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SPECIFIC INFORMATION, GENERAL INFORMATION, AND EMPLOYMENT MATCHES UNDER UNCERTAINITY

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Specific Information, General Information, and Employment Matches under Uncertainty

ABSTRACT

Employment matches under uncertainty are typically accompanied by opportunities for information acquisition. Workers can acquire specific information about productivity lotteries at the firm or general information affecting their probabilistic beliefs about work elsewhere. Enterprises can acquire specific information concerning the productivity of a particular worker or general information about different groups of workers in a production process. In all cases, the market equilibrium with flexible wages is efficient. Moreover, there is no opportunity for strategic behavior that would alter this result. Both forms of information are associated with rising earnings profiles over time, but the steepness is greater in the general case. The negative turnover-wage relation is attributable in part to the lower match termination rate of workers with productive job histories, who earn higher wages than their less productive counterparts. General information is associated with more termination of employment matches by employers and employees than is specific information. The implications of specific/general information for matching processes in many respects parallel the role of that distinction in human capital theory, strengthening the link between matching theories and earlier human capital analyses.

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I. INTRODUCTION

The major post-school investment in individuals' productivity is through worker training. Specific training affects the worker's firm-specific skills, while general training also alters his productivity elsewhere. As the human capital literature of the past two decades has shown, many important employment patterns are consistent with the theory's predictions.[1]

Both forms of training are associated with higher post-training wages, but the extent of the wage increase is greater for general training since these workers are paid their post-training marginal product. The age-earnings profile for generally trained workers is also steepened by the foregone earnings during the initial training period. Training also influences worker turnover, as a larger specific training component will diminish such job changing.

Although this theory has been largely developed in terms of explicit training programs involving direct training costs, the possibility of learning-by-doing as part of a general production process is not ruled out.[2] What is essential is that worker productivity actually increase as a result of some activity at the firm.

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[1]The rather voluminous literature dealing with these patterns includes: Becker (1964), Ben-Porath (1970) Lazear (1976), Mincer (1974), Mincer and Jovanovic (1979), Oi (1962), Parsons (1972), Pencavel (1972), Reder (1962), and Rosen (1972a,b).

[2]The notion of learning-by-doing, which was first analyzed by Arrow (1962), is considered for the training case by Rosen (1972a,b).

A considerable, more recent literature has addressed the properties of marriage and other economic matches in general[3], employment matches with worker search[4], and employment matches with joint learning by firms and workers.[5] The focus here will be on those economic matches formed with imperfect information about the attractiveness of the match, but in which there is the opportunity for resolving this uncertainty through one's experiences. Matches that turn out to be successful have a higher total value, where the rent associated with the relationship may be referred to as the specific capital of the match.

Despite the similarity in terminology, quite different economic processes may be at work in the specific training and general matching problems. Specific human capital investment involves a change in worker productivity that typically takes place in a known environment. In the stochastic matching problem, one can view the worker's productivity at the firm as a lottery on n states of the world, each of which has an associated productivity.[6] The matching process consists of forming judgments about the true state of the world and continuing only employment relationships that are believed to be productive. The worker's state-specific productivity remains unaltered.

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[3]See, particularly, Becker (1974) and Becker, Landes, and Michael (1977).

[4]Analyses by Mortensen (1978,1979), Jovanovic (1979a), and Viscusi (1979c) are primarily of this type.

[5]Studies in this vein include those by Jovanovic (1979b) and Viscusi (1979a,b and forthcoming a,b).

[6]Although I focus on the pure matching model, the mixed case in which better matched workers receive more training is also quite important.

The focus of this paper will be on pure matching models under uncertainty. Within the context of this framework, I will introduce the possibility of specific information and general information that may alter the probabilistic beliefs of firms and workers. Despite the differences in the substantive aspects of human capital investments and pure learning processes, there are striking parallels in the theories. Specific and general information acquisition have implications for worker wages and turnover that are in many respects quite similar to the role of specific and general training. These findings suggest that the most fundamental, generalizable aspect of the human capital training theory involves the specific/general distinction rather than the actual nature of the productivity-enhancing process.

The analysis presented here will consider specific information acquisition by firms and workers in Section II, general learning by workers with specific information acquisition firms in Section III, and general learning by firms with specific and general worker information in Section IV. The role of general information acquisition by firms is perhaps most novel since it has no counterpart in traditional human capital theory and has not been considered by analysts of employment matches under uncertainty.[7] For each of these types of employment relationships, I will assess the efficiency of competitive outcomes, the wage structures that will result, and the turnover properties associated with the match. Section V outlines the broader ramifications of the theory.

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[7]A less complete analysis of general learning by workers appears in Chapter 4 of Viscusi (1979a).

