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Source: *The Bell Journal of Economics*, Autumn, 1978, Vol. 9, No. 2 (Autumn, 1978), pp. 572-586

Published by: RAND Corporation

Stable URL: https://www.jstor.org/stable/3003599

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Specific capital and labor turnover

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Turnover characterizes a dynamic process in which job-worker matches are improved. The problem of searching for a preferred partner is formulated as a two-person game played by the worker and the employer involved in an existing match. The Nash noncooperative quit and dismissal rates exceed those associated with the joint wealth maximizing solution in the absence of a provision for compensation. The joint wealth maximizing turnover rates are independent of the wage paid, but the Nash noncooperative rates are not. Recent empirical evidence is not inconsistent with the joint wealth maximizing hypothesis, although a discriminating test is needed.

1. Introduction

■ In a world of heterogeneous workers and jobs, the problem of matching the two in some best way exists. A centralized competitive market sorts workers among jobs in a manner that maximizes aggregate output, appropriately defined, when information about technology and the abilities of individual workers is perfect. When the locations or characteristics of particular jobs and workers are not known, the instantaneous attainment of a solution that is optimal in this sense is not economic. Because it is not in the interest of either the employer or the worker to wait until the best alternative is located, imperfect matches are formed. The existence of better alternatives for both the employer and the worker involved in a job-worker match motivates search by both. A separation at some future date occurs when either the worker or the employer finds a preferable match. Turnover of this type is a characteristic of the dynamic process by which job-worker matches are improved in a decentralized labor market. The purpose of this paper is to present a framework for analyzing the interrelationship between the choices of search strategies by the two parties involved in an existing match and the nature of the wage bargaining problem.

Given imperfect mobility of the kind just described, future streams of quasi-rents accrue to both parties involved in an existing match. The expected present values of these streams are specific human capital measures of the degree to which each party is attached to the match. This observation is the basis for the principal hypothesis of the theory of labor turnover; namely, the probability

While preparing an earlier version of the paper, the author received financial support from the U.S. Department of Labor. This version was partially supported by the National Foundation Grant #SOC-77-08896. Constructive comments from F. Brechling, R. J. Gordon, K. Burdett, and H. Grossman are acknowledged. Responsibility for any remaining errors rests with the author.

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that either party will terminate the match at some future date is a decreasing function of his own share of the specific capital value of the match.[1] This paper challenges the general validity of this proposition on both theoretical and empirical grounds.

The theoretical analysis is based on the following ideas. Given an employment agreement—a definition of the relationship between employer and worker and a specification of the wage—, the problem of choosing search strategies is a two-person game. The solution to each game determines the value of the specified employment agreement to the worker and the employer. In this way sets of feasible and likely outcomes of the bargaining over employment agreements are generated. This approach accounts for the simultaneity between wage determination and search behavior and generates a far richer theory of the employment relationship along the lines suggested by Simon (1951).[2]

In the simple model developed in Section 2, the quit probability and the dismissal probability are related to the search strategies chosen by worker and employer, respectively. In each case the search strategy has two components, a criterion for acceptance of alternative matching opportunities and a measure of search intensity that determines the frequency with which alternatives are located. Search is viewed as a continuous time process of sampling randomly without recall from the distribution of alternative opportunities. Searching more intensely is assumed to be more costly at the margin.[3] The principal results presented in the section follow.

If the employment agreement is simply a specification of the wage rate, then the noncooperative Nash solution of the game of search strategy choice is such that the quit and the dismissal probabilities are, as others have suggested, respectively decreasing functions of the worker's and the employer's shares of the specific capital value of the match.[4] However, this solution does not maximize the sum of the expected wealth of the worker and the employer because neither party, when terminating the match, takes account of the capital loss that his action imposes on the other. The joint wealth maximizing search strategies are such that both turnover probabilities are smaller than those implied by the noncooperative solution to the game, both decline with the total capital value of the match, and neither depends on its division between worker and employer.

Section 3 examines the following question: Does there exist an employment agreement that will induce both the worker and the employer to pursue joint wealth maximizing search behavior? Two simple agreements, neither of which requires direct monitoring of search activities, are studied. The first is the practice sometimes observed of matching the alternative offers obtained by one's partner in the match. The second is an *ex ante* agreement by each party to compensate the other as a precondition for separation. Severance pay requirements and the existence of nonvested pension plans can be interpreted as such schemes. Although the first mechanism does have the property that the non-

[1] The hypothesis is implicit in Oi (1962) and is discussed by Becker (1964) but is stated most explicitly by Parsons (1972). See Parsons (1977) for a recent review of the literature on the specific human capital approach to labor turnover.

[2] Both the approach and the model developed are applicable to other bilateral matching phenomena. The recent analysis of divorce by Becker *et al.* (1977) is very similar in spirit.

[3] The search model used is a generalization of one recently developed by Burdett (1978).

[4] A more general expression of this idea appears in Viscusi (1977).

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cooperative acceptance criterion is the joint wealth maximizing one, each party still has an incentive to search too intensively. However, the noncooperative solution to the game in which contingent compensation is part of the *ex ante* employment agreement is joint wealth maximizing.

The differentiating empirical implication of the joint wealth maximizing hypothesis is that neither the quit probability nor the dismissal probability depends on the division of specific capital between worker and employer. In Section 4 we review the consistency of this implication with the existing empirical evidence, which in its entirety does not contradict the hypothesis.

