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TURNOVER WAGES AND ADVERSE SELECTION

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Abstract

This paper seeks to explain the observed relationship between voluntary job turnover and wages over the life cycle. To this end, a simple job-matching model is analyzed in the case where a worker has better information than a firm about his potential productivity at the firm. It is shown that the resulting adverse selection is capable of explaining four stylized facts of the labor market: (1) the secular increase of wages over the life cycle for both movers and stayers, (2) the flatter age-earnings profiles for persistent job movers, (3) the lower wage levels for older men who are persistent job changers, and (4) the positive relationship between prior mobility and future mobility.

I. Introduction

The determinants of a workers' income have always been of interest to economists. To date, several studies have investigated the empirical relationship between wages and turnover. Among these are the findings of Mincer and Jovanovic (1981) and Bartel and Borjas (1981). These authors find that persistent job movers have flatter age-earnings profiles. They also find that wages for both movers and stayers increase over the life cycle. In addition, Bartel and Borjas find that while mobility that takes place early in the life cycle may pay, individuals who continue to move later in life will have lower lifetime wage growth compared to workers who eventually stayed at a firm. They also find that the average past wages of job changers are lower than they are for job stayers. The findings of Mincer and Jovanovic complement Bartel and Borjas' study by showing that persistent mobility among older men results in actual lower wage levels. Mincer and Jovanovic also find the probability that a worker changes jobs increases with the number of previous job changes.

This paper develops a model of voluntary turnover that is largely consistent with these stylized facts. A notable exception is that the present model is not able to explain why mobility among younger workers may pay. The conclusion will give a possible explanation for this observation.

Existing models of turnover (permanent job separations) involve workers who are changing jobs because they either receive information regarding their current job match or possible alternative matches that will lead to higher earnings. Jovanovic (1979a) presents a model of job turnover that partially explains the above phenomena. In Jovanovic's model, workers change jobs hoping to obtain a better match with another firm. Since persistent

mismatches lead to frequent job changes and lower wages, Jovanovic's model explains why frequent job changers have lower average past earnings. However, Jovanovic concedes that his model does not explain why persistent job movers have lower future earnings. Similarily, his model does not attempt to explain why prior mobility is an indicator of future mobility.

One possible explanation for these phenomena is to assume that workers have different propensities to change jobs. This will tautologically imply that workers who have moved frequently in the past will be more likely to move again at any point in the future. If firm-specific human capital is introduced, this model will also imply that wages will increase over the life cycle and that workers with a high propensity to change jobs will invest in less firm-specific human capital and have flatter wage profiles over time. However, there is no a priori reason (assuming there are enough firms that do not require firm-specific human capital) why these workers would have lower average wages. Similarly, if firms do not incur training costs when hiring workers, then a better determinant of a worker's future wages can be obtained by replacing prior mobility by a worker's age and current tenure at a firm. If there are training costs, then, since frequent movers would incur these costs more often, and would thus earn lower wages on average. There are two reasons one might think this is not a good explanation for the relationship between wages and turnover. One is that mobility is determined exogenously in this model. A satisfactory explanation of the relationship between turnover and wages mobility would have to be determined endogenously as a property of the equilibrium. The other reason this might not be a good description of the labor market is that it does not adequately explain why job movers have lower wages in the early part of their careers. This model is essentially the one developed by Salop and Salop (1976). They determined that when a worker's

propensity to move is not public information, that the infrequent job movers would post bonds at firms in order to separate themselves from the infrequent job movers. This will imply that the wage rates for job movers should be higher than that of job stayers in the early part of their careers.

The present paper attempts to explain these phenomena without exogenously assuming that workers' have different propensities to change jobs. The model also ignores firm specific human capital since it does not adequately explain the stylized facts of the labor market. Including it in the analysis would not alter the results of the present model.

The model presented here is a basic job-matching model where a worker's productivity varies across tasks or firms. The feature which distinguishes this from similar studies is that a worker's productivity consists of both a firm-specific (matching) component and an individual specific component. The individual component is assumed to be observable only by the worker. This informational asymmetry leads to problems of adverse selection. As is standard, two different types of equilibria can occur: a separating equilibrium or a pooling equilibrium. It is shown that when there is enough variability in the productivity of workers a pure pooling equilibrium results. This statement is true even though workers can post bonds as in Salop and Salop's model.

The existence of a pooling equilibrium implies that the frequent job changers will be the lower productivity workers according to Akerlof's lemon principle. Job movers will then have lower wages on average compared with infrequent job movers. In equilibrium, bonds will also be posted in order to transfer income away from the frequent job movers (the low productivity workers) to the infrequent job movers (the high productivity workers). This

explains why wages for job stayers increase over time and why, despite adverse selection, job movers may also experience wage increases over the life cycle. Since frequent job movers are the low productivity workers, it is shown that this heterogeneity may be able to explain the positive correlation between prior mobility and future mobility.

Other effects of adverse selection are also examined. It is shown that there is less aggregate mobility with adverse selection than would exist in a model without asymmetric information. It is also shown, however, that a government cannot improve welfare by subsidizing mobility. In fact, subsidizing mobility would have no effect on either mobility or a worker's net wages over time.

The paper is organized as follows: In section II, the assumptions of the model are stated and discussed. Section III discusses the model and gives an example to motivate the paper's results. Section IV defines a pooling equilibrium for this economy and characterizes the equilibrium. Questions of existence are postponed until the end of section V. Section V shows that a pooling equilibrium leads to problems of adverse selection and that these problems can explain the relationship between turnover and wages. Another example is then presented to illustrate these results and motivate the conditions necessary to insure the existence of a pooling equilibrium. The section then concludes by proving that a pooling equilibrium exists for this economy, and that in equilibrium bonds will be posted by workers which is indexed on their future mobility. Section VI discusses the question of optimality in the model. Section VII provides concluding remarks and possible extensions for future research.

II. The Environment

The basic structure of the model is similar to Jovanovic (1979a). The productivity of a worker consists of a job-matching component, 8, which is match specific. However, a worker's productivity differs from Jovanovic's model in that it also consists of an individual-specific component, p. Frequently p will be referred to as the "base productivity level" of a worker. For mathematical simplicity, we assume a simple linear production function where a worker's productivity is given by y = p + 8. The following restrictions are placed on the distributions of p and 8: p is assumed to be distributed on the interval [p', p"] with a c.d.f. of F(p) and a d.f. of f(p); θ is assumed to be distributed on the interval [-θ', θ"] with a c.d.f. of G(θ) and a d.f. of g(θ) with E(θ) = 0 and cov(p, θ) = 0. It is also assumed that θ is i.i.d. across different individuals and also i.i.d. for an individual across different jobs. This implies that a worker's current job match does not provide the worker with any information regarding his match at another firm. Similarly, the quality of another worker's match does not provide a worker with any information regarding his own job match at another firm.

The following informational restrictions are placed on the model: A worker's base productivity level is assumed to be known only by the worker. Prior to production, neither firms nor workers know what a worker's job match will be at a firm. However, after working one period the worker's productivity at the firm, y, is assumed to be perfectly observable by both the worker and the firm. Furthermore, it is assumed that a worker's output at a firm is constant over time and that this output cannot be observed by other

firms. [1] Firms are assumed to be able to observe a worker's past wage rates and prior moves.

The following model is a three-period model. Workers are assumed to live and work for three periods indexed by 0, 1, 2. At the end of periods 0 and 1 a worker decides whether to continue working at his present job or to change jobs.

The next section provides a heuristic discussion of the model and shows that when contingent wage contracts are allowed, the model cannot adequately explain the stylized facts of the labor market. An example is then developed for the case where contingent wage contracts are not allowed. The example is used to motivate the paper's main contention that the resulting adverse selection can help explain the observed relationship between turnover and wages.