II. SPECIFIC INFORMATION ACQUISITION

A. Wage Determination

Consider the following two-period situation.[8] In each period, there is a lottery on whether the worker will be productive, with output of y, or unproductive, with output y - x. The employer's prior probability that the worker will be productive in the first period is q. Firms and workers do not begin with perfect information but instead learn about the properties of the match based on the initial period outcomes. I will assume that the productivity lotteries can be viewed as independent Bernoulli trials where these probabilities are updated in Bayesian fashion. The firm's posterior probabilities of successful outcomes (output y) are q^* following a success in period 1, and q^- following an unsuccessful outcome, where

$$q^* > q > q^- \quad .[9]$$

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[8] Issues explicitly related to models with more than two periods, such as the tenure-turnover relation, are excluded. I consider those issues using models akin to those presented here in Viscusi, (1979a,b,c). Also see Jovanovic (1979b) and Mincer and Jovanovic (1979) for analysis along these lines.

[9] Thus, prior probability distributions with one-point measure are ruled out as uninteresting. Workers may acquire either partial or perfect information in period 1. The updating process is considered with illustrative examples in Sections IID and IVA. Both firms and workers are engaged in a two-armed bandit problem. See Berry (1972) for an extensive treatment of the underlying mathematics.

The judgments of a representative worker are defined analogously and indicated by p, p^*, and $\bar{p}$, where

$$p^* > p > \bar{p} .$$

Although p and q values will often be assumed to be equal so as to abstract from complications arising from worker misperceptions, many of the findings are unaffected by differences in probabilistic beliefs so no restrictions will be imposed at the outset.

Workers also have an interest in the job lottery outcome since they suffer a wage loss (or foregone bonus) of c, where

$$0 < c \leq x .$$

Nonzero values of c are utilized to promote some worker sorting, but c cannot exceed x or the company could potentially profit from unproductive job outcomes, creating an adverse incentives problem. Alternatively, the analysis below could be developed assuming fixed output (x = 0) but differences in productive effort (c > 0) when the unproductive state occurs. Such an analysis could also include nonpecuniary rewards in general. The broad implications of the theory would be unaffected by this modification.

The representative worker has a reservation wage rate w_0. The interest rate r leads to a discount factor b for firms and workers given by 1/(1+r). Let w_1 be the wage required if the firm does not terminate the employment relationship after a successful period 1 outcome. Then w_1 must satisfy

$$w_0(1+b) = w_1-(1-p)c + bp\ \text{Max}[w_1-(1-p^*)c, w_0] + b(1-p)\ \text{Max}[w_1-(1-\bar{p})c, w_0] \ .$$

For this class of job choice problems, it can be shown (see Viscusi (1979a)) that the lowest reservation wage is associated with the employment strategy of staying with the job after a successful outcome and leaving after an unsuccessful outcome since the job is less attractive in the latter instance. An offer by the firm to let the worker remain after an unfavorable period 1 outcome consequently does not affect w_1.

The discounted reservation wage is now equal to

$$w_0 + bw_0 = w_1-(1-p)c + bp[w_1-(1-p^*)c] + b(1-p)w_0,$$

or

$$(1) \qquad w_1 = w_0 + c\left[\frac{(1-p)+ bp(1-p^*)}{1+bp}\right]$$

Let w_2 indicate the wage the company must pay if it fires the worker after a successful period 1 outcome.[10] Then the employment choice is analogous to a single period decision where

$$(2) \qquad w_2 = w_0 + c(1-p) \ .$$

The expected wage net of incentive pay is w_0. Since $p^* > p$, the firm benefits by offering workers the opportunity to continue successful matches since

$$(3) \qquad w_1 < w_2 \ ,$$

as one can verify. For the remainder of Section II, equation 3

[10] The enterprise's policy after an unfavorable outcome is irrelevant in analyzing the reservation wage since the worker will never wish to remain on the job in this instance.

summarizes most of what we need to know about the wage structure.

B. Worker Preferences

Once a match is formed, each party has four possible choices at the start of period 2:

1. Continue the match regardless,
2. Terminate the match regardless,
3. Continue the match only if the period 1 outcome is successful, and
4. Continue the match only if the period 1 outcome is unsuccessful.

The worker views the wage rate as independent of his own actions. For enterprise employment policies 1 and 3 above, the wage is w_1 from equation 1, while employment policies 2 and 4 are associated with w_2 from equation 2. Using these wage rates and the other characteristics of the employment problem, the worker calculates the value u_{ij} of different choices by himself and the firm, where i indexes the worker's decision, j indexes the firm's decision, and i and j range from 1 to 4, as above.

For enterprise employment possibilities 1 and 3, there are four possible outcomes. First, the worker could remain at the firm for both periods, yielding

$$u_{11} = (1+b)[w_1-(1-p)c].^{11}$$

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[11] It is well known that the mean value of the prior is all that is of consequence if there is no change in the lottery in which the individual is engaged. Only if there is some job changing are p^* and $\bar{p}$ consequential.

