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Chapter Author: Jacob Mincer, Boyan Jovanovic

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1 Labor Mobility and Wages

Jacob Mincer and Boyan Jovanovic

In this essay we explore the implications of human capital and search behavior for both the interpersonal and life cycle structure of interfirm labor mobility. The economic hypothesis which motivates the analysis is that individual differences in firm-specific complementarities and related skill acquisitions produce differences in mobility behavior and in the relation between job tenure, wages, and mobility. Both "job duration dependence" and "heterogeneity bias" are implied by this theory. Exploration of longitudinal data sets—National Longitudinal Surveys (NLS) and Michigan Income Dynamics (MID)—which contain mobility, job, and wage histories of men in the 1966–76 decade yield the following findings, among others:

1. The initially steep and later decelerating declines of labor mobility with working age are in large part due to the similar but more steeply declining relation between mobility and length of job tenure.

2. Given tenure levels, the probability of moving is predicted positively by the frequency of prior moves and negatively by education. The inclusion of prior moves in the regression reduces the estimated tenure slope because it helps to remove the "heterogeneity bias" in that slope.

3. The popular "mover-stayer model" is rejected by the existence of tenure effects on mobility.

Jacob Mincer is Professor of Economics, Columbia University, and Research Associate, National Bureau of Economic Research.
Boyan Jovanovic is staff economist at Bell Laboratories.

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4. Differences in mobility during the first decade of working life do not predict long-run differences in earnings. However, persistent movers at later stages of working life have lower wage levels and flatter life cycle wage growth.

5. The analysis calls for a reformulation of earnings (wage) functions. Inclusion of tenure terms in the function permits separate estimates of returns to general and specific human capital after correction for heterogeneity bias. A rough estimate is that fifty percent of lifetime wage growth is due to general (transferable) experience and twenty-five percent to firm-specific experience and interfirm mobility.

Sections 1.1–1.8 contain an exposition and empirical analysis which ranges over somewhat wider subject matter than Sections 1.9–1.11 which focus on the stochastic structure of mobility processes.

1.1 Introduction: Renewed Interest in Labor Mobility

Labor mobility is one of the central topics of labor economics and a long-standing subject of empirical research. Earlier studies reflected primarily a concern with the allocative efficiency of the labor market. They analyzed attitudes, job change decisions, and the direction of observed labor mobility in attempts to ascertain whether information, motivation, and behavior of workers were consistent with the postulates of economic theory.

In a comprehensive survey of this literature, Parnes (1970) concluded that the evidence on the operation of market forces was mixed, both among different studies and even within them. Although research in the 1960s was more sophisticated and utilized larger data sets than prior work, it did not provide any change in perspective.

Reviewing the more recent literature, Parsons (1978) finds promise in the emergence of theories of human capital and of search theories as tools for the analysis of labor mobility, labor turnover, and unemployment. However, applied work in search theory has, thus far, only partially touched on problems of labor mobility and of unemployment: its emphasis has been largely on conditions terminating job search, rather than on circumstances which generate it.

The reformulation of labor mobility as a human capital investment decision has been fruitfully applied to migration (Sjastaad 1962, and other work reviewed by Greenwood 1975). The connection between investments specific to the firm (and to larger units) and the incidence of industrial and occupational labor turnover has been elucidated in studies by Becker (1975), Oi (1961), and Parsons (1972).

The novel approaches suggested by human capital and by search theories are producing a renewed interest in the formerly stagnant field of labor mobility. A further source of interest has come from stochastic models of labor mobility. The first of these, the "mover-stayer" model, appeared two decades ago (Blumen, Kagan, McCarthy 1955) and they have recently reappeared in more sophisticated form (Heckman 1977, 1978; Jovanovic 1978b; for a review, see Singer and Spilerman 1976).

The purpose of this essay is to explore the implications of human capital and search behavior for both the interpersonal and life cycle structure of interfirm labor mobility. The apparent ambiguity in the relation between labor mobility and wages which characterizes much of the literature surveyed by Parnes is implicit and reconcilable in human capital analysis; as a response to perceived gains in wages, mobility promotes individual wage growth, but to the extent that on-the-job investments contain elements of specificity, mobility is a deterrent to wage growth. The study of differences in mobility behavior requires information over time; of special importance, in our approach, is information on time spent in the firm (tenure) and on the life cycle changes in job attachments. The availability of longitudinal microdata (especially NLS and MID panels) enables us to study these phenomena.

The economic hypothesis which motivates the analysis is that individual differences in firm-specific human capital behavior lead, via wage effects, to heterogeneity in mobility behavior, and to "tenure effects" on attachment to the firm. Implications for life cycle mobility are then derived in the absence or presence of "aging" (changes in mobility with age, at given tenure levels). Both "tenure dependence" and "heterogeneity bias" are implied by the theory. We explore data sets which contain mobility histories to ascertain the existence of these phenomena and to correct for the predictable biases. Next we investigate corresponding features of the wage structure. Labor mobility and tenure effects are introduced and tested in a reformulated earnings function in which specific and general human capital accumulation can be distinguished.

Sections 1.9–1.11 present a rigorous formulation of the structure of mobility viewed as a stochastic process.

1.2 Tenure, Working Age, and Mobility: Some Definitions and Facts

We define labor mobility as change of employer, whether or not unemployment intervenes. We exclude exits from and entries into the labor force. This exclusion is a minor one for the male labor force which we study.[1] Consequently, job separation is synonymous with job change in our data. Except for one illustration of observed differences (see table 1.2), we do not distinguish here between separations initiated by (or reported as) quit and layoff. Geographic, industrial, and occupational mobility are components of job mobility which are included in our concept but not singled out for separate treatment.[2]

Two probabilistic relations, or time profiles, are basic in our discussion and measurement of labor mobility. (1) The "tenure turnover profile" $S(T)$ is the relation between the probability of separating from a job in period t and the time spent in that job prior to t (current tenure T). In the language of renewal theory, $S(T)$ is the "hazard function." At the individual level this is a profile of "propensity to move" conditional on tenure. Such a profile is not observable. In large homogeneous groups, that is, groups consisting of individuals with the same propensity $S(T)$, we can observe estimates of the probabilities in each period in the form of relative frequencies or separation rates conditional on tenure. (2) The relation between an individual's propensity to move and working age, regardless of his current tenure, is his "experience turnover profile" $S(X)$. Again, this is observable as a relation between experience and separation rates.

The most firmly established fact about labor mobility of all kinds is that it declines with age. It declines much more sharply with length of tenure. The declines in both $S(X)$ and $S(T)$ are strongest initially and decelerate subsequently. Several tenure and age profiles of separation rates are shown in tables 1.1–1.3.

