Economics of Information and Job Search
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ECONOMICS OF INFORMATION AND JOB SEARCH *

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I. Introduction

In the recent literature A. A. Alchian and W. R. Allen,[1] G. J. Stigler,[2] and probably others have suggested that unemployed resources may be productive in a world where uncertainty prevails and information is costly. The activity that renders these resources productive is search. The search activities that unemployed human resources undertake have been discussed by Stigler.[3] This paper, following suggestions from the preceding sources, applies some well-known results from the theory of optimal stopping rules to the unemployment phenomenon.[4] These applications are all performed at the individual or micro level. The implications of this analysis for the macro problems of unemployment are not investigated.[5]

In a labor market characterized by uncertainty and costly information, both employers and employees will be searching. The analysis presented here is directed to the employee's job-searching strategy. Obviously, similar methods could be applied to investigate the employer's job market behavior. These methods could also be used to analyze the unemployment behavior of nonhuman resources like apartments, barber chairs, and baseball stadiums.

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1. A. A. Alchian and W. R. Allen, *University Economics* (Belmont, California: Wadsworth Publishing Company, Inc., 1964).

2. G. J. Stigler, "The Economics of Information," *Journal of Political Economy*, Vol. 69, No. 3 (June 1961), pp. 213–25.

3. G. J. Stigler, "Information in the Labor Market," *Journal of Political Economy*, Vol. 70, No. 5, Part 2 (Oct. 1962), pp. 94–104.

4. For a discussion of the theory of optimal stopping rules, see J. J. McCall, "The Economics of Information and Optimal Stopping Rules," *Journal of Business*, Vol. 38, No. 3 (July 1965), pp. 300–17, and the literature cited therein.

5. A novel presentation of the macro problems of unemployment is contained in R. E. Lucas, Jr., and L. A. Rapping, "Real Wages, Employment and the Price Level: An Integrated Theory of Aggregate Supply," *Journal of Political Economy* (forthcoming).

The amount of search or the period of unemployment depends on the wage rate that the individual thinks his services can command in the labor market and on the opportunity cost of the searching activity. If an individual believes that his skills or services are highly valued, he will reject job offers that fall short of his expectations and remain unemployed. On the other hand, if the cost of information is large, the individual will tend to limit his searching activities.

It is useful to distinguish between the actual outlay on information accumulation and the return that the individual could make if he remained unemployed.[6] These returns include unemployment compensation, welfare payments, and perhaps some leisure benefits. Remaining unemployed is regarded as simply another occupation, say, the null occupation (leisure), that the individual may choose. The optimal search policy when people with unattractive employment opportunities are confronted with relatively high information costs may be to choose the null occupation, i.e., to choose not to search for alternative employment. The dropout or "discouraged worker" phenomenon is no doubt explicable in these terms.[7] Needless to say, from society's point of view the continuing presence of significant numbers of discouraged workers is, by this observation, no less deplorable.

The remainder of the paper presents several models of the quest for employment. In Section II an optimal search policy is obtained for a very simple model. It is assumed that the searcher knows the distribution of wages for his particular skills, and the cost of search is a known constant. Job offers arrive periodically and the searcher accepts or rejects them as they occur. The individual continues to search and remains unemployed as long as the offers are less than some minimally acceptable value. Whenever an offer exceeds this value, it is accepted and employment commences. A critical value is associated with each individual's optimal search policy. The expected length of unemployment is calculated when the individual follows the optimal policy.

6. The utility functions associated with both searching and employment are probably nonlinear, in which case the simple monetary return will be an inadequate guide to decision making. This complication is not discussed in the sequel.

7. Nonparticipants in the labor force (dropouts) comprise two very distinct groups: those with attractive employment opportunities and large personal fortunes who would always choose the null occupation regardless of the cost of search, and those who are truly discouraged workers and choose the null occupation in desperation. The theory developed here applies to both groups of dropouts, but our concern is for the latter.

