETER VALUES FOR EXAMPLES 1 AND 2

Type 1 JOBS			Type 2 JOBS		
$c_1 = -250$	$\alpha_1 = 200$	$\beta = .985$	$c_2 = -250$	$\alpha_2 = 0$	$\beta = .985$
	f_1^H	f_1^L		f_2^H	f_2^L
$w_1 = 1000$	$p_1 = 0$	$p_1 = .25$	$w_1 = 200$	$p_1 = .125$	$p_1 = .125$
$w_2 = 1100$	$p_2 = 0$	$p_2 = .25$	$w_2 = 225$	$p_2 = .125$	$p_2 = .125$
$w_3 = 1200$	$p_3 = .25$	$p_3 = .25$	$w_3 = 250$	$p_3 = .25$	$p_3 = .25$
$w_4 = 1300$	$p_4 = .25$	$p_4 = .25$	$w_4 = 275$	$p_4 = .25$	$p_4 = .25$
$w_5 = 1400$	$p_5 = .25$	$p_5 = 0$	$w_5 = 300$	$p_5 = .125$	$p_5 = .125$
$w_6 = 1500$	$p_6 = .25$	$p_6 = 0$	$w_6 = 325$	$p_6 = .125$	$p_6 = .125$

Type 3 JOBS		
$c_3 = -250$	$\alpha_3 = 0$	$\beta = .985$
	f_3^H	f_3^L
$w_1 = 1000$	$p_1 = 0$	$p_1 = .25$
$w_2 = 1100$	$p_2 = 0$	$p_2 = .25$
$w_3 = 1200$	$p_3 = .25$	$p_3 = .25$
$w_4 = 1300$	$p_4 = .25$	$p_4 = .25$
$w_5 = 1400$	$p_5 = .25$	$p_5 = 0$
$w_6 = 1500$	$p_6 = .25$	$p_6 = 0$

250), that their discount factor (β) equals .985, and that they search across type 1 and type 2 jobs to maximize expected discounted returns.[16]

Although the decision process described in Example 1 is not a multi-armed bandit, it is a Markov decision process and can be solved by conventional methods. Some properties of its solution are displayed in Table 2. There, V_1, V_1^H, and V_1^L denote the value of continued search for Type 1 jobs when no information about the wage distribution has been revealed, when it is known that the wage distribution is f_1^H, and when it is known that the wage distribution is f_1^L, respectively. Additionally, $V_1(w_m)$, $V_1^H(w_m)$ and $V_1^L(w_m)$ denote the value of (temporarily) accepting a Type 1 job with a wage offer of w_m when no information about the wage distribution has been revealed, when it is known that the wage distribution is f_1^H, and when it is known that the wage distribution is f_1^L, respectively, $m = 1, \ldots, 6$. Finally, V_2

[16] One may wish to interpret the length of a period as one month. In this case the yearly discount factor equals .834.

TABLE 2
VALUE FUNCTIONS FOR EXAMPLE 1
TYPE 1 AND 2 JOBS

$V_1 = 95693.0$	$V_1^H = 102456.9$	$V_1^L = 89878.4$	$V_2 = 90860.0$
$V_1(w_3) = 94295.5$	$V_1^H(w_3) = 97626.7$	$V_1^L(w_1) = 84803.6$	$V_2(w_1) = 66666.7$
$V_1(w_4) = 97678.8$	$V_1^H(w_4) = 101010.0$	$V_1^L(w_2) = 88186.9$	$V_2(w_2) = 73333.3$
	$V_1^H(w_5) = 104393.4$	$V_1^L(w_3) = 91570.2$	$V_2(w_3) = 80000.0$
	$V_1^H(w_6) = 107776.7$	$V_1^L(w_4) = 94953.6$	$V_2(w_4) = 86666.7$
			$V_2(w_5) = 93333.3$
			$V_2(w_6) = 100000.0$

