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Experimentation**



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International Economic Review, Vol. 24, No. 2. (Jun., 1983), pp. 313-322.

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EMPLOYMENT RELATIONSHIPS WITH JOINT EMPLOYER
AND WORKER EXPERIMENTATION*

BY W. KIP VISCUSI¹

1. INTRODUCTION

A central feature of the employment relationship is that the employer and the worker are typically uncertain about one or more characteristics of the match — the worker's productivity, the nonpecuniary rewards of the job, or perhaps the manner in which the worker will interact with his co-workers.² This uncertainty can be resolved in part through experience, as both the employer and the worker can observe various properties of the job match after it is formed and revise their probabilistic judgments based on this information.

For concreteness, I will focus on the situation in which the uncertainty pertains to the productivity of the match. Each party can acquire information through experimentation, where the experiment consists of direct experience of the job outcome, i.e., the worker's output in each period. Other forms of information acquisition, such as on-the-job observation of signals of the worker's productivity, have similar properties and will not be considered here.

The task for workers and employers consists of discovering the optimal employment relationships as well as selecting the optimal experimentation policy. This problem is in many respects akin to the classic two-armed bandit problem in which an individual is engaged in a sequence of trials on alternative slot machines with uncertain properties.³ The outcomes of the trials on each machine influence one's perceptions of the chance of success on future trials, which in turn affects the subsequent optimal sequence of play.

The employer and the worker are engaged in a similar situation. Based on the trials on any particular job, each party revises its prior beliefs about the expected future productivity of the employment relationship and decides whether

* Manuscript received June 15, 1981; revised June 28, 1982.

¹ A preliminary version of this paper appeared in 1979 as NBER Working Paper No. 394, "Specific Information, General Information, and Employment Matches under Uncertainty," which I presented at seminars at NBER-Cambridge, Columbia University, University of Chicago, Yale University, Ohio State University, Northwestern University, and at the Summer 1981 meetings of the Econometric Society. Insightful comments by a referee enabled me to simplify the model in Section 2. This research was supported in part by the Center for Study of Business Regulation and by the endowment of the IBM Research Professorship, Fuqua School of Business, Duke University.

² Different aspects of the matching problem have been considered by Johnson [1978], Jovanovic [1979a, b], Leighton and Mincer [1982], Mincer and Jovanovic [1979], Mortensen [1978], and Viscusi [1979, 1980a, b], which most closely parallels my treatment here.

³ See Berry [1972], Berry and Viscusi [1981], and Viscusi [1979, 1980a, b].

or not to continue the match. Unlike the usual experimentation framework, a strategic element is present since experimentation with any job-worker match ends whenever either party chooses to terminate the relationship.

The information in my analysis is shared by both parties as they are learning about the particular match and possibly others as well. In search-based matching models, such as those of Mortensen [1978, 1981], the employer and worker are engaged in independent search processes and are learning about alternative employment relationships. The Nash equilibrium and counteroffer strategies will be inefficient as parties will search too much, though efficient contingent contracts can be constructed. A primary difficulty is that to generate a counteroffer, for example, one must incur search costs, producing inefficiencies.

My focus here will be on a different type of information acquisition. In Section 2, I consider market outcomes under the situation of *specific information* in which the job experiences only convey information about the particular employment relationship. This type of information characterizes existing models in which a single party is resolving job uncertainties. This learning concept is broadened in Section 3 to include what I will call *general information* in which worker experiences on a particular job affect their assessed productivity elsewhere and, in the case of the firm, alters the firm's judgments about the likely productivity of other types of workers in that job. In each case, competitively determined wage structures will generate potentially efficient behavior, i.e., for any job-worker match combination, if the average proportion of successful matches coincides with worker and employer assessments of the probability of success, market outcomes will maximize discounted expected output.

