ASYMMETRIC INFORMATION, MULTIPERIOD LABOR CONTRACTS, AND INTERTEMPORAL ALLOCATION PROBLEMS

by

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March 1983

UCLA Working Paper #288

*I gratefully acknowledge the helpful comments of Armen Alchian, Lee Lillard, Louis Maccini, Mark Plant, Marc Robinson, Hugh Rose, Finis Welch, Michael Waldman, and the participants of the Labor Workshop at UCLA.

Recent developments in implicit labor contract theory have sought to provide an explanation for why we might observe a job separation even when the value of the marginal product of a worker exceeds his reservation wage. Previous studies have focused on the potential inefficient separations induced by either bilateral asymmetric information problems (e.g., Hall and Lazear (1982), Carmichael (1981), and Hashimoto and Yu (1980)) or the interaction between asymmetric information and risk aversion (e.g., Grossman and Hart (1981), Green (1980), Azariadis (1980)). However, in previous studies, analysis has been limited to models in which separations occur only in the final period of the model. In this paper, a simple multiperiod model is developed in which separations may occur in each of several successive periods. The multiperiod specification enables us to distinguish between temporary and permanent separations and to focus attention on the potential for inefficient separations induced by asymmetric information problems in an intertemporal setting.

In an intertemporal model in which separations may occur in any one of several successive periods, intertemporal allocation problems arise because compensation in a given period plays an allocative role not only in that particular period but also in all periods prior to that period. That the terms of compensation may play a multiple intertemporal role in allocating labor has been recognized previously in other contexts. For instance, this argument has been used to explain the observed occurrence of rising wage profiles with tenure in the presence of such factors as worker shirking or firm specific skill acquisition (e.g., Lazear (1979), Carmichael (1981)). In this asymmetric information setting, this intertemporal allocation problem takes on new dimensions. Specifically, we argue that if asymmetric information is present then it is very difficult to design an incentive compatible contract that simultaneously promotes in all periods efficient layoffs, efficient quits, and efficient waiting for recall by workers who have been laid off.

In what follows, we develop a simple multiperiod model that allows us to characterize the intertemporal allocation problems that emerge in an asymmetric information setting. We first examine the predetermined wage contracts that are the focus of much of the earlier work (e.g., Kuritani (1973), Hashimoto (1979), Hashimoto and Yu (1980), Carmichael (1981), Hall and Lazear (1982)). One of the primary initial results is that even in the multiperiod, unilateral asymmetric information setting with all agents assumed to be risk neutral, inefficient turnover is a feature of the optimal predetermined wage contract. This in itself represents a departure from previous work since in previous analyses risk neutrality and unilateral asymmetric information implies an optimal predetermined wage contract that yields efficient turnover (see Hall and Lazear (1982)). We demonstrate that the distinguishing features that account for this difference in results are the intertemporal allocation problems discussed above. It is further shown that a consequence of these intertemporal allocation problems is that the experience-wage profile associated with the predetermined wage contract is steeper than that consistent with efficient layoffs of older workers. Having characterized the properties of the inefficient turnover that results from predetermined wage contracts in this setting, we then consider alternative contract structures that include such institutions as severance pay, pensions, quit penalties, and seniority provisions to determine whether alternative contract structures exist that might alleviate this inefficient turnover. While we find that the introduction of alternative payments instruments helps alleviate this inefficient turnover, we demonstrate that in a multiperiod, bilateral asymmetric information setting, it is not possible, in general, to disentangle the effects of bilateral asymmetric information problems and intertemporal allocation problems. As a result, there is a greater degree of inefficient turnover than would be expected from bilateral asymmetric information problems alone.

The Model

Consider a world in which firm specific skill accumulation and hiring costs imply the development of long term attachments in the labor force. Suppose further that competition in the labor market insures that workers make implicit contracts with firms at the onset of their association so that each worker has an expected discounted income (taking into account the possibility of quits and layoffs) that is as good as is available elsewhere. In a world of uncertainty but in which all parties have identical information at each moment in time, an efficient contract would necessarily imply a wage and employment agreement contingent on the realized values of the worker's value to the firm and the worker's alternatives at each moment in time. However, if asymmetric information is a problem so that either the worker privately observes the realization of his alternative values or the firm privately observes the realization of the value of the worker's product then the full information contingent claims contact is not feasible. It is the properties of the multiperiod labor contracts that emerge under these circumstances that we analyze in this paper.

Formally, we consider a three period model. Three periods are the minimum necessary to model a "true" temporary layoff in which a worker is sequentially employed, laid off, and then recalled. Prior to the beginning of period one (the first period) the worker and the firm under consideration make some sort of implicit contract. In period one, no work occurs but training takes place and therefore in the second and third periods the worker's productivity is enhanced. Specifically, in future periods, if the worker remains attached to his original employer the worker's value in each period i is assumed to be M_i where M_i is a firm specific random variable. The random variable M_i is assumed to have the density function $f_i(M_i)$ where $E(M_i) = \int_0^\infty M_i f_i(M_i) dM_i$ and $Cov(M_i, M_j) = 0$ for $i \neq j$.

The first type of contract that we consider is the "predetermined wage" contract analyzed by Kuritani (1973), Hashimoto (1979), Hashimoto and Yu (1980), Carmichael (1981) and Hall and Lazear (1982). The predetermined wage contract takes the following form. At the outset of their attachment, the worker and the firm agree upon terms of compensation that are not contingent on the realized state of the world in each period. Hence, the firm and the worker agree on the contractual wages (w_1, w_2, w_3) where w_1 is a guaranteed "wage" that acts as a lump sum, non-allocative payment from one party to another to achieve the proper distribution of the benefits from the contract.

With such a contract, now consider the responses of the worker and the firm to random shocks in the worker's alternatives and value, respectively. Before proceeding, it is important to emphasize that although the realization of the worker's alternative is privately observed by the worker and the realization of the worker's value to the firm is privately observed by the firm, it is assumed that both parties have the same ex ante information on the distribution of the relevant random variables.

In considering the quit and layoff decisions, it is helpful to consider the periods in reverse order. In period 3, if the worker is still attached to the firm, the value of the worker's product is revealed to the firm to be

M_3. The firm will thus layoff the worker if:

(1) $M_3 < w_3 = M_3^*$.

This implies that the probability of a layoff in period 3 is given by:

$$(2) \quad L(M_3^*) = \int_0^{M_3^*} f_3(M_3)dM_3.$$

The worker, on the other hand, if he is still attached to the firm at the beginning of period 3 may choose to quit. The worker's alternative income in period 3, net of mobility costs, is taken to be V_3 where V_3 is a worker specific random variable. The random variable V_3 is assumed to have the density function $g_3(V_3)$ where $E(V_3) = \int_0^\infty V_3 g_3(V_3)dV_3$. Following Carmichael (1981) and Hall and Lazear (1982), V_3 may contain a subjective element related to the worker's job satisfaction. Given V_3, the worker quits if:[1]

(3) $V_3 > w_3 = V_3^*$.

The probability of a quit in period 3 is thus given by:

$$(4) \quad Q(V_3^*) = \int_{V_3^*}^\infty g_3(V_3)dV_3.$$

Observe that in period 3 that the worker and the firm can make their respective separation decisions independently of the other's separation decision. This is a property found in most of the previous analyses using this sort of specification. However, as will soon become apparent, this independence does not emerge in period 2 in this analysis and we argue that in an n period analysis would not hold in periods 2,...,n-1.