Table 1.1 shows the decline with age in the proportion of job changers (number of job changers divided by number employed) in 1961. The decline is similar when measured in terms of number of job changes rather than job changers, since a similar fraction (35%–40%) of job movers in each age group changed jobs more than once during the year (BLS 1963, table A).

Table 1.2 shows cross-classifications of separations, quits, and layoffs by experience and tenure in the period 1971–73 in the two NLS samples of men (young men, ages 19–29, and older men, ages 50–64, in 1971). The tenure profiles within working age (experience) classes are steeply declining and decelerating (convex). Mobility does not decline with working age at given tenure levels *within* each of the cohort age ranges. The decline *between* the young and old cohort is pronounced, but it shows mainly in quits.

The separation equations in table 1.3, derived from NLS panel data, summarize the conclusion that *within* the two age panels declines of mobility with working age (experience), shown by $S(X)$ in tables 1.1 and 1.2, are due to the effect of tenure which is revealed in the regression $S(X,T)$: For young men, experience effects (coefficients of X, X^2) vanish when tenure (T, T^2) is included. No experience effects are observed for older men with or without the tenure variables.[3] However, estimates of

Table 1.1 Job Changers as Percent of Employed Men, U.S., 1961

	Age					
	18–19	20–24	25–34	35–44	45–54	55–64
Percent	23.5	24.4	14.9	10.2	7.1	4.0

Source: BLS 1963.

Table 1.2 **Mobility by Experience and Tenure, Pooled, 1967–73 (Percent moving in a two-year period)**

Experience (years)	All	Tenure Level (years) 0–1	1–3	3–5	5–7	7–9	9–11	11–15	15–19	19+	*n*
					A. Separations						
0–4	.47	.73	.58	.28	.07	.12	.04				2,246
5–9	.38	.77	.60	.38	.08	.07	.06				1,197
25–29	.11	.46	.16	.22	.10	.19	.04	.03	.06	.04	441
30–34	.11	.40	.20	.15	.10	.16	.12	.04	.06	.06	1,499
35–39	.12	.51	.19	.19	.11	.08	.08	.06	.04	.04	1,998
40–44	.12	.43	.20	.10	.10	.11	.13	.05	.05	.06	1,542
					B. Quits						
0–4	.32	.48	.41	.20	.06	.08	.04				
5–9	.25	.48	.42	.26	.06	.05	.07				
25–29	.06	.19		.22	.10	.11	.04	0	.01	0	
30–34	.07	.20	.12	.09	.08	.09	.11	.03	.03	.02	
35–39	.05	.18	.10	.10	.06	.05	.06	.03	.02	.01	
40–44	.05	.13	.09	.03	.07	.06	.07	.03	.04	.02	
					C. Layoffs						
0–4	.14	.26	.17	.08	.01	.05					
5–9	.12	.28	.18	.11	.03	.02					
25–29	.05	.27	.16	0	0	.08	0	.02	.03	.01	
30–34	.05	.21	.08	.06	.02	.07	.01	.01	.03	.05	
35–40	.07	.33	.09	.10	.05	.04	.02	.03	.02	.03	
40–44	.07	.30	.12	.06	.03	.05	.05	.03	.01	.03	

$S(X)$ and $S(X,T)$ in Michigan Income Dynamics data which cover the complete age spectrum (table 5, panel C, lines 1 and 2) show that net aging effects remain even after the inclusion of tenure, although they are reduced in size and significance. In all data sets the explanatory power resides mainly in the tenure variables; mobility is convex both in tenure and in experience; and the tenure profile is much steeper than the experience profile.

1.3 Wage and Mobility Structures: Some Theory

We now turn to broad theoretical considerations with which we may analyze the facts of labor mobility. Some skills acquired in a particular firm are not transferable to other firms. The acquisition of such "specific" components of human capital by workers and the consequent wage pattern suffice to produce the tenure effects in the attachment to the firm which we observed in tables 1.2 and 1.3. At the same time, individual differences in amounts of specific capital investment imply a heterogene-

Table 1.3 Separate Equations (1967–73)

Young Men, Pooled

$$S(X) = .486 - \underset{(5.2)}{.034X} + \underset{(3.6)}{.002X^2} \quad R^2 = .02$$

$$S(X,T) = .692 + \underset{(1.0)}{.006X} - \underset{(0)}{.0000X^2} - \underset{(19.7)}{.172T} + \underset{(16.3)}{.009T^2} \quad R^2 = .29$$

Older Men, Pooled

$$S(X) = .015 + \underset{(.4)}{.0028X} - \underset{(.5)}{.000X^2} \quad R^2 = .003$$

$$S(X,T) = .208 + \underset{(.3)}{.0035X} - \underset{(.2)}{.0000X^2} - \underset{(6.4)}{.024T} + \underset{(4.1)}{.0005T^2} \quad R^2 = .10$$

Source: NLS Tapes.

ity in mobility, or in attachment to the firm (length of tenure), as well as in the strength of tenure effects, that is, in slopes of the tenure-separation probability relation.

The effects of acquiring job-specific capital on mobility may be described as follows: successful job matches eventually result in wage levels W which exceed expected alternative wages W_g. The higher the wage W the less incentive to quit, given W_g and the usual fluctuations in demand. Separations are high during the initial "probation" period and then drop to low levels. It is reasonable to assume that a successful match is only a starting point for a continuing employment relation which often involves investments of workers and firms in worker skills, and these are partially nontransferable.[4] Employer investments involve hiring, screening, and training costs which are recouped by a wage policy such that both quits and layoffs are deterred, that is, $W_g < W <$ VMP, where VMP is the worker's value of marginal product in the firm.

Define $W = W_g + W_s$, where W_g is the worker return on his general (transferable) human capital and W_s is the difference between the (higher) wage received in the firm and the opportunity wage elsewhere (also W_g). Similarly, W_e is the employer's return on the costs of investing in workers, the difference between the worker's productivity (VMP) and the wage paid to him (W). Workers are deterred from quitting, and employers from dismissing workers, because of these returns. Total separations are affected by $\Delta = (\text{VMP} - W_g) = W_s + W_e$, that is, by both components of returns to specific capital. In this paper we do not focus on the distinction between quit and layoff or consider the question whether employers and workers engage in joint or in separate optimizing behavior (but see Mortensen 1978). Plausibly, W_s and W_e are expected to be positively related: a good match and opportunity for joint investments are recognized by both employee and employer.