TABLE 3
VALUE FUNCTIONS FOR EXAMPLE 2
TYPE 1 AND 3 JOBS

$V_1 = 95161.8$	$V_1^H = 102456.9$	$V_1^L = 89878.4$	$V_3 = 93160.8$
$V_1(w_3) = 94033.8$	$V_1^H(w_3) = 97626.7$	$V_1^{LL} = 89878.4$	$V_3^L = 90392.6$
$V_1(w_4) = 97417.2$	$V_1^H(w_4) = 101010.0$	$V_1^{LL}(w_1) = 84803.6$	$V_3^{LL} = 80733.7$
	$V_1^H(w_5) = 104393.4$	$V_1^{LL}(w_2) = 88186.9$	$V_3^{LH} = 93316.9$
	$V_1^H(w_6) = 107776.7$	$V_1^{LL}(w_3) = 91570.2$	$V_3^{LH}(w_3) = 80000.0$
		$V_1^{LL}(w_4) = 94953.6$	$V_3^{LH}(w_4) = 86666.7$
			$V_3^{LH}(w_5) = 93333.3$
			$V_3^{LH}(w_6) = 100000.0$

and $V_2(w_m)$ denote the value of continued search for Type 2 jobs and the value of accepting at a Type 2 job with a wage offer of w_m, respectively, $m = 1, 2, \ldots, 6$.

In Example 2, an individual also searches from among two types of jobs. One type of job is identical to Type 1 jobs in Example 1. The other type of job (labeled 3) is similar to a Type 1 job except it has EM uncertainty ($\alpha_3 = 0$). Let V_i^{jk} denote the value of searching for a Type i job when $f_1 = f_i^j$ and $f_3 = f_3^k$ and let $V_i^{jk}(w_m)$ denote the value of accepting a Type i job with a wage offer of w_m when $f_1 = f_1^j$ and $f_3 = f_3^k$, $i = 1, 3, j, k = H, L, m = 1, \ldots, 6$. The interpretation of the value functions V_i, V_i^j, $V_i(w_m)$ and $V_i^j(w_m)$, $i = 1, 3, j = H, L$ is similar to that in Example 1: the superscript j refers to an individual's knowledge about the wage distribution for Type 1 jobs while no information has been received concerning the wage distribution associated with Type 3 jobs. Table 3 displays the relevant value functions for the decision problem of Example 2.

3.1. *Implications for the Behavior of Reservation Wages.* It is clear that in Example 1, once an individual begins searching for a Type 2 job, he/she never again searches for a Type 1 job. In addition, no quits occur from Type 2 jobs, since all information is revealed upon inspection. Table 1 shows that, for the given parameter values, it is optimal to search for Type 1 jobs first ($V_1 > V_2$). The first wage offer from a Type 1 job is accepted by an individual if it is greater than or equal to w_4 ($V_1(w_4) > V_1 > V_1(w_3)$, $V_1^H(w_6) > V_1^H(w_5) > V_1^H$, and $V_2 > V_1^L(w_2)$). This occurs with probability .5. Only with wage offers equalling w_3 does the individual continue to search for Type 1 jobs. With wage offers of either w_1 or w_2 an individual infers that the true wage distribution is f_1^L and starts searching for a Type 2 job. For Type 2 jobs, only wage offers of either w_5 or w_6 are acceptable. So once an individual begins searching for a Type 2 job, their reservation wage *increases* from w_4 to w_5 and their conditional probability of employment falls to .25.[17]

In Example 2, it is also optimal for an individual to search for a Type 1 job first. Wage offers either greater than or equal to w_4 are accepted. A wage offer of w_3 is rejected and the individual continues looking for a Type 1 job. Wage offers of w_1 or

[17] This example was constructed so that if individuals searched *only* for either Type 1 or Type 2 jobs, then their conditional employment probability would remain constant over time. This strategy would be optimal if individuals incurred a large "entry" cost (say k_1 and k_2) the first time they searched for a particular type of job. For example, if $k_1 \gg k_2 \gg 0$, then it may be optimal to search only for Type 2 jobs.

w_2 are also rejected. However, since they reveal that the true wage distribution is f_1^L the individual starts searching for a Type 3 job.