The key feature of period 2 is that there are two distinct types of "quit" decisions that the worker may face in period 2. To understand this, it is important to emphasize that a "quit" in this context is assumed to be a permanent separation. In other words, a quit refers to the worker accepting alternative permanent employment and by construction this implies that the worker is unavailable for recall. This is perhaps an overly strong assumption but is rationalized on the basis that a worker who relocates to an alternative sector has presumably incurred relocation costs (which would be incurred a second time if the worker returned from the alternative sector) and may have begun to acquire specific skills in the alternative sector. Moreover, the firm in question may have to expend resources in finding a worker who has relocated. Thus, an attempt to recall a worker in period 3 who accepted alternative permanent employment in period 2 would result in the worker incurring relocation costs as well as a loss of any specific skills acquired in the alternative sector and the firm incurring search costs in locating the worker. Such factors would, in a more general analysis, presumably mean that the costs to the firm associated with inducing a worker to accept an employment offer in period 3 would be substantially higher if that worker relocated in period 2 than if the worker remained "attached" to the firm during period 2. Rather than explicitly modeling the differential costs of recall, we make the simplifying assumption that a worker who accepts alternative permanent employment is permanently lost to the firm (analogous assumptions have been made in similar contexts in previous analyses, e.g., Parsons (1972) and Ehrenberg (1971)).

Given this definition of a quit, the worker faces different decisions depending upon whether he is offered employment for the period. Specifically, if the firm has made an employment offer to the worker in period 2 the worker will quit if:

$$(5) \quad V_2 > w_2 + \{(1-L_3)[(1-Q_3)w_3 + Q_3(E(V_3|V_3>V_3^*)] + L_3E(V_3)\}\rho = V_2^*, \ \rho < 1$$

where V_2 is the expected discounted income available from the best alternative associated with a permanent separation and ρ is the discount rate. The random variable V_2 is assumed to have the density function $g_2(V_2)$ where $E(V_2) = \int_0^\infty V_2 g_2(V_2)dV_2$ and $Cov(V_2,V_3) = 0$.[2] Given V_2^*, the probability that the worker will quit given that he has an employment offer in period 2, $Q_2^e(V_2^*)$, is defined accordingly.

Alternatively, if the worker is informed that he is laid off in period 2 then his "quit" decision is quite different. In this instance, by "quit" decision we mean the decision on whether or not to wait to be available for recall. It should be emphasized that we do not exclude the possibility that a laid off worker who chooses to wait for recall may be employed while laid off but that such employment is by definition of only a temporary or stopgap nature. Specifically the laid off worker will quit, i.e., not be available for recall if:

$$(6)\quad V_2 > B + \{(1-L_3)[(1-Q_3)w_3 + Q_3E(V_3|V_3>V_3^*)] + L_3E(V_3)\}\rho = V_2^{**}$$

where B is the value associated with the worker's time in period 2 given that the worker remains available for recall. B can be thought of the income equivalent of the value of the additional leisure the laid off worker acquires and may also include any income that the worker earns through temporary or stopgap jobs. The possibility that B may include government financed unemployment benefits is not considered because the inefficient turnover that might result from such government induced distortions has already been well documented (e.g., Feldstein (1976)). Given V_2^{**}, the probability that the worker laid off in period 2, $Q_2^u(V_2^{**})$, is defined accordingly.[3]

Given that the firm must transmit its employment offer prior to the worker making his quit decision, the firm will layoff the worker in period 2 after observing M_2 if:

$$(7) \quad (1-Q_2^e)\,[M_2 - w_2 + (1-L_3)(1-Q_3)[E(M_3|M_3>M_3^*) - w_3]\rho]$$
$$< \max\,[0,(1-Q_2^u)(1-L_3)(1-Q_3)[E(M_3|M_3>M_3^*) - w_3]\rho]$$

In other words, if the expected discounted gain to the firm associated with the worker being employed (given that the worker does not quit) is less than the expected gain associated with the worker being laid off (taking into account the possibility that the worker may not be available for recall), then the worker will be laid off. Observe that the properties of L_3, Q_3, Q_2^u and $E(M_3|M_3>M_3^*)$ imply $(1-Q_2^u)(1-L_3)(1-Q_3)[E(M_3|M_3>M_3^*) - w_3]\rho > 0$ so that (7) may be rewritten as:

$$(8) \quad M_2 < w_2 + [(Q_2^e-Q_2^u)/(1-Q_2^e)][(1-L_3)(1-Q_3)(E(M_3|M_3>M_3^*) - w_3)]\rho = M_2^*.$$

Given M_2^*, the probability of a layoff in period 2, $L_2(M_2^*)$, is defined accordingly.

Observe that the layoff in period 2 may turn out to be either temporary or permanent. As long as $L_3 < 1$, there is a positive probability of recall but the worker may decide to forego that opportunity by quitting. This characterization of a layoff as being inherently indefinite seems to fit the description of many of the layoffs that are observed empirically. In this regard the laid off worker's quit decision embodied in $Q_2^u(V_2^{**})$ reflects the inherent uncertainty faced by a typical indefinitely laid off worker.

The relationship between the values of M_i, the values of V_i and B obviously play a fundamental role in the analysis. In accordance with the presumption of firm specific skill accumulation and the existence of mobility costs, it is assumed that $E[M_2] > E[V_2] - E[V_3]\rho$ and $E[M_3] > E[V_3]$. In order for there to a reasonable probability that a worker might choose to quit in period 2, it is further assumed that $B + E[V_3]\rho < E[V_2]$.

Given L_3, Q_3, L_2, Q_2^e, and Q_2^u it is now possible to specify the maximization process prior to period 1 that establishes the terms of the contract (i.e., w_1, w_2, and w_3). The terms of the contract are chosen so as to maximize the expected joint value associated with the contract (this is equivalent to the maximization of expected profits of the firm subject to a minimum expected income constraint for the worker). The expected joint value is given by:

$$\begin{aligned}
(9)\quad & (1-L_2)[(1-Q_2^e)E[M_2|M_2 > M_2^*]\rho + Q_2^e E[V_2|V_2 > V_2^*]\rho] \\
& + L_2[(1-Q_2^u)B\rho + Q_2^u E[V_2|V_2 > V_2^{**}]\rho] \\
& + [(1-L_2)(1-Q_2^e) + L_2(1-Q_2^u)][(1-L_3)[(1-Q_3)E(M_3|M_3>M_3^*) \\
& \quad + Q_3E(V_3|V_3>V_3^*)] + L_3E(V_3)]\rho^2
\end{aligned}$$

Thus, w_2 and w_3 are chosen so as to maximize (9). After some work, the optimality conditions reduce to:

$$\begin{aligned}
(10)\quad & \frac{-\partial Q_2^e}{\partial w_2}(1-L_2)\ [\pi_2 + (1-L_3)(1-Q_3)\pi_3] \\
& \frac{-\partial L_2}{\partial w_2}(Y_2^e - Y_2^u) = 0
\end{aligned}$$

$$\begin{aligned}
(11)\quad & \frac{-\partial Q_2^e}{\partial w_3}(1-L_2)\ [\pi_2 + (1-L_3)(1-Q_3)\pi_3] \\
& \frac{-\partial L_2}{\partial w_3}[Y_2^e - Y_2^u] - \frac{\partial Q_2^u}{\partial w_3}L_2(1-Q_3)\pi_3 \\
& + [L_2(1-Q_2^u) + (1-L_2)(1-Q_2^e][-\frac{\partial Q_3}{\partial w_3}(1-L_3)\pi_3 - \frac{\partial L_3}{\partial w_3}Y_3^e] = 0
\end{aligned}$$

$$\begin{aligned}
\pi_i &= [E(M_i|M_i>M_i^*) - w_i]\rho^{i-1} \quad , \quad i = 2,\ 3 \\
Y_2^e &= (1-Q_2^e)\ [w_2\rho + (1-L_3)Y_3^e] + Q_2^e E(V_2|V_2>V_2^*)\rho \\
Y_2^u &= (1-Q_2^u)\ [B\rho + (1-L_3)Y_3^e] + Q_2^u E(V_2|V_2>V_2^{**})\rho \\
Y_3^e &= [(1-Q_3)w_3 + Q_3E(V_3|V_3>V_3^*)]\rho^2
\end{aligned}$$

Considerable insight can be gained from (10) and (11) alone. Condition (10) indicates that the benefits associated with a marginal increase in w_2 (less quitting in period 2 and thereby increasing expected profits) ought to be balanced against the losses (more layoffs in period 2 and thus a higher compensating differential to the worker to induce the worker to bear the higher probability of layoffs). Condition (11) illustrates the multiple allocational role that the third period wage must play. The key is that w_3 influences not only the third period quit and layoff decisions but the second period quit and layoff decisions as well. We argue that this intertemporal allocation problem provides another source of inefficient turnover in this framework in addition to the inefficient turnover caused by the bilateral asymmetric information.