2. A simple turnover model

■ In this section we formulate a model of joint search for alternatives by the worker and employer involved in an existing match. The model is designed to emphasize the interrelationship between the decisions of the two parties regarding the criterion used for acceptance of alternatives and the resources allocated for finding the alternatives. Formally, this joint decision problem is a continuously repeated two-person nonzero-sum game played throughout the duration of the match. Two standard solution concepts, the Nash noncooperative and the cooperative joint wealth maximizing solutions, appear to have distinguishable empirical implications.

Consider a current match involving two agents who benefit from some form of exchange. Suppose that each can value the future net benefit flows associated with the match as well as those associated with any alternative prospective match. For each agent assume that alternative opportunities randomly arrive at an average rate per unit time that can be controlled at a cost by the agent. Think of each opportunity that does arrive as a random draw from the set of all possible alternatives and assume that each opportunity must either be accepted or rejected on arrival. The match in question survives a short future time interval if and only if no acceptable alternative is received by either agent during the interval. Each agent must decide on the definition of an acceptable alternative and must set the expected rate at which alternatives arrive.

The framework sketched above embodies the idea that neither party knows the location of an alternative that might be preferred to his existing match as well as the notion that the process of locating a preferred alternative is costly and time consuming. Because the welfare of either party is generally affected by the other's search strategy, the decision problems of the two matched parties constitute a game. To emphasize this we assume that each party values any match according to the expected capitalized net income stream associated with it.

Let y_1 and y_2 represent the worker's and the employer's respective capitalized future income flows were their match to continue into the future. Assume that both apply the same discount rate to future income flows so that

$$y = y_1 + y_2 \tag{1}$$

can be meaningfully interpreted as the total or joint capital value of the match. In this section we suppose that both y and its division between worker and employer are given. Let x_1 denote the capital value of a randomly located alternative in the worker's case and interpret x_2 analogously in the employer's case. Each is a random variable *ex ante* characterized by the c.d.f., $F_i(x)$

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$= \Pr\{x_i \leq x\}$. Let $\bar{x}_i$ denote the upper bound on the support of $F_i(x)$, the best alternative available to agent i.

Finally, null alternatives exist for each party to an existing match; let $\underline{x}_1$ and $\underline{x}_2$ represent the capital values of these. By definition, the null alternative is costlessly available at any point in time. In the worker's case the null alternative can be search while unemployed. Holding the job vacant while seeking an acceptable worker for it is the counterpart in the employer's case. An existing match is viable if and only if

$$(y_1,y_2) > (\underline{x}_1,\underline{x}_2). \tag{2}$$

Two simplifying assumptions are basic to the following derivation. First, opportunities must be either accepted or rejected as they arrive. Second, the arrivals of opportunities are described by independent Poisson processes. This formulation permits a continuous time analysis although the initial derivations are easier to motivate if we consider a discrete period of variable length h.[5]

By virtue of the Poisson arrival assumption

$$\Pr\{n_1,n_2\} = \left[\frac{e^{-\lambda_1 h}(\lambda_1 h)^{n_1}}{n_1!}\right]\left[\frac{e^{-\lambda_2 h}(\lambda_2 h)^{n_2}}{n_2!}\right]$$

is the probability that the worker receives n_1 alternative job opportunities and the employer finds n_2 potential substitutes in a period of length h, where λ_i, $i = 1$ and 2, is the expected number of opportunities obtained by agent i per unit interval. Note that the probability of either a simultaneous arrival of an offer for both or two or more arrivals for either agent is negligible when the time interval is small in the sense that the probability vanishes more rapidly than h. In other words, there are only three possible events during an "instant." Either the worker obtains an outside offer, $(n_1,n_2) = (1,0)$; the employer finds a possible substitute, $(n_1,n_2) = (0,1)$; or neither obtains an alternative opportunity, $(n_1,n_2) = (0,0)$.

Hence, the expected wealth of agent i at the end of an interval of length h as of the beginning of the interval is

$$\begin{aligned} &\lambda_i h[\Pr\{x_i > \eta_i\}E\{x_i \mid x_i > \eta_i\} + \Pr\{x_i \leq \eta_i\}y_i] \\ &\quad + \lambda_j h[\Pr\{x_j > \eta_j\}\underline{x}_i + \Pr\{x_j \leq \eta_j\}y_i] + (1 - \lambda_1 h - \lambda_2 h)y_i + o(h) \\ &\qquad = y_i + \lambda_i h \int_{\eta_i} (x - y_i)dF_i(x) + q_j h(\underline{x}_i - y_i) + o(h), \quad j \neq i \end{aligned}$$

where $o(h)/h \to 0$ as $h \to 0$, η_i, $i = 1$ and 2, is the acceptance criterion of agent i,

$$\lambda_i = \lim_{h \to 0} \Pr\{(n_i,n_j) = (1,0)\}/h, \quad i = 1 \text{ and } 2, \tag{3a}$$

and

$$q_j = \lim_{h \to 0} [\Pr\{(n_i,n_j) = (0,1)\}/h]\Pr\{x_j > \eta_j\} = \lambda_j[1 - F_j(\eta_j)], \qquad j = 1 \text{ and } 2. \tag{3b}$$

As the product of the limit of the probability of an arrival and the probability that the alternative is acceptable, q_1 is the instantaneous *quit* rate and q_2 is the

[5] Feller (1968, pp. 447–448) gives a formal justification of this argument.