2. SPECIFIC INFORMATION

The main feature of the employment problem can be addressed most easily within the context of specific information acquisition by both parties. Consider the following two-period situation in which the discount factor b is $1/(1+r)$, where r is the interest rate. In each period, there is a lottery on whether the worker will be productive, with output y , or unproductive, with output $y-x$. The value of this output is reaped by the employer, who must pay the worker a wage w when he is productive and $w-c$ when he is unproductive, where

$$0 < c \leq x.$$

A base wage rate w is coupled with a productivity premium c used to promote worker sorting and to provide work incentives, neither of which will be considered explicitly here. The value of the wage c cannot exceed x or the company could potentially profit from unproductive job outcomes, creating an adverse incentives problem. In the important case in which workers are risk-neutral, as they are assumed to be here, the employer will set x equal to c so that workers will bear all of the uncertainty regarding their productivity.

Suppose that the employer and worker assess the initial probability of being

productive as equal to p , which they update after observing the worker's initial productivity to a value p^* after a successful outcome (output y) and p^- after an unsuccessful outcome (output $y-x$), where

$$p^* > p > p^-.$$

The assumption that both parties have identical beliefs will be coupled with an assumption that these assessments are unbiased in the sense that p represents the average proportion of new hires who will be productive, while p^* and p^- represent the average proportions of productive workers conditional on the respective first-period outcomes. In the case of specific information, common beliefs and unbiasedness are not required to demonstrate efficiency so long as the initial employment relationship is formed. For general information, both of these assumptions are required to demonstrate efficient match termination and formation. Systematic misperceptions of the probabilities undermine the efficiency properties in the manner one would expect.

Consider first the employment strategies in period 2 conditional on a first-period outcome. Following a first-period success, the worker receives an expected reward on the uncertain job of

$$(1) \quad w - (1-p^*)c > w_0,$$

where w_0 is his alternative wage rate. If the worker found the job acceptable in period 1, when his chance of being productive was only p , this inequality necessarily holds. For fixed values of w and c the attractiveness of the job is greatest after p has been updated favorably. Following an unfavorable outcome, his expected wage on the uncertain job is

$$w - (1-p^-)c < w_0$$

since the job has become less attractive and, if w and c are set so that the two-period contract is set at the worker's reservation wage, it can be shown that it will never be desirable for the worker to remain on the job after a first-period failure. The worker consequently will prefer to stay on the job following a success and to quit after a failure.

Given this preference, the employer's choice affects not only the expected output but also the wage rate. If the employer chooses to continue the match following a success, he pays a base wage w , while a higher base wage w' is required if he terminates a successful match since he is depriving the worker of his preferred employment choice in period 2. As a consequence, it will be in the firm's interest to continue the match in period 2 if

$$y - (1-p^*)x - w + (1-p^*)c \geq y - (1-p)x - w' + (1-p)c,$$

which is always the case. Since $c \leq x$ and p^* exceeds p , even if workers did not perceive that the match would be terminated after a success (so that w would be equal to w'), the firm would have no financial incentive to fire the worker after a first-period success. Although the first-period wage does hinge on the assumed

decisions by the employer in period 2, the implicit contract does not hinge on any assumption on the part of the worker except that the employer will act in his own self-interest.

Following an unsuccessful outcome in the initial period, the firm will find it optimal to terminate the relationship since the expected profits with a new hire will be

$$y - (1-p)x - w + (1-p)c,$$

which is never below

$$y - (1-p^-)x - w + (1-p^-)c,$$

and exceeds this value when $x < c$.

For both the firm and the worker the optimal choice is to continue successful matches and discontinue relationships after an adverse outcome. Each party obtains its first-ranked outcome conditional on the first-period result, so that the possibility of pre-committal is irrelevant.

