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SELF-SELECTION, LEARNING-INDUCED QUITS, AND THE OPTIMAL WAGE STRUCTURE*

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1. INTRODUCTION

In situations in which worker turnover is costly to the enterprise, it will be in the firm's interest to attract and retain more stable employees.[2] The firm may be able to assess the worker's quit propensity at the time of hiring by observing signals of the individual's likely stability, such as his employment history and his level of education.[3] Using such information, it could hire only those who are likely to be stable workers. A second possible policy is not to distinguish workers on the basis of their likely turnover rates but simply to pay them a wage rate sufficient to yield an optimal turnover rate for the firm.[4] Finally, the firm may be able to manipulate the structure of wages to serve as a self-selection device that attracts the more stable workers to the enterprise. Particularly in situations in which the individual has better knowledge of his quit propensity than does the firm, this mechanism for sorting out potential workers will be particularly attractive.

It is the use of the wage structure as a self-selection device that will be of primary concern here. In their seminal analysis of this wage policy, Salop and Salop [1976] demonstrated that by imposing an appropriate hiring fee on workers and raising the wage level in subsequent periods it will be possible to attract only the more stable employees to the firm. Nickell [1976] derived a similar result using a model in which the workers structured their own contracts subject to the constraint that the firm break even.[5] In each of these analyses, the economic process leading to the quit decision was not analyzed as the quit propensities of

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2 See Oi [1962] and Becker [1975] for discussion of the specific training investments by the enterprise.

3 Two early contributions to the sizable literature on signaling and screening are those of Spence [1974] and Arrow [1973]. By interpreting the productivity differences in these models as differences in expected turnover costs, these analyses can be applied in fairly straightforward fashion to differences in worker quitting.

4 See, for example, the dynamic analyses of employment by Pencavel [1972], Salop [1973], and Viscusi [1979a].

5 There are, of course, other aspects of these analyses that are quite different. Nickell, for example, considers the influence of differences in individual discount rates and capital market imperfections.

different groups were assumed to be exogenous.[6] The quit behavior of females who leave the labor market to bear and raise children would seem to be a paradigm of such quit behavior.

However, it has long been noted by economists such as Reynolds [1951] that worker quitting is also part of a job shopping process by workers as they attempt to learn about the properties of different jobs and sort themselves appropriately in the labor market.[7] The empirical analysis in Viscusi [1979a, b] indicates that there is a strong impact on worker quitting of health and safety hazards, work speed, the physical environment, physical effort required, and other aspects of employment for which learning on the job is likely to be of importance. For adaptive contexts such as this, the effectiveness of wage structure manipulations may be quite different since, as will be shown subsequently, the workers who are most likely to quit also will tend to have low reservation wage rates for accepting the job initially.

The analysis in Section 2 formalizes this result and analyzes the determinants of the wage rate using either a flat wage policy or a wage structure linked to worker experience at the firm. That section also indicates that there are circumstances under which temporal variations in the wage structure may be superior to a uniform wage policy even if turnover is not costly to the firm. The situations in which the wage structure can be manipulated to serve as a self-selection device are considered in Section 3. If such a self-selecting wage structure exists, the firm need not necessarily adopt it since the added wage costs may not offset the reduced cost of worker turnover. In Section 4, I analyze the conditions likely to lead to the use of a temporal wage structure. Moreover, it will be shown that if such a self-selection device exists, then it is the least costly wage mechanism for eliminating worker turnover. Section 5 concludes the paper.

2. DETERMINANTS OF WAGE RATES IN ADAPTIVE CONTEXTS

2.1. *Description of the Learning Process.* Consider a situation in which individuals learn about the attributes of their job through their on-the-job experiences. These attributes may concern the general nature of the work, such as the health and safety hazards considered in Viscusi [1979a, b], or they may pertain to the ease with which the worker produces a given level of output. Throughout the analysis, I will assume that each worker produces the same level of output and that this level is independent of the wage structure adopted. Thus

[6] Although Nickell [1976] makes the wage rate-quit relationship endogenous, only the polar cases involving quit probabilities of 1 and 0 are formally articulated. He introduces the possibility of person-specific differences in turnover propensities as an explanation for quit probabilities between 0 and 1. Following the analysis in Viscusi [1979a], one can generate similar results in the models presented in this paper by introducing a distribution of transactions costs for job changes (e.g., search and moving costs) that differs across the population.

[7] More recent conceptual analyses of this learning process include the work by Mortensen [1975], Jovanovic [1977], and Viscusi [forthcoming, 1979a, b], which is closest to the models developed here.

I am abstracting from the use of the wage structure to sort out workers of different ability and to provide incentives for individual work effort.[8]

For the job with uncertain implications, let there be two possible outcomes in each period. State 1 pertains to a favorable outcome, such as the individual finding the work load easy or the physical environment attractive. This outcome will correspond to receiving an additional monetary equivalent of c. If the unfavorable state 2 prevails, no such monetary equivalent is received. Assuming that individuals' von Neumann-Morgenstern utility functions are linear in money, the value of state 1 is $w+c$ while the reward for state 2 is w, where w is the wage rate paid by the firm in that period.