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instantaneous *dismissal* rate. To summarize, we note that the end of interval expected wealth of agent i is the sum of three terms: the end of interval capital value of the match to agent i, the expected capital gain attributable to the possibility that he will receive an acceptable alternative during the interval, and the expected loss in capitalized future rents attributable to the possibility that the other party will terminate the match. Of course, if the match is not viable in the sense that one of its parties prefers his null alternative, then the match terminates with certainty at the end of the interval in any event.

As of the beginning of the interval, the capital value of the match to each party is simply the sum of the net income obtained during the interval plus the present value of his or her expected wealth at the end of the interval. Formally, these are

$$v_1 = [w - c_1(\lambda_1)]h + \beta(h) \times \left[y_1 + \lambda_1 \int_{\eta_1}^{\bar{x}_1} (x - y_1) dF_1(x) + q_2 h(\underline{x}_1 - y_1) \right] + o(h) \quad \text{(4a)}$$

and

$$v_2 = [p - w - c_2(\lambda_2)]h + \beta(h) \times \left[y_2 + \lambda_2 \int_{\eta_2}^{\bar{x}_2} (x - y_2) dF_2(x) + q_1 h(\underline{x}_2 - y_2) \right] + o(h), \quad \text{(4b)}$$

where p denotes the value of the product flow attributable to the match, w is the wage paid the worker, $c_i(\lambda_i)$ is the cost of search to agent i and $\beta(h) = 1/(1 + rh)$ is the common discount factor. Throughout the remainder of the paper the following assumptions are maintained.

Assumption 1: $F_i(x)$, $i = 1$ and 2, is differentiable and has a nondegenerate, compact and convex support.

Assumption 2: $c_i(\lambda)$, $i = 1$ and 2, is an increasing strictly convex function such that $c_i(0) = c_i'(0) = 0$, and $\lim_{\lambda \to \infty} c_i'(\lambda) = \infty$.

Assumption 3: The best alternative available to both agents is viable; i.e., $(\bar{x}_1, \bar{x}_2) > (x_1, x_2)$.

The crucial and interesting assumptions are nondegeneracy of the alternative distributions and convexity of search costs. Viability of the best alternatives is innocuous. All the others are not necessary, but simplify the analysis.

The search strategy for either party to the match during the time interval in question is the choice of an expected arrival frequency and the choice of an acceptance criterion; that is, the choice of a pair (λ_i, η_i). Because one party's strategy affects the other's expected wealth by determining the probability of a capital loss attributable to termination, the joint search strategy choice problem is formally a game. The Nash noncooperative solution is a pair of search strategies, one for each party, designated as (λ_i^0, η_i^0), $i = 1$ and 2, and a vector of associated payoffs (v_1^0, v_2^0) that satisfy

$$v_1^0 = \max_{(\lambda_1, \eta_1) \geq 0} \left\{ [w - c_1(\lambda_1)]h + \beta(h) \times \left[y_1 + \lambda_1 h \int_{\eta_1}^{\bar{x}_1} (x - y_1) dF_1(x) + q_2^0 h(x_1 - y_1) \right] + o(h) \right\} \quad \text{(5a)}$$

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and

$$v_2^0 = \max_{(\lambda_2,\eta_2)\geq 0} \Bigg\{[p - w - c_2(\lambda_2)]h + \beta(h) \times \left[y_2 + \lambda_2 h \int_{\eta_2}^{\bar{x}_2} (x - y_2)dF_2(x) + q_1^0 h(\underline{x}_2 - y_2)\right] + o(h)\Bigg\}, \quad \text{(5b)}$$

where $q_i^0 = \lambda_i^0[1 - F_i(\eta_i^0)]$. In other words, the strategy choice of each maximizes his own expected wealth while taking the other's choice as given.

Given assumptions 1–3, each agent's Nash equilibrium strategy is unique and satisfies the following first-order conditions in the limiting ($h \to 0$) case:

$$c_i'(\lambda_i^0) = \int_{\eta_i^0}^{\bar{x}_i} (x - y_i)dF_i(x) \quad \text{(6a)}$$

$$\eta_i^0 = y_i, \quad \text{(6b)}$$

$i = 1$ and 2. The reservation value of the match to agent i, η_i^0, is that part of the capital value of continuing the match that accrues to agent i. The optimal average arrival frequency, λ_i^0, is such that the cost and return attributable to a larger frequency are equal at the margin. The following result is an immediate consequence of (3), (6) and the assumptions.

Proposition 1: Given the Nash noncooperative equilibrium, the quit (dismissal) rate depends only on and decreases with the worker's (employer's) share of the capital value of the match.[6]

There are at least three reasons for questioning the appropriateness of the Nash noncooperative solution to the two person nonzero-sum game. First, by cooperating the two players can generally improve the payoffs to both. Second, the unspecified costs of coordinating cooperation are likely to be minimal in the two-person case. Finally, the implicit assumption that the strategy choice of one player will not affect the choice of the other is not plausible. All three reasons would seem to have force in our particular case.