The distinction between discouraged workers and searchers is easily interpreted within this simple framework. The framework can also be used in evaluating such policies as training and reducing information costs to reduce the number of dropouts. Costs of search include purely economic considerations such as transportation costs, the value of forgoing alternatives, and the psychic cost of looking for work. The effects of a minimum wage law on the expected unemployment period for searchers and on the number of dropouts are also discussed. Finally, the expected unemployment period is calculated, first when the searcher overestimates the distribution of wages, and then when he underestimates it.

Section III generalizes the simple job search model to include discounting and the length of employment. Each job offer is now composed of two elements, a wage rate and a length of employment. The wage rate is known to the individual before he accepts or rejects the offer, while the length of employment is uncertain, i.e., it is a random variable with a known probability distribution. The optimal policy for this general model has the same structure as that for the simple model. There is a critical value of discounted returns such that if an offer is less than the critical value, it is rejected and search continues. Unemployment terminates whenever an offer exceeds the critical value. Section IV outlines a method for calculating the value of information in these search models when the searcher has imperfect knowledge of his wage rate distribution. The searcher learns about his wage distribution as offers occur. He uses this information simultaneously to revise his estimate of the distribution and to decide whether or not to accept the offer. A simple adaptive policy is outlined in which revisions of the wage distribution are performed in Bayesian fashion. The structure of the adaptive unemployment policy is essentially the same as that of the nonadaptive policies.

II. A Simple Model of Job Search

In the simplest job search model the searcher is assumed to know both the distribution of wages for his particular skills and the cost of generating a job offer. Job offers are independent random selections from the distribution of wages. These offers occur periodically and are either accepted or rejected. Under these conditions it is easy to show that the optimal policy for the job searcher is to reject all offers below a single critical number and to accept any offer above this critical number. In deriving this result, the following symbols will be used:

c = cost per period of search,
x = a random variable denoting the job offer,[8]
$\phi(x)$ = the probability density function of x,[9]
$f(x)$ = maximum return obtainable when a job offer x has just been observed.

The cost, c, is incurred simultaneously with the offer, x.

If the process terminates, i.e., employment commences after N job offers, then the return, f, is simply the value of the N^{th} offer, say x_N, less the cost of search, c, times the number of job offers:

$$f = x_N - cN.$$ [1]

If an x is observed at the first period and the process continues in optimal fashion thereafter, the return is given by

$$f(x) = -c + \max[x, E(f(x))].$$

If we let $\epsilon = E(f(x))$, it is clear from this equation that the optimal policy has the following form:

continue searching if $x < \epsilon$
accept employment if $x \geqslant \epsilon$.[2]

Following K. J. Arrow,[3] the calculation of ϵ is easily accomplished.[4] The conditional expected value, $E(f/N)$, the expected value of the return given that the searcher accepts the N^{th} offer, is calculated first. Then ϵ is obtained by expecting out N. Symbolically,

$$E(f|N) = E(x_N|N) - cN$$

and

$$E(f) = \epsilon = E(E(x_N|N)) - cE(N).$$

Notice that

$$E(x_N|N) = E(x_N|x_N \geqslant \epsilon, x_{N-1} < \epsilon, \ldots, x_1 < \epsilon).$$

8. In general, a job offer is composed of a number of characteristics. Here we assume that these have been converted into utility equivalents.

9. In this analysis we assume one offer per period. If more than one offer is permitted, then clearly the decision maker is concerned with $\max(x_k)$, where k is a random variable. The distribution of $\max(x_k)$ would be used to calculate the critical number.

1. The job offer, which is sometimes referred to as the wage rate, should be interpreted as the discounted expected value of a particular employment opportunity. The search costs should also be discounted. These points are elaborated in Section III.