III. The Model: A Discussion

Without any restrictions on the type of wage contracts that firms can offer, the wage contract that would emerge from this model would have workers being paid their realized output, y, at a firm after every period. This results since firms do not know a worker's base productivity level; contingent wage contracts occur so that workers with different productivities would not be confused in equilibrium. This result is due to the assumption of risk neutrality. We then show that if contingent wage contracts are allowed, the model will collapse down to a simple version of a standard job-matching model. This can be seen by considering that the expected wage for a worker at the beginning of period zero, or after a job change would just be his base

productivity level, p. Defining W(p) to be the expected present discounted value of the future wage payments at the beginning of period zero for a worker with a base productivity level of p, gives the following value function:

$$W(p) = p + \beta Emax[\lambda(p), V(y)]$$

where,

$$\lambda(p) = p + \beta Emax[p, p+\theta]$$

$$V(y) = y(1 + \beta).$$

The expected present discounted value at the beginning of period one for a worker who changed jobs after the initial period, is X; the present discounted value of future wages at the beginning of period one for workers who stayed at their present job, is defined to be V(y). Since information about a worker's job match is perfectly observable after only one period, a worker who does not move after period zero will never change jobs.

It is easy to see that the equilibrium for this simple job-matching model implies that the probability that a worker moves after either period zero or one is the same for all workers. If we further assume that 8 is uniformly distributed over the interval [-θ', 8'1 and β=1, then the probability that a worker moves after period zero would be 9/16, and the probability that a worker moves after period one, given he moved after period zero, would be 1/2.[2]

Since every worker has the same probability of moving, this simple model cannot capture the heterogeneity that is necessary to explain why prior mobility is an indicator of future mobility. At first glance, the model does seem capable of explaining why wages increase for both movers and stayers over the life cycle, albeit at a slower rate for job movers. Job stayers would

experience a wage increase since they are the workers with a good match at their first-period employer. Similarly, job movers also experience a wage increase. This is because they get paid their realized productivity at a firm at the end of period zero, and because job movers are the workers with a bad match at their previous employer. That is, their ex post wage would be less than their base productivity level, p^3. However, since the quality of matches for job movers is not as good as the quality of the matches for job stayers, movers would experience less of a wage increase than would job stayers.

This explanation, however, cannot be complete, since age and tenure are driving the results, and not the number of previous moves. That is, the reason future wages are lower for job changers than they are for job stayers, is because the expected quality of future matches is lower for job movers than the realized matches of job stayers. Therefore, what drives this result is not the number of prior moves that a worker experiences, but the age and tenure of a worker. Workers with the same amount of tenure and the same number of periods until retirement, will, on average, have the same expected future wage rates.[4] Empirical work on the relationship between mobility and wages has controlled for differences in age and tenure, and has found frequent mobility results in lower average wage levels for older workers. Since traditional job matching models cannot explain why prior mobility and future mobility are positively correlated, or why job movers have lower average future wages, it will be assumed that wages cannot be made contingent on the ex post output of workers. This assumption is motivated by the observation that most wage contracts are not contingent on a worker's future output. In a model with risk aversion, this assumption can be justified.[5]

The potential benefit of excluding contingent wage contracts is the ability to have the possibility a pooling equilibrium for the above economy. A pooling equilibrium leads to problems of adverse selection, in that low productivity workers will be the frequent job changers. This occurs since lower productivity workers gain from being confused with the higher productivity workers when changing jobs. To see this, consider the following example:

Example 1:

The following example assumes that there are two types of workers and three possible outputs that each worker can have at a firm. The productivity types and the matching components are given as follows:

P	$f(p)$	θ	$g(\theta)$	$\beta=1$
1	112	-1	1/3	-
-	-	0	113	-
2	1/2	1	1/3	-

Consider first, a candidate equilibrium where no bonds are posted, that is, where a worker's wage in every period is just the firm's estimate of his productivity at the firm. With this assumption the following prices and quantities can be verified:

p	$y^r(p)$	$G(y^r(p)-p)$	$G(w_2-p)$
1	1	2/3	2/3
2	1	1/3	1/3
$w_1 = 4/3$	$w_2 = 6/5$	$w_2(2) = 3/2$	$w_2(3) = 2$

The notation used is as follows: w_1 is the first period wage for workers who changed jobs after the initial period; w_2 is the second period wage for workers who changed jobs after both periods zero and one; $w_2(y)$ is the second period wage for workers who did not change jobs after period zero, but who subsequently changed jobs after the first period. Since the first period wage for a job changer is the worker's realized output, y, the wage for a worker who then changes jobs after period one is a function of the worker's output at his first period employer. In this simple example, a worker who did not change jobs after the initial period would never change jobs; since $w_2(y) < y$, that is, he could earn more by staying employed at his initial employer. The wages for job stayers are not made explicit in the above table since they are simply a worker's realized output, y,. $y^r(p)$ is defined to be the reservation output of a worker with a base productivity level of p, that is, the output level at which a worker is indifferent to staying at his period zero employer or changing jobs. $G(y^r(p)-p)$ is thus the fraction of the productivity p workers who change jobs after period zero, and $G(w_2-p)$ is the fraction of these workers who also change jobs after period one.

If this were an equilibrium, the low productivity workers would be moving twice as often as the high productivity workers; 213 (1/3) of the low (high) productivity workers move after period zero, and 213 (1/3) move again after period one. This is a direct result of adverse selection. However, because of the difference in mobility between the high- and low- productivity workers this cannot be an equilibrium; a firm could earn positive profits by competing away the high-productivity workers. Since high-productivity workers move only half as often as the low-productivity workers, the following bonding scheme would attract the high-productivity workers: requiring workers to post bonds

before beginning employment at a firm and indexing the bonds according to the workers' future mobility, where movers would forfeit the bond and the job stayers would split the proceeds of the bond among them. Since the high-productivity workers move infrequently, this clearly benefits them. Bonds act to redistribute to the high-productivity workers part of the income which the low-productivity workers gain because of adverse selection. We define $_n b_t$ to be the bonus paid to a worker in period **t,** with n previous job changes, (that is, the wage a worker receives in period **t** above his output at a firm.)   These bonuses are funded by workers' posting bonds when they become employed at a new firm.   Bonds are implicit in the wage functons, so that w_t will no longer be the firm's estimate of a worker's productivity. The following can be verified to be an equilibrium for this example.[6]

p	$y^r(p)$	$G(y^r(p)-p)$	$G(w_2-p-_1 b_2)$
1	1	2/3 [2/3]	2/3 [2/3]
2	1	1/3 [2/3]	1/3 [2/3]
$w_0 = 10/9$	$w_1 = 56/45$	$w_2 = 6/5$	$w_2(2) = 3/2$
$w_2(3) = 2$	$_0 b_2 = 7/9$	$_1 b_2 = 1/5$	$_0 b_1 = 0$

In brackets are the values that result when wages can be made contingent on a workers' output.

This is an equilibrium since potential firms cannot compete away either the low-productivity workers or the high-productivity workers. The low productivity workers are still being confused with the high productivity workers and thus do better than they would in autarky. **It** can also be shown that **if** the amount of the bonds that workers have to post were changed, the high-productivity workers would be made worse off.'

This example illustrates the assertions made in the text. Adverse selection is present in the model since 213 (1/3) of the low (high) productivity workers move after period zero, and 213 (1/3) of these will move again after the first period. Because of this, the example illustrates the stylized facts of the labor market. The wages for job movers and job stayers increase over the life cycle (although at a slower rate for job movers). In addition, job movers do worse on average than do job stayers. Notice also that the increase in wages for movers is not monotonic over time, but reaches a maximum in period one and drops off slightly in the last period. Workers who move twice continue to earn more in the last period of their working life than they did in the first period, however, their wages decreased with their last job move. This is consistent with the findings of Bartel and Borjas: for young men a quit is associated with an increase in earnings but for the older men a quit has either a negative or zero effect on wage growth.

It can also be seen from the example that prior mobility is an indicator of future mobile. The probability that a worker changes jobs in the first period is 112, while the conditional probability that a worker changes jobs in the second period, given that he changed jobs in the first period, is 519. In contrast, the probabilities when productivity is public information are 2/3 and 113, respectively.

IV. Equilibrium

In this section, we define a Pooling Equilibrium for the environment given in the previous section. There are assumed to be a large number of firms and workers. Firms are imagined to compete over different sets of contracts in

order to maximize their profits. A necessary condition for an equilibrium is that another contract or set of contracts does not exist which, **if** offered could make positive profits, taking the behavior of other firms as given.[8] The equilibrium notion employed is thus a Nash equilibrium concept.