If complete cooperation could be achieved, then the appropriate criterion for the two players' choice would be the maximization of the total joint wealth at the beginning of the interval, $v = v_1 + v_2$. By simply adding the respective sides of the two equations in (4), it follows that the joint wealth maximizing strategy pair (λ_i^*, η_i^*), $i = 1$ and 2, and the associated maximal total value of the match, v^*, satisfy

$$v^* = \max_{(\lambda_i,\eta_i)i=1,2} \Bigg\{[p - c_1(\lambda_1) - c_2(\lambda_2)]h + \beta(h)\Bigg[y + \lambda_1 h \times \int_{\eta_1}^{x_1} (x + \underline{x}_2 - y)dF_1(x) + \lambda_2 h \int_{\eta_2}^{x_2} (x + \underline{x}_1 - y)dF_2(x)\Bigg] + o(h)\Bigg\}, \quad \text{(7)}$$

where y is the total capital value of the match at the end of the future time interval as defined in (1). Since v is a separable function of the two agents' strategies, assumptions 1 and 2 imply that in the limiting ($h \to 0$) case, a joint wealth maximizing solution to the game of search satisfies

[6] The proof only requires elementary differentiation and the observation that $c_i''(\lambda) > 0$ by assumption.

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$$c_i'(\lambda_i^*) = \int_{\eta_i^*}^{\bar{x}_i} (x + \underline{x}_j - y)dF_i(x) \tag{8a}$$

$$\eta_i^* = y - \underline{x}_j, \tag{8b}$$

$$j \neq i, \quad i = 1 \text{ and } 2.$$

A comparison of (6) and (8) reveals that the Nash solution does not maximize joint wealth if the capital value of the match exceeds the sum of the values of both agents' null alternatives. By pursuing a Nash noncooperative strategy, agent i ignores the fact that agent j would lose the capitalized flow of future expected rents, $y_j - \underline{x}_j$, associated with the match were agent i to terminate. The joint wealth maximizing strategy requires that an alternative to agent i be sufficiently attractive to compensate agent j for this loss. In addition, the expected gain in total rather than private wealth attributable to a marginal increase in the arrival frequency is equated to the marginal cost of search in the joint wealth maximizing case.

The principal empirical difference between the hypothesis that joint wealth maximizing strategies are pursued and the hypothesis of Nash noncooperative search behavior is revealed by comparing the following implications of (8) with Proposition 1.

Proposition 2: Given the joint wealth maximizing strategies, both the quit rate and the dismissal rate decrease with the total capital value of the match and are independent of its division.

With noncooperative behavior, each agent undervalues the match and hence turnover rates are "too high."

Proposition 3: Both the quit rate and the dismissal rate associated with joint wealth maximizing search are smaller than those associated with noncooperative search strategies if $y = y_1 + y_2 < \bar{x}_1 + \bar{x}_2$.

Proof. A comparison of (6) and (8) reveals that Proposition 3 holds only if $\eta_i^* = y - x_j = y_i + y_j - x_j \geqq \eta_i^0 = y_i$, $i = 1$ and 2, and if the inequality is strict for at least one agent. But this condition is implied by (2), the definition of a viable match, and holds strictly if $y = y_1 + y_2 < \bar{x}_i + \bar{x}_2$, the total capital value of the match is less than the sum of the agents' best alternatives. *Q.E.D.*

3. Alternative employment agreements

■ What arrangement could be made that would motivate cooperative search behavior? The issue is one of appropriate incentives. Because of the problems of monitoring either the extent of search activity or the actual acceptance criterion used by either party, we reject as unenforceable any simple agreement to pursue joint wealth maximizing strategies. Instead we consider two mechanisms for cooperation that do not require direct monitoring. The first and most obvious is an *ex ante* agreement by each party to make a counteroffer when the other receives an attractive alternative matching opportunity. The second is an agreement to compensate the other as a precondition for separation.

To investigate the issue of incentives we assume that each party to a match chooses his best Nash noncooperative strategy relative to the agreement. The logic of the method is as follows. Each mechanism can be thought to define

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a new game of search strategy choice. The *a priori* argument for the empirical relevance of the joint wealth maximizing strategies is strengthened if an agreement exists such that the Nash equilibrium relative to the agreement is the joint wealth maximizing strategy pair. In the sequel we show that requiring compensation has this property, but that counteroffering does not.

Consider first the case in which each party is permitted to make a counter offer. Then each is willing to give up that part of his share of the capitalized specific rents, $y_i - \underline{x}_i$, required to prevent the other from terminating the match. Specifically, given the division of the total capital value of the match in the event that no alternatives arrive during the next interval of length h, the counteroffer made by agent j to agent i in response to an alternative of value x_i is x_i if $y_i + y_j - \underline{x}_j \geqq x_i > y_i$. Obviously, no counteroffer needs to be made if $x_i \leqq y_i$, and none will be made if $x_i > y - \underline{x}_j$. As a consequence, agent i accepts the alternative and terminates the match if and only if $x_i > y - \underline{x}_j = \eta_i^*$. Hence, the reservation values of the match are joint wealth maximizing.