The distribution of returns to specific capital (Δ) creates individual (and group) differences in tenure-turnover profiles. Tenure profiles are horizontal only when $\Delta = 0$, in which case tenure has no effect on mobility or on wages. With $\Delta > 0$, tenure profiles of specific capital do not emerge instantaneously as the worker joins the firm. Specific capital is accumulated over time, given a successful match, and the returns grow over time. Both the rate of growth of these returns and their ultimate level affect mobility: the "tenure effect" is positively correlated with both. The convexity of the tenure-mobility profiles, and concavity of the tenure-wage profiles, are due to the eventual completion of specific capital accumulation in the firm.[5]

Thus the economics of specific human capital formation predict the coexistence of heterogeneity and of "tenure dependence" in accounting for mobility. The two aspects of behavior are related and are not to be viewed as mutually exclusive hypotheses: persons who favor large volumes of specific capital investment exhibit relatively little mobility (except for an initial period of repeated search and occasional later moves) and strong tenure effects.[6] Low levels of specific investment behavior, whether intentional or due to inefficiency in job matching, imply high (persistent) mobility levels independent of tenure (zero or small tenure effects). If rates of decline of experience profiles of mobility reflect primarily the slopes of tenure profiles, as appears to be the case, the flat and high profiles of "movers" and the downward-sloping profiles of "stayers" imply a progressive divergence over the life cycle in observed mobility behavior of a heterogeneous population.

The growing divergence of mobility rates over the working age parallels the repeatedly observed divergence of individual life cycle wage profiles (see Mincer 1974). The human capital model can interpret both divergences as lifetime outcomes of unchanging individual differences in abilities and opportunities. This view cautions against literal impressions that older cohorts are more heterogeneous than younger ones, or against the notion that the experience of longer tenure creates a "reinforcement effect," that is, a desire to invest in specific capital. This is not to say, however, that such views are not valid. Habit formation and unexpected events do modify lifetime histories, but they need not be invoked in an initial analysis.

The major implication of specific capital heterogeneity for the structure of mobility is the existence of differential tenure effects. Levels of $S(T)$ are higher and slopes flatter for individuals and groups who acquire little specificity in their human capital, while steeper slopes and eventually lower levels characterize tenure functions of large specific capital investors. Empirical observations should reveal steep downward slopes in tenure-turnover profiles uncorrected for "heterogeneity bias," as well as "true" negative slopes after correction for bias.

A related set of predictions applies to the wage structure: a major one is the existence of tenure effects on wages which are additional to the effects of general human capital accumulation. This suggests a reformulation of the earnings function to include a tenure term. The experience and tenure coefficients should provide a decomposition of worker returns to general (transferable) and specific (nontransferable) human capital investments. As in the case of mobility, it is also necessary to attempt correction for the danger of upward biases in tenure effects which is posed by the existence of heterogeneity.

Other implications of the theory relate to the effects of age (experience) on mobility and wages $S(X)$ and $W(X)$. An interesting conclusion is that mobility declines and wages grow with age even if there are no "aging" effects, that is, even if mobility depended only on levels of tenure and not directly on age (given tenure). Similarly, wages grow (on average) over the life cycle even if no general (experience) capital is accumulated. Also $W(X)$ should be concave if $W(T)$ is concave, and $S(X)$ convex because $S(T)$ is. Indeed, without specific capital phenomena, the convex shape of the age patterns of mobility $S(X)$ would be difficult to understand.

1.4 Tenure Effects on Mobility in Homogeneous and in Heterogeneous Groups

A simple heuristic model makes the notions intuitively clear:[7] The propensity to move at the individual level, or the separation rate in a homogeneous group, is a function:

$$s = f(T, X) \tag{1}$$

where s is the probability of separation in period t, T is length of current employment in the firm up to time t, and X is total work experience (working age). The slope of the age (experience) profile is:

$$\frac{ds}{dX} = \left(\frac{\partial s}{\partial T} \cdot \frac{dT}{dX}\right) + \frac{\partial s}{dX} \tag{2}$$

Here $\partial s/\partial T$ is the slope of the tenure profile, dT/dX is the growth of tenure with working age, and $\partial s/\partial X$ is the true age effect, if any. Note that $0 < dT/dX < 1$. Tenure would grow by the same amount as age only in the case of perfect immobility: it increases initially with age since it is necessarily short at early stages of experience. At later stages dT/dX approaches zero as T approaches the fixed value $[(1/s) - 1]$ in the case of no tenure dependence, that is, when $\partial s/\partial T = 0$. In the case of job specificity or tenure dependence, i.e., when $\partial s/\partial T < 0$, dT/dX remains positive at later ages as well.[8] A regression of T on X, not shown here, reveals a positive slope and slight concavity.

Decomposition (2) yields the following conclusions about the observed decline of mobility with age:

1. Even if there were no "age effects" ($\partial s/\partial X = 0$), mobility would decline with age, because of job specificities, that is, because mobility declines with tenure ($\partial s/\partial T < 0$). No decline would be observed if mobility were independent of tenure (see part 2, theorem 2).

2. Again abstracting from age effects, since $dT/dX < 1$, the slope of the experience profile is less than that of the tenure profile.

3. Convexity in the tenure profile would be reinforced or simply reflected in the age profile if dT/dX decreases over time, or is constant. Moreover, this could happen even if there is an age effect and even if the age effect were concave.

4. Decline of mobility with age is faster the stronger the decline of mobility with tenure, apart from the pure age effect.

Up to this point the analysis applies to a homogeneous group, defined by the identical $S(X,T)$ function for each of its members. Components of life cycle mobility can be observed directly in such groups by estimation of equation (1). Generally, it is not possible to define homogeneous groups empirically, so that estimation of (1) cannot be carried out directly. If in fact individual propensities to move are not reduced by tenure, yet differ among workers, the observed group tenure profile $S(T)$ will have a downward slope, and it is likely to be convex as well, because persons with high propensities to move are more likely to separate at early levels of tenure while those with low propensities are more likely to stay on a long time. The decline in the tenure profile consequently reflects the degree of heterogeneity when measured by the variance in propensities to move, while convexity would reflect a decline in that variance, as only stayers remained in the long-tenure classes.[9]

Let us now define a heterogeneous population in consonance with specific capital heterogeneity as a collection of homogeneous subgroups among which mobility rates differ at given levels of tenure, while tenure curves $S(T)$ decline in some or most of the subgroups. By the preceding argument, any degree of specific capital heterogeneity will lend a downward bias (steeper than average slope) to the observed group tenure curve. We should note that heterogeneity biases can exist without any true tenure effects, for reasons not involving specificity. But, if the tenure effect $(\partial s/\partial T)_i$ is zero in each subgroup i, the observed population experience profile $S(X)$ will be horizontal, since its slope is an average of slopes in the subgroups. Conversely, if $(\partial s/\partial T)_i < 0$ in each or some subgroups, the observed experience profile must slope down. Thus, in the absence of age effects, the age profile of mobility $S(X)$ provides a clear test of the presence or absence of tenure effects in the group, regardless of the group's degree of heterogeneity.

