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Working Paper No. 141
June 1988

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The neoclassical model of the labor market--with a downward sloping labor demand schedule and an upward sloping labor supply schedule at the market level--is a valuable framework for analyzing the determination of wages and employment. However, the neoclassical model of labor market equilibrium is muted in the context of heterogeneous workers and firms. Analysis with heterogeneity often neglects marginal analysis to focus on the matching of workers and firms or on labor turnover. To the extent matching models fail to determine a unique wage rate and the employment levels of firms, and lack a well-defined concept of marginal productivity, valuable features of the neoclassical equilibrium are lost. Consider two points:

First, what is the content of productivity in the matching context? In the prototypical one-to-one matching model of Koopmans and Beckmann (1957), worker productivity is not a meaningful concept. A worker-firm match produces a valuable output, but the worker does not have any private contribution to output. Nevertheless, perhaps relying on an unspecified marginal analysis, the common matching variants of turnover models (e.g., Hashimoto and Yu 1980; Hall and Lazear 1984; Antel 1985) map productivity draws into wage offers and turnover decisions.

Second, how is the value of the match divided between the firm and the worker? In particular, for a given worker, is there a unique wage offer from each firm? In the prototypical matching model, the division of the match

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[*] I thank Marcus Berliant, Eric Bond, John Boyd III, Barbara Mace, Walter Oi, Stephen Trejo, and participants in the Workshop in Applied Economics at the University of Rochester and the Labor Workshop at the University of California, Santa Barbara for their helpful comments. An earlier version of this paper was distributed under the title "Rent Sharing and Turnover in a Model with Efficiency Units of Human Capital."

value is not unique. In analyzing the market solution to the matching problem, one investigates whether a set of prices (wage and profit associated with each potential match) is capable of sustaining the optimal assignment of workers to firms. The heterogeneity inherent in the matching framework implies that the division of the match value into wage and profit in each optimal match is indeterminate: the wage offer from the optimal firm is not unique since there are rents associated with the optimal match.[1] A unique split of the rents is relegated to a cooperative game based on relative bargaining strength.

One purpose of this paper is to develop a model with the following blend of neoclassical and matching features:

(a) At the firm level, the demand for labor is well defined.

(b) A worker's productivity value is well defined and varies across firms.

(c) Wages are flexible, varying with productivity in the observed match and with outside wage offers.

(d) Matching is efficient: in the market equilibrium, a worker matches with the firm in which his productivity value is highest.

The primary purpose of this paper, however, is to analyze the effect of rent sharing on equilibrium matching and turnover. Consequently, the following properties are added:

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[1]While this form of indeterminacy is an essential feature of the matching framework, it should be stressed that the indeterminacy is more fundamental. First, in the absence of "unmatched" reservation values, the addition or subtraction of a constant to all wage offers does not affect the competitive matching solution (Koopmans and Beckmann 1957, 60-61). Second, the set of wage offers which supports the optimal match depends on outside wage offers. Since the best alternative wage offer is not unique, an additional indeterminacy is present.

(e) A worker's wage is increasing in his relative bargaining strength.

(f) Both matching and turnover are efficient and invariant to bargaining strength.

(g) Some turnover is common to the firm and some to the industry; other turnover is frictional, that is idiosyncratic or worker specific.

Items (a) - (g) are features of an equilibrium matching model of the labor market with neoclassical properties.

In section 1, I develop an equilibrium model of matching with efficiency units of human capital which generates a meaningful concept of worker productivity. With this developed, I analyze rent sharing. Firms and workers adopt a sharing rule which divides the difference between productivity within the firm and the best outside wage offer. This implies unique wage and profit offers for each potential match, and hence a determinate solution for wage and profit in the observed matches. Furthermore, this sharing rule induces optimal matching.

Implications for turnover behavior are investigated in section 2. Turnover can result from stochastic variation in the product price or production technology of <u>any firm</u>, or the supply of efficiency units of <u>any worker</u>. With such stochastic variation, the sharing rule generates efficient turnover. Incorporating a joint wealth maximizing model of the quit-layoff distinction, the model implies that the higher the worker's share of the rents to the match, the lower the probability of a quit and the higher the probability of a layoff.

In section 3, the equilibrium model of matching and turnover is applied to analyze the effect of union status on wages and turnover. To the extent union workers capture a higher share of the rents associated with the employment match, they are expected to exhibit higher wages, lower quit rates, and higher layoff rates than their nonunion counterparts.

Section 4 contains a summary of the principal results and several concluding comments.

1. An Equilibrium Model of Matching

In this section, I construct an equilibrium model of matching with rent sharing. The analysis begins with a single period model of a market in efficiency units of human capital.

Firm i is characterized by a neoclassical production function X_i which maps efficiency units of human capital H_i and physical capital K_i into output x_i.

$$(1) \qquad x_i = X_i(H_i, K_i), \qquad i = 1, \ldots, I.$$

Following the matching tradition, I take each firm's production technology as given, and I hold the number of firms fixed.