However, the optimal counteroffer mechanism just described implies that the expected *ex ante* end of the interval wealth for agent i is

$$\lambda_i h E\{\max(x_i, y_i)\} + \lambda_j h E\{\max(y - x_j, \underline{x}_i)\} + (1 - \lambda_1 h - \lambda_2 h) y_i + o(h)$$

$$= y_i + \lambda_i h \int_{y_i}^{\bar{x}_i} (x - y_i) dF_i(x) + \lambda_j h \int_{y_j}^{\bar{x}_j} \max[y_j - x, \underline{x}_i - y_i] dF_j(x) + o(h),$$

$j \neq i$ and $i = 1$ and 2. Agent i makes a gain whenever he obtains an alternative greater than his end of interval value of the match ($x_i > y_i$) and takes a loss whenever agent j finds an alternative of greater value than his end of interval capital value of the match ($x_j > y_j$). Although the expected capital loss attributable to the possibility that the other party will find an attractive offer is smaller than in the original formulation, an increase in the other's arrival frequency still increases that loss at the margin. Since neither takes this effect into account, both have an incentive to search "too much."

Formally, the noncooperative choices of the two arrival frequencies $(\hat{\lambda}_1, \hat{\lambda}_2)$ and their associated payoff vector $(\hat{v}_1, \hat{v}_2)$ satisfy

$$\hat{v}_1 = \max_{\lambda_1 \geqq 0} \left\{ [w - c_1(\lambda_1)]h + \beta(h) \left[y_1 + \lambda_1 h \int_{y_1}^{x_1} (x - y_1) dF_1(x) + \hat{\lambda}_2 h \right.\right.$$
$$\left.\left. \times \int_{y_2}^{\bar{x}_2} \max[y_2 - x, \underline{x}_1 - y_1] dF_2(x) \right] + o(h) \right\} \quad \text{(9a)}$$

and

$$\hat{v}_2 = \max_{\lambda_2 \geqq 0} \left\{ [p - w - c_2(\lambda_2)]h + \beta(h) \left[y_2 + \hat{\lambda}_1 h \right.\right.$$
$$\left.\left. \times \int_{y_1}^{\bar{x}_1} \max[y_1 - x, \underline{x}_2 - y_2] dF_1(x) + \lambda_2 h \int_{y_2}^{\bar{x}_2} (x - y_2) dF(x) \right] + o(h) \right\}^7. \quad \text{(9b)}$$

Hence (9), (8), and (6) imply that $\hat{\lambda}_i = \lambda_i^0 > \lambda_i^*$, $i = 1$ and 2, and, consequently, that $\hat{q}_i = \lambda_i^0[1 - F(\eta_i^*)] > q_i^* = \lambda_i^*[1 - F(\eta_i^*)]$, $i = 1$ and 2. Thus, we obtain:

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[7] Here, as elsewhere, we are using the fact established in (3a) that $\lambda_i h$ approximates $\Pr\{(n_i, n_j) = (1,0)\}$ when h is small.

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Proposition 4: Given the counteroffer mechanism, both turnover rates exceed those associated with the joint wealth maximizing strategy pair if $y = y_1 + y_2 < \bar{x}_1 + \bar{x}_2$.[8]

A compensation scheme requires each agent to compensate the other for any capital loss arising as a consequence of an actual separation. In other words, if agent i accepts an alternative of value x_i, its value net of the required compensation is $[x_i - (y_j - \underline{x}_j)]$. Since agent i will also forego his share, y_i, were he to separate, he will terminate if and only if $x_i > \eta_i^* = y - \underline{x}_j$. Again the reservation values are joint wealth maximizing. Moreover, in this case, because of the compensation received in the event of a separation, the agent j obtains y_j whether the match continues or not. Specifically, with the compensation agreement, the expected end of interval wealth for either agent is given by

$$\lambda_i h[\Pr\{x_i > \eta_i^*\}E\{x_i - (y_j - \underline{x}_j)|x_i > \eta_i^*\} + \Pr\{x_i \leqq \eta_i^*\}y_i|] + \lambda_j h$$
$$\times [\Pr\{x_j > \eta_j^*\}[\underline{x}_i + (y_i - \underline{x}_i)] + \Pr\{x_j \leqq \eta_j^*\}y_i] + (1 - \lambda_1 h - \lambda_2 h)y_i + o(h)$$
$$= y_i + \lambda_i h \int_{\eta_i^*}^{\bar{x}_i} (x + \underline{x}_j - y)dF_i(x) + o(h). \quad (10)$$

It equals the agent's share of the end-of-interval capital value of the match plus the expected joint capital gain attributable to the agent's search. Consequently, each agent's Nash choice of his own arrival frequency is λ_i^*, the joint wealth maximizing value.

The Nash choices of the arrival frequencies given compensation and the division of the end of interval capital value of the match (y_1, y_2) determine the division of the beginning of interval total expected wealth v^* between the employer and worker. Formally, with compensation, the Nash equilibrium payoffs are

$$v_1^* = \max_{\lambda_1 \geqq 0} \left\{[w - c_1(\lambda_1)] + \beta(h) \times \left[y_1 + \lambda_1 h \int_{\eta_1^*}^{\bar{x}_1} [x + \underline{x}_2 - y]dF_1(x)\right] + o(h)\right\} \quad (11a)$$

and

$$v_2^* = \max_{\lambda_2 \geqq 0} \left\{[p - w - c_2(\lambda_2)]h + \beta(h) \times \left[y_2 + \lambda_2 h \int_{\eta_2^*}^{\bar{x}_2} [x + \underline{x}_1 - y]dF_2(x)\right] + o(h)\right\}. \quad (11b)$$

Clearly, the optimal arrival frequencies are $(\lambda_1^*, \lambda_2^*)$ by virtue of (8) and $v_1^* + v_2^* = v^*$ by virtue of (7). In sum, we have established:

Proposition 5: Given the compensation mechanism, the associated Nash noncooperative equilibrium is joint wealth maximizing.