Second, the worker could leave the job after period 1, regardless of the job outcome. This behavior characterizes u_{21}, u_{23}, and u_{43}, which consequently have identical values, where

$$u_{21} = w_1 - (1-p)c + bw_0 .$$

Third, the worker could remain on the job only following a productive period 1 outcome as with u_{31}, u_{33}, and u_{13}. Each of these values equal

$$u_{31} = w_1 - (1-p)c + bp[w_1 - (1-p^*)c] + b(1-p)w_0 .$$

Finally, the worker could remain on the job only after an unfavorable period 1 outcome, yielding

$$u_{41} = w_1 - (1-p)c + b(1-p)[w_1 - (1-\bar{p})c] + bpw_0 .$$

Upon substituting for the value of w_1 from equation 1, one can determine that

$$u_{31} > u_{21} > u_{11} > u_{41} .$$

The relative rank of these outcomes will be indicated by 1,2,3, and 4, where lower-numbered values are preferred. The optimal behavior involves continuation after the job only after a successful period 1 outcome.

Let u'_{ij} indicate the value associated with u_{ij} except that w_1 is replaced by w_2. Then the utility values associated with employment policies 2 and 4 are analogous to earlier values, where

(4) $$u'_{21} = u_{12} = u_{22} = u_{32} = u_{42} = u_{24} = u_{34} ,$$

and

(5) $$u'_{41} = u_{14} = u_{44} .$$

Since $u'_{21} > u'_{41}$, the relative ranking of the values given in equation 4 will be indicated by 2', while those in equation 5 will be 4'. The utility values ranked 2' and 4' are preferred to those ranked 2 and 4, respectively, since in each case the primed terms are associated with the same employment path and a higher wage rate. There will be no need in the subsequent analysis, however, to compare the primed and unprimed rankings.

C. Profit Values

The discounted expected profits π_{ij} associated with action i by the worker and policy j for the firm can be determined similarly. For simplicity, π_{ij} will be calculated per discounted expected employee at the firm, facilitating comparison of the profit values.[12] Enterprise policies 1 and 3 can have three possible values. If the employment match always continues in period 2 or always terminates after the initial period, then the profit/worker is given by

$$\pi_{11} = y - (1-q)x - [w_1 - (1-q)c] ,$$

where π_{11}, π_{21}, π_{23}, and π_{43} are identical. Matches that continue following a successful period 1 outcome (π_{31},π_{33}, and π_{13}) have a value

$$\pi_{31} = y - w_1 - \frac{(1-q)(x-c) + bq(1-q^*)(x-c)}{1+bq} .$$

[12]Calculation of two-period profit levels is somewhat sensitive to the assumption made about the wage paid to new workers in period 2 (w_1 or w_2), but the equilibrium outcome is not. The procedure followed here seemed best suited to putting the alternative π_{ij} values on a comparable basis.

Continuation of only matches with an unfavorable outcome have a value π_{41} given by

$$\pi_{41} = y - w_1 - \frac{(x-c)(1-q)[1+b(1-\bar{q})]}{1+b(1-q)}.$$

The relative ranking of the profit levels depends only on the expected output levels since the wage costs are identical, so that one obtains

$$\pi_{31} > \pi_{11} > \pi_{41},$$

which will be indicated by the rank 1,2, and 3, respectively. The highest profit level is associated with retention of workers with successful period 1 outcomes.

Employment policies 2 and 4 impose wage costs w_2 but otherwise are analogous to earlier profit values since they share the same turnover properties. Following the same notational convention as with utility functions, one has that

(6) $$\pi'_{11} = \pi_{12} = \pi_{22} = \pi_{32} = \pi_{42} = \pi_{24} = \pi_{34},$$

and

(7) $$\pi'_{41} = \pi_{14} = \pi_{44}.$$

Since $\pi'_{11} > \pi'_{41}$, the relative value of the π_{ij} terms in equation 6 will be indicated by 2', while those in equation 7 will be designated 4', since $\pi'_{11} > \pi'_{41}$. Since the π'_{ij} values are associated with the same output and a higher wage rate than their π_{ij} counterparts, the values ranked 2' and 4' rank below 2 and 4, respectively. No further description of the rankings is required for the analysis below.

FIGURE I

SPECIFIC INFORMATION AND PAYOFFS

TO THE WORKER AND FIRM

Worker Strategies

1. Continue Regardless
2. Terminate Regardless
3. Continue if Success
4. Continue if Failure

Enterprise Strategies

	1	2	3	4
1	3, 2	2', 2'	1, 1	4', 3'
2	2, 2	2', 2'	2, 2	2', 2'
3	1, 1	2', 2'	1, 1	2', 2'
4	4, 3	2', 2'	2, 2	4', 3'

D. Market Outcomes

Both the firm and the worker have 4 possible turnover strategies to choose from, generating 16 possible market outcomes. The payoffs to the parties are summarized in the game matrix in Figure I, where payoffs to the worker are in the upper left corners and those to the firm are in the lower right corners.