The remainder of the definition states that workers maximize their utility or present discounted value of their future wage payments. After every period, a worker must decide whether to move or to continue working for his present firm. The decision whether to move or to stay for a worker at the end of period t, with n previous job changes, will be denoted by $m(p,y,n,t)$ where $n,t=\{0,1\}$ and $n \leq t$. A worker bases his decision on his output, y, at his present firm and his base productivity level, p. We define $m=0$ to denote the decision to stay at the present job and $m=1$ to denote the decision to change jobs. Workers are assumed to take wages as given when making their decisions, but in equilibrium wages will be a function of the optimal-decision rules of workers, $m'(p,y,n,t) = \{0 \text{ or } 1\}$. For notational brevity, the functional dependence on p and y will be suppressed. Wages are denoted by $w_t(.)$ where $t = \{0,1,2\}$ and (.) denotes the information-set of the firm at the beginning of time t, (that is, the past wages and prior moves of workers.) The dependence on past wages will be suppressed, except when a worker's previous wage gives his realized output at a firm.

To define an equilibrium we denote A to be the law of motion for the economy. $\Lambda_i(n,t)$ is the fraction of workers who will change jobs at the end of period t, given that they changed jobs n times previously. The subscript i denotes the information set available to the firm at the beginning of period i. We now have the following definition:

Definition of a Pooling Equilibrium: An equilibrium for the economy is a list of wages: $\{w_0, w_1(m'(0,0)=0,y), w_1(m'(0,0)=1, w_2(m'(0,0)=0,m'(0,1)=0,y), w_2(m'(0,0)=0,m'(0,1)=1,y), w_2(m'(0,0)=1,m'(1,1)=0y), w_2(m'(0,0)=1,m'(1,1)=1)\}$ value functions: $\{W(p,y,n,t)\ n=0,1;\ t=0,1,2;\ n<t\}$ and equations of motion: $\{\Lambda_i(n,t)\ i=0,1;\ n=0,1;\ n \lessdot t)$ such that

$$W: \quad [p',p''] \times [p'-\theta,\ p''+\theta] \times \{0,1\} \times \{0,1,2\} \longrightarrow R+$$

$$m: \quad [p',p''] \times [p'-\theta,\ p''+\theta] \times \{0,1\} \times \{0,1\} \longrightarrow \{0,1\}$$

$$\Lambda: \quad \{0,1\} \times \{0.1\} \longrightarrow [0,1].$$

satisfy:

1) $W(p,y,0,1) = \max_m \{w_1(m) + \beta W(p,y,m,2)\}$

2) $W(p,y,0,2) = \max_m {}_0 w_2(m)$

3) $W(p,y,1,2) = \max_m {}_1 w_2(m)$

where,

$\quad w_1(0) = w_1(m'(0,0)=0,y)$

$\quad w_1(1) = w_1(m'(0,0)=1)$

$\quad {}_0 w_2(0) = w_2(m'(0,0)=0,m'(0,1)=0,y)$

$\quad {}_0 w_2(0) = w_2(m'(0,0)=0,m'(0,1)=1,y)$

$\quad {}_1 w_2(0) = w_2(m'(0,0)=1,m'(1,1)=0,y)$

$\quad {}_1 w_2(1) = w_2(m'(0,0)=1,m'(1,1)=1)$

4) $\Lambda_0(0,0) = \iint m'(p,p+\theta,0,0)f(p)g(\theta)dpd\theta$

5) $\Lambda_0(0,0) = \iiint m'(p,p+\theta,0,0)m'(p,p+\theta,1,1)f(p)g(\theta_0)g(\theta_1)dpd\theta_0 d\theta_1$

6) $\Lambda_0(0,1) = \iint (1-m'(p,p+\theta,0,0))m'(p,p+\theta,0,1)f(p)g(\theta)dpd\theta$

7) $\Lambda_1(1,1) = \Lambda_0(1,1)/\Lambda_0(0,0)$

where m' denotes the equilibrium value 0 or 1 obtained in **i**, **ii**, and **iii**.

and such that firms earn zero expected profits:

8) $w_0 + \beta(1-\Lambda_0(0,0))w_1(m'(0,0)=0,y) + \beta^2\Lambda_0(0,1)w_2(m'(0,0)=0,m'(0,1)=0,y)$
      $= E(p) + \beta(1-\Lambda_0(0,0))y + \beta^2\Lambda_0(0,1)y$

9) $w_1(m'(0,0)=1) + \beta(1-\Lambda_1(1,1)w_2(m'(0,0)=1,m'(0,1)=0,y)$
      $= E(p|m''(0,0)=1) + \beta(1-\Lambda_1(1,1))y$

10) $w_2(m'(0,0)=0,m'(0,1)=1,y) = E(p|p+\theta=y,m'(0,0)=0)$

11) $w_2(m'(0,0)=1,m'(1,1)=1) = E(p|m'(0,0)=1,m'(1,1)=1)$

and such that:

12)   there does not exist a new contract or set of contracts, which **if** offered, would make positive profits.

The definition of equilibrium consists of consumers maximizing utility given prices 1-3 and a zero profit condition for firms 8-11.

Given that firms earn zero profits, there are a continuum of wage contracts which solve 8-11. However, **it** will be shown later that there exists only one contract that also satisfies 12. Obvious simplications in notation and recalling the definition of $_nb_t$ gives:

$w_1(m'(0,0)=0,y) = y + {}_0b_1$

$w_2(m'(0,0)=0,m'(0,1)=0,y) = y + {}_0b_2$

$w_2(m'(0,0)=1,m'(1,1)=0,y) = y + {}_1b_2$

$w_2 = E(p|m'(0,0)=1,m'(1,1)=1)$

$w_2(y) = E(p|p+\theta=y, m'(0,0)=0)$

$w_0 + \beta_0(1-\Lambda_0(0,0))b_1 + \beta^2\Lambda_0(0,1)_0b_2 = E(p)$

$w_1 + \beta(1-\Lambda_1(1,1))_1b_2 + E(p|m'(0,0)=1).$

The decision-rules of the workers, $m'(p,y,n,t)$ are easy to solve in this model. A worker who changes jobs in the first period will change jobs again in the second period if $w_2(y) > y + {}_0b_2$, that is, if he earns more at a new firm. Similarly, a worker who does not change jobs after the end of the period zero will only change jobs again if $w_2 > y + {}_1b_2$. Given these rules, the value functions given in 2) and 3) become:

$$W(p,y,0,2) = max[y+{}_0b_2,w_2(y)]$$
$$W(p,y,1,2) = max[y+{}_1b_2,w_2]$$

Recalling the definitions of $V(y)$, and $\lambda(p)$ from the previous section, yields:

$$V(y) = y + {}_0b_1 + \beta W(p,y,0,2)$$
$$\lambda(p) = w_1 + \beta E_1 W(p,p+\theta,1,2)$$

Before determining the optimal decision rule for a worker, that is, whether or not to change jobs at the end of period zero, we will need the following definition and lemmas:

Definition: $y^r(p)$ is defined to be the output at which a worker with a base productivity level of p is indifferent between staying at his present job or leaving after the end of period zero.

$$y^r(p) + {}_0b_1 + \beta max[y^r(p)+{}_0b_2,w_2(y^r(p))]\blacksquare =$$
$$w_1 + \beta Emax[p+\theta+{}_1b_2,w_2]$$

where,

$$y^r(p') = p' + 8 \text{ if } V(p'+\theta) > \lambda(p') \text{ for all } \theta.$$
$$y^r(p'') = p'' + \theta \text{ if } V(p''+\theta) < \lambda(p'') \text{ for all } 8.$$

<u>Lemma 1:</u>

$y^r(p)$ is a reservation output in that for all $y < (>) \; y^r(p)$

$y + {}_0b_1 + \beta \max[y + {}_0b_2, w_2(y)] < (>) \; w_1 + \beta E \max[p + \theta + {}_1b_2, w_2]$

<u>Proof:</u>   The reservation property of $y^r(p)$ above follows from the monotonicity of $V(y)$ in y.   This is satisfied since both y and $w_2(y)$ increase with y.