[8] In their paper on divorce, Becker *et al*. (1977) claim that the counteroffer mechanism does induce joint wealth maximizing behavior. The assertion is incorrect in our model because search intensities are endogenous and because the counteroffer mechanism does not eliminate the externality with respect to this choice.

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The practice of granting severance pay to a dismissed worker is precisely the type of contingent terminal payment suggested. Other restrictions on the employer's freedom to initiate a termination are consistent with the general framework. Arrangements that require direct compensation of the employer before quitting are not common, however. In part, the lack of such compensation reflects the fact that contracts that give the employer a property right to human capital are not legally enforceable. However, paid vacations and nonvested pension plans, payments made contingent on specified periods of previous employment, serve to raise the cost of quitting to the worker. All of these practices are equivalent to paying some portion of the worker's income share into a contingent escrow account. That sum, then, at least partially compensates the employer if the worker does quit.

4. The empirical evidence

■ Whether or not the parties to a match pursue wealth maximizing search strategies is ultimately an empirical question. To seek clues to an answer we examine recent studies by Viscusi (1976), Bartel and Borjas (1976), Medoff (1976), and Freeman (1978) as well as those reviewed by Parsons (1977). Of particular interest are cross section studies using data on either individual workers or industries.

To understand the empirical implications, one must recognize that the choice of strategies, formulated above as a single "instant" game, is repeated continuously throughout the duration of the match. One can account for this fact by noting that all the instantaneous games are sequentially interrelated. The capital value of the match to either agent at the end of any time interval $(t,\ t + h)$ is his expected wealth, given that the match continues beyond date $t + h$. In other words, $v_i(t) = y_i(t)$, $i = 1$ and 2, for all t given that the match continues to at least date $t + h$, in the notation of the previous sections. This observation implies that the end-of-interval expected capital values of the match are conditional on the search strategies that both the worker and the employer will pursue in the future.

Specifically, if at the inception of the match contingent compensation in the event of a future separation is *not* agreed to, then the associated Nash search strategies in each interval $(t,\ t + h)$ satisfy

$$v_1^0(t) = y_1^0(t) = \max_{(\lambda_1,\eta_1)} \Bigg\{ [w(t) - c_1(\lambda_1)]h + \beta(h)\Bigg[y_1^0(t + h) + \lambda_1 h \times \int_{\eta_1}^{\bar{x}_1} [x - y_1^0(t + h)]dF_1(x) + q_2^0 h[\underline{x}_1 - y_1^0(t + h] + o(h)\Bigg]\Bigg\}$$

and

$$v_2^0(t) = y_2^0(t) = \max_{(\lambda_2,\eta_2)} \Bigg\{ [p - w(t) - c_2(\lambda_2)]h + \beta(h)\Bigg[y_2^0(t + h) + \lambda_2 h \times \int_{\eta_2}^{\bar{x}_2} [x - y_2^0(t + h)]dF_2(v) + q_1^0 h[\underline{x}_2 - y_2^0(t + h)] + o(h)\Bigg]\Bigg\}$$

for all t by virtue of (5), where $w(t)$ is the agreed on wage for the interval and $(y_1^0(t + h),\ y_2^0(t + h))$ are the end-of-interval capital values of the match conditioned on the future wage stream, given no agreement to compensate in

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the future. These conditions, of course, are implied by Bellman's principle of dynamic optimality. With the appropriate right-hand end point conditions, they define the entire sequence of Nash equilibria, given no compensation.

For the sake of simplicity assume that both agents have infinite horizons and that all relevant parameters including the wage are stationary. Since all the games in the sequence are identical in this case, so are the equilibria; i.e., $y_i^0(t) = y_i^0(t + h)$ for all t and $i = 1$ and 2. Given this fact and $\beta(h) = 1/(1 + rh)$, by rearranging the equations shown above and letting $h \to 0$, one can show that the equilibrium capital values and search strategies in the continuous time stationary infinite horizon case satisfy

$$ry_1^0 = \max_{(\lambda_1, \eta_1)} \left\{ w - c_1(\lambda_1) + \lambda_1 \int_{\eta_1}^{\bar{x}_1} (x - y_1^0) dF_1(x) + q_2^0(\underline{x}_1 - y_1^0) \right\} \tag{12a}$$

and

$$ry_2^0 = \max_{(\lambda_1, \eta_1)} \left\{ p - w - c_2(\lambda_2) + \lambda_2 \int_{\eta_2}^{\bar{x}_2} (x - y_2^0) dF_2(x) + q_1^0(\underline{x}_2 - y_2^0) \right\} . \tag{12b}$$

In each case the right-hand side is the permanent income of each party to the match, given no compensation.

If compensation is agreed to both now and in the future, then $v_i^*(t) = y_i^*(t)$ for all t. Hence, an analogous argument and the equations of (11) imply the following capital values of the match in the infinite horizon stationary case:

$$ry_1^* = \max_{(\lambda_1, \eta_1)} \left\{ w - c_1(\lambda_1) + \lambda_1 \int_{\eta_1}^{\bar{x}_1} (x + \underline{x}_2 - y^*) dF_1(x) \right\} \tag{13a}$$

$$ry_2^* = \max_{(\lambda_1, \eta_2)} \left\{ p - w - c_2(\lambda) + \lambda_2 \int_{\eta_2}^{\bar{x}_2} (x + \underline{x}_1 - y^*) dF_2(x) \right\} , \tag{13b}$$

where $y^* = y_1^* + y_2^*$ is the maximal total capital value of the match.