Based on this behavior one can then calculate the discounted value of the relationship to each party in the initial period. For the marginal worker, the value of employment matches his opportunities elsewhere, or

$$\begin{aligned} w_0(1+b) = & w - (1-p)c + bp \text{Max} [w - (1-p^*)c, w_0] \\ & + b(1-p) \text{Max} [w - (1-p^-)c, w_0], \end{aligned}$$

which given optimal behavior reduces to

$$(2) \quad w = w_0 + \left[\frac{(1-p) + bp(1-p^*)}{1+bp} \right] c.$$

If the worker were hired for only a single period, he would require a base wage w' such that

$$w' = w_0 + (1-p)c.$$

Since p^* is above p , w' exceeds w so that the firm reduces the expected rewards in period 1, denoted by $w(1)$ and equal to $w - (1-p)c$; in situations of learning the firm raises the expected rewards in period 2, which I will denote by $w(2)$.

This tilting of the wage structure is coupled with a similar tilting of output, where the discounted sum of the two-period profits are

$$\pi = y - (1-p)x + b[y - p(1-p^*)x - (1-p)^2x] - w_0 - w_0b_0,$$

since the firm pays the opportunity cost of labor.

If probability assessments are unbiased, employment relationships will be formed on an efficient basis and will be continued or terminated efficiently as well. There is, however, no mechanism within the model to ensure that perceptions are accurate.⁴ If, for example, the firm and worker correctly assessed

⁴ In the absence of such a restriction, one cannot impose the competitive equilibrium condition that expected profits are driven to zero.

the worker's productivity initially, after updating this value they will overestimate the chances of success in period 2. The more the value of p^* exceeds p , the greater will be the potential for misallocation in this instance.

If, however, probabilistic judgments are accurate in each period, the extent of the updating will exert a strong influence on the gains from experimentation. Assume that the probabilistic beliefs are characterized by a beta distribution, which is ideally suited to Bernoulli processes such as this. Let the beta distribution $\beta(\gamma, p)$ be parameterized so that p is the initial probability of success and γ is a measure of the prior's precision. Then after m successes and n failures in a sequence of independent Bernoulli trials, the posterior probability of a success is $(\gamma p + m)/(\gamma + m + n)$. The value of p^* consequently is $(\gamma p + 1)/(\gamma + 1)$, while p^- is $(\gamma p)/(\gamma + 1)$, so that

$$\frac{\partial p^*}{\partial \gamma} < 0 \text{ and } \frac{\partial p^-}{\partial \gamma} > 0.$$

As $\gamma \rightarrow 0$, the limiting values of p^* and p^- are one and zero, respectively, so that the experimentation in which a worker is identified as being productive or unproductive with probability 1 after a single trial is included as a special case.

Low γ 's are preferred since the employment relationship is terminated after an unfavorable outcome, making the greater downward revision for loose priors irrelevant and the greater upward revision after favorable outcomes the prime matter of interest. The employment relationship is continued on an asymmetric basis — the worker remains after a success but leaves after a failure — so that only the upper right tail is of consequence after period 1. The experimentation aspect of the matching process offers the greatest potential gains when the prior information about the match is least. This preference for matches whose properties are not fully understood does not hinge on the risk neutrality of the participants.⁵

As the precision of the priors declines, the rise in expected output becomes increasingly steep. From the standpoint of the worker, lower values of γ raise p^* , thus lowering the base period wage rate w and consequently the expected net first-period wage, $w(1)$. Similarly, lower values of γ raise the expected net wages in the second period, $w(2)$, and raise the second period net rewards conditional on a success, $w(2|s)$, where

$$w(1) < w_0 < w(2) < w(2|s).$$

Diminishing γ raises the gains from experimentation, increasing the upward slope to the wage-experience profile.

The turnover implications of the experimentation process suggest that in the case of specific information successfully matched workers with high initial wages remain on the job, while workers who were unproductive and consequently had lower wages (due to the wage penalty c) quit. Quitting by less productive workers

⁵ One could, for example, focus on the expected utility of the wage lottery as in Viscusi [1979, 1980a].

would tend to generate a negative relationship between wage rates and worker quitting. In instances in which this relationship has been observed empirically, the usual explanation is that workers find low-wage jobs less attractive and consequently quit. But this explanation begs the more fundamental issue of why these workers accepted such jobs initially, while the experimentation explanation does not.