2. A test of the descriptive or positive content of this model could be accomplished using data like those analyzed in Stigler, "Information in the Labor Market," *op. cit.*

3. Unpublished class notes on dynamic programming, Stanford University.

4. For alternative derivations, see R. A. Howard, "Dynamic Programming," *Management Science*, Vol. 12, No. 5 (Jan. 1966) pp. 317–48; and Ivan Obregon, "Some Extensions of the Action Timing Model," presented at the XIVth International Meeting of the Institute of Management Sciences, Mexico City, August 1967.

That is, employment will commence with the N^{th} offer only if $x_N \geqslant \epsilon$ and all previous offers have been less than ϵ. Further,

$$E(x_N | x_N \geqslant \epsilon, x_{N-1} < \epsilon, \ldots, x_1 < \epsilon) = E(x_N | x_N \geqslant \epsilon)$$

by the assumption that the offers are independent, and

$$E(x_N | x_N \geqslant \epsilon) = E(x | x \geqslant \epsilon)$$

by the assumption that the offers are indentically distributed. Therefore,

$$E(x | x \geqslant \epsilon) = \frac{\int_\epsilon^\infty x\phi(x)\, dx}{P(x \geqslant \epsilon)}$$

and

$$\epsilon = \frac{\int_\epsilon^\infty x\phi(x)\, dx}{P(x \geqslant \epsilon)} - cE(N).$$ [5]

The term $E(N)$ is the expected waiting time until employment occurs when the prevailing strategy is pursued. The appropriate random variable is the number of trials required to achieve the first success, i.e., the number of trials until $x \geqslant \epsilon$. This random variable has a geometric distribution with parameter $P = P(x \geqslant \epsilon)$ and expected value

$$E(N) = 1/P, P > 0.$$

Combining these results, given the following relation between x, c, ϵ, and $\phi(x)$,

$$c = \int_\epsilon^\infty (x - \epsilon)\, \phi(x)\, dx = H(\epsilon).$$

This equation has a simple economic interpretation. The cost, c, is the marginal cost of generating another job offer. The second member is the expected marginal return from waiting another period. The critical value, ϵ, of a job offer is chosen to equate the marginal cost of waiting with its expected marginal return.

It has been shown that $H(\epsilon)$ is a strictly decreasing function of ϵ, and so there is a unique value of ϵ for every value of c, as shown in Figure I.[6]

This model is a convenient device for distinguishing the discouraged workers or dropouts from the frictionally unemployed.

5. This equation is easily interpreted. ϵ is the return from stopping when ϵ is observed. The first term on the right side is the expected return from continuing, and the second, the expected cost.

6. Notice that the derivative of $H(\epsilon)$, i.e., the slope of the curve in Figure I, is equal to $-P$. See K. J. Arrow's unpublished class notes on dynamic programming.

The dropouts are those who do not search at all. As we will see, their decision is based on the relation between the cost of search

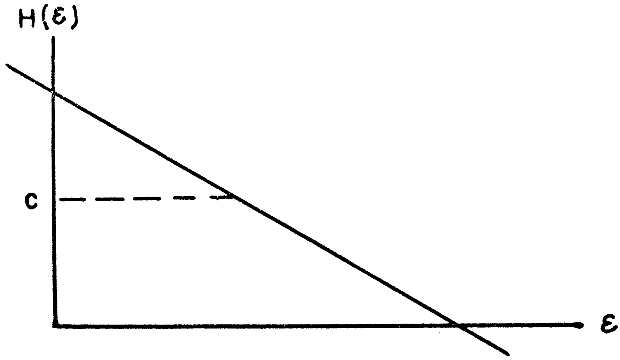

FIGURE I

Relationship between $H(\epsilon)$ *and* ϵ.

and the wage distribution appropriate to their skill level. The frictionally unemployed are those who are looking for jobs, but have not yet obtained a satisfactory job offer, i.e., one for which $x \geqslant \epsilon$.