Central to the analysis is the input H_i. Let H_i be given by an additive function which maps the J workers' skill vectors $\mathbf{a}_j = (a_{1j}, \ldots, a_{nj})$ into a real number.[2]

$$(2) \qquad H_i \equiv \sum_{j=1}^{J} H_{ij} \cdot E_{ij} \equiv \sum_{j=1}^{J} H_i(a_{1j}, \ldots, a_{nj}) \cdot E_{ij}, \qquad i = 1, \ldots, I,$$

[2]This feature of the model has as antecedents the work of Mandelbrot (1962), Sattinger (1975), Heckman and Sedlacek (1985), and Heckman and Scheinkman (1987). In this literature, bundles of worker skills are transformed into "tasks," which is the productive input.

where each indicator variable E_{ij} equals unity if worker j is employed by firm i, and equals zero otherwise. Each worker j is a collection of skills which cannot be unbundled; thus a_{kj} is a stock variable measuring the amount of type-k skill embodied in worker j. $H_i(\mathbf{a}_j)$, which is left unrestricted, is a firm-specific function which maps worker j's vector of skills into efficiency units of human capital, a scalar value H_{ij}. Since $H_i(\mathbf{a}_j)$ is indexed by i, valuations of a particular skill can vary across firms.

Equations (1) and (2) incorporate the efficiency units assumption. All that matters to firm i is the total number of efficiency units of human capital it employs, not the composition among its workforce. For example, the firm is indifferent between N workers of type A each with H_{iA} units of human capital and one worker with $N \cdot H_{iA}$ units. Similarly, the firm is indifferent between worker B with fifteen years of experience with other firms and worker C with one year of experience in its own employment if $H_{iB} = H_{iC}$.[3]

Neoclassical analysis derives the demands of firms for human capital efficiency units: H_i^*, i = 1, ..., I. Taking as given the price of efficiency units of human capital to firm i, ω_i, and the price of firm i's product, P_i, firm i chooses H_i to satisfy

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[3]The efficiency units specification, mapping skills into efficiency units of human capital, is fully consistent with firm-specific and general human capital (Becker 1962). Skills at any point in time may depend on the history of employment. A subset of worker j's skill vector contains general components wich are valued equally across firms. Other skills are valued differently; in particular, some "skills" may be the stocks associated with previous firm-specific investments.

The decision to invest in human capital is ignored throughout the paper. See Murphy (1986) for an analysis of the investment decision in a model with specific capital.

$$(3) \qquad P_i \cdot \frac{\partial X_i}{\partial H_i}(H_i; K_i) = \omega_i, \qquad\qquad i = 1, \ldots, I,$$

with K_i fixed. Thus equation (3) implicitly defines firm i's short-run derived demand for human capital $H_i^* = L_i(\omega_i/P_i; K_i)$, with $L_i(\cdot)$ decreasing in its first argument. This specification allows for different prices of human capital across firms. I show below that this is a property of the market equilibrium.

Although neoclassical analysis is sufficient to determine the level of employment of each firm, whom to employ must be determined in the matching environment. In particular, equilibrium values of the employment indicators E_{ij} depend on each worker's productivity value in every firm.

Worker j's productivity value in firm i is the value of the marginal product of human capital in firm i times the amount of human capital worker j has in firm i.

$$(4) \qquad M_{ij} \equiv P_i \cdot \frac{\partial X_i}{\partial H_i}(H_i; K_i) \cdot H_{ij} = \omega_i \cdot H_{ij}, \qquad\qquad i = 1, \ldots, I, \; j = 1, \ldots, J,$$

where M_{ij} denotes worker j's productivity value in firm i. Worker j's productivity value, which is firm specific, is decomposed into price and quantity components, both of which in general can vary across firms.

Optimal Matching

In the optimal match, is worker j assigned to the firm in which his productivity value is greatest? As a result of the efficiency units assumption, the answer is yes. By definition the optimal match maximizes the value of output <u>in the market</u>. Consequently, if the "maximal productivity" match were suboptimal, then it would be possible to re-assign workers and thereby increase the value of output in the market. Note that every possible re-assignment involves a transfer of efficiency units between firms. Therefore, it is sufficient to show that any transfer of efficiency units from the "maximal productivity" allocation results in a reduction in the value of output in the market: Transferring worker j (i.e., a small amount of human capital) from the firm in which he is most productive to some other firm reduces the value of output in the market: the value of the sending firm's output falls more than the value of the receiving firm's output rises.[4]

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[4]This can be established formally using two first-order Taylor series expansions. Let firm 1 be j's maximal productivity match and firm 2 some other firm. Hence $M_{1j} > M_{2j}$. Let $\Delta[P_1X_1(H_1^*)]$ and $\Delta[P_2X_2(H_2^*)]$ denote the changes in the value of outputs at firms 1 and 2 respectively which result from the transfer of worker j from firm 1 to firm 2.

$$\Delta[P_1X_1(H_1)] + \Delta[P_2X_2(H_2)]$$

$$\equiv [P_1X_1(H_1^*-H_{1j}) - P_1X_1(H_1^*)] + [P_2X_2(H_2^*+H_{2j}) - P_2X_2(H_2^*)]$$

$$= P_1 \frac{\partial X_1}{\partial H_1} (H_1^*)\cdot[H_1^* - H_{1j} - H_1^*] + P_2 \frac{\partial X_2}{\partial H_2} (H_2^*)\cdot[H_2^* + H_{2j} - H_2^*]$$

$$= - (M_{1j} - M_{2j}) < 0.$$

The second step employs Taylor series expansions around H_1^* and H_2^*, and the final step follows from the definition of productivity value. Consequently, the total value of output falls from any such re-assignment from the maximal productivity match.