As an example, the popular "mover-stayer" model (see Blumen, Kogen, and McCarthy 1955; Singer and Spilerman 1976), which assumes heterogeneity and neglects tenure effects, must be rejected by the decline in the age-mobility profile, insofar as the latter is not exclusively due to pure age effects [$\partial s/\partial X<0$ in (1)].

Although the decline in life cycle mobility reflects the existence and strength of tenure effects, it yields no information on the extent of heterogeneity in the population. Assessment of heterogeneity is important, however, both in its own right and as a basis for recognition and correction of bias in the estimated tenure effects.

1.5 Empirical Mobility Functions

An open-ended empirical procedure for estimating tenure effects in the presence of heterogeneity is to enter a number of variables which are likely to capture heterogeneous behavior in a regression of tenure on mobility. The tenure slope estimate in the multiple regression is reduced compared with its value when it is the only right-hand variable. The reduction measures the extent of heterogeneity bias due to these variables. This procedure was applied to the NLS data and the results are shown in table 1.4. In addition to experience, the heterogeneity factors in the regressions were education, health, hours of work, family status variables, industry, and union membership. In terms of controbution to the adjusted coefficient of determination R^2, the last two factors were the most pronounced. The reduction in slope was about 20–30 percent for the young men, and larger (relative to the flatter slope) for the older men. This procedure is clearly incomplete for our purposes here, although of interest in the substantive studies of particular factors.

A scheme that is more general, in the sense that it does not require an enumeration of heterogeneity factors, derives from another definition of

Table 1.4 **Gross and Net Tenure-Separations Slope, NLS, 1967–71**

	Young Men				Older Men			
	1967–69		1969–71		1967–69		1969–61	
	Slope[d]	R^2	Slope	R^2	Slope	R^2	Slope	R^2
Gross Coefficient[a]	−.1420	.182	−.1100	.151	−.028	.12	−.027	.12
Net Coefficient[b]	−.0845	.200	−.0847	.165	−.016	.17	−.006	.20
Heterogeneity Factors[c]		.131		.110		.07		.11

[a]Linear coefficient in the regression of separation of tenure.
[b]Partial coefficient of tenure (linear term) in the multiple regression.
[c]Regression variables other than tenure.
[d]Tenure coefficients always highly significant ($t>4$).

a heterogeneous population: At a given level of tenure, members of a homogeneous group have equal probabilities of moving during the next period regardless of their past mobility, while in a heterogeneous group probabilities differ even at fixed current tenure. Since frequency of past mobility is an indicator of personal probability ("propensity to move"), which differs among workers, its (partial) correlation with mobility in the next period, given tenure, reveals the existence, and estimates the degree, of heterogeneity. And to the extent that the prior mobility variable captures and therefore standardizes for differential mobility levels, its inclusion corrects the bias in the estimated tenure slope.

Information on prior mobility was available in the NLS data for young men as the number of interfirm moves (NM) between 1966 and 1971. For the older men in NLS such information was not available, but we constructed a variable (PM) on the number of (survey to survey) periods between 1965 and 1973 during which at least one move took place.[10]

Table 1.5 presents, in successive steps, regressions for young men (panel A) in which separations (job changes) in the period 1971–73 are predicted by years of work experience (X, X^2) up to 1971; tenure (T, T^2) in 1971; and mobility prior to the current job (NM). The prior mobility variable was also interacted with experience (XNM). The same regressions (except that PM replaces NM) predict job change rates of NLS older men in 1973–75 (panel B), and of all MID men in 1975–76 (panel C).

Briefly, the findings are: Inclusion of tenure (row 2) shows it to be the variable which is responsible for the gross age decline in separations among young NLS men (row 1, panel A). Looking at rows 1 and 2 of panel B, we find that the older NLS men show neither gross nor net age (experience) effects. While net age effects are absent within the limited age ranges in the NLS data (young $\leq$ 29, old $\geq$ 50), they are reduced (going from row 1 to row 2 in panel C) but remain significant in the MID regressions which cover the whole age spectrum. The absence of gross age effects (row 1, panel B) in the older cohort reflects very small tenure effects (slopes) at this stage. This is consistent with a strong convexity of tenure (and age) profiles over the long run. The comparable tenure slopes are much steeper for the young because they are dominated in regressions by early tenure levels. Indeed, in a subsample of older men whose tenure does not exceed eight years (not shown here), the tenure slopes are quite as steep as those of young men. Thus, the differences between the young and the old need not be interpreted as a change in the mobility structure.

The inclusion of prior mobility variables shows the existence of heterogeneity in mobility behavior; the variable is a strong predictor of mobility in the next period given experience and tenure at the beginning of the period. Persons who moved more frequently prior to the current job are

Table 1.5 Mobility Functions $s = f(X, T, \text{NM}, \text{Ed})$

Constant	X	X^2	T	T^2	NM	$X \cdot$NM	Ed	R^2
			A. Job Change Rates of Young Men in NLS, 1971–73 ($n = 1{,}595$, $\bar{s} = .375$)					
.506	−.0424	.0020						.023
	(3.98)	(2.44)						
.612	−.0064	.0002	−.1071	.0057				.124
	(.61)	(.24)	(10.41)	(5.73)				
.547	−.0034	.0001	−.0963	.0051	.0060			.131
	(.32)	(.17)	(9.02)	(5.08)	(3.65)			
.547	−.0171	.0003	−.0822	.0048		.0035		.141
	(1.63)	(.36)	(7.38)	(4.72)		(5.56)		
.850	−.0253	.0004	−.0797	.0047		.0032	−.0211	.149
	(2.37)	(.48)	(7.17)	(4.64)		(5.04)	(3.89)	
Sample means	5.05	40.72	2.82	15.75	5.17	17.28	12.54	

Table 1.5 (continued)

Constant	X	X^2	T	T^2	PM	$X \cdot$PM	Ed	R^2
B. Job Change Rates of Older Men in NLs, 1973–75 ($n = 1{,}282$, $\bar{s} = .091$)								
.1645	−.0063	.0001						.0008
	(.16)	(.22)						
.5060	−.0165	.0002	−.0172	.0003				.065
	(.44)	(.5)	(7.67)	(5.78)				
.5553	−.0282	.0004	−.0045	.00009	.0921			.098
	(.57)	(.85)	(1.57)	(1.49)	(6.82)			
.5680	−.0275	.0004	−.0049	.0001		.0024		.098
	(.76)	(.79)	(1.72)	(1.64)		(6.77)		
.7551	−.0344	.0005	−.0052	.0001		.0024	−.0026	.098
	(.93)	(.93)	(1.82)	(1.75)	(.79)	(6.62)	(.79)	
Sample mean	38.09	1464.78	16.42	415.26	.5226	19.89	11.67	