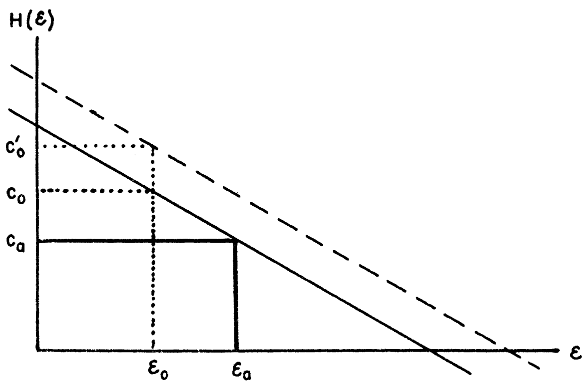

FIGURE II

Relationship between discouraged workers and the frictionally unemployed.

In Figure II, let ϵ_o denote the expected return from remaining unemployed. Note first that since $H(\epsilon)$ is a decreasing function of ϵ, large values of c are associated with small values of ϵ. This in turn implies that, if other things are equal, as c increases, the length of search decreases. Similarly, small values of c are associated with larger values of ϵ and longer periods of search. Consider an individual whose expected returns from remaining unemployed are ϵ_o. If this individual is confronted with search costs in excess of c_o, not searching at all is his best strategy. The value of ϵ associated with any value of c greater than c_o is less than ϵ_o, the expected return from remaining unemployed. This is another way of saying that the optimal policy for such an individual is to drop out or join the ranks of the discouraged workers.

Alternatively, if the costs of search are less than c_o, the individual will continue to seek employment until he receives an offer exceeding the corresponding value of ϵ. The time until such an offer is forthcoming is a period of frictional unemployment.

A description of the structure of the optimal policy is a convenient device for summarizing the preceding discussion. The optimal policy for choosing between dropping out and frictional unemployment has the following form:

if $c \geqslant c_o$, do not search (drop out);
if $0 \leqslant c < c_o$, search (choose frictional unemployment).

The expected length, $E(L)$, of frictional unemployment is given by

$$E(L) = \frac{1}{p},$$

where

$$p = \int_{\epsilon}^{\infty} \phi(x)\ dx.$$

This expected length of frictional unemployment is an increasing function of ϵ, i.e., the larger ϵ, the smaller p, and hence the larger $E(L)$.

The effects of various policies on reducing the number of discouraged workers can be elucidated with this model. Obviously, lowering the cost of search will reduce the number of drop-outs. For example, in Figure II consider again the individual whose return from remaining unemployed is ϵ_o. If his search costs were reduced from an amount larger than c_o to c_a, he would begin seeking employment. In other words, the value of ϵ, ϵ_a corresponding to c_a exceeds ϵ_o, and therefore search is worthwhile. The value to the individual of lowering search costs is $\epsilon_a - \epsilon_o$, while the value to society could be as high as ϵ_a if all of ϵ_o were a welfare payment.

Another method for reducing the number of dropouts is to upgrade the skills of the individual. If a training program is successful, it will shift the individual's wage distribution, $\phi(x)$, to the right.[7]

7. Throughout this discussion it is assumed that training programs affect only the mean of the wage distribution.

That is, the skills that an individual acquired during the training program will on the average command a higher wage than his pre-training skills. In Figure II the effect of a successful training program is to shift the solid line representing $H(\epsilon)$ outward to the dotted line. If we assume that the returns from unemployment remain fixed at ϵ_o, the individual will now drop out only if $c > c'_o$. This inequality is obviously more difficult to satisfy than the previous pretraining condition, $c > c_o$.

The choice between these two methods of reducing the number of discouraged workers depends on the cost of each relative to the induced reduction in the number of dropouts. It seems that lowering information costs is less costly than training programs, but perhaps training has a more salubrious effect on the discouraged workers. An important topic for further research is determining the relative merits of each.