Unlike Type 2 jobs, some learning also occurs with respect to Type 3 jobs. For Type 3 jobs, only the wage offers w_5 and w_6 are acceptable. So, like Example 1, the reservation wage increases from w_4 to w_5, and the conditional probability of employment falls from .5 to .25, when an individual starts searching for a Type 3 job.[18] Wage offers of either w_3 and w_4 do not change beliefs about the wage distribution and the individual continues searching for a Type 3 job. However, with wage offers of either w_1 or w_2, the individual infers that the true wage distribution for Type 3 jobs is f_3^L. In this circumstance, the individual again searches for Type 1 jobs ($V_1^{LL} > V_3^{LL}$) and continues to do so for the remainder of the unemployment spell with a reservation wage of w_3 ($V_1^{LL}(w_3) > V_1^{LL}$) and their conditional probability of employment returning to .5.

3.2. *Implications for Duration Dependence of the Employment Hazard Function.* In this subsection we shall investigate the implications of these examples for the duration dependence of the (re)employment hazard function when the type of job that an individual is seeking at any particular moment during their unemployment spell is not observed. This sort of data is usually unavailable.

Let T be a discrete random variable which represents the unemployment duration of an individual and let $p(T = t|T > t - 1)$ denote the probability of (re)employment in period t, conditional on unemployment lasting more than $t - 1$ periods. We shall refer to these conditional probabilities simply as the (re)employment hazards.[19] Now, let $p(i, t|T > t - 1)$ denote the probability that an individual searches for a Type i job at time t, conditional on unemployment lasting more than $t - 1$ periods and let $p(T = t|T > t - 1, i)$ denote the probability of (re)employment in period t, conditional on searching for a Type i job and unemployment lasting more than $t - 1$ periods, $i = 1, 2$. Then, for Example 1,

$$p(T = t|T > t - 1) = p(1, t|T > t - 1)p(T = t|T > t - 1, 1) + (1 - p(1, t|T > t - 1))p(T = t|T > t - 1, 2).$$

Since for this example $p(t, 1|T > t - 1)$ decreases over time and

$$p(T = t|T > t - 1, 1) = .5 > P(T = t|T > t - 1, 2) = .25,$$

$P(T = t|T > t - 1)$ decreases over time. This is portrayed in Figure 2.

Example 1 shows that caution should be used when interpreting (reduced form) estimates of (re)employment hazards. Since most sequential search models with constant job offer rates predict that reservation wages are either constant or

[18] Also, as in Example 1, the conditional reemployment probability is constant over time when it is optimal for an individual to search for only one type of job due to say large entry costs.

[19] Let T be a random variable with absolutely continuous c.d.f. G and p.d.f. g. Then the hazard function associated with T, $\lambda(t)$ satisfies

$$\lambda(t) = \lim_{dt \to 0} \frac{Pr(t \leq T < t + dt|T \geq t)}{dt} = \frac{g(t)}{1 - G(t)}.$$

Thus, $p(T = t|T > t - 1)$ is not formally a hazard function, but the discrete-time analog of $\lambda(t)dt$.