Note that equations (12) and (13) implicitly define the capital values of the match to both the worker and the employer as functions of the value of the product flow p and the wage w for the case of no agreement to compensate and for the case of compensation, respectively. By adding the equations of (13), one can easily verify that the joint maximal capital value of the match, $y^* = y_1^* + y_2^*$, is a strictly increasing function of p and is independent of w. In other words, the wage serves only to divide the total between the two parties, given a contingent compensation agreement. Similarly, the equations of (12) imply that the total capital value of the match, given no compensation, $y_1^0 + y_2^0$, increases with the value of the product flow. However, in this case the total also depends on the wage because an increase in w, by increasing the worker's share and decreasing the employer's, results in a decrease in the instantaneous quit rate and an increase in the instantaneous dismissal rate (recall Proposition 1). In general, the impact of these two effects on the total capital value are not offsetting. Finally, Propositions 3 and 5 imply that $y^* \geq y_1^0 + y_2^0$ with strict equality holding when the maximal total capital value of the match is less than the sum of the workers' and employers' best alternatives ($y^* < \bar{x}_1 + \bar{x}_2$).

An important empirical implication common to the specific human capital approach, whether search is joint wealth maximizing or not, is that all turnover rates decline with the specific capital value of the match. In the joint wealth maximizing version of the model, this implication is obtained as follows. First

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Proposition 2 states that both the quit probability and dismissal probability for any match decline with the maximal capital value of the match. Second, the equations of (13), when added, imply that the maximal capital value of any match increases with the value of the match-specific flow, p, holding the distributions of alternatives available to both employer and worker constant. If the wage paid to the worker and the profit obtained by the employer both increase with the value of the joint product flow, as Parsons (1972), Pencavel (1972), and others have argued, then the implication that turnover rates decline with the specific capital value of the match also holds for the nonjoint wealth maximizing case by virtue of Proposition 1 and the equations of (12).

The empirical problem in testing this implication of the theory arises because specific human capital is not directly observable. Standard worker characteristic variables such as education and age account for differences in general rather than in specific human capital. Although the value of the product of a specific match may increase with the general human capital of the worker, so do the capital values of all the worker's alternatives. The predicted effect on the quit probability is ambiguous, although the dismissal probability should decline with general ability.

The duration of the match or job tenure is a variable which can be interpreted as an indicator of specific human capital differences because the extent of job-specific training increases with the tenure of the match through a process of learning on the job. Although there are reasonable alternative interpretations of the phenomenon, all existing evidence supports the prediction that turnover rates decline with tenure.

Certainly the major empirical implication that distinguishes the joint wealth maximizing hypothesis from the alternative is that both the probability of a worker-initiated separation and the probability of termination by the employer are independent of at least marginal changes in the wage rate. Evidence from most of the earlier work on quit behavior including studies by Stoikov and Raimon (1968), Burton and Parker (1969), and Pencavel (1972) seem to contradict this implication. The most important contradictory evidence is Parsons' (1972) result that quit rates are negatively associated and layoff rates are positively associated with wages across industries. This last study offers the strongest support for the proposition that neither party takes account of the loss that his search behavior imposes on the other. However, more recent evidence, when interpreted in the context of the theory developed here, suggests another explanation.

Essentially, the basis of the alternative explanation is that the wage serves as a proxy for unobserved determinants of the capital value of the match. The details of the argument are best expressed in terms of the following simple econometric model. Let z represent a vector of relevant variables sufficient to explain all systematic differences between the maximal capital values of all possible matches. Assume that $y = \alpha_0 + \alpha z + \epsilon_1$, where ϵ_1 is a random error term with zero mean and is uncorrelated with z. Without loss of generality, the elements of z can be defined so that the vector of coefficients, α, is positive. In other words, an increase in the kth element, the tenure of the match for example, increases the maximal capital value. If the total capital value of each match is "shared" by worker and employer, then the wage also increases with z across job-worker matches; i.e., $w = \beta_0 + \beta z + \epsilon_2$, $\beta > 0$, where ϵ_2, with $E\epsilon_2 = 0$, represents nonsystematic random variation not correlated with z.

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In any given study not all the components of z are observed. Partition the vector z into its observed component, z_1, and unobserved component, z_2, respectively. Then

$$y = \hat{\alpha}_0 + \alpha_1 z_1 + u_1, \quad Eu_1 = 0 \tag{14}$$

and

$$w = \hat{\beta}_0 + \beta_1 z_1 + u_2, \quad Eu_2 = 0, \tag{15}$$

where $\hat{\alpha}_0 = \alpha_0 + \alpha_2 Ez_2$, and $\hat{\beta}_0 = \beta_0 + \beta_2 Ez_2$ are new constants and where $u_1 = \alpha_2(z_2 - Ez_2) + \epsilon_1$ and $u_2 = \beta_2(z_2 - Ez_2) + \epsilon_2$ are new error terms resulting in part from incomplete observation. Because $\alpha_2 > 0$ and $\beta_2 > 0$, u_1 and u_2 are positively correlated if ϵ_1 and ϵ_2 are independent. The relationship between the two error terms can always be represented as

$$u_1 = \delta u_2 + \epsilon, \quad \delta > 0, \quad E\epsilon = 0, \tag{16}$$

where by construction $E(u_2 \cdot \epsilon) = 0$ so that $\delta = E(u_1 u_2)/E(u_2^2)$.