Finally, it may be decided that for one reason or another the individual is unemployable. Society must then determine whether ϵ_o is an adequate income. If it is not, then an income transfer of some sort is warranted. An individual receiving such a transfer will, of course, shun employment even more than before. Given the original goal of poverty alleviation, however, this is not a serious side effect.[8]

The effects of a minimum wage law on the number of discouraged workers and the number of employed can also be interpreted within this framework. First, consider an individual who has dropped out. The level of the minimum wage will have no influence on his decision. Regardless of whether the minimum wage is above or below ϵ_o, if it was optimal to drop out before the minimum wage legislation, it will be optimal after. For example, if the minimum wage is less than ϵ_o, it has no effect on the individual because he has the superior alternative of remaining inactive with respect to the labor market. On the other hand, if the minimum wage exceeds ϵ_o, it is ineffective because it is beyond the range of alternatives he considers.

Consider now an individual who is frictionally unemployed and faces a distribution of job offers given by Figure III. He is following an optimal policy and waiting until an offer exceeds the critical number, ϵ_c. If the minimum wage, ϵ_m, is less than ϵ_c, it will have no influence on his behavior. If, however, ϵ_m exceeds ϵ_c, offers between ϵ_c and ϵ_m, which the individual previously would have accepted, are

8. For a discussion of the optimal allocation of a fixed budget between training and income maintenance, see J. J. McCall, "An Analysis of Poverty: A Suggested Methodology," the RAND Corporation, RM-5739-OEO, Oct. 1968.

now excluded to him by the minimum wage legislation. Consequently, the expected period of frictional unemployment is increased.

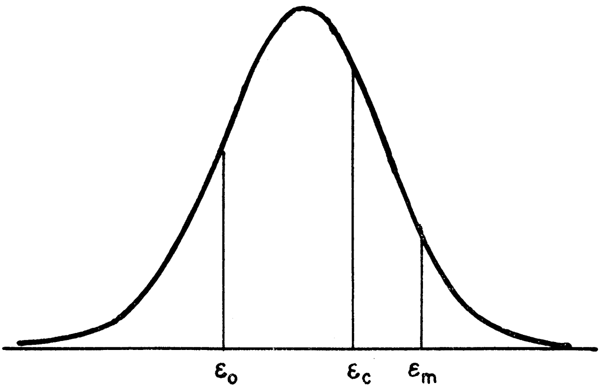

FIGURE III

The distribution of job offers for a particular individual.

In Figure III, for example, the expected period of frictional unemployment before the minimum wage was

$$E(L) = 1/p, \text{ where } p = \int_{\varepsilon_o}^{\infty} \phi(x)\, dx.$$

The expected period of frictional unemployment after the minimum wage is [9]

$$E'(L) = 1/p', \text{ where } p' = \int_{\varepsilon_m}^{\infty} \phi(x)\, dx.$$

Clearly, $E'(L) > E(L)$.

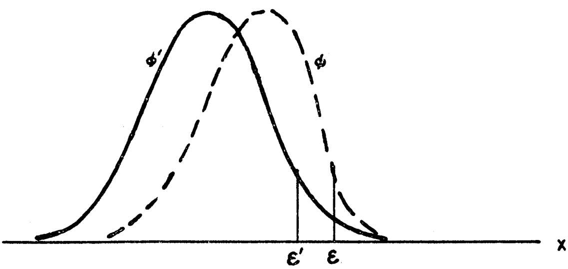

FIGURE IV

True and estimated wage distributions for a particular individual.

9. This assumes that minimum wage eliminates all job offers less than ϵ_m and has no effect on those greater than ϵ_m. This means that the density function $\phi(x)$ is truncated below ϵ_m *and* acquires mass at $x = o$.