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The decision whether or not to change jobs after period zero, depends on the inequality $V(y) < (>) \; \lambda(p)$.   The optimal decision rules for the worker are then:

$m'(p,y,0,0) = 0(1) \; \mathbf{iff} \, y_0 > (<) \; y^r(p)$

$m'(p,y,0,1) = 0(1) \; \mathbf{iff} \; y_0 > (<) \; w_2(y) - {}_0b_2$

$m'(p,y,1,1) = 0(1) \; \mathbf{iff} \; y_1 > (<) \; w_2 - {}_1b_2$

These rules can be substituted into the equilibrium wage rates and laws of motion.   The next lemma gives equivalent expressions for the value function $W(p,y,1,2)$, the laws of motion $\Lambda_i(n,t)$, and the expected value of the productivity of job changers.

<u>Lemma 2:</u>

1) $\Lambda_0(0,0) = \int G(y^r(p) - p)f(p)dp$

2) $\Lambda_0(1,1) = \int G(y^r(p) - p)G(w_2 - p - {}_1b_2)f(p)dp$

3) $\Lambda_0(0,1) = \int |G(y' - p) - G(y^r(p) - p)|f(p)dp$

4) $EW(p,y,1,2) = E \max[p + \theta + {}_1b_2, w_2] =$
= $G(w_2 - {}_1b_2 - p)w_2 + \beta(1 - G(w_2 - {}_1b_2 - p))(p + {}_1b_2) + (w_2 - p - {}_1b_2)\int \theta g(\theta)d\theta$

5) $E(p|m'(0,0)=1) = \int pG(y^r(p)-p)f(p)/\Lambda_0(0,0)$

6) $E(p|m'(0,0)=1,m'(1,1)=1) = \int pG(y^r(p)-p)G(w_2-p-_1b_2)f(p)/\Lambda_0(1,1)$

7) $E(p|p+\theta=y,m'(0,0)=0) = w_2(y) = \int^{p(y)}pf(p|p+\theta=y)dp/K$

where,

$y^r(p(y)) = y$

$K = \int^{p(y)}f(p|p+\theta=y)dp$

$w_2(y') = y' + _0b_2$

Proof: See Appendix 1.

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        The intuition behind these equalities can be gotten from Lemma 1.   The

necessary condition for a worker to change jobs after period zero is $y<y^r(p)$

or $\theta<y^r(p)-p$. $G(y^r(p)-p)$ is then the fraction of the productivity, p,

workers who change jobs after the initial period, while $G(y^r(p)-p)f(p)/\Lambda_0(0,0)$

is the proportion of these job changers with a base productivity level of p.

        The intuition behind 2 and 6 is similar to that above, but now the firm

has two pieces of information.   The firm estimates p on the conditions

necessary for a worker to change jobs in both periods: $\theta_0<y^r(p)-p$, and

$\theta_1<w_2-p-_1b_2$, where the subscripts 1 and 2 represent different draws of

θ.   Since these draws are i.i.d., $G(y^r(p)-p)G(w_2-p-_1b_2)f(p)/\Lambda_0(1,1)$ is

the proportion of the productivity, p, workers who change jobs both periods and may

be interpreted as a density function.

        In the next section, we show that a pooling equilibrium leads to adverse

selection and this adverse selection can explain the relationship between turnover

and wages. It will then be shown that an equilibrium exists for this

economy so that the above discussion is not vacuous. It is also established that, in equilibrium, workers will post bonds that are indexed according to their future mobility.

V. Job Mobility and Adverse Selection

In a model with perfect information, or when wages can be made contingent on the output of the worker, all workers will have the same propensity to change jobs. Adverse selection is present when low-productivity workers have a higher probability of changing jobs than do high-productivity workers. Since $G(y^r(p)-p)$ is the fraction of workers with a productivity of p who change jobs in the first period, the proof of adverse selection is that this is a decreasing in a worker's productivity, p. The proof relies on whether $dy^r(p)/dp < 1$. Adverse selection is present in the market for workers switching jobs again in the second period, since $G(w_2-p-_1b_2)$ is the fraction of workers with a productivity, p, who change jobs in the second period, which is obviously decreasing in p. This effect is accentuated by the model's finite horizon.

The next proposition proves that adverse selection is present in this labor market.

Proposition 1:

$dy^r(p)/dp < 1$ for all p.

Proof: From the definition of $y^r(p)$, Theorem 1, and Lemma 2:

$$V(y^r(p) = y^r(p) + \beta max[y^r(p)+_0b_2, w_2(y^r)]$$

$$= \lambda(p) = w + \beta Emax[p+\theta+_1b_2, w_2]$$

Since $w_2(y)$ is increasing in y, $dV(y^r)dy^r > 1$. Therefore **it** is sufficient to show that $d\lambda(p)/dp < 1$. Differentiating λ yields:

$d\lambda(p)/dp = \beta(1=G(w_2-p-_1b_2)) < 1.$

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Adverse selection results because the lower-productivity workers move more often due to the potential for confusing them with the higher-productivity workers. The job-matching component of a worker's productivity provides the necessary noise to insure that mobility exists in equilibrium. The key to adverse selection is that the wage rates w_1 and w_2 are not conditional on the output of the worker.

Adverse selection also implies that wages for job changers will be lower on average than the wages for job stayers.

Theorem 1:

The average future wages (output) of workers who do not change jobs are greater than the wages of workers who change jobs once after the initial period, and of workers who change jobs after both periods.

a) $E_{p,\theta}(V(y)|y > y^r(p)) > E_p(\lambda(p)|y<y^r(p))$

b) $E\{w_2(m'(0,0)=1,m'(1,1)=0,y)\} > w_2$

Proof:

a) $E_{p,\theta}(V(y)|y>y^r(p)) = \int\{_y r_{(p)}\int V(y)h(y)dy/(1-H(y^r(p)))\}f(p)dp$

$> \int V(y^r(p))f(p)dp = \int\lambda(p)f(p)dp$

$> \int\lambda(p)G(y^r(p)-p)f(p)dp/\Lambda_0(0,0)$

$= E_p[\lambda(p)|y<y^r(p)]$

The second inequality follows from Proposition 1, which implies $\mathrm{cov}(G(y^r(p)-p),p) < 0$ -- that is, mobility and productivity are negatively related.

b) Follows from the definition of w_2.

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There are two reasons why future wages are lower for job changers. One is the standard effect in finite horizon job-matching models. As mentioned in the previous section, this effect is due to the age and tenure of a worker. The second effect is due to the low-productivity workers being the frequent job changers. Mobility acts as a signal to firms of a worker's potential productivity at the firm. This effect is not dependent on (although accentuated by) the assumption of a finite horizon. In more general models, which include human capital, including a worker's age and tenure would not be a proxy for a worker's prior mobility.

To show why adverse selection can help explain why prior mobility is an indicator of future mobility, Proposition 1 has to be employed. To see why this model might be able to explain the positive correlation between the number of past job changes and the probability of changing jobs in any subsequent period, recall that the frequent job changers are the lower-productivity workers who have a higher propensity to change jobs. However, in conjunction with this is an opposing effect. Since workers who change jobs in the first period are primarily the lower-productivity workers, their wages and thus incentives to change jobs in the future are lower. A similar effect is present in any job-matching model with a finite horizon since the expected benefits of future matches decrease with age.

Theorem 2:

a) The probability that a worker changes jobs at the end of period one, given that he changed jobs after the end of period zero, is greater than it would be if adverse selection were not present or, equivalently, if the distribution of the productivity of workers who have changed jobs before was identical to the original distribution of workers, $f(p)$, then $\Lambda_1(1,1) > \int G(w_2-p)f(p)dp$.

b) Without adverse selection, the fraction of workers who change jobs after period zero is greater than the fraction of these workers who change jobs again after the first period, $\int G(y^r(p)-p)f(p)dp < \int G(w_2-p-_1b_2)f(p)dp$.

Proof:

a) $\Lambda_0(1,1) = E\{G(y^r-p)G(w_2-p-_1b_2)\}$

> $E\{G(y^r-p)\}E\{G(w_2-p-_1b_2)\} = \Lambda_0(0,0)\Lambda_1(1,1)$

The proof relies on $cov\{G(y^r-p)G(w_2-p-_1b_2)\} > 0$. This follows from Proposition 1.

b) The proof follows from Lemma 2 and the definition of w_2.