Consider first the choice by the worker. The relative ranking of the u_{ij} versus u'_{ij} terms is not consequential since it affects comparisons across different columns, not the choice of the row by the worker. Row 3 is the dominant strategy for the worker since it offers the highest payoff for each possible strategy by the firm. Similarly, column 3 is the dominant strategy for the firm, producing a stable, cooperative equilibrium at (3,3), where each party continues the match only if the worker is productive in period 1.

This outcome is considerably stronger than a Nash equilibrium. Each party receives its highest valued reward. There is no incentive to behave otherwise, nor would either party alter its behavior in response to such strategic efforts. The sequence of moves is irrelevant, as is the possibility to pre-commit oneself to a strategy as, for example, the enterprise might do by adopting a predetermined employment policy.

The turnover characteristics of the equilibrium associated with specific information are that successfully matched workers continue the relationship while those with a low productivity lottery outcome terminate the relationship. Specific information promotes the stability of successful matches. Section III will address the issue of whether specific or

general information is more conducive to worker turnover.

In assessing the economic efficiency of the outcome, the level of the wage payments is irrelevant since they involve transfers between the parties that net out in the social welfare calculation. The equilibrium behavior will lead to maximization of discounted expected output so that the specific information competitive equilibrium will be efficient.[13]

The magnitude of the gain associated with the policy of terminating unsuccessfully matched workers increases with the extent of the updating of the probability (q^* or p^*) after a favorable outcome. Loose prior probability assessments are preferred, for any mean value of the prior, since they are updated more.

Consider, for example, the beta distribution $\beta(\gamma, q)$ of priors parameterized so that q is the mean value of the prior and γ is a measure of its tightness.[14] Then after m successess and n failures in a sequence of independent Bernoulli trials, the posterior probability of a success is $(\gamma q+m)/(\gamma+m+n)$. The value of q^* consequently is $(\gamma q+1)/(\gamma+1)$, while q^- is $(\gamma q)/(\gamma+1)$, so that

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

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[13] Efficiency is judged based on the expectations using the employer's probabilistic beliefs. Clearly, if these perceptions are systematically wrong, the outcome may not be efficient. Expected output levels with imperfect information never exceed those with perfect information when evaluated using the true probabilities.

[14] As Raiffa and Schlaifer (1961) emphasize, the beta distribution is ideally suited to analysis of Bernoulli-type trials and has properties superior to the normal distribution in such instances.

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. This preference for uncertainty does not hinge on the risk neutrality of workers.[15]

Consider the expected wage levels of workers during their tenure at the firm. In period 1, the expected wage is

$$w_1 - (1-p)c = w_0 + c\left[\frac{bp(p-p^*)}{1+bp}\right] ,$$

while in period 2 the expected wage assuming the worker remains at the firm is

$$w_1 - (1-p^*)c = w_0 + \frac{c(p^*-p)}{1+bp} .$$

The worker's wage rises over time as he receives an expected wage below w_0 in period 1 and above w_0 in period 2. The period 2 wage gain following a success is greater than the period 1 loss both because of the role of discounting and the belief that there will only be a probability p that the wage gain will occur.

The company has no incentive to renege on the offered wage contract. If this possibility were perceived, company profits would be π_{32}, which

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[15]The case of risk-averse workers is considered in Viscusi (1979a, forthcoming-a).

is below π_{33}. If the termination policy were not perceived by workers, the firm's profits would be the same as π_{21}, which is also below π_{33}. In short, the turnover properties and incentives to alter behavior over time have been included as endogenous elements of the model and involve no additional behavioral stipulations.

These findings also suggest that the observed negative wage-turnover relation may not be simply due to the compensating differential situation in which members of a homogeneous group of workersquit if the wage is insufficient. The negative relation between the observed period 1 wage and turnover reflects the fact that poorly matched workers earn lower wages and are more likely to quit than are successfully matched workers. This property holds for all models considered in subsequent sections as well. The negative turnover-wage relation is an endogenously determined aspect of matching processes with imperfect information.

Although the particular wage level does not affect the specific information equilibrium[16], the competitive firm will set the wage level for the marginal worker using equation 1, appropriating all of the surplus associated with training.[17] The worker has no incentive to take retaliatory action such as quitting, nor will he have any effective means of doing so. Market competition is assumed to drive any profits reaped by the company to zero, although this property is not required for any of the results here.

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[16]This assumes of course that some worker does not earn such a great rent from the job that he remains after an unfavorable period 1 experience.

[17]This statement pertains to the marginal worker. Infra-marginal workers may, of course, reap a surplus.

III. GENERAL WORKER INFORMATION AND SPECIFIC INFORMATION FOR ENTERPRISES

A. Outcomes with No Wage Policy Changes

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.[18] This generality is of no direct consequence to the firm, which continues to engage in specific information acquisition.

Following an unfavorable job outcome, the worker can still pursue his null alternative w_0. Following 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 $w_s > w_0$.[19] Since the possibility of remaining on the uncertain job after an unfavorable outcome remains a dominated alternative, general information introduces a fifth worker strategy -- choosing the null alternative (w_0) after an unfavorable outcome and switching to the independent uncertain job offering w_s after a success.