Therefore, the optimal match assigns each worker to the firm in which his productivity value is highest.

The importance of this result draws in part from the absence of such a property in prototypical matching models. Consider the model of Koopmans and Beckmann (1957). A key feature of the model is that assignments are one-to-one such as in a monogamous marriage market (Becker 1973). In such a model, the optimal match does not in general assign a worker to the firm in which the output of the match is greatest <u>for the specific worker</u> (Koopmans and Beckmann 1957, 55; Becker 1973, 824-25).

One way to structure the Koopmans-Beckmann model is to let the match values, denoted V_{ij}, be generated by a continuous function of indices of firm and worker quality: $V_{ij} = f(k_i, h_j)$, where f is an increasing, concave function and $f_{kh} > 0$ (Becker 1973; Sattinger 1980, 98-101). This structure adds two features to the Koopmans-Beckmann model. First, worker productivity is well defined and given by f_h. Second, this is an ordered model. Matched with a firm of any quality level k, high h workers are more productive than low h workers. The optimal assignment matches the best worker with the best firm, down to the worst worker with the worst firm. In the ordered model, only the best worker matches with the firm in which his productivity value f_h is greatest.

As a consequence of relaxing the "monogamy" restriction, the matching model with efficiency units of human capital exhibits an intuitive property: in the optimal assignment, each worker is matched with the firm in which his productivity value is highest. The next step is to determine whether a decentralized labor market supports the optimal assignment. It is here that rent sharing plays an important role.

<u>Matching, Rent Sharing, and Wage Offers</u>

With the value of worker j's productivity at each firm i well defined and given by $M_{ij} = \omega_i \cdot H_{ij}$, one can ask: must worker j be paid his productivity value in his optimal match? The answer is no. The shadow price of human capital ω_i determines the worker's productivity value, not his wage payment. The marginal worker in firm i must be paid his productivity value, but firm i can price discriminate against the infra-marginal workers. Of course, each infra-marginal worker has bargaining power as well, so the bilateral monopoly problem inherent in the matching context supports the indeterminacy.

A simple solution to the problem of indeterminacy is rent sharing. The worker and firm divide up rents such that worker j is paid his productivity value in his best alternative match plus a fraction of the difference between the productivity values with his optimal and best-alternative matches. A problem with this rule is in its informational requirements. Firm i must know the productivity value of worker j in j's next best match. Hence wage offers follow from knowledge of the matching solution. If one is interested in how wage offers induce matching, rather than vice versa, this is a deficiency.

An alternative rent sharing scheme employs a weaker informational requirement. Let w_{ij} denote firm i's wage offer to worker j, and let $w'_{ij} \equiv \max_{k \neq i} w_{kj}$ define worker j's best alternative wage offer. Worker j matches with firm i if his wage offer from firm i exceeds all other wage offers; that is, if $w_{ij} > w'_{ij}$. The rent sharing scheme employed in this paper requires that worker j's <u>best</u> alternative wage offer w'_{ij} be verifiable and that the worker's productivity value M_{ij} be verifiable <u>if the employment relationship</u>

is consummated.[5] Therefore, firm i and worker j can sign a contract which pays the worker, if employed, a wage equal to his opportunity wage w'_{ij} plus a share of the rents to the match: the wage employed is a convex combination of productivity within firm i, M_{ij}, and worker j's best alternative wage offer, w'_{ij}. Such a contract describes the accepted wage which depends on the wage offers of other firms. If all firm-worker pairs write such contracts, does the labor market have a unique equilibrium set of wage offers $\mathbf{w}^*_j = (w^*_{ij}, \ldots, w^*_{Ij})$, j = 1, ..., J? If so, what properties does the equilibrium exhibit?

The following expression formalizes the decision rules for each of the I firms bidding for worker j:

$$(5) \qquad w_{ij} = \beta_{ij}M_{ij} + (1-\beta_{ij})\cdot \mathrm{MIN}\{M_{ij}, w'_{ij}\}, \qquad \begin{array}{l} i = 1, \ldots, I, \\ j = 1, \ldots, J, \end{array}$$

where $0 < \beta_{ij} \leq 1$ is the rent sharing parameter.[6] Consequently, the rule is to offer $w_{ij} = \beta_{ij}M_{ij} + (1-\beta_{ij})w'_{ij}$ if $w'_{ij} < M_{ij}$, and $w_{ij} = M_{ij}$ otherwise.