3. GENERAL INFORMATION

Suppose that the worker's experiences at the firm alter his probabilistic beliefs regarding his expected performance at some other job. In much the same fashion as general training alters the worker's productivity elsewhere, general information affects the worker's expected productivity at another firm as well as his firm-specific productivity. I will begin by assuming that this generality is of no direct consequence to the firm.

Following an unfavorable job outcome, the worker can still pursue his null alternative w_0 , but after a successful job outcome he can switch to a related job at another enterprise for which his probabilistic perceptions have been altered by the period 1 success. This job offers an expected wage w_s , where I will assume that this value exceeds $w - (1 - p^*)c$, or else the problem reduces to that of Section 2. After substituting for w from equation 2, this condition reduces to

$$(3) \quad w_s - w_0 > \frac{c(p^* - p)}{1 + bp}.$$

To judge the efficiency of worker quitting in this situation, it is instructive to compare the output of the worker and his possible replacement, who is assumed to produce w_0 in the null alternative and $y - (1 - p)x$ in the uncertain job. Wage payments are simply transfers and are irrelevant to the efficiency issue. If the worker remains on his job in period 2 following an initial period success, the total output of the two workers would be

$$w_0 + y - (1 - p^*)x.$$

If, however, the worker left his position and was replaced by the worker who previously earned w_0 , the total output would be

$$w_s + y - (1 - p)x.$$

The condition under which total output is greater when the worker leaves after a success than when he does not reduces to

$$(4) \quad w_s - w_0 > x(p^* - p),$$

or the increase in the worker's productivity outside the firm must exceed his increased productivity within the firm following a success. The worker's criterion for choosing to leave given by equation 3 differs from the efficiency criterion in equation 4. The worker will quit a job where he would have been more pro-

ductive even if c is set at a maximum value ($c=x$) that fully reflects the worker's changing productivity. The difficulty is that the base wage rate is not altered to reflect the worker's changing opportunities, resulting in too much turnover.

Firms, however, are not constrained to such wage policies. One possibility is to impose a match termination fee which, while efficient, raises the practical problem of collecting the fee. A more viable possibility is to vary the base wage rate in the two periods. The minimal period 2 base wage that will keep the worker following a favorable period 1 outcome is w_β , where

$$(5) \quad w_\beta = w_s + (1-p^*)c.$$

As before, the worker and the firm find it optimal to terminate the match following an unfavorable outcome.

The worker's expected post-success wage is thus w_s whether he switches to the alternative job or is offered a sufficient wage to keep him at the firm since equation 1 must be satisfied. The lowest first-period base wage w_α that will attract the worker to the firm consequently satisfies

$$w_\alpha = w_0 + bp(w_0 - w_s) + (1-p)c < w.$$

Whether or not the worker chooses to quit, the firm can reduce its wage costs in the initial period by lowering the base wage rate from w to w_α . This reduction is made possible by the improvement in the worker's earnings prospects in period 2.

The key issue for the firm is whether it should let the worker quit in period 2 or whether it should raise the period 2 wage to w_β following a success. These two options have the same output and wage costs in period 1 and in period 2 following an unsuccessful outcome. The only matter of interest is which is preferable following a success. The profits π_c associated with continuing the match are

$$\pi_c = y - x(1-p^*) - w_s,$$

where w_s is the net expected wage calculated using equation 5. The value of discontinuing the match and hiring a new worker for one period is π_d , where

$$\pi_d = y - x(1-p) - w' + (1-p)c = y - x(1-p) - w_0.$$

The condition for the firm continuing the match ($\pi_c > \pi_d$) reduces to equation 4. The stay-on-the-winner rule is no longer applicable, as employment matches are continued only if the increased expected productivity of the worker at the firm is greater than the increase elsewhere. These efficiency gains associated with experimentation increase with the imprecision of the initial probabilistic judgments, i.e., for beta priors, $\pi_c - \pi_d$ decreases with γ , the precision of the prior. The wage schedule that achieves this outcome always lowers the worker's period 1 wage as the worker in effect pays for information acquisition in much the same manner as he would for general training in a human capital model. Unlike search-based matching models, the counteroffer strategy yields efficient outcomes.