The inefficient turnover caused by the bilateral asymmetric information is easy to illustrate. Consider that efficient turnover in period 3 entails the worker not being employed if

(12) $M_3 < V_3$.

Yet, the worker quits in period 3 if $V_3 > w_3$ and the firm lays off the worker if $M_3 < w_3$. Regardless of the value of w_3, these decision rules cannot attain (12) because neither party takes into account the other party's private valuation.

The inefficient turnover generated by the intertemporal allocation problems is a little more difficult to discern. For simplicity (and also for the purpose of focusing on this feature of the model) suppose for the moment that $g_3(V_3)$ is a degenerate density function centered on $V_3 = \bar{V}_3$ (where $\bar{V}_3$ is a positive constant). In this event, the worker will not quit in period 3 as long as $w_3 > \bar{V}_3$. Since $V_3 \equiv \bar{V}_3$ in this special case, (12) indicates that efficient turnover implies separation only if $M_3 < \bar{V}_3$. Hence,

$w_3 = \bar{V}_3$ will in this case generate efficient turnover in period 3. This is consistent with the findings of previous studies analyzing predetermined wage contracts in a unilateral asymmetric information setting (which is essentually what we have imposed in period 3). However, in this multiperiod framework, while setting $w_3 = \bar{V}_3$ generates efficient turnover in period 3, it generates inefficient turnover in other periods. To see this, observe that efficient turnover in period 2 entails the worker being laid off (in period 2) if:

$$(13)\quad M_2 + \left(\int_{\bar{V}_3}^{\infty} M_3 f_3(M_3)dM_3 + \int_0^{\bar{V}_3} \bar{V}_3 f_3(m_3)dM_3\right)\rho <$$

$$\max\left(V_2,\ B + \left(\int_{\bar{V}_3}^{\infty} M_3 f_3(M_3)dM_3 + \int_0^{\bar{V}_3} \bar{V}_3 f_3(M_3)dM_3\right)\rho\right)$$

and waiting for recall if:

$$(14)\quad V_2 < B + \left(\int_{\bar{V}_3}^{\infty} M_3 f_3(M_3)dM_3 + \int_0^{\bar{V}_3} \bar{V}_3 f_3(M_3)dM_3\right)\rho$$

Yet, when $w_3 = \bar{V}_3$, by the decision rules L_3, and Q_2^u, the worker waits for recall if (given $V_3 \equiv \bar{V}_3$):

$$(15)\quad V_2 > B + \bar{V}_3\rho.$$

First, observe that equation (14) and (15) together imply that if $w_3 = \bar{V}_3$ then the probability of a quit by a worker laid off in his "middle-aged" years is suboptimally high. This is because when $w_3 = \bar{V}_3$ the worker laid off in period 2 does not take into account the loss of the third period firm specific capital that occurs when he quits. On the other hand, if w_3 is chosen so that (14) and (15) are synonymous (which would require $w_3 > \bar{V}_3$) then while this would eliminate suboptimal quitting by a worker laid off in period 2, it causes an excessively high probability of layoffs in period 3. Hence, there is a trade-off between promoting efficient waiting for recall by a worker laid off in one period and promoting efficient layoffs in a later period. This is a classic case in which attempts to reduce a distortion on one margin implies that the distortion on another margin is necessarily increased.

It is this type of intertemporal tradeoff that is one of the distinguishing features of this analysis. Since no first best solution is possible given the structure imposed upon the model (i.e., predetermined wage contracts with no direct payments to laid off workers), it is of interest to fully characterize the properties of the optimal second best contract. In the next section, we focus our attention on the inefficiencies caused by intertemporal allocation problems by assuming that $V_2 \equiv \bar{V}_2$ and $V_3 \equiv \bar{V}_3$ (where $\bar{V}_2$ and $\bar{V}_3$ are positive constants) so that only unilateral asymmetric information is present. We demonstrate that with the optimal predetermined wage contract in the unilateral asymmetric information setting there is a bias towards excess layoffs of older workers who are in their final period(s) of potential employment (which may be interpreted as forced retirement) and a bias towards overemployment of middle-aged workers. We then demonstrate the role that non-employment contingent payments to workers (such as a vested pension would provide) might play towards alleviating the inefficiencies associated with the simple predetermined wage contract. Following this analysis, we return to the bilateral asymmetric information setting to investigate whether the mechanisms that help alleviate inefficient turnover in the unilateral asymmetric information setting are of help in the bilateral asymmetric information setting.

Unilateral Asymmetric Information

Under the unilateral asymmetric information specification, the worker's quit decisions become discrete. That is, the worker quits in period 3 if $w_3 < \bar{V}_3$ but stays otherwise; the worker offered employment in period 2 quits if w_2 and w_3 in combination are such that $w_2 + (1-L_3)(1-Q_3)w_3\rho + (L_3+(1-L_3)Q_3)\bar{V}_3\rho < \bar{V}_2$ but stays otherwise; and the worker laid off in period 2 "quits" if w_3 is such that $B + (1-L_3)(1-Q_3)w_3\rho + (L_3+(1-L_3)Q_3)\bar{V}_3\rho < \bar{V}_2$ but waits to be recalled otherwise. Given these discrete decision rules that now underly Q_3, Q_2^e, and Q_2^u respectively, the optimal contract is derived by maximizing the appropriately modified expected joint value. Analysis and derivation of the optimality conditions (which with these discrete decision rules involves dividing the problem into mutually exclusive regimes, calculating the optimal contract under each regime, and then comparing the expected joint value across regimes -- see the appendix) allows us to prove the following proposition.

Proposition 1: In the unilateral asymmetric information setting, the optimal predetermined wage contract satisfies the following properties:

(i) $w_3 > \bar{V}_3$ (implying that $Q_3 = 0$).

(ii) $w_2 + (1-L_3)(1-Q_3)w_3\rho + (L_3+(1-L_3)Q_3)\bar{V}_3\rho = w_2 + (1-L_3)w_3\rho + L_3\bar{V}_3\rho > \bar{V}_2$ (implying that $Q_2^e = 0$).

(iii) there exists a B^* such that if $B < B^*$ (denote this as regime I_w), then $w_3(I_w) = \bar{V}_3$ and $w_2(I_w) = \bar{V}_2 - \bar{V}_3\rho$ (which implies $Q_2^u = 1$). Alternatively, if $B > B^*$ (denote this as regime II_w), then $w_2(II_w) = B$ and $w_3(II_w) = (\bar{V}_2-B-\bar{V}_3\rho \int_0^{w_3} f_3(M_3)dM_3)/(\int_{w_3}^{\infty} f_3(M_3)dM_3)\rho$ (which implies $Q_2^u = 0$) where B^* is such that:

$$\bar{V}_2 - \left(\int_{\bar{V}_3}^{\infty} M_3 f_3(M_3)dM_3 + \int_0^{\bar{V}_3} \bar{V}_3 f_3(M_3)dM_3\right)\rho < B^* < \bar{V}_2 - \bar{V}_3\rho$$

(iv) If $B < \bar{V}_2 - \left(\int_{\bar{V}_3}^{\infty} M_3 f_3(M_3)dM_3 + \int_0^{\bar{V}_3} V_3 f_3(M_3)dM_3\right)\rho$ or $B = \bar{V}_2 - \bar{V}_3\rho$,

then the optimal predetermined wage contract yields efficient turnover.