For each worker j, (5) is a system of I equations in I unknowns. In the appendix, I use the contraction mapping theorem to establish that a unique Nash solution exists. The solution, $\mathbf{w}_j$, is the vector of offers received by worker j. For convenience index firms such that $w_{1j} \leq \ldots \leq w_{Ij}$. Since

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[5]Verifiability in this context precludes bluffing or fraud in presenting alternative wage offers. I assume that once worker j reveals w'_{ij} to firm i, firm i can check its validity costlessly. In addition, firm i must know worker j's productivity value M_{ij} even if the match is not consummated. If the match is consummated, M_{ij} must be costlessly verifiable to the worker; however, verification need not be prior to production.

[6]At this stage, β_{ij} is parametric. Determination of β_{ij} is discussed at the end of section 1.

$w_{ij} \leq w_{Ij}$ for all $i \neq I$, wage offers are

$$(6.1) \qquad w_{ij} = M_{ij} \qquad\qquad i = 1, \ldots, I-1.$$

Therefore, the accepted wage is

$$(6.2) \qquad w_{Ij} = \beta_{Ij}M_{Ij} + (1-\beta_{Ij})w_{I-1,j}$$

$$= \beta_{Ij}M_{Ij} + (1-\beta_{Ij})M_{I-1,j}$$

$$= M_{I-1,j} + \beta_{Ij}\cdot(M_{Ij} - M_{I-1,j}).$$

The resulting wage offers to worker j can be thought of in the context of an auction. Consider the wage offers of the I firms in an auction for worker j. In the bidding process for worker j, firm i observes both M_{ij} and w'_{ij}. If some firm k offers a wage greater than M_{ij}, firm i offers a wage equal to M_{ij}. But if $w'_{ij} < M_{ij}$, firm i offers a convex combination of the two observables, M_{ij} and w'_{ij}. Equations (6.1) and (6.2) imply convergence to $\mathbf{w}_j$ in two rounds of bidding. In the first round, each firm i can do no better than to offer M_{ij} to worker j. In the second and final round, every firm i but the one in which worker j is most productive again offers M_{ij}; firm I offers a wage which shares the rents as given in equation (6.2).

Labor Market Equilibrium

In generating the wage offers represented by equations (6.1) and (6.2), firms take the vector of prices of human capital efficiency units $\boldsymbol{\nu}$ =

$(\omega_1, \ldots, \omega_I)$ as given. The next step of the analysis is to solve for the equilibrium vector of shadow prices $\boldsymbol{\omega}^* = (\omega_1^*, \ldots, \omega_I^*)$. A key result is that human capital is not perfectly elastically supplied to any firm. Hence there are well-defined demand and supply functions at the firm level resulting in equilibrium shadow prices $\boldsymbol{\omega}^*$. These in turn generate equilibrium productivity values, equilibrium wage offers, and equilibrium matching.

The supply of human capital to firm i is given as the solution to the J workers' matching choice problem. The supply of human capital is an increasing function of ω_i, since each wage offer w_{ij} is increasing in ω_i. The supply function $H_i^S(\cdot)$ is the sum of individual supplies.

$$(7) \qquad H_i^S(\boldsymbol{\omega}) \equiv \sum_{j=1}^{J} H_i(\mathbf{a}_j)\cdot D_{ij}(\boldsymbol{\omega}), \qquad i = 1, \ldots, I,$$

where each indicator variable $D_{ij}(\boldsymbol{\omega})$ equals one if the wage offers satisfy $w_{ij} > w'_{ij}$, and equals zero otherwise.[7] Supply $H_i^S(\boldsymbol{\omega})$ is an increasing function of ω_i and an decreasing function of the ω_k for $k \neq i$; in particular, supply is an increasing step function of ω_i. Taking the ω_k as given, firm i's wage offers to all J workers are increasing in ω_i. This results in some marginal worker switching from some other firm to firm i. A sufficiently higher ω_i draws in another worker. Thus variation of ω_i "sweeps out" the distribution of workers. For large J, it is innocuous to abstract from the discontinuity of supply and to treat each firm's supply function $H_i^S(\boldsymbol{\omega})$ as a continuous function of ω_i. Thus indivisibilities are ignored.

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[7]It is convenient at this point to relax the indexing convention which was adopted in writing equations (6.1) and (6.2).

With a rising supply price at the firm level, the <u>competitive</u> equilibrium solves

$$(8) \qquad P_i \cdot \frac{\partial X_i}{\partial H_i}(H_i^S(\omega);\ K_i) = \omega_i, \qquad i = 1, \ldots, I,$$

with the solution vectors $\omega^* = (\omega_1^*, \ldots, \omega_I^*)$ and $H^* = (H_1^*, \ldots, H_I^*)$.[8] Consequently, efficiency units of human capital have firm-specific shadow prices. In contrast with hedonic pricing models (e.g., Tinbergen (1956) and Rosen (1974)), the underlying skills are not priced out in equilibrium.