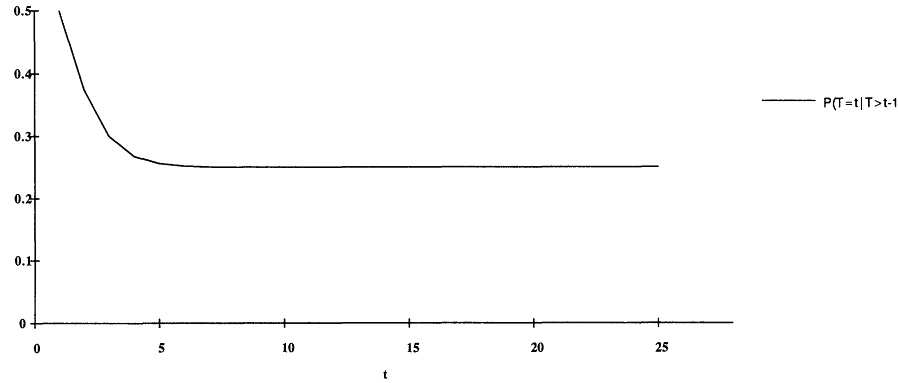

FIGURE 2

CONDITIONAL REEMPLOYMENT PROBABILITIES: EXAMPLE 1

declining over the unemployment spell and, hence, (re)employment hazards are constant or increasing, findings of negative duration dependence have been used in support of theories of declining offer rates, like the stigma or the discouraged worker effect. In Example 1 (and in the analysis of Section 2) neither of these phenomena occur by assumption, since the job offer rate is fixed at one job offer per search period. Nevertheless, the employment hazard exhibits negative duration dependence because an individual may search for different types of jobs while unemployed.

The omission of a time-constant regressor can also lead to negative duration dependence in the employment hazard. Mixing the likelihood function is a statistical method designed to control for such unobserved heterogeneity (see Lancaster 1979 and Heckman and Singer 1984, for example). Although the duration dependence observed in the hazard function shown in Figure 2 is a result of time-varying heterogeneity, it can also be described as a mixture of two geometric distributions.[20] Estimation of such a mixture model may lead one to erroneously conclude in this case that reservation wages are constant over an unemployment spell when, in fact, they increase. Without further identifying information, though, it is not possible to statistically distinguish between the competing explanations for the hazard function depicted in Figure 2.

The employment hazard implicit in Example 2, however, cannot be described as any mixture of geometric distributions. Recall that in this example, an individual may search for a Type 1 job after inspecting a Type 3 job. This, along with the fact that the employment hazard while searching for Type 1 jobs is larger than the employment hazard while searching for Type 3 jobs (.5 for Type 1 jobs versus .25 for Type 3 jobs), results in the U-shaped employment hazard portrayed in Figure 3. This hazard cannot be described as a mixture of geometric distributions, since mixtures of geometric distributions are characterized by hazard functions which decrease over time.

[20] The two geometric distributions have parameters .75 and .25 and receive equal weights in the mixture.

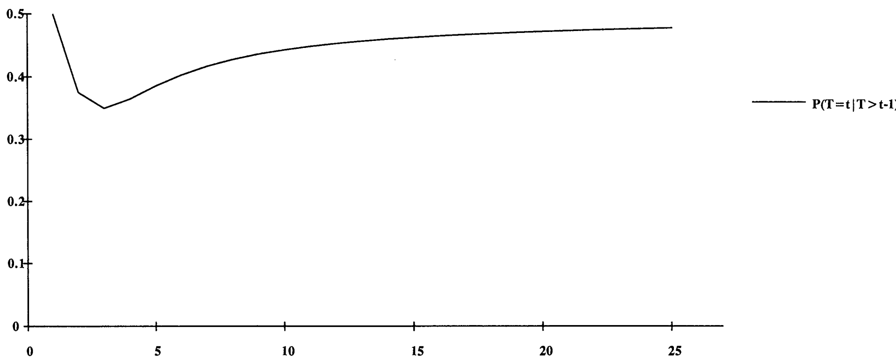

FIGURE 3

CONDITIONAL REEMPLOYMENT PROBABILITIES: EXAMPLE 2

Thus, controlling for time-constant unobserved heterogeneity in Example 2 will lead to a finding of duration dependence. Although it can be shown that the continuous-time analog of the employment hazard in Example 2 also cannot be described by a mixture of decreasing hazard functions, a mixture of increasing hazard functions can yield a hazard function with a shape such as that in Figure 3 (see Vaupel and Yashin 1985).[21] So, controlling for time-constant unobserved heterogeneity in Example 2 may lead one to erroneously conclude that reservation wages fall over the unemployment spell when, in fact, they rise over part of it. Again, further identifying information is needed to statistically distinguish between the two alternative explanations for the hazard function depicted in Figure 3.

3.3. *Implications for Search Behavior over the Life Cycle.* So far, only the job search behavior of new entrants has been analyzed. Intuitively, one would expect youths to be more likely than older workers to consider many job types while unemployed. Older workers will have had time to find a suitable job type (occupation and/or industry) and would tend to search a more homogeneous set of jobs.