The individual starting work on the job is assumed to be uncertain of its properties.[9] In particular, he has a prior probability assessment with a mean value of p $(0<p<1)$ that state 1 will prevail and a probability $1-p$ for state 2. The learning process is assumed to be based on the individual's job outcome experiences in each period.[10] After m favorable outcomes and n unfavorable outcomes in $m+n$ periods of work on the uncertain job, the individual's posterior probability assessment becomes $p(m, n)$. These Bernoulli trials are assumed to be independent and identically distributed.

For stochastic processes such as this, the Beta family of distributions is ideally suited to capturing the revision of prior assessments that may assume a wide variety of skewed and symmetric shapes.[11] Let the Beta prior for the worker be given by $\beta(\gamma p, \gamma)$, where the distribution has been parameterized so that p is the mean value of the prior and γ is a measure of its tightness, where $\gamma>0$ and larger values of γ correspond to more precise priors. Then the posterior probability $p(m, n)$ is given by

$$p(m, n) = \frac{\gamma p + m}{\gamma + m + n}. \tag{1}$$

In the following section, I will examine both how individuals who update their perceptions in this fashion will behave and how this behavior affects the wage level requires to attract workers to the firm.

2.2. *Determinants of the Required Wage Rate.* Consider a two-period choice situation in which the hypothetical worker must choose in each period between the job with uncertain properties and an alternative position whose implications are known with precision. Let the wage rate at the uncertain job be w in each period and that for the job alternative be w_0. The individual faces an interest rate r, leading to a discount factor b equal to $1/(1+r)$. Since the worker facing such

[8] These issues are considered in detail by Akerlof [1976] and Stiglitz [1975].

[9] The adaptive process sketched below is motivated more fully in Viscusi [1979a, b].

[10] The generalization to signals of job characteristics and other indirect experiences is straightforward and is presented in Viscusi [1979a].

[11] See Raiffa and Schlaifer [1961], who also emphasize the superiority of using Beta distributions rather than normal approximations for such stochastic processes.

a two-armed bandit problem will never leave the job with known properties once he has started it, the worker's dynamic programming problem is to

$$\text{Max}\,\{w_o + bw_o,\ w + pc + bp\,\text{Max}\,[w_o,\ w + p(1,0)c] + b(1-p)\,\text{Max}\,[w_o,\ w + p(0,1)c]\}, \tag{2}$$

where $w+bw_0$ is the reward for the known job, $w+pc$ is the expected reward in period 1 for the uncertain job, $w+p(1, 0)c$ is the expected second period reward for that job after a favorable experience in period 1, and $w+p(0, 1)c$ is the reward after an unfavorable experience.

The primary matter of concern here is the lowest value of w that will attract the individual to the uncertain job in the initial period. For all situations in which workers update their prior assessments,

$$p(0,1) < p < p(1,0),$$

so that this minimal w will not be sufficient to retain the worker after an unfavorable outcome but will prevent turnover if his period 1 experiences are favorable.[12] For employment paths of this nature, the discounted expected value of the uncertain job becomes

$$w + pc + bp[w + p(1,0)c] + b(1-p)w_o.$$

To determine the value of w needed to make the worker indifferent to the two jobs in period 1, set this expression equal to w_0+bw_0 and solve for w, producing the result that

$$w = w_o - \frac{pc + bpp(1,0)c}{1 + bp}. \tag{3}$$

I will refer to wage policies that set the wage in each period according to equation (3) as type 1 wage structures (WS1).

Since $p(1, 0)$ exceeds p, this value of w is less than the comparable wage value of w_0-pc which would be required if there were only a single period to the choice problem. The reason for the worker's greater willingness to accept the job in multi-period contexts is that the uncertain job's attractiveness will be enhanced in period 2 if his experiences in period 1 are favorable, and the worker can switch jobs if the period 1 outcome is unfavorable.

The gains from information acquisition and adaptive behavior diminish as the sharpness γ of the individual's prior assessment increases since information acquired on the job has less effect on his probabilistic judgments. Differentiating equation (3) with respect to γ one finds that

$$\frac{\partial w}{\partial \gamma} = -\frac{bp}{1+bp}\left[\frac{p}{(\gamma+1)} - \frac{\gamma p + 1}{(\gamma+1)^2}\right] = -\frac{bp}{1+bp}\,\frac{(p-1)}{(\gamma+1)^2} > 0,$$

[12] This assertion can be readily verified. In particular, the value of w given by equation (3) below clearly satisfies these properties.

or the required w increases with the sharpness of the prior.

For any mean value p of a worker's prior, those individuals with the loosest prior assessments will be most likely to quit after an unfavorable experience since $p(0, 1)$ diminishes as γ is reduced. In conjunction with the preceding result for workers' reservation wage rates, this implies that the workers most likely to quit as a consequence of their learning about job attributes are also the workers most willing to accept the job in the initial period.