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[18] In the general information case, if experiences on one job affect the probabilistic beliefs on the other position, then interdependence is mutual. Selecting one position as the initial job is completely arbitrary.

[19] For simplicity, I have replaced complete specification of the component terms of that lottery by its expectation w_s.

FIGURE II

GENERAL WORKER INFORMATION

AND PAYOFFS TO THE WORKER AND FIRM

Worker Strategies

1. Continue Regardless
2. Terminate Regardless
3. Continue if Success
4. Continue if Failure
5. Switch to w_s if Success, w_0 if Failure

Enterprise Strategies

	1	2	3	4
1	3, 2	2', 2'	1, 1	4', 3'
2	2, 2	2', 2'	2, 2	2', 2'
3	1, 1	2', 2'	1, 1	2', 2'
4	4, 3	2', 2'	2, 2	4', 3'
5	0, 2	0', 2'	0, 2	0', 2'

The associated discounted expected utility values are

$$u_{51} = u_{53} = w_1 - (1-p)c + bpw_s + b(1-p)w_0 ,$$

and

$$u'_{51} = u_{52} = u_{54} .$$

If $u_{33} > u_{51}$, the problem reduces to that of Section II. This would occur if the firm-specific learning is more valuable to the worker, or

$$w_1 - (1-p^*)c > w_s .$$

If the inequality is reversed, the two highest ranked outcomes by the worker are u'_{51}, indicated by rank 0', and u_{51}, indicated by rank 0, where 0 > 1. The latter case will be considered here.

General information acquisition by the worker that leads to certain worker turnover simply transforms the situation into a dominated case considered earlier, where

$$\pi_{51} = \pi_{53} = \pi_{11} ,$$

and

$$\pi_{52} = \pi_{54} = \pi'_{11} .$$

Figure II presents the expanded payoff matrix for this game. The worker will adopt his dominant strategy 5, which is the only turnover path that offers the possibility of either of his two most highly valued rewards. Strategy 3 remains dominant for the firm. As before, the order of moves and strategic behavior is irrelevant, as the stable equilibrium is necessarily (5,3).

An important issue is whether this equilibrium is efficient. Since the wage payments remain simply transfers, the problem is whether the expected product has been maximized. A competitive market will set w_s equal to the worker's expected general output so that the decision to switch firms after a successful outcome will be efficient if the profit to the firm if the worker did not quit plus the opportunity cost of a replacement (w_0) is below w_s plus the expected product of a replacement. This condition reduces to

$$w_s > w_0 + x(q^*-q) ,$$

or

$$w_s - w_0 > x(q^*-q) . \tag{8}$$

If one sets p equal to q and p^* equal to q^* to abstract from problems of differing probabilistic beliefs, the worker will choose to quit following a period 1 success if

$$w_s - w_0 > \frac{c(q^*-q)}{1+bq} . \tag{9}$$

Even if c is set at its maximum value (c=x) that fully reflects the worker's productivity, the right-hand term in equation 9 will be smaller than in equation 8. There will be too much turnover and a bias toward opportunities elsewhere if the wage structure remains the same as in the specific information case. The difficulty lies in the denominator of equation 9, or the fact that the base wage rate is the same in each period and is not manipulated to reflect the worker's changing opportunities. The next two sections will explore alternative wage mechanisms.

B. Contract Termination Fees

If workers acquire general information and their period 2 productivity is always greater elsewhere after a success, a simple solution would be to hire workers for a single period only and lower the initial wage rate to keep the workers at their reservation wage level in view of their improved opportunities. While efficient, if the worker's productivity is greater elsewhere, this situation is not particularly interesting since it provides no mechanism that assures that job allocations will be efficient for different relative productivity levels.

The first possible mechanism that will take such ramifications into account is to charge all workers a contract termination fee f. Workers with a period 1 successful outcome will stay if

$$w_s - f < w - (1-p^*)c \ ,$$

or

$$f > w_s - [w - (1-p^*)c] \ , \tag{10}$$

while those with unfavorable outcomes will quit if

$$w_0 - f > w - (1-\bar{p})c \ ,$$

or

$$f < w_0 - [w - (1-\bar{p})c] \ . \tag{11}$$

I will assume equation 11 is satisfied and that equation 10 is potentially satisfied or else the highest attainable profit will be π_{11}, which is

below π_{33}. Workers with low period 1 productivity consequently leave the firm.[20]

The firm sets its reservation wage w such that

$$(12) \qquad w_0 + bw_0 = w - (1-p)c + bp\ \text{Max}[w_s - f,\ w - (1-p^*)c] + b(1-p)(w_0-f) \ .$$

Two situations must be considered: a) the worker switches to w_s following a successful period 1 outcome and b) the worker remains at the firm following a successful outcome. The firm can select either of these situations by manipulating f.