However, if $\bar{V}_2 - \left(\int_0^{\bar{V}_3} \bar{V}_3 f_3(M_3)dM_3 + \int_{\bar{V}_3}^{\infty} M_3 f_3(M_3)\rho\right) < B < \bar{V}_2 - \bar{V}_3\rho$ then the optimal contract yields inefficient turnover. Moreover, in the inefficient turnover range, if $B < B^*$ then the inefficient turnover is characterized by overemployment of a worker in his "middle-aged" years (period 2) and an excess probability of quitting by a worker laid off in his "middle-aged" years. Alternatively, if $\bar{V}_2 - \bar{V}_3\rho > B^*$, then the inefficient turnover is characterized by too high a probability of a layoff in a worker's older years (period 3).

Proof: Provided in the Appendix.

Proposition 1 fully characterizes the optimal predetermined wage contract in this setting. First, given the discrete quit decision rules, it should not be surprising that it is optimal for the terms of compensation to be such that a worker with an employment offer does not quit. For otherwise, the firm would obviously be foregoing profits. However, Proposition 1 indicates that the decision on whether to induce a worker laid off in period 2 not to quit is not so straightforward. Recall that efficiency requires that a worker be laid off in period 2 if:

$$(16) \quad M_2 + \left(\int_{\bar{V}_3}^{\infty} M_3 f_3(M_3)dM_3 + \int_0^{\bar{V}_3} \bar{V}_3 f_3(M_3)dM_3\right)\rho < \max(\bar{V}_2, B + \left(\int_{\bar{V}_3}^{\infty} M_3 f_3(M_3)dM_3\right) + \int_0^{\bar{V}_3} \bar{V}_3 f_3(M_3)dM_3)\rho)$$

waits to be recalled when laid off in period 2 if:

$$(17) \quad B + \left(\int_{\bar{V}_3}^{\infty} M_3 f_3(M_3)dM_3\right) + \int_0^{\bar{V}_3} \bar{V}_3 f_3(M_3)dM_3)\rho > \bar{V}_2$$

and that the worker should be laid off in period 3 if:

$$(18) \quad M_3 < \bar{V}_3.$$

However, with the predetermined wage contract, (16)-(18) may be very difficult to achieve. For the only way to induce a worker laid off in period 2 not to quit is to pay a sufficiently high third period wage. Yet this generally implies inefficient turnover in period 3.

The decision on whether to induce a worker laid off in period 2 to wait for recall depends on how much the firm must increase w_3 in order to do so. It should, therfore, not be surprising that for extreme values of B (relative to the other parameters) that the decision is straightforward. However, when B falls in an intermediate range the decision becomes more difficult because as Proposition 1 indicates either regime results in some inefficient turnover. We can say, however, that for sufficiently high B, (i.e., $B > B^*$), the required compensation for inducing a worker laid off in period 2 to wait for recall becomes sufficiently small that the gains (i.e., the additional third period profits associated with the laid off worker being available for recall and the additional second period profits associated with no longer overemploying the worker in the second period for fear that the worker would be unavailable for recall) outweigh the costs (i.e., the loss in third period profits associated with the excess layoffs in the third period) of doing so.

An interesting property of the optimal predetermined wage contract in this setting is that it implies that we should expect to observe different experience-wage profiles depending upon the (endogenous) profitability of recall. In particular, if B is relatively low, i.e., $B < B^*$, then inducing a worker to wait for recall is not profitable and in such situations we would not expect to observe rising experience-wage profiles. Alternatively, if B is marginally higher than B^*, then it is profitable to induce the worker to wait for recall but doing so requires a very steep wage-experience profile. It is precisely because the experience-wage profile must be so steep that inducing a worker to wait for recall is only marginally profitable in this situation. However, as B increases and approaches $\bar{V}_2 - \bar{V}_3\rho$, inducing a worker to wait for recall is very profitable precisely because doing so does not require a very steep experience-wage profile. This discussion suggests that steep experience-wage profiles are associated with situations when it is only marginally profitable to induce workers to wait for recall.

Given these findings, the natural question to ask is whether there exists an alternative to the predetermined wage contract that has no additional information requirements but can alleviate the inefficient turnover. In light of this question, we now examine the potential role that might be played by institutions such as separation penalties (e.g., severance pay), seniority provisions and pensions. Since we are concerned with the problem of inefficient turnover, we will henceforth assume that $\bar{V}_2 - (\int_{\bar{V}_3}^{\infty} M_3 f_3(M_3) dM_3 +$

$\int_0^{\bar{V}_3} \bar{V}_3 f_3(M_3)dM_3)\rho < B < \bar{V}_2 - \bar{V}_3\rho$. Moreover, since $Q_2^e = Q_3 = 0$ are optimal in all situations in the unilateral asymmetric information setting, we will henceforth assume that this is the case (with the accompanying restrictions on the decision variables.)

First, consider severance pay. Severance pay generally takes the form of a payment made to a worker upon an employer initiated separation that is not contingent on the worker agreeing to provide or to be available to provide future services to the firm. Letting S_i be the severance payment in period i, the layoff and quit decisions are modified in the following manner. The worker is laid off in period 3 if:

(19) $M_3 < w_3 - S_3$;

the worker is laid off in period 2 if:

(20) $M_2 < w_2 - S_2 - Q_2^u\ [(1-L_3)\ [E(M_3|M_3 > M_3^*) - w_3]\rho - L_3S_3\rho]$;

and the worker laid off in period 2 waits for recall if:

(21) $B + (1-L_3)w_3\rho + L_3(\bar{V}_3+S_3)\rho > \bar{V}_2$.

Given these decision rules, the terms of the contract are chosen so as to maximize the appropriately modified expected joint value. It is easily demonstrated that the optimal contract calls for $S_3\rho = (w_3-\bar{V}_3)\rho > \bar{V}_2 - B$ and $B + S_2 = w_2$. Observe that this implies that the decision rules embodied in (19)-(21) satisfy the necessary and sufficient conditions for efficient turnover given by (16)-(18). The key to the apparent success of this severance pay contract is that the severance pay is chosen so that the worker's income is independent of his employment status in both periods 2 and 3. By making the guaranteed income in period 3 sufficiently high the worker laid off in period 2 is induced to not quit suboptimally. Moreover, since the net cost to the firm of employing the worker with the severance pay becomes equal to $\bar{V}_3$, the firm has the incentive to make the efficient layoff decision.