For Example 1, this intuition is correct. In this example, turnover occurs only in Type 1 jobs. Let *EXP* represent the amount of periods an unemployed individual spent in type 1 jobs and *PWAGE* an individual's wage in their previous job. Assume *PWAGE* is not observed.[22] Then,

[21] In the continuous-time version of the model, job offer rates are assumed to arrive according to a Poisson process and EM information arrives according to an exponential distribution. Let T_j denote the waiting time between the jth and $(j+1)$th offers and T_{EM} denote the waiting time until EM information arrives. Then setting the discount rate β and the parameters of the Poisson and exponential distribution such that $E(\exp(-\beta T_j)) = E(\exp(-\beta T_{\mathrm{EM}})) = .985$ yields the continuous-time equivalent of Example 2.

[22] In this simple example if *PWAGE* is observed, then the conditional reemployment probabilities are $p(T = t|T > t-1, PWAGE = w_5, EXP = x) = p(T = t|T > t-1, PWAGE = w_5) = p(T = t|T > t-1, PWAGE = w_6, EXP = x) = p(T = t|T > t-1, PWAGE = w_6) = .5$ and $p(T = t|T > t-1, PWAGE = w_4, EXP = x) = p(T = t|T > t-1, EXP = 0)$. However, in more general models, $p(T = t|T > t-1, PWAGE = w, EXP = x) \neq p(T = t|T > t-1, PWAGE = w)$.

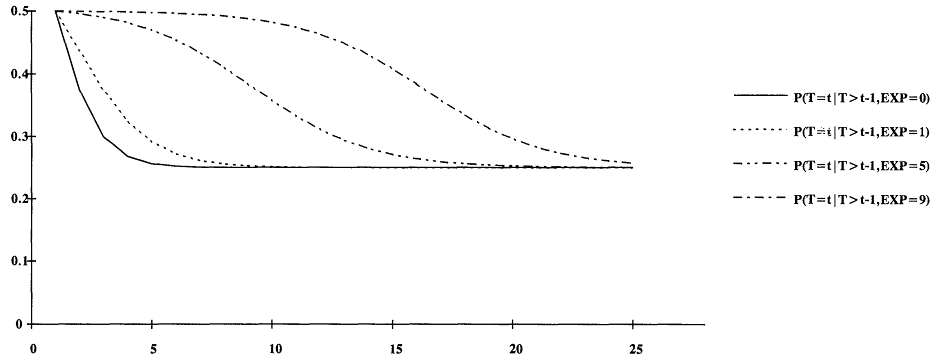

FIGURE 4

CONDITIONAL REEMPLOYMENT PROBABILITIES BY EXPERIENCE: EXAMPLE 1

$$p(T=t|T>t-1,\ EXP=x)=p(PWAGE=w_5 \text{ or } w_6|EXP=x)(.5) + (1-p(PWAGE=w_5 \text{ or } w_6|EXP=x))p(T=t|T>t-1).$$

Since all information is revealed after one period of work in Type 1 jobs, unemployed individuals have worked at x different Type 1 jobs (and no Type 2 jobs). When x is large, the $p(PWAGE = w_5$ or $w_6|EXP = x)$ is large since it is unlikely that *all* previous jobs paid w_4.

Figure 4 graphs $p(T = t|T > t - 1, EXP = x)$ as a function of time for $x = 0$, 1, 5 and 9. Although the reemployment hazards of individuals with nine periods of experience in Type 1 jobs still exhibit negative duration dependence, it is approximately constant throughout the first 10 periods of unemployment. Also, notice that $p(T = t|T > t - 1, EXP = x)$ is convex only for low x.

3.4. *Examples with Risk Averse Individuals.* One assumption that has been maintained throughout this paper is the assumption of risk neutrality. Risk neutral individuals prefer more EM uncertainty because they can quit if EM information is unfavorable so limiting the (larger) downside risk of accepting a job. Risk averse individuals can also limit the downside risk of jobs with large EM uncertainty by quitting. But since the consequences of quitting are uncertain, risk averse individuals will find quitting a less attractive alternative than risk neutral individuals and hence, may be less inclined to use it. This, in turn, would expose them to more of the downside risk of jobs with large EM uncertainty. It seems reasonable to conjecture that whether these negative effects make jobs with more EM uncertainty less attractive to risk averse individuals depends on the extent of their risk aversion.