Using equation 12, one can solve for the respective wage rates in each of these situations, yielding

$$w_a = w_0 + bf + (1-p)c - bp(w_s-w_0) \ ,$$

and

$$w_b = w_0 + \frac{b(1-p)f}{1+bp} + c[\frac{(1-p) + bp(1-p^*)c}{1+bp}] \ .$$

The worker is unaffected by increases in f because his wages increase accordingly.

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[20] Alternatively, the firm could avoid these complications by imposing f only if a worker terminates a match with a successful outcome. This modification would alter the wage level but leave the equilibrium outcome and its properties unaffected. The change would, however, raise the practical issue of whether the worker and employer could agree on the period 1 outcome if the worker were to be penalized on the basis of that judgment.

The profits over two periods[21] for each policy are given by

$$\pi_a = y - (1-q)x + (1-q)c - w_a + bf + b[y - (1-q)x - w_0],$$

and

$$\pi_b = y - (1-q)x + (1-q)c - w_b + bq[y - (1-q^*)x + (1-q^*)c - w_b] + b(1-q)[y - (1-q)x - w_0 + f] .$$

Substituting for w_a and w_b and ignoring possible differences in the probabilistic beliefs of the worker and firm (i.e., setting $p = q$, $p^* = q^*$), one finds that π_a exceeds π_b if

$$w_s - w_0 > x[q^* - q] ,$$

and conversely. The choice of whether to retain the worker or not using f coincides with the efficiency criterion outlined above in equation 8. The particular level of f is irrelevant, provided that equation 11 is satisfied and the f value yields the desired turnover properties for π_a and π_b, as determined using equation 10. The use of the f mechanisms raises period 1 wages and lowers expected period 2 rewards for workers.

Although efficient, fees for contract termination are difficult to enforce since the worker has no incentive to reimburse the firm after he leaves. Imperfectly portable or not fully vested pension plans can serve

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[21] Unlike the specific information case, it is not appropriate to look at profits on a discounted worker basis for employment paths. That approach would be biased in favor of general information, whose gains would appear to be reaped in every period through lower wages, whereas specific information only offers deferred rewards. In reality, the time lags for each are identical.

this function to the extent that the worker loses his benefit rights when he leaves the firm. Recent pension regulations (ERISA) limit the use of pensions as a mobility-reducing instrument by imposing minimal standards on pension benefit transferability.

C. The Optimal Wage Structure

A more viable alternative to contract termination fees is a temporal variation in the wage structure. Suppose that the worker would quit in period 2 if w_1 were offered or else the problem is not particularly interesting.[22] The minimal period 2 wage that will keep the worker following a favorable period 1 outcome is w_β, where

$$w_s = w_\beta - (1-p^*)c \ , \tag{13}$$

or

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

As before, the worker finds it optimal to quit following an unfavorable outcome, as does the company.

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 13 will be satisfied. The lowest first-period wage w_α that will attract the worker to the firm consequently satisfies

$$w_0 + bw_0 = w_\alpha - (1-p)c + bpw_s + b(1-p)w_0 \ ,$$

or

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

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[22] The problem then is the same as that in Section II.

The 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.[23] 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

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

where w_s is the net expected wage from equation 13 ($w_\beta - (1-p^*)c$), assuming p^* and q^* coincide. The value of discontinuing the match and hiring a new worker for one period is π_d, where

$$\pi_d = y - x(1-q) - w_2 + (1-p)c = y - x(1-q) - w_0 ,$$

assuming p equals q. The firm will continue the match ($\pi_c > \pi_d$) provided that

$$x(q^*-q) > w_s - w_0 .$$

This criterion coincides with the efficiency criterion in equation 8. Employment matches are continued only if the expected productivity at the firm is greater than the worker's productivity elsewhere.

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. The expected period 2 wage following a success is always w_s whether the

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[23] In either case, workers are assumed to know this wage structure in advance.

firm adopts π_c or π_d. The period 2 wage after an unfavorable outcome is w_0, as before.

D. Implications of General Information

General information acquisition steepens the age-earnings profile more than would the specific information component of the process. Whenever the temporal wage structure is adopted, as is optimal when workers quit successful matches when w_1 is offered, there is a reduction in the period 1 wage and an increase in the expected period 2 reward. The resulting equilibrium is efficient if the wage structure is varied in this manner. Contract termination fees, if feasible, also would be efficient.

As with specific learning, the experimentation process offers greater expected gains the more one's prior beliefs are updated after a successful outcome. Both types of information lead to termination of the employment relationship after an unfavorable outcome, producing a negative wage-turnover relationship. A productive work experience, however, will always lead to continued employment with specific information, but will only result in a continued relationship in the general case if the worker is more productive at the firm than he is elsewhere. The turnover rate associated with general information acquisition will exceed that for specific information. Both the wage structure and turnover properties of general information are similar in many respects to those for general training.