The severance payment contract, while appearing to yield efficient turnover, suffers from the same limitations that are common to any contract with separation penalties (either layoff or quit penalties). Separation penalties are problematic if one party can manipulate the separation decision of the other party. There is a clear incentive to do so in order to avoid having to pay a separation penalty and to be potentially eligible for a separation penalty from the other party. To understand this, consider a firm that has decided to layoff a worker. By inducing a quit (through, say, affecting the worker's job satisfaction) rather than laying off the worker, the firm may be able to avoid any severance payment. The possibility that such manipulation might occur casts doubt on the ability of separation penalty mechanisms to promote efficient turnover.[4]

Another interesting alternative is a seniority system. By a "seniority system" we mean a system in which older workers are essentially granted immunity from layoffs.[5] In the present context, this is taken to mean that workers in their third period of attachment with the firm would not be subject to layoff. Given the problems encountered above in designing an incentive compatible contract with efficient turnover, seniority provisions have some natural appeal. For with a seniority system, the worker's third period wage could be increased to induce a worker laid off in the second period to wait for recall, without increasing the layoff probability in the third period (which is constrained to be zero). However, a seniority system would be subject to manipulation by the firm in that the firm would in some circumstances have an incentive to induce older workers to quit. Moreover, it must be recognized that a contract with seniority provisions will necessarily yield some inefficient turnover for it precludes the efficient layoffs of older workers. Hence, while it may be of interest to determine whether a contract with a seniority provision can do better than the simple predetermined wage contract, the seniority system, by itself, cannot alleviate the inefficient turnover.[6]

The moral hazard problem common to both the severance pay contract and the seniority provision contract is that the firm can potentially circumvent the intent of such mechanisms by inducing employee initiated separations. This suggests that it may be of interest to introduce a compensation mechanism that provides a guaranteed payment to senior workers independent of their employment status (i.e., independent of whether the worker is employed, quits, or is laid off). In the present context, a vested pension system (where the pension becomes vested for a worker who is still attached to the firm at the beginning of the third period) provides a means for a payment to a senior worker independent of his employment status. The third period vested pension system provides no incentive for the firm to induce quits, since the pension must be paid even if the worker quits.[7]

Specifically, letting P be the (endogenous) value of the pension that becomes vested at the beginning of the third period, the layoff and quit decisions are modified in the following manner. The worker is laid off in period 3 if:

(22) $M_3 < w_3$

the worker is laid off in period 2 if:

(23) $M_2 < w_2 - Q_2^u[-P + (1-L_3)(E(M_3|M_3 > M_3^*) - w_3)]\rho$

and the worker laid off in period 2 waits for recall if:

(24) $B + P\rho + [(1-L_3)w_3 + L_3\bar{V}_3]\rho > \bar{V}_2$.

Given these decision rules, the terms of the contract are chosen so as to maximize the appropriately modified expected joint value. Derivation and analysis of the optimality conditions (see the appendix) allow us to prove the following proposition:

Proposition 2: The optimal predetermined wage contract with a pension that becomes vested in period 3 has the following properties:

(i) $w_3 = \bar{V}_3; \quad w_2 = B$

(ii) $P > \bar{V}_2 - \bar{V}_3\rho - B$

(iii) the contract yields efficient turnover.

Proof: provided in the appendix.

Proposition 2 demonstrates that by introducing a payment to the worker in the third period that is contingent on the worker being attached to the firm at the beginning of the third period but is not contingent on the worker's third period employment status, the inefficient turnover associated with the predetermined wage contract in a multiperiod unilateral asymmetric information setting is eliminated. Introduction of such a payment independent of a worker's employment status allows for inducing a laid off worker to remain attached to the firm in one period without distorting the separation decisions in later periods.

In summarizing this multiperiod unilateral asymmetric information analysis, a key feature is that the compensation agreed upon for a given period influences not only the separation decisions in that period but in all previous relevant periods as well. The issue that highlights this intertemporal allocation problem is whether an incentive compatible and information feasible contract exists that will simultaneously induce laid off workers to wait for recall efficiently while not distorting other separation decisions. The predetermined wage contract cannot, in general, accomplish this and yields either excess employment of middle-aged workers or excess layoffs of older workers. A severance payment contract appears to provide a means to produce efficient turnover but, is problematic if either party in the agreement can manipulate the separation decision of the other party. A seniority system, on the other hand, necessarily generates some inefficient turnover and suffers from this same manipulation problem. However, a vested pension system avoids this manipulation problem and thus provides a means for alleviating the inefficient turnover associated with the simple predetermined wage contract in this unilateral asymmetric information setting. In the next section, we return to the bilateral asymmetric information setting to investigate the interaction between the potential inefficiencies induced by bilateral asymmetric information and the intertemporal allocation problems analyzed in this section.

Bilateral Asymmetric Information

In the last section, we demonstrated that in a multiperiod, unilateral asymmetric information setting, it is possible to design a relatively simple contract which includes a special payment instrument (e.g., a vested pension) designed to induce laid off workers to wait for recall efficiently while not distorting other separation decisions. In other words, in the multiperiod unilateral asymmetric information setting, only intertemporal allocation problems prevent the optimal predetermined wage contract from yielding efficient turnover and such intertemporal allocation problems can be alleviated with the careful choice of an additional payment instrument. However, in the more general multiperiod, bilateral asymmetric information setting, from the optimality conditions (10) and (11) we know that the optimal predetermined wage contract yields inefficient turnover because of both bilateral information asymmetric information problems and intertemporal allocation problems. Given the results from the last section, the natural question to ask is whether it is possible to use the alternative payments mechanisms introduced in the last section to eliminate the intertemporal allocation problems in the multiperiod, bilateral asymmetric information setting. In essence, we are asking whether it is possible to design a contract in this setting that yields excessive turnover only because of bilateral asymmetric information problems.

A contract with separation penalties (quit penalties or severance pay) or a seniority provision would, in this bilateral asymmetric information setting, have the same moral hazard problems of manipulation that a contract with such provisions has in the unilateral asymmetric information setting. Hence, we focus our attention on a contract with a third period payment that is contingent on the worker being attached to the firm at the beginning of the third period but independent of the worker's employment status (e.g., a vested pension). Again, letting P be the (endogenous) value of the third period vested pension, the relevant layoff and quit decisions are modified in the following manner. The worker is laid off in period 3 if:

(25) $M_3 < w_3$;

the worker quits in period 3 if:

(26) $V_3 > w_3$;

the worker offered employment in period 2 quits if:

(27) $V_2 > w_2 + P\rho + \{(1-L_3)[(1-Q_3)w_3 + Q_3E(V_3|V_3 > V_3^*)] + L_3E(V_3)\}\rho$

the worker laid off in period 2 waits for recall if

(28) $V_2 < B + P\rho + \{(1-L_3)[(1-Q_3)w_3 + Q_3E(V_3|V_3 > V_3^*)] + L_3E(V_3)\}\rho$

and the worker is laid off in period 2 if:

(29) $M_2 < w_2 + [(Q_2^e - Q_2^u)/(1-Q_2^e)][-P\rho + (1-L_3)(1-Q_3)[E(M_3|M_3 > M_3^*) - w_3]\rho]$.

Given these decision rules, the terms of the contract are chosen so as to maximize the appropriately modified expected joint value. After some work, the optimality conditions are:

$$(30) \quad -\frac{\partial Q_2^e}{\partial w_2}(1-L_2)[\pi_2 - P\rho + (1-L_3)(1-Q_3)\pi_3]$$

$$-\frac{\partial L_2}{\partial w_2}[Y_2^e - Y_2^u] = 0$$

$$(31) \quad -\frac{\partial Q_2^e}{\partial P}(1-L_2)[\pi_2 - P\rho + (1-L_3)(1-Q_3)\pi_3]$$

$$-\frac{\partial L_2}{\partial P}(Y_2^e - Y_2^u) - \frac{\partial Q_2^u}{\partial P}L_2[-P\rho + (1-L_3)(1-Q_3)\pi_3] = 0$$

$$(32) \quad -\frac{\partial Q_2^e}{\partial w_3}(1-L_2)[\pi_2 - P\rho + (1-L_3)(1-Q_3)\pi_3] - \frac{\partial L_2}{\partial w_3}[Y_2^e - Y_2^u]$$

$$-\frac{\partial Q_2^u}{\partial w_3}L_2[-P\rho + (1-L_3)(1-Q_3)\pi_3]$$

$$+ [L_2(1-Q_2^u) + (1-L_2)(1-Q_2^e)] \cdot [-\frac{\partial Q_3}{\partial w_3}(1-L_3)\pi_3 - \frac{\partial L_3}{\partial w_3}Y_3^e] = 0$$

where $\pi_i = [E(M_i|M_i > M_i^*) - w_i]\rho^{i-1}, \quad i = 2,3$

$Y_2^u = (1-Q_2^u)[B\rho + P\rho^2 + (1-L_3)Y_3^e] + Q_2^u E(V_2|V_2 > V_2^{**})\rho$

$Y_2^e = (1-Q_2^e)[w_2\rho + P\rho^2 + (1-L_3)Y_3^e] + Q_2^e E[V_2|V_2 > V_2^*)\rho$

$Y_3^e = [(1-Q_3)w_3 + Q_3 E(V_3|V_3 > V_3^*)]\rho^2$

Comparing (31)-(33) with the original optimality conditions (10)-(11) yields considerable insight. In (10) and (11), the burden of inducing workers laid off in period 2 to wait for recall falls solely on the third period wage. In contrast, in (30)-(32) both the third period wage and the third period pension affect the wait for recall decision in the second period. Whether the introduction of the third period pension relieves the third period wage of its intertemporal allocational role is the issue that we are concerned with. The following proposition addresses this issue.