2.3. *Temporal Wage Structures.* An enterprise generally is not constrained to offering the worker the same wage rate irrespective of his tenure with the firm. For the two-period model being considered, the firm may adopt a temporal wage structure offering a wage w in period 1 and a wage $w+x$ in period 2, where x may be either positive or negative. For the purposes of this analysis, I assume that there is no uncertainty regarding the nature of the wage structure or the individual's future status with the firm. If the company could revise the wage structure in period 2 or fire the employee, one would have to incorporate individual assessments of the probabilities of these outcomes into the analysis.[13]

If the company can manipulate the wage level in each period, the worker's optimization problem given by equation (2) becomes

$$\text{Max}\,\{w_o + bw_o,\ w + pc + bp\,\text{Max}\,[w_o,\ w + x + p(1, 0)c] + b(1 - p)\,\text{Max}\,[w_0,\ w + x + p(0, 1)c\}. \tag{4}$$

There are three cases that must be considered. First, the company could set the value of x so low that the worker always quits after period 1, or

$$x < w_o - w - p(1, 0)c.$$

In this instance, the firm would be hiring workers for single periods only at a wage rate given by

$$w = w_o - pc.$$

Since this value exceeds that given by equation (3) for the uniform wage policy, this type of temporal wage structure can be ruled out.

The second possible wage structure is to set the second-period wage level so that only workers with favorable experiences will remain with the firm, implying that

$$w + x = w_o - p(1, 0)c, \tag{5}$$

or

$$x = w_o - w - p(1, 0)c. \tag{6}$$

From equation (4) we know that this wage policy must satisfy

[13] Alternatively, one could ascertain the conditions under which the employer would not find it in his self-interest to renege on the contract even if workers did not accurately perceive this possibility. See Salop and Salop [1976].

$$w_o + bw_o = w + pc + bp[w + x + p(1, 0)c] + b(1 - p)w_o.$$

To find the value of w required to attract the worker to the firm using this form of wage contract, substitute for $w+x$ from equations (5) and (6), solve this equation for w, leading to the result that

$$w = w_o - pc. \tag{7}$$

Substituting this value into equation (6), one finds that

$$x = [p - p(1, 0)]c. \tag{8}$$

Equations (7) and (8) define the temporal wage structure that prevents turnover if the worker's experiences are favorable. This wage policy will be referred to as the type 2 temporal wage structure (TWS2). The value of w is the same as for the wage policy that attracts and retains workers for only a single period. However, after the worker has experienced a favorable job outcome, the company can lower the wage it pays and still attract the worker to the firm since the value of x is negative. The circumstances under which such wage variations will be superior to uniform wage rates defined by equation (3) will be explored later in Section 2.

The third and final temporal wage structure is to set x at a sufficiently high level to always prevent turnover by the hypothetical worker. This policy must prevent quitting after an unfavorable experience, implying that

$$w + x = w_o - p(0, 1)c, \tag{9}$$

or

$$x = w_o - w - p(0, 1)c. \tag{10}$$

To attract the worker to the firm in the initial period, these values must satisfy

$$w_o + bw_o = w + pc + bp[w + x + p(1, 0)c] + b(1 - p)[w + x + p(0, 1)c].$$

Substituting for $w+x$ from equation (9) and solving for w produces the result that

$$w = w_o - pc - bpc\,[p(1, 0) - p(0, 1)], \tag{11}$$

and using equation (10) a value of x given by

$$x = [p - p(0, 1) + bpp(1, 0) - bpp(0, 1)]c. \tag{12}$$

The wage structure defined by equations (11) and (12) will be called the type 3 temporal wage structure (TWS3).

The no turnover wage structure sets a lower value for w and a higher x than the wage structure that prevents quits only after favorable experiences. This result is to be expected since the second period wage rate must rise to retain workers who consider the job less attractive than they did initially. Given this boosted second-period wage level, the value of w required in period 1 will be diminished. Table 1 summarizes the wage structure properties for future reference.

TABLE 1
SUMMARY OF WAGE RATE RESULTS

Wage Structure	w	x
Flat Wage Policy (WS1)	$w_o - \frac{pc + bpp(1, 0)c}{1 + bp}$	0
Temporal Wage Structure that Prevents Turnover if State 1 Occurs (TWS2)	$w_o - pc$	$[p - p(1, 0)]c$
Temporal Wage Structure that Eliminates Turnover (TWS3)	$w_o - pc - bpc[p(1, 0) - p(0, 1)]$	$[p - p(0, 1) + bpp(1, 0) - bpp(0, 1)]c$

2.4. *The Optimal Wage Structure: the No Turnover Cost Case.* No existing analysis would suggest that temporal variations in the wage structure are desirable if worker turnover is costless to the firm. To analyze whether this result pertains to situations with adaptive behavior, let q be the probability the firm attaches to the occurrence of state 1, where q is assessed with precision based on the firm's past experience. Also assume that any replacement for a worker who quits after an unfavorable outcome in period 1 is hired for period 2 only at a required wage of $w_0 - pc$. In Section 2.3, this value was found to be the wage cost for hiring a worker for a single period. The respective, discounted expected costs over two periods of the wage policies are

$$C_1 = (1 + bq)w + b(1 - q)(w_o - pc),$$

where w is the value for WS1,

$$C_2 = w + bq(w + x) + b(1 - q)(w_o - pc),$$

where w and x are the values associated with TWS2, and

$$C_3 = w + b(w + x),$$

where w and x pertain to TWS3.