IV. GENERAL INFORMATION FOR THE FIRM

A. Specific Information for Workers

Thus far, workers have been viewed as acquiring information about

their productivity at the firm and elsewhere, while firms are only concerned with the worker's firm-specific productivity and any change in the worker's reservation wage that results from general information. However, the firm may also be engaged in a form of general information acquisition in which it learns not simply about the productivity of a particular worker or class of workers, but he also updates his judgments regarding the productivity of other groups of workers in that employment situation. The enterprise may, for example, be resolving uncertainty about a production process. If high school educated workers always meet a production quota, one might infer that the expected productivity of less educated workers might be sufficient to warrant some lowering of the educational standard.

Suppose that there are two types of workers, types 1 and 2, each of which have the same reservation wage rates w_0. Within each group, the workers are identical. The firm assesses the prior probability that a member of group i will be productive as q_i. Experiences of each class of worker influence the posterior probability assessment for each group since the probabilistic beliefs are assumed to be interdependent. The firm must choose which class of worker to hire in each period, where one worker is hired in each period.[23] The expected output in a period using type i worker after observing c_1 successful outcomes for type 1 workers, c_2 unsuccessful outcomes for type 1 workers, c_3 successful outcomes for type 2 workers,

[23] As examination of the analysis below will indicate, the implications of the model are equally applicable to hiring N workers consisting of a mix of type 1 and 2 workers in each period.

TABLE I

DATA FOR GENERAL LEARNING PROBLEM

	State of World	
	θ_1	θ_2
State Probability	.1	.9
Type 1 Worker's Probability of Success	.8	.1
Type 2 Worker's Probability of Success	1	0

and c_4 unsuccessful outcomes for type 2 workers will be indicated by $E_i(c_1,c_2,c_3,c_4)$. The optimal turnover policy for the firm is assumed to be known to workers and their probabilistic beliefs are assumed to be accurate (i.e., $p_i = q_i$, $p_i^* = q_i^*$) so that expected net wage payments in each period are w_0 in this situation of specific worker information.

The firm's decision problem is to choose which type of worker to hire in each period, or to optimize

$$\begin{aligned}\pi = \text{Max}\{&[E_1(0,0,0,0) + bq_1\text{Max}[E_1(1,0,0,0),\ E_2(1,0,0,0)] \\ &+ b(1-q)\text{Max}[E_1(0,1,0,0),\ E_2(0,1,0,0)], \\ &E_2(0,0,0,0) + bq_2\text{Max}[E_1(0,0,1,0),\ E_2(0,0,1,0)] \\ &+ b(1-q_2)\text{Max}[E_1(0,0,0,1),\ E_2(0,0,0,1)] - w_0 - bw_0 .\end{aligned}$$

Since the wage costs are predetermined and reflect the worker's general productivity, the maximization of π simply maximizes discounted expected output. Profit maximization and social welfare maximization coincide. As in the case of general information for workers, general learning by firms may lead to termination of an employment relationship that was successful in period 1.

This possibility and the underlying motivation for the above model can be illustrated further with the following example. Since wage costs are identical for all possible options, they will be ignored. Moreover, the interest rate r will be set equal to zero, resulting in a b value of 1. Output y for a productive match is 1 and for an unproductive match is 0 (i.e., x = 1).

Table I summarizes the probabilistic structure of the problem.

Suppose there are two possible states of the world, Θ_1 and Θ_2. There is a .1 probability that Θ_1 pertains and a .9 probability that Θ_2 is the actual state. In Θ_1 type 1 workers have a .8 probability of being productive while type 2 workers always produce y equal to 1. In state Θ_2 type 2 workers are always unproductive and type 1 workers have a .1 chance of being productive. The issue is to select the optimal employment sequence.

Before doing so, one needs two additional sets of information. The expected probabilities of each group being productive in period 1 can be readily calculated from the data in Table I, implying that q_1 is .17 and q_2 is .1. The posterior probabilities of being productive hinge on the first period outcome. Since there is only one trial, there will be no ambiquity in letting $P(\Theta_i|c_j = 1)$ denote the conditional probability that Θ_i is the state after observing c_j value of 1 where all of the other c_k terms ($k \neq j$) equal 0. Using Bayes' Theorem, one can calculate $P(\Theta_1|c_1)$ as

$$P(\Theta_1|c_1) = \frac{P(c_1|\Theta_1)P(\Theta_1)}{P(c_1|\Theta_1)P(\Theta_1) + P(c_1|\Theta_2)P(\Theta_2)} = \frac{.8(.1)}{.8(.1) + .1(.9)} = .47 .$$

In similar fashion, one finds the $P(\Theta_1|c_2)$ equals .02, $P(\Theta_1|c_3)$ equals 1, and $P(\Theta_1|c_4)$ equals zero.

The value of π given the numerical values above and ignoring w_0 is

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

The optimal sequence of decisions is to hire a type 1 worker in period 1, switch to a type 2 worker after a favorable period 1 outcome (c_1), and continue to hire type 1 workers if the period 1 outcome is unfavorable (c_2).