Proposition 3: The optimal third period wage has a higher value than that consistent with maximizing the conditional expected joint value of the match in the third period (conditional on the worker being attached to the firm at the beginning of the third period). This implies that there is a higher probability of layoffs in the third period than that caused by bilateral asymmetric problems alone.

Proof: Provided in the appendix.

The intuition underlying Proposition 3 is that in a bilateral asymmetric information setting, there is some value to inducing workers laid off in one period to wait for recall through high employment contingent deferred compensation. This is because, in this setting, if it is a pension that becomes vested in a future period that induces the worker to wait for recall, then the firm may find itself in the position of having "paid" the worker to wait for recall, but having the worker quit in the future taking his vested pension with him. In essence, we are arguing that there is not a straightforward answer to the question of what method, in a bilateral asymmetric information setting, should be used to institute a rising experience-compensation profile (that is used to induce junior workers to remain attached to the firm). On the one hand, instituting a rising experience-compensation structure through using payment instruments for senior workers that are independent of a worker's employment status (e.g., vested pensions) is beneficial because it provides a means through which a junior worker can be induced to remain attached to the firm without distorting the firm's employment decision of senior workers. On the other hand, using a rising experience-wage profile to induce junior workers to wait for recall is beneficial in a bilateral asymmetric information setting because it permits delaying of the commitment to pay the "carrot" used to induce the worker to remain attached until the worker has additional information about the value of continuing the match.

Broadly speaking, Proposition 3 suggests that it is, in general, not possible, in a multiperiod, bilateral asymmetric information setting, to disentangle the potential inefficiencies associated with the bilateral asymmetric information problems and the intertemporal allocation problems. The previous section demonstrated that intertemporal allocation problems can be overcome in a unilateral asymmetric information setting with careful choice of payment instruments. However, Proposition 3 suggests that intertemporal allocation problems in a bilateral asymmetric information setting are not so easily overcome, and that as a consequence, the intertemporal allocation problems contribute to a greater degree of inefficient turnover than would be expected from bilateral asymmetric information problems alone.

Concluding Remarks

The issue that highlights the problems induced by asymmetric information in a multiperiod labor contract setting is whether an incentive compatible and information feasible contract exists that simultaneously promotes in all periods efficient layoffs, efficient quits, and efficient waiting for recall by workers who have been laid off. We demonstrate that inducing laid off workers to not "quit" suboptimally may be, at least partially, accomplished through specifying a wage structure that rises with firm specific experience. However, this, in general, requires an experience-wage profile that is steeper than that consistent with promoting efficient layoffs of older workers. On the other hand, if the experience-wage profile is not sufficiently steep then "middle-aged" workers who are laid off may quit suboptimally and accordingly, firms, fearing that laid off workers may not be available for recall, overemploy "middle-aged" workers.

Introduction of alternative payment instruments (e.g., severance pay, pensions) or contract provisions (e.g., seniority provisions) appears to help alleviate the inefficient separations induced by such intertemporal allocation problems. However, careful consideration reveals that some of these alternative contract structures are subject to potentially severe moral hazard problems of manipulation. Specifically, severance pay and seniority provisions create an incentive, under some circumstances, for the firm to attempt to circumvent the intent of these mechanisms through inducing workers to quit. This manipulation problem motivates the introduction of a payment instrument that specifies payment to a worker in a given period contingent on the worker being attached to the firm at the beginning of the period but independent of the worker's employment status in the period (i.e., independent of whether the worker is employed, is laid off, or quits). A pension that becomes vested in a particular period is an example of such an instrument.

Instituting a rising experience-compensation structure through using payment instruments for senior workers that are independent of a worker's employment status provides a means through which a junior worker can be induced to remain attached to the firm (in spite of being laid off) without distorting the firm's employment decision of senior workers. However, we demonstrate that in a multiperiod, bilateral asymmetric information setting, the contractual experience-wage profile is still likely to be steeper than that consistent with promoting efficient layoffs of senior workers. The reason for this is that if the rising experience-compensation profile is accomplished entirely through using payment instruments for senior workers that are independent of their employment status, then the firm will occasionally find itself in the position of having "paid" a junior worker to remain attached to the firm but having the same worker upon becoming a senior worker quit taking his "vested pension" system with him. In other words, there is some value in instituting at least part of a rising experience-compensation profile through a rising experience-wage profile because it delays the commitment of the payment of the "carrot" used to induce the worker to remain attached until the worker has acquired additional information with regard to his alternatives.

In summary, this analysis suggests that it is, in general, not possible to disentangle the effects of bilateral asymmetric information problems and intertemporal allocation problems in a multiperiod labor contract setting. This results in a greater degree of inefficient turnover than would be expected separately from bilateral asymmetric information problems or intertemporal allocation problems alone. Moreover, the combination of bilateral asymmetric information problems and intertemporal allocation problems suggests that the optimal compensation structure calls for a rising experience-compensation profile that is accomplished partially by a rising experience-wage profile and partially by the introduction of payment instruments for senior workers that are independent of their employment status (e.g., vested pensions).

Footnotes

[1]Note that if V_3 is large and M_3 is small there can be a simultaneous quit and layoff.

[2]It is further assumed that $Cov(M_i,V_j) = 0$ for all i,j.

[3]This specification of Q_2^e and Q_2^u presumes that the firm must transmit its employment offer to the worker prior to the worker making his quit decision. This appears to be a reasonable characterization but alternative possibilities exist. For instance, suppose the worker in each period had to make a binding decision on whether or not he would be available to the firm for employment in that period prior to knowing whether he would actually be employed in that period. This would change the whole nature of the decision rules. For in this case, there would only be one type of quit decision in period 2. Considering such an alternative sequence of decision making is of interest not so much because it represents a more accurate depiction of the dynamics of the labor market (which it probably does not) but rather because it highlights the potentially critical role played by the assumed sequence of separation decisions. In the present analysis, we focus our attention on the type of contracts that emerge under the structure embodied in the decision rules Q_2^e and Q_2^u but recognize that an in-depth analysis of the significance of the assumed sequence of decision making is of interest.

[4]Carmichael (1981) emphasizes this possibility of manipulation in his analysis of a two period, bilateral asymmetric information model.

[5]Carmichael (1981) also considers "seniority provisions" but his concept of a seniority provision is quite different than that modeled here. In his two period model, he arbitrarily imposes a steady-state number of workers that the firm will employ and a steady state number of workers who will in their

second period of employment be promoted to a higher paying job. This promotion ladder concept is his version of a seniority provision. Consideration of such promotion ladders would be of interest in the present framework although a more general specification in which the number of jobs and high paying jobs are not imposed would be preferable.