The first inequality reflects the additional information about a worker's productivity that is gained from knowing that a worker has changed jobs in the preceding period. It says that the unconditional probability that a worker with a base productivity level of p moves in the first period is positively correlated with the probability that the worker will move during the last

period conditional on having moved before. The second inequality reflects the fact that job mobility decreases with age in a finite horizon model, as the benefits of moving decrease over time. If the first effect dominates, then the following inequality will hold:

3.1 $\int G(y^r(p)-p)f(p)dp < \int G(y^r(p)-p)G(w_2-p-_1b_2)f(p)dp / \int G(y^r(p)-p)f(p)dp$

This will give the desired result. The probability of changing jobs increases with the number of previous job changes.

This result is, in general, not true. It will be true, however, when $y^r(p)$ and w_2 are approximately equal, or, in the many-period case, when the reservation outputs in succeeding periods are nearly equal." The intuition behind this result is that a pool of workers who have changed jobs many times previously will be composed primarily of the low productivity workers who have a higher propensity to change jobs. However, the force that helps counteract this result is that since this pool of workers will primarily be the low productivity workers, they will earn a lower wage if they change jobs, reducing the incentives for mobility.

Example 2:

The following example is a two-period version of the model presented above. The matching component, 8, is assumed to be uniformly distributed between $-\theta'$ and θ'. Following Example 1, a candidate equilibrium for this example can be obtained by choosing a wage-bonus package (w, b) which maximizes the expected return of the highest productivity worker.

Problem E:

$$\max_{w,b} \{w + \beta E\max[p''+\theta+b, w_2]\}$$

s.t.

1) $w + \beta(1-\Lambda)b \leq E(p)$

2) $\Lambda = \int G(w_2-p-b)f(p)dp$

3) $w_2 = \int pG(w_2-p-b)f(p)dp/\Lambda$

In Appendix 2 the solution to Problem E is shown to satisfy:

$b = w_2 + p'' - 2E(p)$ if $2(E(p)-p'')\geq\theta'$.

$b = w_2 + \theta'/2 - E(p|p<p_1)$ otherwise

where,

$E(p|p<p_1) - p_1 = -\theta'/2$

If we further assume that $p\sim U[\theta', 2\theta']$, then $b = w_2-p'$, and from Lemma 2, the corresponding prices and quantities are:

$A = 114$ $b=\theta'/3$ $w_1 = 5\theta'/4$

$w_2 = 4\theta'/3$ $G(w_2-p-b) = 1 - p/2\theta'$

The assumption that θ is uniformly distributed is not necessary to derive $b = w_2-p'$. All that is necessary is for p to be uniformly distributed. Before verifying that this is an equilibrium for this example, notice that it is consistent with the stylized facts; workers experience a wage increase when they change jobs, yet they earn less over time than job stayers.

Proposition 2:

The above are the equilibrium prices and allocations for this example.

Proof:

The proof proceeds in two steps. The first step establishes that there does not exist a new contract that could compete to hire away a subgroup of the higher productivity workers, $[p_h, p'']$. The second step is to show that there does not exist a feasible contract which could attract a subgroup of the lower productivity workers, $Cp', p_L]$.

The first step can be established as follows. The necessary conditions for a contract to attract the higher productivity workers are $d\lambda_h(p)/dp > d\lambda(p)/dp$ and $\lambda_h(p_h) = \lambda(p_h)$. That is, the marginal worker is indifferent between the two contracts and the higher productivity workers must strictly prefer the new contract. Using Proposition 1 these conditions imply:

$$(1-G(w_{2h}-p-b_h)) > (1-G(w_2-p-b))$$

or

$$w_{2h} - b_h < w_2 - b = p'$$

Since a property of the proposed equilibrium is that the highest productivity worker never moves, the above condition also implies that he would never move with the new contract. Therefore, if the highest productivity worker is to prefer this contract, we must have:

$$w_h + w_{2h} > w + w_2$$

To establish a contradiction, we now show that the lowest productivity worker under this condition also prefers the new contract:

$$w_h + Emax[p'+\theta+b_h, w_{2h}]$$

$$= \quad w_h + w_{2h} + Emax[p'+\theta+b_h-w_{2h}, 0]$$

$$> \quad w_h + w_{2h} + Emax[\theta, 0]$$

$$> \quad w + w_2 + Emax[\theta,0]$$

$$= \quad w + Emax[p'+\theta+w_2-p', w_2]$$

$$= \quad w + Emax[p'+\theta+b, w_2]$$

This establishes the contradiction, which proves that a group of the higher-productivity workers cannot be competed away. The rest of the proof shows that a feasible contract cannot compete away a group of the lower-productivity workers. For a contract to attract a subgroup of the lower-productivity workers there must exist some marginal worker, p_L, such that $\lambda_L(p_L) = \lambda(p_L)$. Since the highest productivity worker of this subgroup is p_L from Problem E, the best contract for the marginal worker is given by $b_L = w_{2L} - p'$. Therefore, establishing that this contract is not preferred by a worker with a productivity level of p_L implies that $\lambda_L(p_L < \lambda(p_L)$.

$$w_L + Emax[p_L+\theta+b_L, w_{2L}]$$

$$= \quad w_L + w_{2L} + Emax[p_L+\theta-p', 0]$$

$$< \quad w + w_2 + Emax[p_L+\theta-p',0]$$

$$= \quad w + Emax[p_L+\theta+w_2-p', w_2]$$

$$= \quad w + Emax[p_L+\theta+b, w_2]$$

The next to last step uses the feasibility condition, $w_L = E(p|p < p_L) - (1-\Lambda_L)b < E(p) + \Lambda w_2$, which follows since $\Lambda_L < \Lambda$.

This establishes the contention that there does not exist a feasible contract to attract a subgroup of the lower-productivity workers.

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The key to the proof is that the allocation that satisfying Problem E implies is that the highest productivity worker never changed jobs. A

necessary condition for a Nash equilibrium to exist in this model is for there to be enough variability in the productivity types of the workers to insure that the highest productivity workers never change jobs. In this example, it amounts to assuming that $p''-p' \geq \theta'$. If this condition does not hold, we may not have an equilibrium in this model. This is identical to the problems of nonexistence encountered in the literature. (See, for example, Rothschild and Stiglitz, Riley [1975], and Wilson [1977].) If we adopt Wilson's nonmyopic equilibrium concept, so that firms take into account that a new contract might imply some of the existing contracts will be withdrawn, then existence can again be proven. The equilibrium in this case typically involves a pooling equilibrium for a finite number of subgroups.

We are now ready to prove a sufficient condition for the existence of a pooling equilibrium in this model. The major difference between the following theorem and the preceding example is the inclusion of the third period. The theorem also establishes that bonds will be posted in equilibrium.

Theorem 3:

If $p \sim U[p', p'']$ and if there is "enough" dispersion in workers' productivity types, then a pooling equilibrium will exist for this model. Furthermore, a characteristic of this equilibrium is that workers will post bonds indexed on their future mobility such that the highest productivity worker will never move.

Proof: See Appendix 3

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These are sufficient conditions for an equilibrium to exist in this model. The distribution on p can be arbitrary as long as **it** is not "too" skewed to the right. With a two-period model, existence can be established by just assuming "enough" dispersion in p. Sufficient variability is assumed so that the highest productivity worker will never move.

There are two reasons why a separating equilibrium for this model is, in general, not possible. The first is that the benefits to the low-productivity workers to pass themselves off as high-productivity workers can be quite large in a multiperiod model. This occurs since future employers can observe a worker's productivity by his choice of an initial wage contract. The assumption that there is "enough" dispersion in p insures that the benefits from lying are large enough so that the low-productivity workers always prefer a pooling contract. The second reason why a separating equilibrium is, in general, not possible is that the mobility of workers is endogenously determined. This does not allow us to use Riley's theorems to establish sufficient conditions for a separating equilibrium. The standard models for a separating equilibrium to exist (see, for example, Spence [1973], Rothschild and Stiglitz [1976], Wilson [1977], etc.) depends on the assumption that some unobservable characteristic is correlated with something that is observable. **It** is natural to argue that mobility plays that role in the current model as **it** did in Salop and Salop's. However, in the present model, a worker's propensity to move is a property of the equilibrium; **it** is not determined exogenously as was the risk type of consumers in Rothschild and Stiglitz's model.