Table 1.5 (continued)

Constant	X	X^2	T	T^2	$X \cdot \mathrm{SM}$	SM	Ed	R^2
				C. Job Change Rates of All Ages, MID, 1975–76 ($\bar{s}=.116$, $n=1{,}562$)				
.2285	−.0099	.0001						.027
	(4.08)	(2.61)						
.2402	−.0054	.00009	−.0149	.0004				.043
	(2.11)	(1.66)	(4.35)	(3.09)				
.2014	−.0063	.0001	−.0097	.0002		.2300		.058
	(2.46)	(1.95)	(2.71)	(1.91)		(5.01)		
.2329	−.0078	.0001	−.0107	.0003	.0112			.049
	(2.92)	(2.16)	(2.91)	(2.25)	(3.09)			
.3484	−.0062	.00008	−.0099	.0002		.2175	−.0105	.066
	(2.42)	(1.43)	(2.82)	(2.05)		(4.74)	(3.46)	
Sample mean	18.71	516.37	7.26	113.38	1.27	.095	12.64	

Note: X = years of work experience; T = years of tenure on the current job; Ed = years of schooling; NM = number of interfirm moves in the period 1966–71 of young men in NLS. Adjusted to length of period if experience started after 1966; PM = number of 2-year periods between 1965 and 1973 during which a job change occurred among older men in NLS; SM = number of annual periods between 1968 and 1975 during which a job change occurred among men in MID. Adjusted work experience started after 1968; w = logarithm of hourly wage; $\bar{w}$ = mean of w; $\bar{s}$ = mean rate of job change (over a 2-year period in NLS, annual in MID); n = sample size; R^2 = adjusted coefficient of determination; t = statistics in parentheses.

more likely to leave the job earlier than others. Prior mobility appears to be a stronger predictor at older than at younger ages. When converted into an elasticity, prior mobility is also several times larger in the older group. Evidently, repeated mobility at an advanced age represents persistent mobility, suggesting little stake in job tenure or lack of opportunity, while repeated mobility at young ages does not have the same connotation. We tried to test the proposition that prior mobility at older ages is a better index of heterogeneity *within* each of the panels: the experience–prior mobility interaction variable, shown in row 4 of each panel, with positive and significant. Incidentally, the existence of this interaction implies that age (experience) profiles of mobility are not only higher but also flatter for movers (PM large) than for stayers (PM small), as we theorized in section 1.3.

The introduction of the prior mobility variable was designed to separate "movers" from "stayers." If effective, such "standardization" should reduce the tenure slope in the regression. Tenure slopes are indeed reduced in row 3 and below in all three data panels. The reduction is small among the young and large among the old, as would be expected since PM is a stronger indicator of persistent mobility at older ages. The average reduction in the linear tenure term at mid-experience levels (MID) is about one-third. That is, heterogeneity biases the steepness of tenure-turnover profile upward by about fifty percent, on average. The education variable shown in the last rows of table 1.5 appears to predict some reductions in mobility at given levels of initial mobility, but has no additional predictive power among the old.

1.6 Net Age Effects on Mobility

Although they do not appear in the NLS regression of table 1.5, age effects (coefficients of experience $\partial s/\partial X$) on mobility are present in the MID regressions in panel C and were seen in the decline of mobility rates at fixed levels of tenure when the older cohort was compared with the younger (table 1.2). The economics of this downward shift in tenure curves may be found in the more traditional aspects of labor mobility: job change is a response to higher wage levels beckoning elsewhere as well as a search for specific investment opportunties.

For a given wage gain, the supply response would diminish with working age (at given levels of tenure), since the payoff period declines. Such effects, however, would not become pronounced until late in the working life, especially in view of positive and not negligible discounting. Emphasis on the effect of finite life (working age) on expected returns cannot produce a convex experience-turnover profile, nor can it rationalize the fact that the observed net age declines ($\partial s/\partial X$) occur relatively early in the working life (see rows 3 to 5, panel C). However, the gain from mobility may decline early in the life cycle not because of the declining payoff period but because of rising costs: in particular, costs of geographic mobility rise with family size and the presence of school-age children.

Age effects are, indeed, more important in migration than in local job mobility. The decline in migration with age is steeper than the decline in local job mobility: one-third of young compared to less than ten percent of older job changers migrate. But the greater costs of migration include also costs due to locational specificities which exist in addition to job specificity, so stronger "pure aging" is not the only reason for a sharper age decline in migration than in local job mobility: Tenure effects which reflect both job and location specificities are, indeed, sharper migrants.

Another set of age factors, unrelated to location, may operate in the early years of work experience: the range of quality of jobs and of the job match cannot be ascertained by mere search, and some knowledge must be acquired by actual experimentation. Also, job training and opportunities for investment in general human capital may present themselves sequentially in different firms. Beyond the first decade of working life, we may expect that human capital investors who eventually find a reasonably compatible work place develop a strong attachment to the job.

1.7 Tenure and Mobility Effects in the Wage Function

Specific capital investments imply tenure effects on wages which cause the tenure effects in mobility. Wage heterogeneity due to differential specificities similarly produces some of the heterogeneity in mobility. Consequently, we should observe tenure effects in addition to general work experience effects in wage functions. Moreover, these effects may be exaggerated in empirical estimates in view of interpersonal diversity in specific investment behavior.

Information on job mobility can and should be built into the standard earnings function. The inclusion of the tenure variable should capture returns to specific (nontransferable) capital accumulation, permitting the experience term to measure returns to general (transferable) capital accumulation. Information on prior mobility should also be used in correcting for heterogeneity bias. The explanatory power of the enriched wage function ought to be enhanced.

The coefficients of experience (X) in the standard wage function, which includes only education in addition to the experience terms, reflect a gross effect dw/dX which is a mixture of returns to general and specific capital:

(2a) $$\frac{dw}{dX} = \left(\frac{\partial w}{\partial t} \cdot \frac{dT}{dX}\right) + \frac{\partial w}{\partial X}$$

The standard wage function has an upward-sloping and concave experience profile (the concavity is more pronounced when w = log wage) in cross-sections and in longitudinal data.[11] Its slope has been derived in human capital theory and in econometric studies. In view of (2a), it is incorrect to interpret the coefficients of experience dw/dX as measures of returns to general human capital stocks. Such returns are measured by $\partial w/\partial X$, that is, by coefficients of experience *when tenure is included in the wage function*. Clearly dw/dX overstates $\partial w/\partial X$ if specific capital is of any importance. The experience coefficients in the earnings function which omits tenure is an upward-biased measure of returns to general human capital accumulated on the job.