[6]It is easily demonstrated that under some circumstances the contract with a seniority provision dominates the simple predetermined wage contract. However, since there are some circumstances under which the simple predetermined wage contract yields efficient turnover and the seniority contract necessarily yields some inefficient turnover, there will also be circumstances under which the simple predetermined wage contract dominates.

[7]It might be suggested that the worker may be able to take advantage of this situation by deceiving the firm with respect to his availability for recall. That is, in this situation, a worker would always have an incentive to claim to be available for recall because there is no penalty associated with such a deception. Two remarks are worth making on this point. First, a penalty mechanism could be introduced that penalized workers who claimed to be available for recall, were recalled, and then rejected the recall offer. Secondly, and perhaps more importantly in the context of this model, because of the factors which we argue make it difficult (and in this model, impossible) for a worker who quits in one period to be recalled by the firm in a later period, the potential for credible deception of this type seems remote.

References

Azariadis, C., 1980, "Employment with Asymmetric Information," CARESS Working Paper 80-22, University of Pennsylvania, May.

Carmichael, L., 1981, "Firm Specific Human Capital and Promotion Ladders," Discussion Paper No. 452, Queen's University.

Ehrenberg, R., 1971, "Heterogeneous Labor, the Internal Labor Market, and the Dynamics of the Employment-Hours Decision," Journal of Economic Theory, February, 85-104.

Feldstein, M., 1976, "Temporary Layoffs in the Theory of Unemployment," Journal of Political Economy, June, 937-957.

Green, J., 1981, "Wage-Employment Contracts," Harvard Institute of Economic Research Discussion Paper 807.

Grossman, S. and O. Hart, 1981, "Implicit Contracts, Moral Hazard, and Unemployment," American Economic Review, May.

Hall, R. and E. Lazear, 1982, "The Excess Sensitivity of Layoffs and Quits to Demand," NBER Working Paper No. 864.

Hashimoto, M., 1979, "Bonus Payments, On-the-Job Training, and Lifetime Employment in Japan," Journal of Political Economy.

Hashimoto, M., and B. Yu, 1980, "Specific Capital, Employment Contracts, and Wage Rigidity," Bell Journal of Economics, Autumn.

Kuritani, M., 1973, "Theory of Training, Earnings and Employment: An Application to Japan," unpublished Ph.D. dissertation, Columbia University.

Lazear, E., 1979, "Why Is There Mandatory Retirement?" Journal of Political Economy.

Mortensen, D., 1978, "Specific Capital and Labor Turnover," Bell Journal of Economics, Autumn.

Parsons, D., 1972, "Specific Human Capital: An Application to Quit Rates and Layoff Rates," Journal of Political Economy, November/December.

APPENDIX

Proof of Proposition 1: It is helpful to consider (i) and (ii) in reverse order. (ii) Suppose that w_2 and w_3 are chosen so that $w_2 + (1-L_3)(1-Q_3)w_3\rho + (L_3+(1-L_3)Q_3)\bar{V}_3\rho < \bar{V}_2$. This implies $Q_2^e = 1$. Denote this as regime I. The expected joint value under this regime is given by:

$$\text{(A1)} \qquad E(JV|I) = (1-L_2(I))\bar{V}_2\rho + L_2(I)[Q_2^u(I)\bar{V}_2\rho + (1-Q_2^u(I))[(B\rho + (1-L_3(I))[(1-Q_3(I))E(M_3|M_3 > M_3^*(I)) + Q_3(I)\bar{V}_3]\rho^2 + L_3(I)\bar{V}_3\rho^2]]$$

Now consider an alternative regime (regime A) where $w_3(A) = \max(\bar{V}_3, w_3(I))$ but $w_2(A)$ and $w_3(A)$ together are such that $w_2(A) + (1-L_3(A))(1-Q_3(A))w_3(A) + (L_3(A) + (1-L_3(A)Q_3(A))\bar{V}_3\rho = \bar{V}_2$. Under this alternative regime, $Q_2^e(A) = 0 < Q_2^e(I)$, $Q_2^u(A) = Q_2^u(I)$, and $0 = Q_3(A) < Q_3(I)$. Expected profits under regime A are given by:

$$\text{(A2)} \qquad E(JV|A) = (1-L_2(A))[E(M_2|M_2 > M_2^*(A))\rho + (1-L_3(A))[E(M_3|M_3 > M_3^*(A)]\rho^2 + L_3(A)\bar{V}_3\rho^2] + L_2(A)[Q_2^u(A)\bar{V}_2\rho + (1-Q_2^u(A))[B\rho + (1-L_3(A))[E(M_3|M_3 > M_3^*(A)]\rho^2 + L_3(A)\bar{V}_3\rho^2]]$$

Comparing (A1) and (A2) reveals that $E[JV|A] > E[JV|I]$. Hence, $Q_2^e = 1$ cannot be optimal.

(i) Given that choosing w_2 and w_3 so that $Q_2^e = 0$ is optimal, suppose nevertheless that $w_3 < \bar{V}_3$. This implies $Q_3^e = 1 = Q_2^u$. The expected joint value associated with such a contract is given by (denote this as regime II):

$$\text{(A3)} \qquad E(JV|II) = (1-L_2(II))[E(M_2|M_2 > M_2^*(II))\rho + \bar{V}_3\rho^2] + L_2(II)\bar{V}_2\rho$$

Now consider an alternative regime (regime A) where $w_2(A) = w_2(II)$ but $w_3(A) = \bar{V}_3 > w_3(II)$. Under this regime $Q_3^e(A) = 0$ and $Q_2^u(A) = 1$. The expected joint value under regime A is given by:

(A4) $$E(JV|A) = (1-L_2(A))[E(M_2|M_2 > M_2^*(A))\rho + (1-L_3(A))E(M_3|M_3 > M_3^*(A))\rho^2 + L_3(A)\bar{V}_3\rho^2] + L_2(A)\bar{V}_2\rho$$

Comparison of (A3) and (A4) (taking into account that $L_2(A) < L_2(II)$ and $L_3(A) < 1$) reveals that $E[JV|A] > E[JV|II]$. Hence, $w_3 > \bar{V}_3$ and $Q_3 = 0$ are optimal.

(iii) Since $w_3 > \bar{V}_3$ and $w_2 + (1-L_3)w_3\rho + L_3\bar{V}_3\rho > \bar{V}_2$ are optimal, there are essentially two possible remaining regimes. Either w_3 is chosen to be sufficiently large that $Q_2^u = 0$ or w_3 is chosen so that $Q_2^u = 1$. For the latter regime (denote this as regime I_w), the optimal contract under the constraints that insure $Q_2^e = Q_3 = 0$ and $Q_2^u = 1$, calls for $w_2(I_w) = \bar{V}_2 - \bar{V}_3\rho$ and $w_3(I_w) = \bar{V}_3$. The expected joint value is thus given by:

(A5) $$E(JV|I_w) = (1-L_2(I_w))[E(M_2|M_2 > M_2^*(I_w))\rho + (1-L_3(I_w))E(M_3|M_3 > M_3^*(I_w))\rho^2 + L_3(I_w)\bar{V}_3\rho] + L_2(I_w)\bar{V}_2\rho$$

On the other hand, for the alternative regime (denote as regime II_w) w_3 is chosen so that $Q_2^u = 0$. For regime II_w, the optimal contract is such that $w_2(II_w) = B$ and $w_3(II_w) = (\bar{V}_2 - B - \int_0^{w_3}\bar{V}_3\rho f_3(M_3)dM_3)/\rho\int_{w_3}^{\infty}f_3(M_3)dm_3$. The expected joint value associated with regime II_w is thus given by:

(A6) $$E(JV|II_w) = (1-L_2(II_w))[E(M_2|M_2 > M_2^*(II_w))\rho + (1-L_3(II_w))E(M_3|M_3 > M_3^*(II_w))\rho^2 + L_3(II_w)\bar{V}_3\rho^2] + L_2(II_w)[B\rho + (1-L_3(II_w))E(M_3|M_3 > M_3^*(II_w))\rho^2 + L_3(II_w)\bar{V}_3\rho^2]$$

Comparison of (A5) and (A6) reveals that if $B = \bar{V}_2 - \bar{V}_3\rho$, then $E[JV|II_w] > E[JV|I_w]$ but that if $B < \bar{V}_2 - (\int_{\bar{V}_3}^{\infty}M_3f_3(M_3)dM_3 + \int_0^{\bar{V}_3}\bar{V}_3f_3(M_3)dM_3)\rho$ then

$E[JV|II_w] < E[JV|I_w]$. Since $E[JV|II_w] - E[JV|I_w]$ is a continuous function over the relevant intermediate range, then by the intermediate value theorem there exists a critical B^* such that for $B < B^*$, $E[JV|II_w] < E[JV|I_w]$ and for $B > B^*$, $E[JV|II_w] > E[JV|I_w]$ where B^* is such that:

$$\bar{V}_2 - (\int_{\bar{V}_3}^{\infty} M_3 f_3(M_3)dM_3 + \int_0^{\bar{V}_3} \bar{V}_3 f_3(M_3)dM_3)\rho < B^* < \bar{V}_2 - \bar{V}_3\rho$$

(iv) Efficiency requires (16)-(18) to hold. If $B < \bar{V}_2 - (\int_{\bar{V}_3}^{\infty} M_3 f_3(M_3)dM_3 \int_0^{\bar{V}_3} (\bar{V}_3 f_3(M_3)dM_3)\rho$, then by (17) the worker laid off in period 2 should quit and in regime I_w, since $w_3(I_w) = \bar{V}_3$, this is the case. Moreover, $w_3(I_w) = \bar{V}_3$ implies that (18) holds. As for condition (16), $B < \bar{V}_2 - (\int_{\bar{V}_3}^{\infty} M_3 f_3(M_3)dM_3 + \int_0^{\bar{V}_3} (\bar{V}_3 f_3(M_3)dM_3)\rho$ implies that condition (16) becomes:

$$\text{(A7)} \qquad M_2 < \bar{V}_2 - (\int_{\bar{V}_3}^{\infty} M_3 f_3(M_3)dM_3 + \int_0^{\bar{V}_3} \bar{V}_3 f_3(M_3)dM_3)\rho$$

Since $M_2^*(I_w)$ is equal to the RHS of (A7), regime I_w induces efficient layoffs in period 2 under these circumstances. Hence, if $B < \bar{V}_2 - (\int_{\bar{V}_3}^{\infty} M_3 f_3(M_3)dM_3 + \int_0^{\bar{V}_3} (\bar{V}_3 f_3(M_3)d\eta_3)\rho$, then regime I_w induces efficient turnover.

On the other hand, if $B = \bar{V}_2 - \bar{V}_3\rho$, then $w_2(II_w) = \bar{V}_2 - \bar{V}_3\rho$, $w_3(II_w) = \bar{V}_3$ and $Q_2^u(II_w) = 0$. In this event, (16)-(18) are obviously satisfied under regime II_w.

However, if $\bar{V}_2 - (\int_{\bar{V}_3}^{\infty} M_3 f_3(M_3)dM_3 + \int_0^{\bar{V}_3} \bar{V}_3 f_3(M_3)dM_3)\rho < B < \bar{V}_2 - \bar{V}_3\rho$, and $B < B^*$ so that regime I_w is optimal, then by (16)-(18), there is overemployment of the worker in period 2, an excess probability of quitting by a worker laid off in period 2, and efficient turnover in period 3. Alternatively, if $B < \bar{V}_2 - \bar{V}_3\rho$ but $B > B^*$ so that regime II_w is optimal, then by (16)-(18), there is efficient turnover in period 2 but an excessively high probability of layoffs in period 3.

Proof of Proposition 2: (i) and (ii): Given the decision rules (22)-(24), the terms of the contract are chosen so as to maximize the expected joint value given by:

$$(1-L_2)[E(M_2|M_2 > M_2^*)\rho + (1-L_3)E(M_3|M_3 > M_3^*)\rho^2 + L_3\bar{V}_3\rho^2]$$
$$+ L_2[Q_2^u\bar{V}_2\rho + (1-Q_2^u)[B\rho + (1-L_3)E(M_3|M_3 > M_3^*)\rho^2 + L_3\bar{V}_3\rho^2]]$$

Derivation of the optimality conditions reveals that w_2, w_3 and P should be chosen so that: $w_2 = B$, $w_3 = \bar{V}_3$ and $P > \bar{V}_2 - \bar{V}_3\rho - B$.

(iii) Efficiency requires (16)-(18) to hold. Substituting $w_2 = B$, $w_3 = \bar{V}_3$ and $P > \bar{V}_2 - \bar{V}_3\rho - B$ in to (22)-(24) reveals that (22)-(24) are equivalent to (16)-(18).

Proof of Proposition 3: The pension, by definition, does not affect the third period separation decisions. To determine the third period wage that maximizes the conditional expected joint value of the match in the third period, we maximize:

$$\max_{w_3} (1-L_3)[(1-Q_3)E(M_3|M_3 > M_3^*) + Q_3E(V_3|V_3 > V_3^*)] + L_3E(V_3)$$

After some work, the optimality condition reduces to (it is assumed that an interior maximum exists):

$$\text{(A8)} \qquad -\frac{\partial Q_3}{\partial w_3}(1-L_3)\pi_3 - \frac{\partial L_3}{\partial w_3}Y_3^e = 0$$

Denoting the solution to (A8) as $\bar{w}_3$, since the expected joint value must be concave in w_3 at $\bar{w}_3$, we know that

$$\text{(A9)} \qquad w_3 \gtrless \bar{w}_3 \quad \text{as} \quad -\frac{\partial Q_3}{\partial w_3}(1-L_3)\pi_3 - \frac{\partial L_3}{\partial w_3} Y_3^e \lesseqgtr 0.$$

The question under concern is whether the w_3 that satisfies the optimality condition (32) is equal to $\bar{w}_3$. First, it is easy to demonstrate that at the optimum:

$$\text{(A10)} \qquad -\frac{\partial Q_2^e}{\partial w_3}(1-L_2)[\pi_2 - P\rho + (1-L_3)(1-Q_3)\pi_3] - \frac{\partial L_2}{\partial w_3}[Y_2^e - Y_2^u]$$

$$-\frac{\partial Q_2^u}{\partial w_3} L_2[-P\rho + (1-L_3)(1-Q_3)\pi_3]$$

$$> -\frac{\partial Q_2^e}{\partial P}(1-L_2)[\pi_2 - P\rho + (1-L_3)(1-Q_3)\pi_3]$$

$$-\frac{\partial L_2}{\partial P}[Y_2^e - Y_2^u] - \frac{\partial Q_2^u}{\partial P} L_2[-P\rho + (1-L_3)(1-Q_3)\pi_3].$$

By (31), the RHS of (A10) is equal to zero. This implies with (32) that at the optimum we have:

$$\text{(A11)} \qquad -\frac{\partial Q_3}{\partial w_3}(1-L_3)\pi_3 - \frac{\partial L_3}{\partial w_3} Y_3^e < 0$$

Condition (A11) and (A9) imply together that the optimal third period wage is strictly greater than $\bar{w}_3$. Hence, the third period wage is greater than that consistent with maximizing the conditional expected joint value of the match in the third period. Moreover, since L_3 is an increasing function of w_3, this implies that the probability of layoffs in the third period is higher than that caused by bilateral asymmetric information problems alone.