Upon substitution for the wage values, it can be readily shown that turnover prevention (TWS3) is never optimal. The choice between the other wage structures is less clear. In particular, C_1 will be less costly than C_2 if

$$(q - p) > (q - p)\frac{p(1, 0)}{p}, \tag{13}$$

and conversely. The wage structures WS1 and TWS2 are equally costly if workers' prior beliefs coincide with the firm's (i.e., $p = q$). If workers underestimate the probability of a favorable outcome as compared with the firm's assessment, TWS2 is preferable. Experimentation by overly pessimistic workers is encouraged by a high initial wage that is later reduced after the worker has observed the job outcome in the initial period. A uniform wage policy (TWS1) is optimal for overly optimistic workers (i.e., $p > q$).

3. THE EXISTENCE OF SELF-SELECTING WAGE MECHANISMS

The heterogeneity of workers' prior beliefs and quit propensities is not of great interest to the firm if turnover is costless. The enterprise adopting a WS1 policy, for example, will simply set the wage level sufficiently high to attract workers to the firm. Although the distribution of workers' prior beliefs is relevant to choosing among wage structures or to setting the wage level if the workers who replace those who have quit have a shorter time horizon, worker heterogeneity assumes its greatest analytic interest if there are hiring and training costs associated with worker turnover.[14] It is in these situations that the wage structure will be of potential usefulness as a self-selection mechanism to attract the more stable employees to the firm.

Let there be two classes of workers that are indistinguishable to the firm. The high quit workers will be referred to as Type 1 individuals. These potential employees have beta priors $\beta(\gamma_1 p_1, \gamma_1)$. Similarly, Type 2 workers are the low quit workers characterized by $\beta(\gamma_2 p_2, \gamma_2)$. As was shown in Section 2.2, the workers with the loosest priors will exhibit higher turnover. Assume that Type 1 workers' priors are less precise, or that, $\gamma_1 < \gamma_2$. For Type 1 workers to exhibit greater quitting due to adverse on-the-job experiences, they must regard the job more unfavorably after an adverse job outcome than do Type 2 workers, that is $p_1(0, 1)$ is below $p_2(0, 1)$, or

$$\frac{\gamma_1 p_1}{\gamma_1 + 1} < \frac{\gamma_2 p_2}{\gamma_2 + 1}, \tag{14}$$

so that

$$p_1 < \left(\frac{\gamma_1\gamma_2 + \gamma_2}{\gamma_1\gamma_2 + \gamma_1}\right) p_2, \tag{15}$$

where the right-hand term is larger than p_2 since γ_2 exceeds γ_1. Thus p_1 can exceed p_2, but not by too great an amount. Equation (15) assures that, after a failure in period 1, the high quit Type 1 workers will consider the uncertain job more unattractive than do Type 2 workers. If this condition were not satisfied, one could construct situations in which only the low quit Type 2 workers exhibited learning-induced turnover.

This condition also rules out situations in which Type 1 workers would dominate Type 2 workers in terms of both the wage and turnover costs that determine their attractiveness to the firm. If equation (15) is not satisfied, Type 1 workers would impose the same or lower turnover costs. Moreover, since $\gamma_1 < \gamma_2$, failure of this inequality to hold would imply p_1 exceeds p_2. The value of $p(1, 0)$ also would be higher for Type 1 workers. From Table 1, one can verify that Type 1

[14] The analysis of the optimal wage policies with a distribution of worker prior assessments is presented in Viscusi [1979a].

workers consequently would require a lower wage rate to attract them to the firm regardless of the wage structure employed. The only heterogeneous worker situation of interest consequently is that in which equation (15) is satisfied.

In this section I will ascertain under what circumstances there exists a wage structure that will serve as a self-selection mechanism that attracts only the low quit Type 2 workers. Thus, as in the studies of Salop and Salop [1976] and Nickell [1976], I am attempting to determine whether the wage structure can be used to lead the workers themselves to reveal their quit propensities. The principal difference is that the quit behavior in this essay is generated by adaptive behavior as workers learn about the job's properties in Bayesian fashion.

Two situations will be considered. First, in Section 3.1 I will consider self-selecting wage structures that prevent Type 2 workers from quitting only if state 1 prevails, while Section 3.2 analyzes wage structures that always prevent Type 2 worker quits. It will be shown that temporal wage structures are effective in a greater range of situations than time-invariant wage rates. Moreover, all wage structures share a common limitation. *If $p_1 \leq p_2$ and $\gamma_1 < \gamma_2$, no self-selecting wage structure (WS1, TWS2, or TWS3) that attracts only Type 2 workers to the firm exists.*

3.1. *Self-Selection Mechanisms that Partially Reduce Turnover.* Suppose the firm's objective is to devise a wage structure that attracts only Type 2 workers to the firm and prevents them from quitting if their on-the-job experiences are favorable. The turnover properties are satisfied by both the flat wage policy WS1 and the temporal wage structure TWS2, where the probability assessments pertain to Type 2 workers. What remains to be shown is that the high quit Type 1 workers will also not find employment at the firm attractive given this wage structure.