The difference arises because there are no external search costs associated with on-the-job experimentation.

In situations in which the employer's judgments about workers are interdependent and consequently represent general rather than specific information, one can show that market allocations will be efficient. The employer will adopt a flexible wage structure when workers are learning generally and a uniform base wage otherwise, where in each case the wages reflect worker opportunity costs. The market-determined wage rate in effect internalizes the externality to the worker so that the resulting profit-maximizing decisions by the firm will be efficient.⁶

If either the employer or the worker is learning generally, the turnover properties will be quite different from the specific case. Suppose that the firm must choose one worker from two possible categories of workers. Whether a particular worker leaves is not of consequence, but the employer would like the most efficient type of worker (e.g., a high school graduate) in the job.

The chance that a worker of each type will be a success (productivity=1) or a failure (productivity=0) varies according to the true state of the world θ_1 or θ_2 . Let r equal zero. Using these data one can calculate the posterior probabilities for each state, which are summarized at the bottom of Table 1.

TABLE 1
DATA FOR GENERAL LEARNING PROBLEM

	State of World		Initial Value of p
	θ_1	θ_2	
State Probability	.1	.9	—
Category 1 Worker's Probability of Success	.8	.1	.17
Category 2 Worker's Probability of Success	1	0	.10
Observed Event	Posterior Probabilities		
	θ_1	θ_2	
Success for Category 1	.47	.53	
Success for Category 2	1	0	
Failure for Category 1	.02	.98	
Failure for Category 2	0	1	

Based on this information, one can then determine the profits to the firm, which are given by

$$\pi = \text{Max} \{ .17 + .17 \text{Max} [.43, .47] + .83 \text{Max} [.114, .02], \\ .1 + .1 \text{Max} [.8, 1.0] + .9 \text{Max} [.1, 0] \} = .34.$$

⁶ The proofs are straightforward and are provided in my NBER Working Paper 394.

The optimal sequence of decisions is to hire a category 1 worker in period 1, switch to a category 2 worker after a favorable period 1 outcome, and continue to hire category 1 workers if the period 1 outcome is unfavorable. Initial experimentation with type 1 workers is preferred because they offer sufficiently greater expected initial productivity. If the category 1 worker is productive in the initial period, the probability that θ_1 is the true state rises, making it optimal to switch to a category 2 worker. If the category 1 worker is unproductive initially, the probability that θ_2 prevails is enhanced, making it optimal to retain the category 1 worker.

Whereas in the specific information case it is always optimal to follow a stay-on-a-winner and leave-losers match termination policy, this procedure may not be optimal for general information. For the example above, the opposite procedure is optimal, as it is desirable to terminate productive matches and continue seemingly unproductive ones.

4. CONCLUSION

Despite the intrinsic externalities involved in the employment relationship, a market-determined wage structure will generate cooperative interests and efficient outcomes if probability assessments are unbiased. The wage structures used will vary with the nature of the information acquisition since with general information there is greater tilting of the wage structure. In each case, the presence of experimentation tilts the wage structure upward. The efficiency gains from experimentation and the steepness of the earnings profile both increase as the precision of the initial probabilistic judgments declines.

The subsequent turnover behavior is sensitive to the nature of information acquisition. In the specific case, employment relationships are terminated after unfavorable outcomes and continued after favorable outcomes. One cannot be confident that this is the case for general information, however. If productive workers leave their jobs because their expected wages elsewhere are boosted sufficiently by a favorable job experience, this behavior will dampen and possibly reverse the usual negative wage-quit relationship. In the case of both types of information, the generation of the quit behavior is consistent with the match being formed initially.

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