Rent Sharing and Turnover in a Model with Efficiency Units of Human Capital
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The problem I address in this paper is how <u>unique</u> wage offers obtain in a matching model. Two questions characterize the problem. 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. How is it that 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? The matching variants of turnover models are actually two-period simplifications of Becker's (1962) model of general and firm-specific human capital augmented for randomness (see McLaughlin 1987, Chapter 1). As such, an efficiency units assumption is invoked.

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 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.

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[1] I thank Marcus Berliant, Barbara Mace, Stephen Trejo, and participants in the Workshop in Applied Economics at the University of Rochester for their helpful comments.

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. Second, the set of wage offers which supports the optimal match depends on outside wage offers. Since the best suboptimal wage offer is not unique, an additional indeterminacy is present.

In this paper, I develop an explicit 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--from outside the model--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.

The sharing rule generates optimal matching, and carries important implications for turnover behavior. Turnover can result from stochastic variation in either the production technology of <u>any firm</u>, or the supply of efficiency units of <u>any worker</u>. With such stochastic variation, the implications of the sharing rule for turnover are:

(i) All turnover is efficient.

(ii) Wages are flexible.

(iii) The higher the worker's (firm's) share of the rents to the match, the lower the probability of a quit (layoff).

Item (iii), which relies on my model of the quit-layoff distinction (McLaughlin 1987), can be applied to analysis of the effect of union status on turnover. To the extent union workers capture a higher share of the rents associated with the employment match, they are expected to exhibit lower quit rates and higher layoff rates than their nonunion counterparts.

Efficiency Units of Human Capital

In this section, I consider a single period model of a market in efficiency units of human capital. The analysis begins with I types of human capital corresponding to the I firms in the market, but simplifies to general and firm-specific human capital. The decision to invest in human capital is ignored throughout.[2]

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

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

My principal concern is with the input H_i. Let H_i be given by an additive function which maps the J workers' skills (or investment histories) into a real number.[3]

$$(2) \qquad H_i \equiv \sum_{j=1}^{J} H_{ij} \equiv \sum_{j=1}^{J} H_i(h_{1j}, \ldots, h_{Ij}), \qquad i = 1, \ldots, I.$$

Thus each worker j is a collection of skills which cannot be unbundled. h_{ij} is a stock variable measuring the amount of firm-i-type human capital accumulated by worker j, so h_{ij} captures worker j's employment history. $H_i(\cdot)$ is a firm-specific function which maps worker j's vector of human capital into

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[2]See Murphy (1986) for an analysis of the investment decision in a model with specific capital.

[3]The model has as antecedents the work of Mandelbrot (1962), 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.

$$P_i \cdot \frac{\partial X_i}{\partial H_i}(H_i;\ K_i) = P_{Hi}, \qquad i = 1, \ldots, I, \tag{5}$$

with K_i fixed. Thus equation (5) implicitly defines firm i's short-run derived demand for human capital $H_i^*(P_{Hi}/P_i;\ K_i)$, with H_i^* decreasing locally in its first argument. Note that this specification allows for different prices of human capital across firms. I show below that this is a property of the market equilibrium.

<u>Matching</u>

The supply of human capital efficiency units to the particular firms is given as the solution to the matching problem. 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 a vector of equilibrium shadow prices P_{Hi}, $i = 1, \ldots, I$.

Begin by defining worker productivity. 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:

$$M_{ij} \equiv P_i \cdot \frac{\partial X_i}{\partial H_i}(H_i;\ K_i) \cdot H_{ij} = P_{Hi} \cdot H_{ij}, \qquad i = 1, \ldots, I,\ j = 1, \ldots, J, \tag{6}$$

where M_{ij} denotes worker j's productivity value in firm i. Note that worker j's productivity value depends on i, the identity of j's employer. Worker j's productivity value is decomposed into price and quantity components, both of which in general vary by firm.

a scalar value H_{ij}. Since $H_i(\cdot)$ is indexed by i, firm i can "value" h_{ij} more than h_{kj} $(k \neq i)$, and vice versa for firm k.

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 worker A with fifteen years of experience with other firms and worker B with one year of experience in its own employment if $H_{iA} = H_{iB}$. Similarly, the firm is indifferent between N workers of type C each with H_{iC} units of human capital and one worker with $N \cdot H_{iC}$ units.