The wage policy WS1 will serve as a self-selection device if the wage rate needed to attract the Type 1 worker exceeds the Type 2 worker's reservation wage rate. Using the results in Table 1 with appropriate subscripts, this condition is that

$$w_o - \frac{p_1 c + b p_1 p_1(1, 0)c}{1 + bp_1} > w_o - \frac{p_2 c + b p_2 p_2(1, 0)c}{1 + bp_2},$$

or

$$(16) \quad p_2 + bp_2 p_2(1, 0) + b^2 p_1 p_2 p_2(1, 0) > p_1 + bp_1 p_1(1, 0) + b^2 p_1 p_2 p_1(1, 0).$$

Equation (16) is never satisfied unless p_2 exceeds p_1. Since γ_1 is less than γ_2, $p_1(1, 0)$ would exceed $p_2(1, 0)$ if p_2 were not greater than p_1, leading to a clear violation of this inequality.

The wage structure TWS2 offers a wage w equal to $w_0 - p_2 c$ in period 1 and $w + x$ equal to $w_0 - p_2(1, 0)c$ in period 2. Since the Type 2 worker will quit if state 2 prevails given this wage structure, the Type 1 worker will do so as well due to the restriction imposed by equation (15). The employment path for the Type 1 worker is still not clear-cut. Two cases must be considered. For Case (i), the Type 1 worker will remain on the job if state 1 occurs. This condition is satisfied if

$$w + x + p_1(1, 0)c \geq w_o,$$

or upon substituting for $w+x$ and simplifying,

$$p_1(1, 0) \geq p_2(1, 0). \tag{17}$$

Case (ii) consists of situations in which this condition is not satisfied so that the Type 1 worker will always quit in period 2. Neither of these cases assumes that the Type 1 worker would accept the job in period 1. Rather they are intended solely to define the individual's actions in period 2 of his dynamic programming problem.

Consider the use of TWS2 in Case (i), where the worker switches to the job alternative if state 2 prevails. This wage structure will serve as a self-selection device if the Type 1 worker prefers the alternative job in the initial period, or

$$w_o + bw_o > w_o - p_2c + p_1c + bp_1[w_o - p_2(1, 0)c + p_1(1, 0)c] + b(1 - p_1)w_o,$$

which reduces to

$$p_2 + bp_1p_2(1, 0) > bp_1p_1(1, 0) + p_1. \tag{18}$$

As with WS1, the wage structure will not serve as a self-selection device if p_2 does not exceed p_1.

Similarly, for Case (ii) in which the Type 1 worker always quits in period 2, TWS2 will be effective if

$$w_o + bw_o > w_o - p_2c + p_1c + bw_o,$$

or

$$p_2 > p_1.$$

While this inequality must be satisfied by all self-selecting wage structures that partially affect Type 2 workers' turnover, the circumstances under which the wage mechanisms are effective may differ. In particular, it can be shown that TWS2 will serve as a self-selection device in a wider variety of situations than can WS1.

From equation (16), we know that WS1 will be effective if

$$p_2 - p_1 > bp_1p_1(1, 0) + b^2p_1p_2p_1(1, 0) - bp_1p_2(1, 0) - b^2p_1p_2p_2(1, 0). \tag{19}$$

The TWS2 screens in Case (i) if, using equation (18), worker probability assessments satisfy

$$p_2 - p_1 > bp_1p_1(1, 0) - bp_1p_2(1, 0). \tag{20}$$

The right-hand side of equation (19) always exceeds that for equation (20) if $p_1(1, 0)$ exceeds $p_2(1, 0)$, while the requirements on $p_2 - p_1$ are identical if these posterior probabilities are identical. Since Case (i) includes only those situations defined by equation (17), TWS2 will be effective under the same circumstances as will WS1 if the equality prevails and under more general conditions if the inequality in equation (17) holds since TWS2 imposes less stringent conditions on the amount by which p_2 must exceed p_1.

For Case (ii) to exist, the inequality expressed by equation (17) must be reversed. Since p_2 must always exceed p_1 for this condition to be true (since $\gamma_1 < \gamma_2$), TWS2 will always serve as an effective self-selection device in this instance, as will WS1 since equation (19) will also be satisfied.

In short, neither wage structure is completely effective in attracting only Type 1 workers and retaining them after favorable period 1 outcomes. Both mechanisms are ineffective unless p_2 exceeds p_1 sufficiently. This limitation is due to the fact that Type 1 workers have looser priors and hence greater willingness to accept the job initially for any mean value of the prior. These quit-prone workers will always find it desirable to experiment with the uncertain job that is acceptable to the Type 2 worker unless the latter individual has a sufficiently greater expected initial probability of a favorable outcome.

3.2. *Self-Selection Mechanisms that Eliminate Turnover.* If the enterprise's objective is to attract only Type 2 workers and always prevent them from quitting regardless of the period 1 outcome, the wage structure must be more attractive than that considered in the previous section. For this wage structure also to serve as a viable self-selection mechanism, one would expect that p_1 must be sufficiently below p_2.