The equilibrium shadow prices ω^* are employed directly in determining equilibrium productivity values M_{ij}^*, equilibrium wage offers w_{ij}^*, and equilibrium values of the indicator variables, E_{ij}^* and D_{ij}^*, for each firm-worker pair. Equilibrium productivity values are $M_{ij}^* \equiv \omega_i^* \cdot H_{ij}$. Again adopt the indexing convention that $w_{1j} \leq \ldots \leq w_{Ij}$. Then worker j's vector of equilibrium wage offers w_j^* satisfies

$$(9.1) \qquad w_{ij}^* = M_{ij}^* \qquad i = 1, \ldots, I-1,$$

$$(9.2) \qquad w_{Ij}^* = \beta_{Ij} M_{Ij}^* + (1-\beta_{Ij}) M_{I-1,j}^*.$$

Equilibrium wage offers are flexible as they vary with productivity values.

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[8]For simplicity, I work with the partial equilibrium. Establishing the existence of a general equilibrium in the labor market is entirely conventional if indivisibilities are ignored. Since the units of human capital are gross substitutes across firms, a unique, globally stable, general equilibrium is guaranteed to exist.

The observed wage, that is the accepted wage offer, is increasing in the rent sharing parameter β_{Ij} and the worker's productivity value within the consummated match M^*_{Ij}; w^*_{Ij} is also increasing in the worker's best alternative productivity $M^*_{I-1,j}$.

The equilibrium wage offers induce efficient matching.[9] <u>The market's allocation of labor is efficient</u> even though each worker is paid less than his productivity value; for $i \neq I$, $M^*_{ij} = w^*_{ij} \leq w^*_{Ij} \leq M^*_{Ij}$.[10] Since the β_{ij} govern the sharing of <u>rents</u>, the rent sharing parameters do not influence the market's allocation of labor.

Several additional properties of the equilibrium are neoclassical. Consider first how, in a partial equilibrium, wage rates and employment vary with product price and marginal productivity. An increase in product price P_i or the marginal product of human capital $\partial X_i/\partial H_i$ raises demand for human capital in firm i; thus the equilibrium shadow price of human capital ω^*_i, as well as the equilibrium level of employment H^*_i, rises. Equilibrium wages in firm i rise as a result of the increase in each worker's productivity value.

Turn next to the determinants of supply. A neutral (across skills) technical change in firm i increases $H_i(\cdot)$ which increases the supply of human capital to firm i and reduces its equilibrium shadow price of human capital thereby. The lower equilibrium shadow price of human capital reduces the

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[9]Equilibrium values of the indicator variables are $E^*_{Ij} = D^*_{Ij} = 1$ because $M^*_{Ij} \geq w^*_{Ij}$ and $w^*_{Ij} \geq w^*_{kj}$ for all $k \neq I$; and $E^*_{ij} = D^*_{ij} = 0$ for all $i \neq I$.

[10]In pairwise comparisons of workers within a firm, the ratios of wages do not equal the ratios of marginal products even if the rent sharing parameters are not worker specific. Hence two non-neoclassical properties of the model are that wages do not equate to productivity values and that wage ratios do not equate to ratios of productivity values.

equilibrium accepted wage, and increases the equilibrium employment of human capital. Non-neutral technical change in $H_i(\cdot)$ has an ambiguous effect on supply, and hence on the shadow price of human capital, wage rates, and employment in equilibrium.[11]

Discussion

The function generating wage offers, equation (5), is merely postulated. An attraction of postulating such behavior is that it generates economic outcomes with desirable properties. At this point, it is valuable to clarify two features of the wage-offer generating function: the informational requirements, and determination of the rent sharing parameters.

The wage-offer generating function requires that each firm-worker pair can write a contract with the productivity value and best alternative offer of the worker as parameters.[12] Recent work on labor contracting emphasizes unresolved asymmetries in the information structure which would preclude such contracts (e.g., Hashimoto and Yu 1980; Hall and Lazear 1984). Realize that the current model does not preclude initial asymmetric information; it is sufficient that the firm can verify the worker's best alternative wage once the worker reveals it, and that the worker can verify his productivity value once production occurs and the firm reveals the information. In short, the contract requires information transmission with costless verification. The value of such an abstraction from unresolved asymmetric information is in

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[11]Analysis of the effect of an increase in the supply of skills requires general equilibrium considerations since supply shifts in every firm.

[12]A subtle point is that, in order to know M^*_{ij}, each firm must know the supply of human capital which it faces.

delivering the neoclassical properties of the model.

A second issue is how each rent sharing parameter β_{ij} is determined? Following much of the applied research on efficient bargaining (e.g., Hall and Lilien 1979; McDonald and Solow 1981), I have avoided the difficult issue of how cooperative bargainers determine the split--that is, the particular bargaining solution. Since income is transferred linearly, the Nash bargaining solution (Nash 1950) yields $\beta_{ij} = 1/2$ for all firms i and workers j. Other bargaining games (e.g., Nash 1953) allow the sharing parameters to deviate from one-half with a higher β_{ij} indicating greater bargaining strength of the worker.

2. Turnover

Research in the economics of labor turnover typically takes a worker's productivities (or productivity profiles) as given (e.g., Becker 1962; Parsons 1972; Jovanovic 1979; Hashimoto and Yu 1980; Hall and Lazear 1984; Antel 1985; McLaughlin 1987, Chapter 3; Mortensen forthcoming). Indeed, the two papers in the recently published Handbook of Labor Economics which analyze job attachment and turnover take productivity values as given without reference to an equilibrium model (Mortensen 1986; Parsons 1986). In providing an equilibrium foundation, the current model supports these analyses.