It is interesting to note, according to (2a), that even if no general capital were accumulated in the work career, wages would still rise over the life cycle, and, as a group average, the wage profile would tend to be concave so long as the tenure wage profile is concave and dT/dX does not increase over the life cycle.

Wage functions with tenure variables $w(X,T)$ can be estimated in homogeneous groups without bias (homogeneity defined as the same tenure wage profile), but no such groups can be defined a priori: in the presence of heterogeneity, the tenure coefficient is likely to be exaggerated, as in the case of mobility, and corrections need to be devised. More precisely, the bias arises because greater specificity produces larger discrepancies between the marginal product in the firm and the opportunity wage $\Delta = \text{VMP} - W_g = W_s + W_e$, where W_s is the specific return to the worker, and W_e to the employer, and Δ as well as W_s differ among workers and firms. Δ affects the length of tenure. It is plausible for W_s and W_e to be positively correlated, because a fruitful match has to be recognized as such by both parties. Therefore W_s is a good index of Δ, and the tenure-wage coefficient which attempts to measure W_s is likely to be correlated with expected tenure (see discussion of theorem 3 below). Heterogeneity in W_s is thus likely to produce an upward bias in the estimates of tenure effects of wages, that is, of returns to specific worker investments. An additional source of bias could result from a positive correlation between general and specific investments; here steeper tenure-wage curves would start at higher levels. To the extent that general returns to capital (W_g) are not fully measured (standardized) by regression variables, the bias will arise.

Of course, positive tenure coefficients need not reflect wage growth in the firm. Higher wage levels (not growing with tenure) for the same labor in some firms also create incentives to stay there longer. Although transitional, this relation is likely to be widespread in a dynamic economy as an equilibrating phenomenon. Such supply adjustments to shifting demands are most likely to involve younger people whose mobility is less costly especially in terms of specific capital losses. Note that in this case prior mobility is not a good index of wage heterogeneity. Similar and more long-lasting effects can be created by above-equilibrium union wages and nepotism.

Can information on prior mobility be used in the wage function as an index of relevant heterogeneity, that is, of individual differences in W_s and consequently in the wage-tenure coefficient? The answer is less clear in the wage equation than in the mobility equation. Positive serial correlation in mobility makes the link between length of tenure and mobility almost definitional whatever the source of heterogeneity in mobility. The problem for the wage equation is that bias in the tenure coefficient is only in part due to heterogeneity in specific capital, and the latter is responsible for only a part of the heterogeneity in mobility. Thus prior mobility may be a weak instrument for elimination of heterogeneity bias. Its role in wage formation is nevertheless of interest to our study.

Table 1.6 presents wage functions of the younger and older NLS men, and of all men in MID. The independent variables are the same as in the mobility functions in table 1.5; the dependent variable is the logarithmic wage.[12] Row 1 is the "standard" wage function where the independent variables are education and experience. In the next row the tenure terms are added. In the third row we add the prior mobility variable, and in the last row we observe its interaction with experience.

In the young men's panel (A), the introduction of tenure reduces the experience coefficients. At this stage (on average, five years of experience), wages grow 6.6 percent per year of experience (row 1); 4.3 percent as returns to general postschool human capital accumulation (row 2); and the remaining 2.3 percent owing to specific capital accumulation. The tenure coefficients are large and significant. Prior mobility is not related to current wages and does not affect the tenure coefficients. The coefficient of the interaction variable (XNM) is positive but quite small, and its introduction raises the tenure coefficient slightly. Apparently differences in early mobility of young men are not indicative of future differences in specific capital investments, nor do they capture differences in wage levels which are positively related to the length of current tenure.

In the wage function for NLS older men (panel B), the experience profile is a plateau, but tenure slopes are positive (and concave) though much flatter than for young men.[13] Still, the observed tenure effect is biased upward. Introduction of prior mobility cuts the linear term in half and reduces its significance. We may conclude that repeated mobility at an advanced stage of the life cycle is an indicator of persistent turnover, denoting little investment in specific capital. The mobility variable has a negative effect, showing that frequent movers have lower wages than stayers, given education, experience, and current tenure. This is in contrast to the young whose past mobility did not imply a downward selection. We may conclude that intensive early mobility—about a half of

Table 1.6 Wage Functions

Constant	Ed	X	X^2	T	T^2	NM	$X \cdot \mathrm{NM}$	R^2
			A. Wage Functions of Young Men, NLS, 1971 ($\bar{w}_{71} = 1.28$, $n = 1{,}442$)					
−.0311	.0847	.0658	−.0022					.194
	(17.93)	(7.36)	(3.23)					
.0021	.0079	.0433	−.0011	.0702	−.0052			.229
	(16.50)	(4.70)	(1.52)	(7.27)	(5.24)			
.0026	.0779	.0432	−.0011	.0702	−.0052	−.00003		.229
	(16.47)	(4.69)	(1.53)	(6.99)	(5.17)	(.03)		
−.0343	.0790	.0401	−.0010	.0780	−.0055		.0011	.231
	(16.64)	(4.29)	(1.46)	(7.49)	(5.49)		(1.98)	
Sample mean	12.52	4.97	39.94	2.78	15.06	5.29	17.48	

Table 1.6 (continued)

Constant	Ed	X	X^2	T	T^2	PM	$X \cdot$PM	R^2
B. Wage Functions of Older Men, NLS, 1973 ($\bar{w}_{73} = 1.59$, $n = 982$)								
.6733	.0696	.0113	−.0002					.175
	(10.37)	(.14)	(.22)					
.5359	.0683	.0130	−.0002	.0136	−.0002			.199
	(10.19)	(.17)	(.24)	(2.99)	(1.58)			
.6105	.0666	.0157	−.0003	.0067	−.00006	−.0482		.202
	(9.88)	(.2)	(.3)	(1.09)	(.4)	(1.8)		
.5996	.0668	.0146	−.0003	.0080	−.00009		−.0011	.201
	(9.90)	(.2)	(.28)	(1.32)	(.57)		(1.52)	
Sample mean	11.58	38.05	1462.28	15.23	367.19	.573	21.83	

Table 1.6 (continued)

Constant	Ed	X	X^2	T	T^2	SM	$X \cdot$SM	R^2
			C. Wage Functions of All Ages, MID, 1975–76 ($\bar{w}_{75} = 1.69$, $n = 1{,}560$)					
.2437	.0741	.0467	−.0007					.263
	(17.45)	(14.07)	(9.56)					
.2351	.0732	.0372	−.0006	.0305	−.0007			.295
	(17.57)	(10.70)	(8.08)	(6.59)	(4.25)			
.2791	.0722	.0378	−.0006	.0264	−.0006	−.1842		.298
	(17.33)	(10.91)	(8.32)	(5.44)	(3.49)	(2.94)		
.2541	.0725	.0404	−.0007	.0249	−.0006		−.0150	.299
	(17.43)	(11.15)	(8.55)	(5.01)	(3.39)		(3.04)	
Sample mean	12.63	18.72	516.96	7.27	113.53	.094	1.26	

Note: Regression variables same as in table 1.5.

the first decade in our NLS data—is not necessarily an inverse index of longer-run tendencies to acquire specific capital or an index of inability to acquire a good job match. It may even be a positive index of efficiency in making wage gains by moving across firms or of greater intensity of search for an optional career.