The next section discusses questions of optimality of the model.

VI. Welfare Implications:

The preceding examples illustrated another aspect of the model: In equilibrium there is less job mobility than occurs in a world with perfect information, or when wages can be made contingent on a worker's output. However, this is not true for all workers. The high-productivity workers move less often than they would in a world without adverse selection, while the low-productivity workers may or may not move less often than they would in a world without adverse selection. There are two reasons for this effect, both of which are due to adverse selection. The first is identical to that in Akerlof's model. Adverse selection reduces the future wages for workers when they move and thus reduces the incentive to move. The second effect is due to the posting of bonds in equilibrium, which further reduces the incentives for mobility.

The results of this section will be shown with a two-period model assuming that θ is uniformly distributed. For most of the results, these assumptions can be relaxed. Without bonds, the probability that a productivity, p, worker changes jobs is $G(w_2-p)$; the average probability that a worker changes jobs is given by $E\{G(w_2-p)\} = G(w_2-E(p)) < G(0)$, where $G(0)$ is the probability that a worker would change jobs in a model without adverse selection. The posting of bonds accentuates this effect. In Example 2 the unconditional probability that a worker moved was 1/4, with the lowest-productivity worker moving one half of the time, and the highest-productivity worker never moving.

Since aggregate mobility is less than in a model with complete information, it is natural to ask whether there is any potential for a

government to increase welfare in this model. An example of a government action, which one might argue does this, is unemployment insurance. In our model, workers do not incur any cost **if** they change jobs, therefore, unemployment insurance cannot be directly included in the model. However, **it** can be shown that **if** the model is extended, so there is a waiting period that workers must incur when they change jobs, then introducing unemployment insurance is identical to subsidizing the wages of job movers. In particular, this paper asks whether a government can achieve a Pareto improvement by subsidizing the wages of job movers. Not surprisingly, **if** we assume that a government does not have superior information about a worker's productivity, the answer is no. This is because subsidizing mobility would not benefit the highest–productivity workers, therefore, taxing them to pay for this subsidy would make them worse off. However, a stronger welfare result can be proven in this model. That is, a government cannot tax wage income to subsidize mobility and increase aggregate welfare.[10] In fact, **it** is shown that **if** a government subsidized the wages of job movers there would be no effect on the equilibrium allocations. This can be seen most simply **if** we assume that the government has access to lump–sum taxation. Without such a subsidy, the equilibrium prices and allocations from Problem E are:

1) $b = w_2 + \theta'/2 - E(p|p<p_1)$

2) $A = \int G(p_1-\theta'-p)f(p)dp$

3) $w_2 = \int^{p_1} pG(p1-\theta'-p)f(p)dp/\Lambda$

4) $w_1 = E(p|p<p_1) - (1 - \Lambda)b$

where,

$E(p|p<p_1) - p_1 = -\theta'/2$

To verify that subsidizing w_2 by s and taxing first–period income by As has no real effect, consider the above equations. Since the wage paid to

job movers by the firms, w_n would not change, then from 1) the equilibrium amount of the bonus would increase by s (or bonds would increase by 1 - s. In other words, the amount of the bonus paid to the job stayers would change one for one with the subsidy on w_2 leaving mobility the same and thus implying that the wage paid by the firm to job movers, w_2, remains the same. Therefore, second-period income would increase by s for both movers and nonmovers, and first-period income would decrease by s. The following are the new equilibrium allocations:

1') $b' = w_2' + s + \theta'/2 - E(p|p<p_1)$

2') $A = \int G(p_1-\theta'-p)f(p)dp = A$

3') $w_2' = \int^{p^1} pG(p1-\theta'-p)f(p)dp/\Lambda' = w_2$

4') $w_1' = E(p|p<p_1) - (1 - \Lambda)b' = w_1 - s$

The preceding assumed that a government had access to lump-sum taxation, that is, that firms did not take into account their influence on tax rates. By changing the amount of the bond that workers post, firms can influence aggregate mobility and hence tax rates. If firms did take this into account, then they would choose the amount of the bond that has to be posted to maximize the expected return of the highest productivity worker. The following proposition proves that even when firms take into account their effects on taxes, that subsidizing mobility would have no effect on the equilibrium allocations.

Proposition 3:

Even when a government does not have access to lump-sum taxation, the equilibrium prices and allocations are given by 1')-4').

Proof:

Following Problem E the new equilibrium will be chosen to satisfy

$$\max_{w,b}\{w - \Lambda s + \beta E\max[p''+\theta+b, w_2+s]\}$$

s.t.

1) $w + \beta(1-\Lambda)b \leq E(p)$

2) $\Lambda = \int G(w_2+s-p-b)f(p)dp$

3) $w_2 = \int pG(w_2+s-p-b)f(p)dp/\Lambda$

The solution to this maximization problem parallels that given in Appendix 2 and is omitted.

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The intuition behind this result is straightforward. Subsidizing mobility would benefit the frequent job movers, the low-productivity workers. In a pooling equilibrium, however, the returns to the highest-productivity workers are maximized. Since the highest-productivity workers never move in equilibrium, they never benefit from the subsidy. The amount of the bond that would be posted in equilibrium would change one for one with the amount of the taxes to eliminate the effects of a government's action. It can be shown that if the amount of the bond does not change, then subsidizing mobility could increase aggregate welfare. (Although it could not result in a Pareto improvement.)

It is informative to compare the results of this model to that of Jovanovic (1983) who also analyzed a labor market with adverse selection. Unlike the present model, he concluded there would be too much job mobility.

To derive his results, Jovanovic assumes there are an equal number of workers and islands (or plants). Each island is endowed with a given productivity, p, drawn from a known distribution, f(p). Workers are assumed

to be randomly distributed across the islands. Workers are identical except they work at plants with different productivity potentials. After working at an island one period, a worker decides whether to continue working at his present island, or to leave and select a vacated island. Islands are vacated because of either death or because a worker decides to change islands. A constant birth-death rate is assumed so that a fixed fraction of plants are vacated every period. This supplies the necessary noise to support an equilibrium. Otherwise, only the lowest-productivity plant would be vacated.

Workers at low-productivity plants would then be the job changers. Because of this adverse selection, the newborn will have a lower productivity island on average, and thus the young will be more likely to change jobs than other workers. Since the behavior of the newborn is fixed, there will be too much job mobility because workers currently at low productivity plants will switch islands, knowing that some of the high productivity plants will also be vacated.

The crucial difference between Jovanovic's model and the present one is that plants are endowed with the production technology in Jovanovic's model, while workers are endowed with the production technology in the present model. Jovanovic also ignores the market for plants. If plants could be bought and sold there would not be a one to one trade-off between islands vacated due to death and those vacated because the island was a low-productivity island. The price for plants would be determined analogously to the determination of the wage rates for workers in the present model. Since plants are immobile and have different production technologies, there will be too much job mobility in Jovanovic's model. Not enough job mobility exists in the present model because workers are endowed with the production technology, and plants or firms bid to attract these workers.

VI. Conclusion

In an attempt to explain several empirical regularities of the labor market, adverse selection was incorporated into a standard job-matching model. The model showed that the negative relationship between turnover and wages is a result of adverse selection. Another prediction of the model is that wages will increase with tenure since bonds are posted in equilibrium in order to punish job changers (the low productivity workers) and reward the job stayers (the high productivity workers). Two examples were also constructed to demonstrate that this model is also capable of explaining two other stylized facts of the labor market. The first is the positive correlation between prior mobility and future mobility, and the second is the notion that wages for (older) job changers may actually decrease after each job change.

The model given in the paper is abstract and, as such, cannot hope to adequately explain the many empirical facts of the labor market. One such fact that the model failed to explain is why quits lead to increased lifetime earnings when they occur early in the life cycle. The major weakness of this model (and similar models) is that it concentrates on only one reason why a worker might quit his present job. Bartel and Borjas find that the reason why a worker quit his job has a significant impact on earnings. They divide quits into three categories: quits due to job dissatisfaction (PUSH), quits occurring because a worker found a better job (PULL), and quits occurring for personal reasons. They find that a pull quit implies a significantly higher wage growth, while a push quit does not significantly affect wage growth, and that quits due to personal reasons implies a significant decrease in wage growth. Furthermore, they find that quits occuring early in the life cycle

are primarily due to workers finding better jobs, while push quits are more likely to occur later in the life cycle. This is a puzzle for this model and traditional job-matching models, since turnover due to the matching process, and thus quits due to job dissatisfaction, should occur early in the life cycle.[11] Unlike the traditional job-matching model, however, this paper explains why these movers should experience less wage growth than job stayers.