This model also clearly reveals the consequences of either overestimating or underestimating the wage distribution, $\phi(x)$. For simplicity, assume that these errors are always with respect to the mean of the distribution. Let the true distribution be ϕ' in Figure IV, and let ϵ' denote the critical value of the wage rate. Suppose that the individual overestimates the value of his skills, and in particular believes his wage distribution to be given by ϕ. Let ϵ be the critical value of the wage rate corresponding to ϕ. Under these circumstances, the anticipated expected search will be

$$E(L)=\frac{1}{p}, \text{ where } p=\int_{\epsilon}^{\infty}\phi(x)\,dx,$$

whereas the actual expected period of search will be

$$E'(L)=\frac{1}{p'}, \text{ where } p'=\int_{\epsilon}^{\infty}\phi'(x)\,dx.$$

If the individual knew that ϕ' were the true distribution, the expected period of search would be

$$E^*(L)=\frac{1}{p^*}, \text{ where } p^*=\int_{\epsilon'}^{\infty}\phi'(x)\,dx.$$

It is instructive to compare the actual expected period of search with the expected period the searcher anticipates. From Figure IV it is clear that $E'(L)$, the actual expected period of search, is greater than $E(L)$, the expected period anticipated by the overoptimistic searcher. If the searcher knew the true distribution, he would accept all offers in excess of E'. Hence, again from Figure IV, it is clear that the actual expected period of search also exceeds the expected period of search if the searcher knew the true distribution. Overoptimism leads to excessively long periods of frictional unemployment. Similar arguments show that overpessimism leads to excessively short periods of frictional unemployment and could indeed cause an individual to drop out. Nonadaptive behavior could also account for persistent unemployment in periods of recession. This point is discussed by Alchian and Allen.[1]

Information about market conditions can be of great value to the job searcher and the economy. A policy that adapted to market conditions would also be very desirable. Using elementary decision theory, one can calculate the value of information. These computations are straightforward.[2] The design of an adaptive policy is not as clear-cut and will be outlined in Section IV.

1. *Op. cit.*
2. A decision-theoretic analysis will be presented in a future paper.

III. A More General Model of Job Search

The previous section presented a simple model of job search that embodied some of the essential features of the unemployment problem. This section indicates how some of the more serious limitations of the simple model can be removed.

Obviously, a searcher in the labor market is concerned not only with the wage rate (be it hourly, weekly, or annual), but also with the anticipated period of employment. If other things are equal, the longer the period of employment, the more favorable the job opportunity. In this section the period of employment is included as an important variable affecting the job searcher's decision making.

The introduction of an expected period of employment necessitates comparisons between current and future income. A discount rate makes these comparisons possible. Consequently, a discount factor will be explicitly introduced into the unemployment model.

Each offer is now composed of two elements, a wage rate, x, and a period of employment, T. For simplicity, assume that x and T are independent random variables with probability density functions, $\phi(x)$ and $\psi(T)$, respectively. Successive draws from each distribution are also assumed to be independent and identically distributed. As before, job offers occur periodically and are either accepted or rejected by the job searcher. A fixed cost, c, is associated with each offer, (x, T).[3] The individual knows the wage rate when he makes his decision. However, T, the period of employment, is a random variable with a known probability distribution. That is, the cost, c, generates an exact value for x, but not for T. If the job searcher accepts the N^{th} offer, the return is the discounted value of earning x for T periods less the discounted cost of search. The discount factor is denoted by a, where

$$a=\frac{1}{1+r},$$

and r is the appropriate interest rate.

Assume that the cost of search is incurred simultaneously with job offers and the decision to accept or reject the offer. Then, $f(x, T)$ is the maximum return obtainable when a job offer (x, T) has just

3. In fact, different costs are probably associated with different job offers. In this case c should be interpreted as the average cost. Also job offers may not arrive periodically. The introduction of a continuous model does not seriously affect the results. Finally, job offers may be accumulated with the job searcher always holding on to his best offer to date. This factor can be introduced without altering the analysis.

been received. More specifically, if (x, T) is the first offer received,

$$f(x, T) = -c + \max\{W, \epsilon\},$$

where ϵ now denotes the discounted expected value of $f(x, T)$, i.e.,

$$\epsilon = \alpha E f(x, T)$$

and

$$W = x + \sum_{i=1}^{T} \alpha^i x.$$

The optimal search policy has the same form as before and is given by

continue searching, if $W < \epsilon$;
accept employment, if $W \geqslant \epsilon$.