To examine the effect of rent sharing on turnover, the matching model must be set in a stochastic, intertemporal setting: in a sequence of spot markets, stochastic shocks hit the market making it desirable to re-match. All the variables which effect the productivity values M^*_{ij} are potential sources of turnover-inducing stochastic variation. These include:

(a) the price of the product, P_i

(b) the production function, X_i

(c) the human capital function, H_i

(d) skills of the worker, $\mathbf{a}_j$

for any i = 1, ..., I, or any j = 1, ..., J. Fluctuations in product prices and productivity shocks affect only the equilibrium prices of human capital ω^*; declining firms, those i for which the value of the marginal product of human capital falls over time lose marginal workers to other firms. Shocks to supply or the functions mapping supply into efficiency units affect both the prices ω^* and the efficiency units H_{ij}; turnover resulting from such shocks are more idiosyncratic, although a common firm-effect persists through ω_i^*. Thus items (c) and (d) can induce separations from growing firms. Whatever the primary source of variation, all that matters for turnover is that the M_{ij}^* be stochastic. With the productivity values stochastic, optimal matches change from period to period.

An immediate result of the preceding section is that the rent sharing parameters do not affect the rate at which workers change employers. Since the rent sharing rule generates optimal matching in each period, worker j's optimal match in any period is independent of the β_{ij}. Therefore, worker j's probability of changing employers (i.e., the separation rate) is independent of the sharing parameters.[13]

What does the model imply regarding quits and layoffs? Since all turnover is efficient, the analysis is based on the joint wealth maximizing approach to

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[13]Formal derivations of this result and those in the following paragraph are available from the author on request.

the quit-layoff distinction (McLaughlin 1987). In that approach, quits separate to higher paying employment, layoffs to lower paying employment. Therefore, the quit (layoff) rate is the probability that the following joint event obtains: the worker separates from his incumbent employer, and the wage offer from the new employer exceeds (falls short of) the wage the worker had been paid by the incumbent employer. For any worker j, the higher is his rent sharing parameter with his incumbent employer i, β_{ij}, the higher was the wage of worker j when employed by firm i in period t; hence the lower (higher) the probability worker j leaves <u>to a higher (lower) paying employer</u> in period t+1: the quit (layoff) rate is decreasing (increasing) in the worker's share of the rents in the incumbent match.

The turnover model can be recast in a search environment. With endogenous intensity of on-the-job search, Mortensen (1978) indicates that "counter-offer matching" generates excessive search intensity as a form of rent seeking. The function generating wage offers, equation (5), includes a counter-offer-matching component. As such there is a force toward excessive search. More recently Mortensen (1986) argues that, with endogenous search intensity, rent sharing induces a suboptimally low level of search: the worker in failing to capture the full benefit of discovering a superior match searches insufficiently. (Also, firms recruit with suboptimal intensity.) It is conceivable that the two counteracting effects exactly offset leaving no distortion.[14] Nevertheless, the strong results regarding the efficiency of

[14]Magnitudes of the two search effects depend on the sizes of the rent sharing parameters. For worker j in firm i, the larger is β_{ij} the weaker is the rent-seeking incentive to generate wage offers. The larger are the rent sharing parameters of other firms, the greater the intensity of on-the-job search for the purpose of separation.

turnover are tempered in the search environment to the extent the two effects are present and are not offsetting.

3. An Application to Unions

The equilibrium model developed in sections 1 and 2 produces implications for the effects of union status on wages and turnover. Extending the recent efficient contracting models of unionism (McDonald and Solow 1981; MaCurdy and Pencavel 1986; Brown and Ashenfelter 1986) to the matching environment, I assume that the only difference between union (u) and nonunion (n) workers is in their abilities to extract rents. In particular, unions are assumed not to redistribute rents across workers.[15] To illustrate this application, also assume all firms are either fully unionized or not unionized at all. Any worker employed in a union firm receives a share β_u of the rents to his match. In a nonunion firm the share is β_n which is less than β_u. The presence or absence of a union in any particular firm is given exogenously.

With the wage rate increasing in bargaining power, a union wage premium is immediate. However, in applying the efficient contracting model of unions to the matching environment a novel feature arises. The gain to union employment exists only if the match is optimal (i.e., if rents are positive). Because only infra-marginal workers earn rents, the relative attractiveness of union employment depends on worker-specific productivity differences between union

[15] A redistributive union lets β_{ij} depend on rents in the i,jth match. In deriving the unique rent sharing equilibrium in the appendix, I treat β_{ij} as parametric. If β_{ij} depends on rents in the i,jth match, the analysis in the appendix is not sufficient to guarantee the existence of an equilibrium set of wage offers.

and nonunion firms. Consequently, there exists a wage premium for union workers without queuing for union employment.