This requirement can be readily obtained for the time-invariant wage structure. If the wage rate is to prevent Type 2 worker quits, it must be set so that

$$w = w_o - p_2(0, 1)c. \tag{21}$$

Since equation (15) is assumed to be satisfied, the Type 1 worker would always quit if state 2 occurred. Moreover, he would always remain on the job in period 2 after a favorable outcome if he accepted the job initially. Consequently, the Type 1 worker will not find this uncertain job attractive in period 1 if

$$w_o + bw_o > w_o - p_2(0, 1)c + p_1 c + bp_1[w_o - p_2(0, 1)c + p_1(1, 0)c] + b(1 - p_1)w_o,$$

or

$$p_2(0, 1) > \frac{p_1 + bp_1 p_1(1, 0)}{1 + bp_1}. \tag{22}$$

Using the formula for Beta prior in equation (1), this condition is that

$$p_2 > p_1\left(\frac{\gamma_2 + 1}{\gamma_2}\right)\left(\frac{1 + bp_1(1, 0)}{1 + bp_1}\right). \tag{23}$$

Since each of the two terms in parentheses exceeds 1, the wage policy characterized by equation (21) will be an effective self-selection device if p_2 exceeds p_1 by a sufficient amount.

Consider the use of the temporal wage structure TWS3 summarized in Table 1, where the probability terms pertain to the Type 2 worker. Since a worker would never quit after a favorable outcome with a wage structure that rises over time, only two possible period 2 situations need be considered. For Case (i), the Type 1 worker does not quit after an unfavorable outcome. For the value of $w+x$ associated with TWS3, this requirement is that

$$w_o - p_2(0, 1)c + p_1(0, 1)c \geq w_o,$$

or

$$p_1(0, 1) \geq p_2(0, 1).$$

This situation was ruled out by equation (15) so that Case (i) can never arise.

For Case (ii), the Type 1 worker quits if state 2 occurs. The TWS3 will serve as an effective self-selection device if

$$w_o + bw_o < w_o + p_1 c + bp_1(w + x) + b(1 - p_1)w_o.$$

Substituting for w and x from the third line of Table 1 and collecting terms, we have

$$p_2 + bp_2p_2(1, 0) + bp_1p_2(1, 0) > p_1 + bp_2p_2(0, 1) + bp_1p_1(1, 0). \tag{24}$$

After substituting for the Beta values for these posterior probabilities, one can solve for p_2 yielding

$$p_2 > p_1 \frac{[(\gamma_1\gamma_2 + bp_1\gamma_1\gamma_2 + 1 + b + \gamma_1 + \gamma_2) + b(\gamma_2 + \gamma_1 p_1)]}{[(\gamma_1\gamma_2 + bp_1\gamma_1\gamma_2 + 1 + b + \gamma_1 + \gamma_2) + b(\gamma_2 + \gamma_2 p_1)]}.$$

The first terms in these bracketed expressions are equal. The numerator will exceed the denominator provided that

$$\gamma_2 + \gamma_1 p_1 > \gamma_1 + \gamma_2 p_1,$$

or

$$1 > p_1,$$

which we have assumed. Thus, the Type 2 worker must have a sufficiently higher mean value for his prior for TWS3 to serve as a self-selection mechanism.

A requirement that p_2 must exceed p_1 by some amount is associated with all self-selection mechanisms considered in this and the previous section. The reason is clear. Since Type 1 workers have looser priors, if they also had the same or lower mean value of the prior they would find the uncertain job more attractive than would the Type 2 worker since the benefits of learning about the job are greater to them. This property was reflected in Section 2's result that the worker's reservation wage rate diminishes as γ is reduced. Unlike the situation of exogenously determined quits, the wage structure does not always serve as an effective self-selection mechanism with learning-induced quit behavior.

If it can be shown that TWS3 imposes a less stringent requirement on p_2 than does the uniform wage policy, then this wage mechanism will be a viable self-selection mechanism under more general circumstances. Suppose that

$$p_2 \geq p_1 \frac{(1 + bp_1(1, 0))}{(1 + bp_1)} . \tag{25}$$

It is clear that the right side of equation (25) is less than that for equation (23) since $(\gamma_2 + 1)/\gamma_2$ exceeds 1.

It can readily be shown that even for the minimal p_2 value satisfying equation (25) that TWS3 will be effective even though this p_2 value is outside of the range for which a time-invariant wage structure is effective. Let the first p_2 term in equation (24) be given by the right-hand term from equation (25). Upon simplification, this equation becomes

$$p_2(1, 0) > p_1 \frac{(1 + bp_1(1, 0))}{(1 + bp_1)} .$$

Since $p_2(1, 0)$ always exceeds p_2 for all updated priors, this condition always holds if equation (25) is satisfied. Thus, TWS3 will serve as a self-selection mechanism under less stringent circumstances than will a time-invariant wage policy. Whether TWS3 is also superior in terms of its cost in situations in which both wage structures are effective self-selection techniques will be determined in the following section.