Although all the results that follow are entirely consistent with the model at this level of generality, for simplicity let $H_i(\cdot)$ be parameterized as follows.

$$(3) \qquad H_i \equiv \sum_{j=1}^{J} H_i(h_{ij}, \sum_{k \neq i} h_{kj}) \equiv \sum_{j=1}^{J} H_i(h_{ij}, \bar{h}_{ij}), \qquad i = 1, \ldots, I.$$

Therefore, firm i considers human capital to be of two types: general and firm-i specific. Presumably, firm i places a premium on firm-i specific capital, so the marginal contribution of general capital $\bar{h}_{ij}$ (for any worker j) is dominated by the marginal contribution of firm-i specific capital h_{ij}.

$$(4) \qquad \frac{\partial H_i}{\partial \bar{h}_{ij}} < \frac{\partial H_i}{\partial h_{ij}} \quad \text{for } \bar{h}_{ij} = h_{ij}, \qquad \begin{array}{l} i = 1, \ldots, I, \\ j = 1, \ldots, J. \end{array}$$

Neoclassical analysis derives firm demands for human capital efficiency units: H_i^*, $i = 1, \ldots, I$. Taking as given the price of efficiency units of human capital to firm i, P_{Hi}, and the price of firm i's product P_i, firm i chooses H_i to satisfy

In the optimal match, is worker j assigned to the firm in which his productivity value is greatest? The answer is yes, due to the efficiency units assumption.[4] Note that by definition the optimal match maximizes the value of output in the market. 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.[5]

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[4]For the moment, the P_{Hi}, i = 1, ..., I, are taken as given. This is relaxed below.

[5]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.

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

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

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

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

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

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 other matching models. Consider the model of Koopmans and Beckmann (1957). In that model, the optimal match does not in general assign a worker to the firm in which the output of the match is greatest for the specific worker. Worker j can match with any one of I firms. The set of possible match values available to worker j thus has I elements: $\mathbf{V}_j = \{V_{1j}, \ldots, V_{Ij}\}$. Let i(j) denote the firm associated with the maximum over the set $\mathbf{V}_j$. In general, the solution to the optimal matching problem does not assign worker j to firm i(j).

One way to structure the Koopmans-Beckmann model is to let the elements of $\mathbf{V}_j$, j=1, ..., J, be generated by a continuous function of indices of firm and worker quality: V = f(k, h), where f is an increasing, concave function and $f_{kh} > 0$. 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.

Consequently, the matching model with efficiency units of human capital exhibits a novel, albeit 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 the decentralized market supports the

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productivity match.

optimal assignment. It is here that rent sharing plays an important role. In preparation for that analysis, it is important to characterize the shadow value of human capital at each firm under the assumption that each firm chooses its employment level competitively.

Return to equation (6). Worker j's productivity in firm i depends on the value of marginal product of human capital in firm i. At the firm's optimum, $M_{ij} = P_{Hi} \cdot H_{ij}$, but what determines P_{Hi}? From the solution to the matching problem, the supply of human capital to firm i is an increasing function of P_{Hi}. This follows because the optimal match assigns a worker to the firm in which his productivity is highest, and a higher P_{Hi} increases the probability that firm i is best. Hence a higher P_{Hi}--with P_{Hk}, k≠i, given--sweeps in part of the distribution of workers. Let $H_i^S(\cdot)$ denote the function mapping P_{Hi} into the supply of human capital efficiency units to firm i. With a rising supply price at the firm level, the <u>competitive</u> equilibrium solves

$$(7) \qquad P_i \cdot \frac{\partial X_i}{\partial H_i}(H_i^S(P_{Hi}), K_i) = P_{Hi}, \qquad i = 1, \ldots, I,$$

with the solution values denoted P_{Hi}^*, $i = 1, \ldots, I$.[6] Consequently, efficiency units of human capital have firm-specific shadow prices; but unlike in hedonic pricing models (e.g., Tinbergen (1956) and Rosen (1974)), the underlying skills are not priced out in equilibrium. Equation (7) captures a key feature of the model: firm size and the matching problem are solved simultaneously since P_{Hi} is endogenous.

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[6]For simplicity, I establish the partial equilibrium; the extension to the general equilibrium is, I suspect, entirely conventional if indivisibilities are ignored.

Rent Sharing

With the value of worker j's productivity at each firm i well defined and given by $M^*_{ij} = P^*_{Hi} \cdot H_{ij}$, 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 P^*_{Hi} determines the productivity value, not the wage payment. In short, 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 second best match plus a fraction of the difference between his best and second best productivity values. 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. In determining whether a set of wage offers is capable of sustaining the optimal match, one is interested in how wage offers induce matching, rather than vice versa.