To see how risk aversion alters the conclusions for risk neutral individuals, two additional examples (Examples 1a and 2a) were analyzed. In these examples it was assumed that individuals were expected utility maximizers with constant relative risk aversion utility functions $U(x) = x^{\gamma}/\gamma$, $0 < \gamma < 1$. The remaining structure and parameter values of Examples 1a and 2a were similar to Examples 1 and 2, respectively, except that search costs (c_1, c_2, and c_3) were set to zero. The optimal search strategies, and their implications for the (re)employment hazards, of risk averse individuals were similar to those of risk neutral individuals when $\gamma > .05$.[23]

4. CONCLUDING REMARKS

This paper developed a model of job search with heterogeneous job opportunities. Jobs were characterized by both inspection (search) and experience uncertainty the relative importance of which differed across jobs. Under these circumstances it was shown that the optimal search strategy does not necessarily entail falling or constant reservation wages over an unemployment spell. A simple example demonstrated how negative duration dependence of the (re)employment hazard can arise when offer rates are constant over an unemployment spell, reemployment hazards are constant while searching for a particular type of job, and an individual considers a variety of different jobs while unemployed. Although unobserved heterogeneity is the culprit, mixing the likelihood function is an inappropriate solution, since the unobserved heterogeneity is time varying. It was shown that incorrect inferences about the behavior of reservation wages over an unemployment spell are possible when such techniques are applied in the presence of job heterogeneity.

Although the results of this paper indicate that caution should be exercised when interpreting reduced form estimates of (re)employment hazards, they do not necessarily imply that search theory lacks any testable implications (or, in other words, that the classical sequential search model developed by McCall (1970) and Mortensen (1970) and its various extensions which predict either constant or declining reservation wages are not good approximations of reality under any circumstances). For example, it seems reasonable to suppose that the freshly minted tax lawyers or heart surgeons search a fairly homogenous set of jobs and so should exhibit constant or declining reservation wages. However, such an assumption for high school graduates first entering the job market may be less appropriate.[24]

The model developed in this paper ignored equilibrium considerations. In at least some circumstances, however, the equilibrium outcome would not differ. Suppose that job types refer to occupations and that match information is perfectly correlated across jobs within an occupation.[25] Interpret w_i as the expected productivity of an individual in occupation i upon inspection, α_i as the revision of that expectation which takes place after one period of work, and c_i as the (one time) cost of inspecting occupation i. Assume that there are a large number of potential

[23] This result is dependent on the specific parameter values used in these examples. If β is instead fixed at .8 then only risk averse individuals with $\gamma > .60$ have search strategies identical to risk neutral individuals.

[24] For tax lawyers and heart surgeons, entering the job market may actually be the culmination of a search process which may have begun with the decision to enter college.

[25] Although in this situation the number of jobs of each type is effectively reduced to one, reservation wages will still rise over the unemployment spell if the condition specified in (8) is satisfied.

employers within each occupation and that all observe an individual's expected productivity after inspection (w_i) (for example, there may be N different hiring halls where employers come to bid for an employee services). Furthermore, assume that all employers in occupation i observe an individual's experience in that occupation. If we assume that (implicit) long-term contracts made when an individual begins work are enforceable (perhaps through a reputation effect), then those contracts which pay workers their expected productivity in each period are in the set of equilibrium contracts.[26] In this case, an individual with previous experience in occupation i who seeks new employment in this occupation will be inferred to be of low quality and paid $w_i - \alpha_i$.

If instead we interpret α_i as nonpecuniary match uncertainty unrelated to the individual's productivity then the equilibrium outcome also would not differ. In this case there need not be any long term relationship between employer and employee.

Although these simple equilibrium stories are suggestive, fuller development of equilibrium considerations would be useful. This is left to future research.