Taken together the findings in both NLS panels (A and B) show that tenure effects on wages are significant, reflecting the firm-specific component of wage progress on the job. This component accounts for about one-third of wage growth per year in the early part of working life. At young ages, past mobility does not clearly distinguish tendencies toward firm-specific human capital behavior. It does so, however, at older ages. At that stage lesser specific investments also result in lower wages, apparently as a result of slower growth over the past decades.[14]

The wage function in the MID panel (C), which covers all working ages, indicates that an average (and in mid-career) the firm-specific component accounts for 20–25 percent of wage growth per year (difference between the X-coefficients in rows 1 and 2). Prior mobility is negatively related to wages. The interaction term is also negative suggesting that men who continue to be frequent movers in the third decade of their working lives have both lower wages and flatter experience profiles of wages. The inclusion of prior mobility variables reduces the tenure slope by close to 20 percent. Thus, heterogeneity biases the tenure-wage slope coefficient upward by about 25 percent, half as much as it biased the tenure-mobility slope (panel C of table 1.5).

1.8 Tenure, Experience, and Mobility: Additional Remarks

We used the generalized term "specific human capital behavior" to cover both the informational aspect of job matching and the theory of specific human capital investment. The former is a necessary condition for the latter, and both are required for completeness.

There is another and popular view that the reality of tenure effects on mobility and on wages is largely institutional. The effects we analyzed are seen as "seniority rights" which include job security, pension rights, vacations, and seniority-based pay and promotion advantages. But the distinction is superficial. The "rights" themselves may well derive from human capital specificities in the presence or absence of formal, especially union, regulations. Indeed, recent research shows that tenure turnover profiles decline and tenure wage profiles grow as much and more (!) in the nonunion as in the union sector.[15]

In the past, experience coefficients dw/dX were sometimes crudely interpreted as returns to on-the-job general investments. In the wage function which includes tenure, the experience coefficients $\partial w/\partial X$ effectively segregate returns to general human capital investments, but they contain both returns to on-the-job general investment and across-jobs wage gains due to mobility (but not to tenure). These across-jobs wage changes are positive in purposive quits especially in migration, but are often negative when job change results from layoff, "exogenous" quit, and job dissatisfaction (Bartel and Borjas, chapter 2, below).

Over the life cycle, the effects of mobility on wages become increasingly less favorable at least as measured by money wages. Quits, migration, and occupational upgrading predominate in mobility of the young, but they become relatively unimportant at older ages. Since the frequency of job change declines over the life cycle for reasons already spelled out, the mobility component of wage growth declines over the life cycle as a result of declines both in the size and in the frequency of wage gains across firms. This is another aspect of the well-known concavity of the experience profile of wages.

Some models elevate the across-firm wage change to a single explanation of the typical concave life cycle wage profile: the worker is envisaged as moving up a fixed offer-wage distribution over his lifetime. Successful on-the-job search results in across-jobs wage growth. With a fixed offer-wage distribution, turnover declines with labor market experience. Thus older workers have a higher wage and a smaller probability of future separation.[16]

Although they produce concavity in the wage profiles, such models are quite inadequate as major explanations of magnitudes of wage growth over the life cycle (dw/dX). In a calculation based on the Coleman-Rossi data, Bartel (1975) shows that no more than 25 percent of personal wage growth can be attributed to across-firms wage changes during the first fifteen years of work experience, when mobility is most pronounced. The models, therefore, neglect the bulk of the phenomenon they are trying to explain. Moreover, concavity in the wage profile does not require job mobility, in human capital theory, or in fact: Borjas (1976) found the typically pronounced concavity in wage profiles of NLS workers who spent all of their working life in a single firm.

Although crude, our estimates of tenure and experience wage effects suggest that about 25 percent of life cycle wage growth, which abstracts from economy-wide changes, is due to specific capital investment. Taken together, the estimates provide a complete though very rough decomposition of lifetime wage growth: about 25 percent of it is due to interfirm mobility; another 20–25 percent to firm-specific experience; and over 50 percent to general (transferable) experience.

Perhaps the best way to summarize the life cycle relation between mobility and wages is to recognize that initial (first decade ?) job search has two major purposes: to gain experience, wages, and skills by moving across firms; and to find, sooner or later, a suitable job in which one can settle and grow for a long time. The life cycle decline in mobility is, in part, evidence of successful initial mobility, an interpretation which is corroborated by corresponding life cycle growth in wages.

In both older and younger age groups, stayers and successful searchers grow faster than unsuccessful searchers or "noninvesting" movers. However, a comparison of movers and stayers puts successful searchers in the category of movers among the young, but in the category of stayers (they moved when younger) among the old. As a result, comparisons of stayers and movers show that young movers do as well as or better than stayers, but ultimate stayers show superior wage growth and higher wage levels in the later decades.

We note, in conclusion, that "tenure and heterogeneity effects" are not restricted to job mobility. Whenever specific capital matters, comparable dualities between returns ("wages") and turnover may be expected. Some evidence on this generalization is available in analyses of location decisions (Da Vanzo 1976), and of marital instability (Becker, Landes, Michael 1977).

In the second part of our paper we shall treat labor mobility and wage growth over the life cycle as related stochastic processes. We first focus on the evolution of these processes for a given worker, interpreting our formulation within the context of existing theories of turnover and of wage growth and listing some of the implications of these theories. Next we take up the question of unmeasured heterogeneity in the population, and the problem of sample selection over time, known as the "mover-stayer" problem. A simple result is proved (theorem 3) which relates the behavior of a heterogeneous group to the behavior of the individual members of that group. In interpreting the result, we pay particular attention to the on-the-job-training hypothesis. Lastly, we describe a method to estimate various parametrizations of the separation and wage equations.