Given joint wealth maximization, the two turnover rates decline with y; i.e.,

$$q_i = \gamma_{0i} + \gamma_{1i} y; \quad \gamma_{1i} < 0 \tag{17}$$

for $i = 1$ and 2. By using equations (14), (15), and (16) to eliminate y, u_1 and u_2, one obtains the regression model

$$q_i = \hat{\gamma}_{0i} + \gamma_{1i}\delta w + \gamma_{1i}(\alpha - \delta\beta_1)z_1 + \gamma_{1i}\epsilon, \quad i = 1 \text{ and } 2, \tag{18}$$

where $\hat{\gamma}_{0i} = \gamma_{0i} + \gamma_{1i}[\hat{\alpha}_0 - \delta\hat{\beta}_0]$.

Since the errors in equations (14) and (15) are positively correlated ($\delta > 0$) and since the quit rate declines with total capital ($\gamma_{11} < 0$), in any particular study of quit behavior the predicted sign of the wage coefficient in (18) is negative, as often observed, although the wage has no causal effect on the quit rate under the joint wealth maximizing hypothesis. Furthermore, the absolute values of the estimated coefficients of z_1 are biased downward as estimates of the true effects of observed capital value determinants on the quit rate, because positive differences in z_1 contribute positively to observed wage differences across job-worker matches. Similar conclusions can be drawn on the assumption that the elements of z are imperfectly measured. In this case variations in the wage will enter the regressions as a proxy for these errors in variables.

The most important implication of the econometric model concerns comparisons of estimates obtained from different studies. Formally, as more elements of the sufficient capital value determinant vector z are included in the observed vector z_1, the correlation between u_1 and u_2 generally declines, and in the limit when $z = z_1$, the correlation is zero if ϵ_1 and ϵ_2 are uncorrelated. Hence, labor turnover studies in which more and better capital value proxies are used should obtain estimated wage effects and estimated capital value proxy coefficients that are, respectively, smaller and larger in absolute value.

In the earlier studies of quits referred to above, cross industry data were used. When tenure is included, it is crudely measured by rough indicators of tenure distribution differences. More recent studies, such as those of Viscusi (1976) and Bartel and Borjas (1976), use data on individual workers. The data sets include exact job tenure information. Both studies also include measures of fringe benefits, and in the results for older men based on the National Longitudinal Survey there is a variable representing coverage by a pension plan. In light of our theory, these latter variables, particularly pension coverage, can be regarded as additional measures of the capital value of the match. In all

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results reported by Viscusi and by Bartel and Borjas, the wage effect is weakly negative, while tenure, the extent of fringe benefits, and coverage by a pension plan all have significant negative coefficients in a quit probability model. Indeed, the estimated wage effect is neither statistically significant nor robust with respect to sign in the results that Viscusi reports, in which quit intensions are used as the dependent variable. The reported tendency for union members, when other things are equal, to be less likely to quit than nonunion members (Freeman, 1978; Medoff, 1976; Viscusi, 1976) can be interpreted as additional support for the hypothesis. In fact, Freeman and Medoff (1977) argue that reduction in turnover is both an incentive for and an effect of unionization because cooperation is facilitated by the existence of a union.

Of course, the argument used to obtain equation (18) applies equally well to the case of employer-initiated separations ($i = 2$). Here we seem to have a clear contradiction since $\gamma_{12} < 0$ and $\delta > 0$ imply that the estimated wage effect is negative, but Parsons (1972) in a study of cross industry data on layoff rates and Bartel and Borjas (1976) in a cross worker study of layoff probabilities both report a significant *positive* wage effect in layoff equations.

Our first point in rebuttal is that the theory developed in this paper is not an explanation of layoffs as usually defined. This point is important because theoretical work by Feldstein (1976) and Baily (1977) suggests and empirical studies by Lilien (1977) and Medoff (1976) substantiate the hypothesis that the majority of all terminations initiated by the employer "without prejudice" to the worker—as layoffs are defined by the Bureau of Labor Statistics—are temporary. The theory has little to do with the process of job-worker matching. Indeed, Medoff's results imply that layoff rates across industries have a significant positive association with the extent of unionization and that wage rate differences have no independent explanatory power. This suggests that wage rates have simply acted as proxies for unionization in earlier studies.

Our second point of rebuttal is also an appeal to Medoff's (1976) empirical work. In other regressions reported in that paper, when the discharge rate (as defined by the Bureau of Labor Statistics) is the dependent variable, the wage rate has a significant negative coefficient, and the coefficient on the extent of unionization is also negative, though not particularly significant. These results can be interpreted as strong evidence in support of the argument used to derive equation (18) for the case of $i = 2$, particularly since the regressions do not take differences in tenure into account.

It should be clear that the arguments and evidence reported in this section do not confirm the joint wealth maximizing hypothesis. However, they do establish that our current empirical knowledge about turnover behavior does not contradict the hypothesis as one's first impression might suggest. A definitive test is clearly going to require a much more sophisticated methodology. Its development is a topic for future research.

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