4. CHOICE OF THE WAGE STRUCTURE

Even if wage structures exist that will serve as viable self-selection mechanisms, they need not be adopted if turnover costs are not very large. In this section, I will explore the conditions likely to lead to the adoption of different wage mechanisms. Since the principal ramifications of differences in the probabilistic perceptions of workers and firms were considered in Section 2.4, the values of q_i and p_i for each worker type will be assumed to be identical.[15] The mean values of workers' priors are thus assumed to be unbiased. Let the hiring and training cost per worker equal h. Before investigating the optimal wage strategy, I will first ascertain the least costly wage mechanism within the class of policies that eliminates worker turnover.

4.1. *Optimal Turnover Prevention.* Although the temporal wage structure TWS3 is superior to a uniform wage policy in terms of the circumstances under which it will serve as a self-selection device, in instances in which they both can act as a self-selection mechanism the enterprise will prefer the wage structure with

[15] The results in this section can be generalized to permit q_i and p_i to differ. The more general formulation is presented in an earlier, longer version of this paper, available from the author.

lower wage costs since each structure has the same turnover properties. Moreover, if a self-selecting, time-invariant wage structure does not exist, it still must be shown that TWS3 is less expensive than a wage policy that attracts and prevents quits by all worker types. Otherwise there would be no rationale for utilizing this self-selection mechanism.

Since all workers produce the same output, the enterprise's objective is to minimize the discounted expected cost per worker for the two periods. For wage policies that eliminate turnover, the only hiring and training cost is the value h incurred in the initial period.

The cost $C(\text{TWS3*})$ of the temporal wage structure that self-selects Type 2 workers and prevents them from quitting is given by

$$C(\text{TWS3*}) = h + w + b(w + x)$$

or, upon substitution for the w and x values for TWS3,

$$C(\text{TWS3*}) = h + w_o + bw_o - p_2c - bc[p_2p_2(1, 0) - p_2p_2(0, 1) + p_2(0, 1)].$$

This expression simplifies considerably for the Beta family of priors updated using equation 1. Letting $p_2(1, 0)$ equal $(\gamma_2 p_2+1)/(\gamma_2+1)$ and $p_2(0, 1)$ equal $\gamma_2 p_2/(\gamma_2+1)$, one obtains the result that

$$C(\text{TWS3*}) = h + (1 + b)(w_o - p_2c). \tag{26}$$

The cost associated with this wage policy is independent of the precision γ_2 of the worker's prior as it depends only on the mean of the prior p_2. The wage costs are identical to those associated with hiring workers for a single period only. The difference of TWS3 from such a policy is its turnover properties.

The wage associated with a time-invariant wage policy that self-selects Type 2 workers and prevents them from quitting is equal to $w_0 - p_2(0, 1)c$, as indicated in equation (21) above. Since $p_2(0, 1)$ is less than p_2, this wage policy is necessarily more costly than TWS3* since it involves identical turnover costs and higher wage costs than those in equation (26). Not only is the temporal wage structure more widely applicable, but it is also always cheaper than using a self-selecting uniform wage rate.

If TWS3* is a viable self-selection mechanism but the time-invariant wage structure is not, the firm has an additional turnover-preventing wage policy. In particular, it could pay a wage rate sufficiently high to attract both types of workers and prevent them from quitting. This wage must be sufficient to retain the high quit Type 1 workers if state 2 prevails, or w equals $w_0 - p_1(0, 1)c$. Since $p_1(0, 1)$ is less than $p_2(0, 1)$ from equation (15) and $p_2(0, 1)$ is less than p_2 for all updated priors, the costs associated with this policy always exceed $C(\text{TWS3*})$. In short, the temporal wage structure is the least costly wage mechanism that eliminates worker turnover.

4.2. *Choice of the Wage Policy.* The firm has a variety of wage policies to choose from, each of which may have different turnover properties and wage costs. The importance of reducing worker turnover is increased as the level of hiring costs h rises. Rather than consider all possible wage structures in detail, the discussion here will focus on two different situations in an effort to obtain some general insight into the relation of worker learning to the decision to reduce turnover costs using different self-selection devices.

In the first situation, suppose that WS1, TWS2, and TWS3, can serve as self-selection mechanisms to attract only Type 2 workers. Assuming that q_i and p_i coincide, the results from Section 2.4 indicate that both the uniform wage policy (WS1) and the two-part wage (TWS2) have identical wage and turnover properties. The analysis consequently can be restricted to a choice between TWS2 and TWS3 or, in effect, the decision whether or not to prevent all turnover of Type 2 workers once they have been attracted to the firm by a self-selecting wage mechanism.