The calculation of ϵ is easily accomplished, using the same methods as those of Section II. The expected value of f, given that the N^{th} offer is accepted, is

$$E(f|N) = E(W_N|N) - \sum_{i=1}^{N} \alpha^i c.$$

The expected value of f is then given by

$$E(f) = \epsilon = E(E(W_N|N)) - c a_N,$$

where $a_N = E\left(\sum_{i=1}^{N} \alpha^i\right)$. Arguing as before,

$$E(W_N|N) = E(W_N|W_N \geqslant \epsilon, W_{N-1} < \epsilon, \ldots, W_1 < \epsilon)$$
$$= E(W_N|W_N \geqslant \epsilon),$$

since the W's are independent, and

$$E(W_N|W_N \geqslant \epsilon) = E(W|W \geqslant \epsilon) \cdot E(\alpha^{N-1}),$$

since the W's are identically distributed and $W_N = \alpha^{N-1} W$.[4] Finally,

$$E(W|W \geqslant \epsilon) = \frac{\int_{\epsilon}^{\infty} W \eta(w)\, dW}{P(W \geqslant \epsilon)},$$

where $\eta(W)$ is the probability density function for W, and

$$\epsilon = \frac{\int_{\epsilon}^{\infty} W \eta(W)\, dW}{1 - \alpha P(W < \epsilon)} - c a_N,$$

since

$$E(\alpha^{N-1}) = \frac{P(W \geqslant \epsilon)}{1 - \alpha P(W < \epsilon)}.$$

4. Since

$$W_N = \sum_{i=N-1}^{N+T-1} \alpha^i X.$$

The distinction between the discouraged workers and the frictionally unemployed, the effects of a minimum wage, and all the other implications of the model of Section II have a corresponding interpretation here. For example, the expected length, $E(L)$, of frictional unemployment is simply

$$E(L)=\frac{1}{p},$$

where

$$p=\int_{\epsilon}^{\infty} \eta(w)\,dw.$$

IV. An Adaptive Search Model

The job searcher frequently possesses inadequate knowledge about the distribution of wages appropriate to his skills. In this circumstance, it is important that he revise his estimate of the wage distribution as offers are made. If his initial estimate is high, an adaptive policy reduces the period of frictional unemployment, and conversely if his initial estimate is low. This section sketches out the form of an adaptive search policy. It is done within the simple unemployment model of Section II.

The job searcher is assumed to have imperfect information about the k parameters, $\gamma=(\gamma_1, \ldots, \gamma_k)$, of the wage distribution, $\phi(x)$. He does, however, have a prior distribution, $h(\gamma|\theta)$, over the unknown parameters, where θ is a vector representing the parameters of the prior. This prior distribution summarizes the imperfect information that the searcher has about the mean and other moments of the wage distribution. As offers are observed, θ is revised in Bayesian fashion and a new value is calculated, say

$$\theta'=T(\theta, x_1, x_2, \ldots, x_n),$$

where T is a transformation illustrating the dependence of θ' on θ and the n observations. After each observation the prior distribution is revised, and a decision is then made either to accept that job offer or to continue searching.

Let $f_n(x, \theta)$ be the maximum expected return when an offer of x has just been made and θ represents the parameters of the prior distribution. The n indicates that a total of n offers will be forthcoming. If none of these offers is accepted, assume that a return of amount a is realized. Then

$$f_n(x, \theta)=-c+\max(x, \int\int f_{n-1}(x, \theta')\,\phi(x|\mu)\,(\gamma|\theta)\,dx\,d\gamma).$$

Let ϵ_{n-1} denote the second term in the maximization. Then the optimal search policy has the same form as before, i.e.,

accept employment if $x \geqslant \epsilon_{n-1}$,
continue searching if $x < \epsilon_{n-1}$.

An iterative method for calculating the E_i's is presented in Obregon [5] for the simple case where the wage distribution is exponential with unknown parameter, λ, on which a gamma prior distribution is placed.

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5. *Op. cit.*