If w_i is viewed as the initial forecast of expected productivity after inspection and α_i as the revision which takes place after one period, then w_i and α_i are uncorrelated. However, this need not imply that w_i and α_i are independent, as was assumed in the analysis above. If the independence assumption is relaxed, then a reservation wage policy may not be optimal.[27] Suppose, for example, that $\alpha_i = b_i w_i + a_i$. Then a reservation wage policy is optimal only when $b_i > -(2 - \beta)/\beta$. Assuming that this condition holds, the results of this paper remain unchanged when reinterpreted in terms of a_i.

This model may give additional insight into such empirical regularities as the pattern of industry mobility, the existence and persistence of interindustry wage differentials (Krueger and Summers 1988), and firm size wage differentials (see Brown et al. 1990). For example, if different job types are interpreted as different industries, then these results imply that, ceteris paribus, individuals would tend to first inspect those industries with greater EM uncertainty. If industry rankings are similar across individuals then greater EM uncertainty industries would be characterized, on average, by younger workers, lower starting wages and higher turnover rates.[28,29] In addition, these industries would be characterized by, on

[26] This equilibrium is similar to that in Jovanovic (1979).

[27] For a reservation wage to be optimal, the index Z must be increasing in w. See Goldberg and Borjas (1978) for another instance in which a reservation wage strategy may not be optimal.

[28] Suppose that in Example 1 Type 1 and Type 2 jobs are thought of as belonging to different industries. Then, average starting wages would be lower and the probability of turnover would be higher in Type 1 jobs than in Type 2 jobs (recall that there is no turnover in Type 2 jobs).

[29] In the January 1992 Current Population Survey, there is evidence that (among full-time workers not in school) young workers tend to be heavily concentrated in Trade. As age goes up this proportion declines (43.7 percent for 16–19 year olds, 35.1 percent for 20–24 year olds, 25.0 percent for 25–44 year olds, and 22.23 percent for 45–64 year olds) while the proportion in Services increases (25.0 percent for 16–19 year olds, 29.4 percent for 20–24 year olds, 32.4 percent for 25–44 year olds, and 34.6 percent for 45–64 year olds). In other research using the National Longitudinal Survey Youth Cohort (some of which is reported in McCall 1990b), I have found some evidence of lower starting wages and higher quit rates (conditional on wages) for individuals whose first full-time job out of school is in Trade versus Service. This is consistent with Trade jobs being characterized by more EM uncertainty than Service jobs.

average, larger wage growth among "stayers."[30] Whether a stayer is defined at the firm or industry level depends on whether learning is firm or industry specific. Further development and empirical testing of these ideas awaits future research.

Finally, the results of this paper imply that future empirical research needs to focus on identifying the source of the duration dependence commonly found in empirical studies of unemployment durations. However, such an endeavor may require more detailed information about the activities of individuals during their unemployment spell than is currently available in most data.

University of Minnesota, U.S.A.

APPENDIX

PROOF OF LEMMA 1. Solving equation (5) for $Z_i(0, 0)$ and differentiating with respect to α_i yields

$$\text{(A1)} \qquad \frac{.5\beta^2(F(w_i^{2*}) - F(w_i^{1*}))}{[1 - \beta F(w_i^{1*}) - .5\beta^2(F(w_i^{2*}) - F(w_i^{1*}))][1 - \beta]} > 0$$

if $w_i^{2*} > w_i^{1*}$. Q.E.D.