For these self-selection mechanisms to be viable, p_2 must necessarily exceed p_1 so that the period 2 replacement of any worker who has quit after period 1 will impose a wage cost $w_0 - p_2 c$. The cost $C(\text{TWS2*})$ policy is the same as the cost of WS1 and is given by

$$C(\text{TWS}\,2^*) = h + b(1 - p_2)h + (1 + bp_2)w + bp_2x + b(1 - p_2)(w_o - p_2c),$$

where w and x pertain to TWS2. The firm incurs an initial hiring cost h in the first period and an expected hiring cost $(1-p_2)h$ in the second period, which is discounted by the factor b. Upon substitution for the TWS2 wage values, this expression becomes

$$\text{(27)} \qquad C(\text{TWS}\,2^*) = h + b(1 - p_2)h + (1 + b)w_o - p_2c - bp_2p_2(1, 0)c - b(1 - p_2)p_2c.$$

The costs associated with $C(\text{TWS3*})$ were given by equation (26). Complete turnover prevention is optimal if $C(\text{TWS3*})$ is less than $C(\text{TWS2*})$. After canceling the common terms in equations (26) and (27), this condition is

$$- bp_2c < b(1 - p_2)h - bp_2p_2(1, 0)c - b(1 - p_2)p_2c,$$

which can be rewritten after substituting for the Beta value $(\gamma_2 p_2 + 1)/(\gamma_2 + 1)$ of $p_2(1, 0)$ as

$$\text{(28)} \qquad h > \frac{p_2c}{\gamma_2 + 1} = h^*.$$

Turnover prevention is optimal only if the hiring and training costs exceed h^*. This critical value increases as learning and adaptive behavior become more important to the worker. More specifically, h^* increases as the value c assiciated with the learning process increases, that is, $\partial h^*/\partial c > 0$. In addition, as the tightness of the worker's prior increases, the informational value of his on-the-job experiences declines, thus lowering the critical h^* value, or $\partial h^*/\partial \gamma_2 < 0$.

Similar considerations affect the choice of the wage structure in other situations. Consider a second case in which TWS2 and TWS3 can serve as self-selection mechanisms, but WS1 will not because Type 1 workers have a lower reservation wage when a time-invariant wage structure is employed. Choice between TWS2 and TWS3 is still dictated by whether equation (28) is satisfied.

To assess whether it is worthwhile for the firm to screen out the high quit Type 1 workers, one must first ascertain the cost of WS1. This value is given by

$$C(\text{WS } 1^*) = h + b(1 - p_1)h + (1 + bp_1)w + b(1 - p_1)(w_o - p_2 c),$$

where w is the value for a Type 1 worker under WS1 and $b(1-p_1)h$ is the discounted expected period 2 turnover cost. As before, $p_2 > p_1$ so that any worker who has quit will be replaced by a Type 2 worker.

The condition that $C(\text{TWS2}^*)$ be less than $C(\text{WS1}^*)$ can be simplified to the requirement that

$$h > \frac{c}{b(p_2 - p_1)} [p_1 + bp_2 + bp_1 p_1(1, 0) - p_2 - bp_2 p_2(1, 0) - bp_1 p_2] = h^{**}. \tag{29}$$

The critical turnover cost level h^{**} increases with the value c associated with worker learning. Moreover, the h^{**} required to self-select Type 2 workers instead of hiring the lower wage, higher quit Type 1 workers decreases as prior information possessed by Type 1 workers rises (i.e., $\partial h^{**}/\partial \gamma_1 < 0$) and is an increasing function of the prior information possessed by Type 2 workers (i.e., $\partial h^{**}/\partial \gamma_2 > 0$). Unlike the case of h^*, the value of the learning for both Type 1 and Type 2 workers must be considered.

A common property of the h^* and h^{**} results is that the critical h level for switching to a lower turnover wage policy increases both with the value of c of the learning process and with the informational content of on-the-job experiences for workers under the alternative higher turnover option.

5. CONCLUSION

Temporal variations in the wage structure will be of substantial importance in situations in which worker quitting is generated by an adaptive process in which workers learn about the properties of the job. Even if turnover is costless, the firm may find it desirable to raise the initial wage rate to lead workers to experiment with jobs in instances in which workers' priors are overly pessimistic.

Once turnover costs and differences in workers' prior beliefs are introduced, temporal wage structures assume an additional role as self-selection mechanisms to attract more stable employees. Due to workers' systematic preference for dimly understood jobs associated with loose priors, it will not always be possible to self-select only the low quit workers. If this were not the case, one would be forced to reconcile the self-selection result with previous findings regarding the empirical importance of learning-induced quits.

Nevertheless, temporal wage structures are likely to be instrumental as a self-selection mechanism even though they do not always serve as a perfect self-selection device. Whether the objective is to eliminate worker quitting or to attract workers less likely to quit, a temporal wage structure will be effective in a broader range of situations than will a time-invariant wage. Moreover, a temporal wage structure that is an increasing function of worker experience with the firm will be the least costly means of eliminating worker quitting.

The desirability of utilizing the wage structure as a self-selection device depends on the level of the hiring and training costs, as in earlier analyses of self-selection mechanisms. The level of turnover costs needed to justify the use of a self-selection mechanism increases with the value of workers' process of learning about different jobs. When the discrepancy c between the value of different possible job outcomes is large or the precision γ of workers' priors is low, the benefits of adaptive behavior will be particularly great. In these instances, the hiring and training costs must be particularly large for the firm to find it desirable to eliminate this behavior.

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