The findings that persistent mobility among older men results in lower wages appears to be true in the aggregate, however, it is not true for all groups of workers. Murphy (1985) finds that for executives the opposite is true, that is, an executive's earnings are positively related to his previous job mobility. The present model cannot explain this, but it does suggest that adverse selection will be less important for executives since they are paid more frequently by bonuses and stock options (which are forms of contingent wage contracts). If workers are paid their realized productivity every period, then an executive's wage will be on the average his base productivity level. Even if executives are not perfectly separated according to their productivity, adverse selection will be less important since more information is available about their base productivity levels.

A full explanation of the relationship between wages and mobility would have to include tenure. Tenure could conceivably be introduced into the previous analysis in one of two ways. The role of tenure in Jovanovic's (1979a) model is for workers to learn over time about the quality of their current job matches. The second possibility would be to introduce firm-specific human capital into a matching model as in Jovanovic (1979b). These exclusions were made to increase the clarity of the analysis, and because solving the model with an arbitrary number of periods has proven, as of this time, to be intractable.

The basic model given above is general in that **it** can be modified to have additional implications for mobility and wages. **If** the informational requirements of the model are modified so that firms cannot perfectly observe a worker's past wage rates, the resulting adverse selection implies that workers who move because of differences in either tasks (personal reasons) or technologies will earn lower wages over time. For example, **if** the matching component, θ, is interpreted to be the utility or disutility a worker receives at a job, the above analysis implies that workers who have a taste for changing jobs will earn less over time. Similarly, **if** workers quit because of unobservable shocks to their household production functions, then adverse selection will imply that workers who drop out of the labor force frequently will also earn lower wages over time. This effect complements existing explanations for the wage differential between men and women.

Endnotes

1. This assumption is not crucial since observing a worker's output at a previous firm would only give a potential employer a noisy signal of a worker's base productivity level.

2. $G(O)$ is the probability that a worker moves again after period one and $G(\beta\theta'/(1+\beta))$ is the probability that a worker moves after period zero. Using the assumption that θ is uniformly distributed gives the results in the text.

3. If we keep the assumption that $\beta=1$ ands θ is uniformly distributed, the average wage for a worker with a base productivity level of p in period zero would be $p + E(\theta|\theta<\theta'/8) = p - 71168'$.

4. Jovanovic himself mentions in a footnote that his model cannot explain why persistent job movers have lower future wages compared to the future wages of infrequent job movers.

5. This is because the model has more than one period. In a one period model, one could again obtain a separating equilibrium. Workers would be paid a piece rate wage, with the high productivity workers receiving a large percentage of their wage in terms of their realized output at a firm. In a multi-period model a separating equilibrium would not be as easily obtained, since the contract a worker accepts in the first period would signal to all future employers the productivity type of the worker.

6. Since 213 (1/3) of the (low) high productivity workers move after period zero and again after period one, the expected productivity of a worker who changes jobs after the first period is (2/3X1/2X1 + 1/3X1/2X2)/(2/3X1/2 + 1/3X1/2) = 413; the expected productivity of a worker who changes jobs after both periods is (2/3X2/3X1/2X1 + 1/3X1/3X1/2X2)/(2/3X2/3X1/2 + 1/3X1/3X1/2) = 615; and the expected productivity of a worker in the initial period is simply (1/2X1 + 1/2X2) = 312. The wages reported in the text can be obtained as follows: In the initial period, the probability that a worker stays at his present job is 112, therefore $w_o = 3/2 - (1/2)_o b_1 = 1019$; similarly, the conditional probability that a worker changes jobs after the **first** period given that he changed jobs before 419, is therefore $w_1 = 413 - (4/9)_o b_2 = 56/45$; and the wage for a worker who changes jobs twice is just his expected productivity, $w_2 = 716$.

7. We are imposing a restriction that bonds cannot be made contingent on the realized output of a worker output. Bonds are only allowed to be made contingent on a worker's decision either to move or stay at the firm. The more general case, when the bond can depend on y, has proven to be intractable. Intuition suggests that including this more general case would make **it** more likely that a separating equilibrium will exist, but **if** there is enough variability in the job matching component, θ, that a pooling equilibrium will still result. For the remainder of the paper, we maintain the assumption that the return on bonds cannot depend on y.

8. We ignore the mechanism that forces a firm to honor its contract with workers. Workers who have a good job match at their current firm do not have the same expected opportunities at other firms, so that competition cannot

force the firm to pay the worker his output at the firm. Similarly, because of the asymmetric information in the model, neither a court system nor other workers would know whether a firm had honored its contract with the worker.

9. Another effect that will help the desired result is that workers will generally post larger bonds earlier in their life cycle which will help give the desired result. Example 1 showed an example of this.

10. This is in contrast to the welfare implications of Akerlof's model where the government could subsidize the trading of cars and increase aggregate welfare in the sense that owners of the low-quality cars would gain more than the owners of high-quality cars would lose.

11. The unconditional probability that a worker quits his job is greater early in the life cycle; it is the probability that a worker quits his job conditional on his previous quits, which this paper shows is not necessarily greater early in the life cycle.

Appendix 1

This appendix proves Lemma 2.

1) $\Lambda_0(0,0)$ = $\int\{\int m'(p,p+\theta,0,0)g(\theta)d\theta\}f(p)dp$
   $= \int\{\int^{y^r-p}g(\theta)d\theta\}f(p)dp$
   $= \int G(y^r(p)-p)f(p)dp$

2) $\Lambda_0(1,1)$ = $\int\{\int\int m'(p,p+\theta,0,0)m'(p,p+\theta,1,1)g(\theta_0)g(\theta_1)d\theta_0d\theta_1\}f(p)dp$
   $= \int\{\int^{(y^r-pi)}\int^{(w2-pi-_1b2)}g(\theta_0)g(\theta_1)d\theta_0d\theta_1\}f(p)dp$
   $= \int G(y^r(p)-p)G(w_2-p-_1b_2)f(p)dp$

3) $\Lambda_0(0,1)$ = $\int\{\int(1-m'(p,p+\theta,0,0))m'(p,p+\theta,0,1)g(\theta))d\theta\}f(p)dp$
   $= \int\int\{(m'(p,p+\theta,0,1)-min[m'(p,p+\theta,0,0),m'(p,p+\theta,0,1]\}g(\theta)d\theta f(p)dp$
   $= \int\int^{y'-p}g(\theta)f(p)d\theta - \int\int^{min[y',y^r]-p}g(\theta)f(p)d\theta dp$
   $= \int\{G(y'-p) - G(min[y^r,y']-p)\}f(p)dp$
   $= \int|G(y'-p) - G(y^r(p)-p)|f(p)dp$

The proof uses the reservation property of $m'(p,y,0,1)$, that is, the worker will stay (leave) **iff** $y > (<) y'$. This reservation property follows since $dw_2(y)/dy < 1$.

4) $Emax[p+\theta+_1b_2,w_2]$
   $= G(w_2-p-_1b_2)w_2 + (1-G(w_2-p-_1b_2))(p + _1b_2 + E(\theta|0 > w_2-p-_1b_2)$

where,

$E(\theta|\theta > w_2-p-_1b_2) = (w_2-p-_1b_2)\int\theta g(\theta)d\theta/\int G(w_2-p-_1b_2)f(p)dp$

5) $E(p|m'(0,0)=1)$ = $E(p|p+\theta < y^r(p))$
   $= \int p(\int^{y^r}f(p|p+\theta=y(h(y)dy)/\Lambda_0(0,0)$
   $= \int\int^{y^r}pf(p)g(y-p)dy/\Lambda_0(0,0)$
   $= \int pf(p)G(y^r(p)-p)/\Lambda_0(0,0)$

The second step expresses the posterior distribution of p, when p and θ are independent. See Degroot (1979) for details. The third step uses the definition of the convolution product.