PROOF OF LEMMA 2. Let $0 < \lambda < 1$ and let α_i and α_j be two arbitrary values of α. Define $\bar{\alpha} = \lambda\alpha_j + (1 - \lambda)\alpha_j$ and $\bar{Z} = \lambda Z(\alpha_i) + (1 - \lambda)Z(\alpha_j)$ where $Z(\alpha_i)$ and $Z(\alpha_j)$ are the indices for jobs in state (0, 0) when $\alpha = \alpha_i$ and $\alpha = \alpha_j$, respectively. Denote by $Z(\bar{\alpha})$, the index when $\alpha = \bar{\alpha}$. Equation (5) is of the form

$$\text{(A2)} \qquad Z = k(w^{1*}, w^{2*}) + c(w^{1*}, w^{2*})Z.$$

Let $\bar{w}^{1*}$ and $\bar{w}^{2*}$ be the optimal values of w^1 and w^2 when $\alpha = \bar{\alpha}$ and $M = Z(\bar{\alpha})$. Then,

$$\text{(A3)} \qquad Z(\alpha_i) \geq k(\bar{w}^{1*}, \bar{w}^{2*}) + c(\bar{w}^{1*}, \bar{w}^{2*})Z(\alpha_i)$$

and

$$\text{(A4)} \qquad Z(\alpha_j) \geq k(\bar{w}^{1*}, \bar{w}^{2*}) + c(\bar{w}^{1*}, \bar{w}^{2*})Z(\alpha_j)$$

which in turn implies that

$$\text{(A5)} \qquad \bar{Z} \geq k(\bar{w}^{1*}, \bar{w}^{2*}) + c(\bar{w}^{1*}, \bar{w}^{2*})\bar{Z}.$$

But by definition,

$$\text{(A6)} \qquad Z(\bar{\alpha}) = k(\bar{w}^{1*}, \bar{w}^{2*}) + c(\bar{w}^{1*}, \bar{w}^{2*})Z(\bar{\alpha}).$$

Since $c(\bar{w}^{1*}, \bar{w}^{2*}) \leq 1$, this implies that $Z(\bar{\alpha}) \leq \bar{Z}$. Q.E.D.

PROOF OF LEMMA 3. Job j will be accepted after it is inspected if and only if

[30] Assuming that some EM uncertainty is productivity uncertainty and no significant "front-loading" of contracts occurs.

(A7) $$Z_j(w, 0) \geq Z^*.$$

Substituting from equation (6), we have that a job is accepted if and only if

(A8) $$w(1-\beta)^{-1} + \beta[(1-\beta)(2-\beta)]^{-1}\alpha_j > Z^*$$

or

(A9) $$w \geq Z^*(1-\beta) - \beta(2-\beta)^{-1}\alpha_j. \qquad \text{Q.E.D.}$$

PROOF OF PROPOSITION 1. Since $\alpha_i = \alpha'$ for $i \leq J$, $Z(\alpha_i) = Z(\alpha')$ for $i \leq J$. Hence, from (7), $\xi_i = \xi_{J-1}$ for $i < J-1$. An analogous argument shows that $\xi_i = \xi_{J+1}$ for $J+1 < i < N-1$. Now,

(A10) $$\xi_{J-1} - \xi_{J+1} = (Z(\alpha_J) - Z(\alpha_{J+2}))(1-\beta) - \beta(2-\beta)^{-1}(\alpha_{J-1} - \alpha_{J+1}).$$

But $\alpha_{J-1} = \alpha_J = \alpha' > \alpha'' = \alpha_{J+1} = \alpha_{J+2}$. So,

(A11) $$\xi_{J-1} - \xi_{J+1} = (Z(\alpha') - Z(\alpha''))(1-\beta) - \beta(2-\beta)^{-1}(\alpha' - \alpha'').$$

The convexity of $Z(\alpha)$ implies that

(A12) $$\xi_{J-1} - \xi_{J+1} \leq Z'(\alpha')(\alpha' - \alpha'')(1-\beta) - \beta(2-\beta)^{-1}(\alpha' - \alpha'') < 0,$$

where Z' denotes the (right) derivative of Z with respect to α and the last strict inequality follows from the substitution of equation (A1) and some algebraic manipulations.

That $P(\xi_J < \xi_1) = 1$ follows because $\alpha_1 = \alpha_J$ and with a continuous wage distribution $P(Z_1^* > Z_J^*) = 1$. An analogous argument shows that $P(\xi_N < \xi_{J+1}) = 1$. Q.E.D.

PROOF OF PROPOSITION 2. The proof of Proposition 2 simply involves applying Proposition 1 repeatedly. Q.E.D.

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