Initial experimentation with type 1 workers is preferred because they offer sufficiently greater expected initial productivity. However, a successful outcome raises the conditional probability of θ_1 sufficiently so that type 2 workers become more attractive. As was indicated above, general information by the firm may lead to termination of employment matches after successful productive efforts, whereas specific information never has this effect.

B. General Information for Both Parties

Suppose that the firm is engaged in the acquisition of information that affects its general probabilistic beliefs regarding both classes of workers, while the workers are also engaged in a general information acquisition process. Following a period 1 success, type 1 workers can earn an expected wage w_{s1} elsewhere while type 2 workers can earn w_{s2}. The firm has no incentive to keep any particular worker or to fire unproductive workers since its learning is about classes of worker types not specific individuals. Assuming the worker and employer probabilistic beliefs coincide, the expected net period 2 wage rate will be w_0. In period 1, the job offers workers the chance for general information and a higher period 2 wage elsewhere, producing a net wage rate of $w_0 - bq_1(w_{s1}-w_0)$ and $w_0 - bq_2(w_{s2} - w_0)$ for type 1 and 2 workers, respectively.

The wage structure will attract workers, and the turnover properties are irrelevant. What remains an issue is whether the competitive firm's employment policies will be efficient. Using the same notation as in Section IV A, one finds the discounted expected profits are given by

$$\pi = \text{Max}\{E_1(0,0,0,0) - w_0 + bq_1(w_{s1}-w_0) +$$

$$bq_1\text{Max}[E_1(1,0,0,0) - w_0,\ E_2(1,0,0,0) - w_0] +$$

$$b(1-q_1)\text{Max}[E_1(0,1,0,0) - w_0,\ E_2(0,1,0,0) - w_0]\ ,$$

$$E_2(0,0,0,0) - w_0 + bq_2(w_{s2}-w_0) + bq_2\text{Max}$$

$$[E_1(0,0,1,0) - w_0,\ E_2(0,0,1,0) - w_0] +$$

$$d(1-q_2)\text{Max}[E_1(0,0,0,1) - w_0,\ E_2(0,0,0,1) - w_0]\}\ .$$

This expression can be rewritten as

$$\pi = \text{Max}\{E_1(0,0,0,0) + bq_1\text{Max}[E_1(1,0,0,0) + w_{s1} - w_0\ ,$$

$$E_2(1,0,0,0) + w_{s1} - w_0] + b(1-q_1)\text{Max}[E_1(0,1,0,0),$$

$$E_2(0,1,0,0)],\ E_2(0,0,0,0) + bq_2\text{Max}[E_1(0,0,1,0) +$$

$$w_{s2} - w_0,\ E_2(0,0,1,0) + w_{s2} - w_0] +$$

$$b(1-q_2)\text{Max}[E_1(0,0,0,1),\ E_2(0,0,0,1)] - w_0 - bw_0\ .$$

This reformulation highlights the efficiency of the firm's objective. The enterprise maximizes the expected initial product plus the discounted expected period 2 output at the firm and any gain in the worker's productivity (e.g., $w_{s1}-w_0$), less the opportunity cost of labor. As in all of the cases considered thus far, market outcomes will be efficient. The general information situation has the high turnover and steep wage structure that one would expect from a combination of the two general information models.

V. CONCLUSION

For employment matches undertaken with initial uncertainty, one can draw a distinction between general and specific information in much the same manner as the traditional human capital treats specific and general training. For

the worker, specific information only affects his probabilistic beliefs about his productivity at his current place of employment, while general information alters his probabilistic beliefs about work elsewhere. Specific information for the firm influences only its assessment of a particular worker's productivity, whereas with general information the firm in effect learns about the nature of the production process and the productivity of different types of workers.

With wage rates that can vary over time, the competitive equilibrium contracts will result in efficient job allocations and levels of turnover. There is no potential for strategic behavior that would alter this equilibrium outcome. Both general and specific information steepen workers' earnings profiles, though the extent of the increase is greater in the general case. General information also leads to more termination of employment relationships than does specific information. In both types of learning there will be an observed negative relationship between turnover and wages. This relation would hold apart from any compensating differential argument because workers who are unproductive in the initial period earn lower wages and are more likely to switch to an alternative job in the subsequent period.

Throughout the analysis, no explicit training costs were incurred and no changes in productivity took place. What did occur is that information generated by work experiences enabled employers and workers to better identify the true state of the world and to select the optimal match for that state, where all state-specific productivity levels were assumed fixed. The diverse parallels of the specific/general distinction in both the human capital training theory and the employment matching analysis suggest that it is the specific/general

nature of the productivity-enhancing activity which is more important than the features of the process itself. This analysis of general and specific information acquisition also strengthens the conceptual linkage between traditional human capital theory and the more recent theory of marriage and other matching problems.

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