6) $E(p|p+\theta_1 < y^r(p), p+\theta_2 < w_2-_1b_2$
   $= \int p\{\int^{y^r}\int^{w2-_1b2}f(p|p+\theta_0=y_0,p+\theta_1=y_1)h(y_0,y_1)dy_0dy_1/\Lambda_0(1,2)$
   $= \int p\{\int^{y^r}\int^{w2-_1b2}f(p)g(y_0-p)g(y_1-p)dy_0,dy_1\}\Lambda_0(1,1)$
   $= \int pf(p)G(y^r(p)-p)G(w_2-p-_1b_2)/\Lambda_0(1,1)$

The steps in 6 are identical to those before, except the following identity is used in the proof.

$h(y_0,y_1)$ = $\int h(y_0,y_1|p)f(p)dp$
   $= \int g(y_0-p)g(y_1-p)f(p)dp$

7) The proof follows since $f(p|p+\theta=y)$ is truncated above by $y^r(p) < y$.

Appendix 2

Using constraint 1), Problem E can be rewritten as

$$\max_{b} \{E(p) + \beta(\Lambda - G)b + \beta G w_2 + \beta(1-G)p + {}_{w_2-p-b}\int \theta g(\theta)d\theta$$

s. t.

constraints 1) and 2) hold.

There are two cases to consider: when $G(w_2-p''-b) > 0$, and when $G(w_2-p''-b) = 0$. The first case leads to the following first order condition:

$$\beta\{\Lambda + (\Lambda'(.)b + G)(dw_2/db - 1)\} = 0$$

Using the definition of A and w_2 gives:

$$\beta\Lambda\{1 + (\theta'+w_2-p'')/(E(p)-w_2-2\theta'\Lambda)\}$$

Rearranging gives the equilibrium amount of the bond as discussed in the text:

$$b = w_2 + p'' - 2E(p)$$

The second part of the maximization problem assumes that $G(w_2-p''-b) = 0$. Defining p1 such that $w_2-p1-b = -\theta'$, that is, the smallest productivity that a worker can have and never change jobs, the following is the relevant maximization problem:

$$\max_{b}\{E(p) + \beta\Lambda b + p''\}$$

s.t.

constraint 1) holds.

This implies the following first-order condition:

$$\Lambda + b(dw_2/db - 1)/2\theta'$$

$$= \beta\Lambda(1 + b/\{E(p|p<p1)-w_2-2\theta'\Lambda)\}$$

$$= \beta\Lambda(2E(p|p<p1)-2w_2-\theta'+2b)/(2E(p|p<p1)-2w_2-2\theta'\Lambda)$$

This implies the second equation in the text: $b = w_2 - E(p|p<p1) + \theta'/2$.

Appendix 3

In this appendix, we prove the existence of an equilibrium for this economy. The proof is in two major steps. The first step is to verify that there exists a wage contract which satisfies conditions 1 – 11 of the definition of equilibrium. The second part is to show condition 12, that there does not exist a new contract which, if offered, could make positive profits.

$$y^r(p) + \beta\max[y^r(p)+_0b_2, w_2(y^r(p))]$$

$$= w_1 + \beta E\max[w_2, p+\theta+_1b_2]$$

$$= w_1 + \beta G(w_2-p-_1b_2)w_2 + \beta(1-G(w_2-p-_1b_2)(p+_1b_2) + {}_{w2-p-1b2}\int\theta g(\theta)d\theta$$

$$= w_1 + \beta(\Lambda_1(1,1)-G(.))_1b_2 + \beta G(.)w_2 + (1-G(.))p + {}_{w2-p-1b2}\int\theta g(\theta)d\theta$$

where,

$$w_1 = \int G(y^r(p)-p)f(p)dp/\Lambda_0(0,0)$$

$$w_2(y) = E(p|p+\theta=y>y^r(p))$$

$$w_2 = \int G(y^r(p)-p)G(w_2-p)f(p)dp/\Lambda_0(1,1)$$

implies,

$$y^r(p) = f(w_1, w_2)$$

implies,

$$w_1 = w_1(w_1, w_2)$$

$$w_2 = w_2(w_1, w_2)$$

To prove there exists a solution to this set of equations, we must verify compactness and continuity. Compactness follows since p is distributed on the interval [p', p"]. Continuity follows since w_1, w_2 are continuous in $y^r(p)$ (since G is continuous), and $y^r(p) = f(w_1, w_2)$ is continuous in its arguments. Therefore, w_1, w_2, $w_2(y)$ are continuous in $y^r(p)$ and, from the Brower Fixed Point Theorem, there exists a solution to w_1, $w_2(y)$, and w_1.

We now establish that there does not exist a new contract that could break the pooling equilibrium. We already know that of the pooling contracts, the only one which could be an equilibrium is the one that maximizes the returns of the highest productivity worker.

The remainder of the proof is as follows: First we show that for a subgroup of the high-productivity workers to be competed away in the initial

period, that $y^r H(p) < y^r(p)$. The second step proves that the original contract implies that the highest productivity worker would never move after the initial period, and thus there does not exist a contract that could only attract a subgroup of the higher-productivity workers. The next step shows that a subgroup of the lower-productivity workers cannot be competed away. The rest of the proof then establishes that a new contract could not break the pooling equilibrium in the first period. The crux of the proof is to show that the highest-productivity worker of those who changed jobs after the initial period will not move again after the first period. Many of these steps are sketched because of the similarity to Proposition 2.

$$W(p) = w_0 + \beta E \max[\lambda(p), V(y)]$$

For a subgroup $[p_H, p"]$ to be competed away, we must have $W')p) < W_H'(p)$. Differentiating with respect to p implies $y^r(p) > y^r H(p)$. We next show that $V(p"-\theta') > \lambda(p")$, or equivalently, that the highest-productivity worker will not move.

$$V(p"-\theta') > (p"-\theta')(1+\beta) > \beta(p"+_1 b_2)$$

Since $w_1 + \beta \Lambda_1 (1,1)_1 b_2 < E(p)$ this series of inequalities holds **if** p is sufficiently dispersed.

Therefore, for $p"$ to prefer a new contract we must have $w_0 + \beta V(y) < w_{0H} + \beta V(_H(y)$. However, p' would also prefer this contract since

$$w_0 + \beta E \max[\lambda(p'), V(p'+\theta)] < w_{0H} + \beta E \max[\lambda_H(p'), V_H(p'+\theta)]$$

This follows since $\lambda < \lambda_H$. The last inequality says that low-productivity workers would gain in the later periods by pretending to be a high productivity worker in the initial period.

To prove a contract does not exist which can compete away a subgroup of the lower productivity workers, we note that the highest-productivity worker also prefers this contract.

$$w_{0L} + \beta E \max[\lambda_L(p), V_L(y)]$$

$$< \quad w_{0L} + \beta E \max[\lambda(p), V_L(y)]$$

which implies

$$w_{0L} + \beta L_L(y) > w_0 + \beta V(y)$$

From Proposition 2 **it** is sufficient to show that the highest-productivity job changer will not change jobs again, i.e. $w_2 - p_2 -_1 b_2 < -\theta'$, where, $V(p_2 - \theta') = \lambda(p_2)$.

To prove this, we show that $_1 b_2 > w_2 - p'$. To see that this is sufficient, note that $w_2 - p_2 -_1 b_2 < p' - p_2$ when the above condition holds, and that **if** $p' - p_2 < -\theta'$, then $V(p') > \lambda(p_2)$ which could never be true.

To show that $_1b_2 > w_2 - p'$ note that $_1b_2$ is chosen to

$$\max_b \{\Lambda_1(1,1)b\}$$

Proceeding as Appendix 2 gives the following first-order condition.

$$\Lambda_1(1 + b\int g(\theta)G(y^r-p)f(p)dp/K)$$

where $K = \int(p-w_2)g(w_2-p-b)G(y^r-p)f(p)dp - \int G(w_2-p-b)G(y^r-p)f(p)dp$

This implies that the solution to b satisfies:

$$\int(p-w_2+b)G(y^r-p)g(w_2-p-b)f(p)dp - \int G(y^r-p)G(w_2-p-b)f(p)dp$$

Integrating by parts and recalling from proposition 1 that $dy^r(p)/dp < 1$ gives the desired result.

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