Since the sharing parameters do not affect the separation decision, union status is not predicted to affect the separation rate. But if some workers leave the union sector, $\beta_u > \beta_n$ implies a lower quit rate and higher layoff rate for union workers. The union wage premium, which is present if and only if the match is optimal, reduces the probability that a subsequent separation is to a higher paying match. This result is fairly robust to the modeling of unionism. If unionization affects the marginal product of efficiency units of human capital, then unionization would affect the size of firms. If unions promote featherbedding, then unionization would reduce firm size. Alternatively, if unions increase productivity as in the collective-voice approach (e.g., Freeman and Medoff 1984), then unionization would increase firm size.[16] However, a productivity increasing or decreasing union would have no effect on the separation rate after the transition associated with union certification. The implications of unions for turnover are robust to this modification of the effect of unions.

That union status reduces quits relative to layoffs is documented in McLaughlin (1987, Chapter 4). However, the evidence on the effect of union status on total separations is mixed. Freeman (1980a) reports evidence from a variety of sources that union status lowers the separation rate. In McLaughlin (1987, Chapter 4), I find similar evidence: "The separation rate of union members is 5.7 ... percentage points lower than" that of their

[16]To be consistent with the equilibrium model of rent sharing and turnover, the increased productivity which is central to the collective-voice approach cannot come from reduced turnover.

nonunion counterparts. Although this estimate is drawn from a probit regression which controls for the usual human capital and demographic variables, the regression does not control for the workers' pre-separation wage rate. Controlling for the pre-separation wage, I find that the effect of union status on separations falls to about one-half of one percentage point. Controlling for the pre-separation wage is appropriate if it proxies for unobserved differences which are correlated with union status; it is inappropriate if the pre-separation wage captures wage differentials related to relative bargaining strength.[17]

The model can also be applied to analyze the effect of unions in compressing the distribution of wages (Freeman 1980b). Equation (9.2) implies that the variance of the accepted wage σ_w^2 depends on the variances and covariance of the two relevant productivity values, M^*_{Ij} and $M^*_{I-1,j}$.

$$(10) \qquad \sigma_w^2 = \beta^2 \cdot \sigma_m^2 + (1-\beta)^2 \cdot \sigma_{m-1}^2 + 2\beta(1-\beta) \cdot \sigma_{m,m-1},$$

where β is β_u if the worker is in a union firm and β_n otherwise, and the j subscript is suppressed. Note that if variation in productivity values were due to variation in general skills alone, then there would be no compression for any value of β. ($\sigma_{m,m-1} = \sigma_m \cdot \sigma_{m-1} = \sigma_m^2$ for this case; thus $\sigma_w^2 = \sigma_m^2 = \sigma_{m-1}^2$.) Therefore, the interesting case is where the correlation between M^*_I and M^*_{I-1} is less than one: $\sigma_{m,m-1} < \sigma_m \cdot \sigma_{m-1}$. Assuming common variances, that

---

[17]Although these results are instructive, they are not structural estimates. To reach a definitive conclusion, one must control for self-selection (on the unobservables) into and out of the union sector. Such estimates are not available.

is $\sigma_m^2 = \sigma_{m-1}^2$, one can establish that the variance of the accepted wage is not monotonically related to the bargaining power of the worker.

$$\frac{\partial \sigma_w^2}{\partial \beta} = 2 \cdot [2\beta - 1] \cdot [\sigma_m^2 - \sigma_{m,m-1}] \gtrless 0 \quad \text{as} \quad \beta \gtrless 1/2. \tag{11}$$

Thus for unions to increase compression, the rent sharing parameter must be less than one half.

Use of the two <u>conditional</u> variances of wages indicates a similar ambiguity in the analysis of wage compression by union status. First condition on the productivity value in the best alternative match. This conditional variance of wages is a fraction of the variance of productivity values in the consummated match: $\sigma_w^2 = \beta^2 \cdot \sigma_m^2$. Since $\beta_u > \beta_n$, there is less compression for union workers. Alternatively, condition on the productivity value in firm I to generate that $\sigma_w^2 = (1-\beta)^2 \cdot \sigma_{m-1}^2$. With $\beta_u > \beta_n$, the wage of a nonunion worker is more responsive to outside productivity values, consequently unions induce greater compression.

A single rent sharing parameter for union workers does not appear to be adequate in capturing the empirical regularity of greater compression of union wages. To capture the greater compression of union wages in the context of the equilibrium rent sharing model, rent sharing in unions must include a redistributional element.

4. Summary and Conclusions

In this paper, I analyze rent sharing in the matching environment. Rents are defined as the difference between the worker's productivity value in his optimal match and the worker's best alternative wage offer. Hence the analysis requires a meaningful concept of productivity in the matching context. An equilibrium model of efficiency units of human capital is developed to give content to worker productivity and to allow each worker's human capital efficiency units to vary in number across firms.

In terms of rent sharing, I demonstrate that a simple sharing rule generates wage flexibility, and efficient matching and turnover. Using a recently developed model of the quit-layoff distinction, I find that the higher the worker's share of the rents associated with the match, the lower the quit rate and the higher the layoff rate. Furthermore, the two are exactly offsetting, leaving no effect of the worker's share on total separations.