The following rent sharing scheme, which employs a weaker informational requirement, has several desirable properties: Assume firm i is characterized by a sharing parameter β_i such that

$$(8) \qquad W_{ij} = W_{i'j} + \beta_i(M^*_{ij} - W_{i'j}), \qquad \begin{array}{l} i = 1, \ldots, I, \\ j = 1, \ldots, J, \end{array}$$

with i' denoting the firm in which worker j's productivity value is second highest. To be viable, this sharing requires that both firm i and worker j know the productivity value associated with their match M^*_{ij}, and j's best alternative wage offer $W_{i'j}$.

Under this rent sharing rule, wage offers are flexible: wage offers covary positively with both the productivity value of worker j and j's best outside wage offer. Of course, equation (8) is one equation in a simultaneous system. In the two firm case (i = 1, 2)

$$W_{1j} = W_{2j} + \beta_1(M^*_{1j} - W_{2j}), \tag{9.1}$$

$$W_{2j} = W_{1j} + \beta_2(M^*_{2j} - W_{1j}), \qquad j = 1, \ldots, J. \tag{9.2}$$

Under the Nash assumption, the solution to this system is a set of wage offers to each worker:

$$W_{1j} = \frac{\beta_1 M^*_{1j} + \beta_2(1-\beta_1)M^*_{2j}}{1 - (1-\beta_1)(1-\beta_2)}, \tag{10.1}$$

$$W_{2j} = \frac{\beta_2 M^*_{2j} + \beta_1(1-\beta_2)M^*_{1j}}{1 - (1-\beta_1)(1-\beta_2)}, \qquad j = 1, \ldots, J. \tag{10.2}$$

for $0 < \beta_i \leq 1$, $i = 1, 2$. The wage offers associated with this rent sharing rule have several desirable properties. First, worker j's wage offers are flexible: j's two offers are increasing in both M^*_{1j} and M^*_{2j}. Second, j's accepted wage offer is increasing in the rent sharing parameter of the accepted firm. Third, wage offers generated by such a rent sharing rule support the optimal match:

$$W_{1j} \gtrless W_{2j} \quad \text{as} \quad M^*_{1j} \gtrless M^*_{2j}, \qquad j = 1, \ldots, J. \tag{11}$$

That is, the sharing parameters β_i, i = 1, 2, have no effect on the market's allocation of workers to firms.[7]

Turnover

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

(i) the price of the product, P_i

(ii) the production function, X_i

(iii) the human capital functions, H_i

(iv) the composition of supply, $(h_{ij}, \bar{h}_{ij})$

for any i = 1, ..., I, or any j = 1, ..., J. Productivity shocks affect only the price of human capital (in equilibrium); shocks to supply or the functions mapping supply into efficiency units affect both P^*_{Hi} and H_{ij}. 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 preceeding section is that the rent sharing parameters do not affect the rate at which workers change employers. Worker j's optimal match in any period is independent of the β_i, i = 1, ..., I; the rent sharing rule generates optimal matching in each period; therefore, worker

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[7]These properties also follow from the more general specification which allows the rent sharing parameter to be match specific: β_{ij}.

j's probability of changing employers (i.e., the separation rate) is independent of the sharing parameters.

Based on the model of the quit-layoff distinction in McLaughlin (1987), the higher is firm i's rent sharing parameter β_i, the lower is its quit rate and the higher is its layoff rate. In that model of the quit-layoff distinction, 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. The higher is β_i, the higher was the wage of firm i's workers; hence the lower (higher) the probability any one of these workers leaves <u>to a higher (lower) paying employer</u>: the quit (layoff) rate is decreasing (increasing) in the worker's share of the rents in the incumbent match.

<u>Effect of Union Status on Turnover</u>

This model produces implications for the effect of union status on turnover. Assume that the only difference between union (u) and nonunion (n) workers is in their abilities to extract rents. To illustrate this application, also assume all firms are either fully unionized or not unionized at all. Any worker employed in a union firm gets 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. 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. In short, 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.

That union status reduces quits relative to layoffs is documented in McLaughlin (1987, Chapter 3). However, the evidence on the effect of union status on total separations is mixed. Freeman (1980) reports evidence from a variety of sources that union status lowers the separation rate. In McLaughlin (1987, Chapter 3), I find similar evidence: "The separation rate of union members is 5.7 ... percentage points lower than" that of their 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 [8]

<u>Summary</u>

In this paper, I analyze rent sharing in the matching environment. In doing so, I define rents to be the difference between the worker's productivity value in his optimal match and the worker's best outside 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 recent 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

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[8] While 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.

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 turnover.

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