The principal application of the model is to the effect of union status on wages and turnover. The analysis embeds a strong form of the efficient contracting model of unions in the equilibrium matching model: workers in union firms capture a larger fraction of the rents than do nonunion workers. This implies a positive union-nonunion wage differential; furthermore, unionization lowers the quit rate, and increases the layoff rate, but has no effect on matching efficiency or the total separation rate. No clear result regarding the effect of unions on wage compression is implied.

A second application is to inter-industry wage differentials (e.g., Krueger and Summers 1987 and 1988; Murphy and Topel 1987). Krueger and

Summers conclude that estimated inter-industry wage differentials are inconsistent with competitive labor markets and are indicative of rent sharing. The equilibrium model of rent sharing developed in section 1 is capable of accounting for inter-industry wage differentials through differential rents or bargaining power. For instance, some industries' matches might be more specific, inducing greater rents and higher wages. Thus lower separation rates are predicted in high paying industries if rents are not entirely transitory. The analysis of section 1 establishes that a noncompetitive labor market with rent sharing can be fully consistent with market clearing. Indeed, the rent-sharing equilibrium efficiently allocates workers to firms. Consequently, the normative implications described by Krueger and Summers (1987, 43) do not follow from the equilibrium model.

The model is offered as a parsimonious representation of rent sharing and turnover in a matching environment. Perhaps at the expense of parsimony, a useful extension would be to allow for optimal investment in skills. Such an extension would invalidate the assumption of spot markets but might generate valuable insights for the effect of rent sharing on investment decisions.

APPENDIX

Equilibrium Wage Offers

The purpose of this appendix is to establish the existence of a unique solution to (5), a the system of I equations for each worker j.[18] To do so, I employ the contraction mapping theorem which also guarantees convergence.

The system of I equations (5) can be written as a single functional equation. For $i \in D = \{1, \ldots, I\}$, the wage-offer function $w(i)$ maps from D into the non-negative subset of the real line:

$$\text{(A.1)} \qquad w\colon D \subseteq R \rightarrow R^{+}.$$

Consequently, the single functional equation is

$$\text{(A.2)} \qquad \begin{aligned} w(i) &= \beta(i)M(i) + [1-\beta(i)]\cdot \text{MIN}\{M(i),\ f[v(i)]\} \\ &= (Tv)(i) \qquad\qquad \text{for all } i \in D, \end{aligned}$$

where $\beta(i) \in (0, 1]$, $M(i) \in [0, \bar{M}]$, $f[v(i)] = \max\limits_{k \neq i} v(k)$, and T is a functional operator.

Let $S = \{w\colon D \rightarrow [0, \bar{M}]\}$ be the space of bounded functions w with the sup norm as its metric. Note that, in equation (A.2), T maps S into S.

<u>Proposition</u>: In (A.2), $T\colon S \rightarrow S$ is a contraction mapping.

<u>Proof</u>: By Blackwell (1965), it is sufficient to establish the following two conditions:

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[18] j subscripts are suppressed throughout the appendix.

(i) (*monotonicity*) $w, v \in S$ and $w(i) \leq v(i)$ for all $i \in D$ implies that $(Tw)(i) \leq (Tv)(i)$ for all $i \in D$.

(ii) (*discounting*) for $w \in S$, $\alpha \in R^+$, and some $\gamma \in [0, 1)$, $[T(w+\alpha)](i) \leq (Tw)(i) + \gamma\alpha$ for all $i \in D$.

Since $w(i) \leq v(i)$ implies $\max_{k \neq i} w(k) \leq \max_{k \neq i} v(k)$ for all $i \in D$, monotonicity is immediate:

$$\text{(A.3)} \qquad (Tw)(i) - (Tv)(i) \leq 0 \quad \text{as} \quad \text{MIN}\{M(i), f[w(i)]\} \leq \text{MIN}\{M(i), f[v(i)]\}.$$

For discounting,

$$
\begin{aligned}
\text{(A.4)} \qquad [T(w+\alpha)](i) &= \beta(i)M(i) + [1-\beta(i)]\cdot\text{MIN}\{M(i), f[w(i)+\alpha]\} \\
&= \beta(i)M(i) + [1-\beta(i)]\cdot\text{MIN}\{M(i), f[w(i)] + \alpha\} \\
&\leq \beta(i)M(i) + [1-\beta(i)]\cdot\text{MIN}\{M(i) + \alpha, f[w(i)] + \alpha\} \\
&\leq \beta(i)M(i) + [1-\beta(i)]\cdot\text{MIN}\{M(i), f[w(i)]\} + [1-\beta(i)]\cdot\alpha \\
&\leq (Tw)(i) + [1-\beta(i)]\cdot\alpha.
\end{aligned}
$$

With $\beta(i) \in (0, 1]$, define $\gamma = 1 - \max_i \beta(i) \equiv 1 - \bar{\beta}$ so $\gamma \in [0, 1)$. This establishes the discounting condition. Therefore, T is a contraction mapping.

∎

By the contraction mapping theorem, there exists a unique function $w^*: D \to R^+$ which solves the functional equation $w(i) = (Tw)(i)$. In addition, from any initial function $w_0 \in S$, the sequence $w_{n+1}(i) = (Tw_n)(i)$ converges to $w^*(i)$.

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