1.9 Evolution of Stochastic Processes

Definitions:

z = parameter indexing a particular worker

X = the worker's labor market experience

t = the worker's job tenure

X_0 = market experience at which the worker started on his current job, so that, at each moment in time, $X_0 + t = X$

Let

$F(t|X_0, z) \equiv$ probability that for a worker of type z, job tenure does not exceed t on a job which started at X_0

Let $f(t|X_0, z) = \partial F/\partial t$ be the associated density, and let $\hat{s}(t, X_0, x)$ be the "hazard function" of this distribution, defined by $\hat{s} = f/(1-F)$. Then $\hat{s}$ is the conditional density of job separation at tenure t, given that a tenure level t has been attained. The definitions of $\hat{s}$ and f imply that F may be written as

$$(3) \qquad F(t|X_0, z) = 1 - \exp\left[-\int_0^t \hat{s}(y, X_0, z)\, dy\right]$$

There may be a positive probability that a job episode never terminates, in which case

$$\lim_{t\to\infty} F(t|X_0, z) < 1, \text{ i.e., } \int_0^\infty \hat{s}(y, X_0, z)\, dy < \infty$$

It should be noted that F determines $\hat{s}$ uniquely and vice versa. Since $f \geq 0$, $\hat{s} \geq 0$ so that F is nondecreasing.

One purpose of this section is to draw some parallels between wage rates and separation probabilities. Let $\hat{w}(t, X_0, z)$ be the mathematical expectation of the wage that worker z, with experience $X_0 + t$, and tenure t, will receive. It may be noted that both $\hat{w}$ and $\hat{s}$ are mathematical expectations conditional upon t, X_0, and z.

Hereafter it is assumed that when a particular job episode terminates, it is immediately followed by a new job episode. That is, there are assumed to be no unemployment spells or spells of market nonparticipation. Given this assumption, consider now the special case in which $\partial\hat{s}/\partial X_0 = \partial F/\partial X_0 = 0$. Then each job episode is identically distributed. If, in addition, the job episodes are also assumed to be independently as well as identically distributed, then turnover becomes a pure renewal process (see Feller 1966, chapter 11). In what follows, we study processes that are more general than the renewal process.

Let $a(X, z)$ be the probability density that worker z will experience a job separation at the point in time at which his market experience is equal to X. (For the special case where turnover is a renewal process, $a(X, z)$ is known as the renewal density.) Also let $h(t|X, z)$ be the probability density that a worker with market experience x will have current job tenure equal to t. Note that for this statement to be true, the worker must have experienced a job separation at exactly $X = t$ level of market experience, and no subsequent separations. Therefore,

$$(4) \qquad h(t|X, z) = \begin{cases} 1 - F(X|0, z) & \text{if } t = X \\ a(X-t, z)\,[1 - F(t|X-t, z)] \\ \text{if } 0 \leq t < X \end{cases}$$

Then

(5) $$a(X, z) = \hat{s}(X, 0, z)\,[1 - F(X|0, z)] + \int_0^X \hat{s}(t, X-t, z)\, h(t|X, z)dt$$
$$= \hat{s}(X, 0, z)\,[1 - F(X|0, z)] + \int_0^X \hat{s}(t, X-t, z)\, a(X-t, z) \times [1 - F(t|X-t, z)]\, dt$$

Define $y(X, z)$ as the mathematical expectation of worker z's wage conditioned only on his market experience. Then

(6) $$y(X, z) = \hat{w}(X, 0, z)\,[1 - F(X|0, z)] + \int_0^X \hat{w}(t, X-t, z) \times a(X-t, z)\,[1 - F(t|X-t, z)]\, dt$$

Now define two new functions

$$s(t, X, z) = \hat{s}(t, X-t, z) \rightarrow s_X = \hat{s}_{X_0} \text{ and } s_t = \hat{s}_t - \hat{s}_{X_0}$$

and

$$w(t, X, z) = \hat{w}(t, X-t, z) \rightarrow w_X = \hat{w}_{X_0} \text{ and } w_t = \hat{w}_t - \hat{w}_{X_0}$$

(where subscripts denote partial derivatives).

Making the substitution into (5) and (6).

(7) $$a(X, z) = s(X, X, z)\,[1 - F(X|0, z)] + \int_0^X s(t, X, z) \times a(X-t, z)\,[1 - F(t|X-t, z)]\, dt$$

and

(8) $$y(X, z) = w(X, X, z)\,[1 - F(X|0, z)] + \int_0^X w(t, X, z) \times a(X-t, z)\,[1 - F(t|X-t, z)]\, dt$$

There are several reasons for choosing this approach. First, the deterministic earnings function approach (see, for example, Mincer 1974) is a special case of the above formulation. In the earnings function approach, turnover is not considered explicitly, so that job tenure is not included in the regressions. Such regression equations are here interpreted as expectations conditional on X and on the measured component of z, and the expressions that characterize such conditional expectations are provided in equations 8 and 11. A set of sufficient conditions under which the conditional expectation of the wage is a monotonically increasing function of experience is provided below.

Second, the job-matching theory of turnover as developed in Jovanovic (1978b) is fully consistent with the above formulation when the latter is restricted to $s_X = w_X = 0$ for all (X, t, z), so that the turnover process is predicted by the theory to be one of pure renewal. The key assumptions in generating such a result are a constant rate of discount and an infinite horizon, and an assumption about the job search process that makes the latter "pure experience search," in the terminology of Nelson (1970). The model implies $w_t > 0$ for all t, and $s_t < 0$ for large enough t and perhaps for all t.

Two other search models that explicitly look at the implications for life cycle mobility are those of Burdett (1973) and of Jovanovic (1978a). Both models involve the worker's moving up a fixed wage-offer distribution over his lifetime, with search of the "pure search" kind (Nelson's terminology again). Both models imply that in the absence of on-the-job training, $s_X < 0$ and $w_X > 0$, while $s_t = w_t = 0$ for given X. When firm-specific human capital investment is introduced (Jovanovic 1978a), the latter prediction changes to $s_t < 0$ and $w_t > 0$ for all workers except the very old, for whom $s_t > 0$ and $w_t < 0$ as they allow their human capital to depreciate toward the end of their lifetime.

General on-the-job training raises wages, implying $w_X > 0$ given a monotonic increase in general training over time. Since general training raises the worker's productivity in many firms, it is not expected to affect turnover, and therefore $s_X = 0$ is consistent with $w_X > 0$ and with the presence of general training. A somewhat different argument asserts that the presence of general training is the cause of turnover at younger ages, because it may be optimal for the training to be acquired in several different firms and such turnover is planned in advance. To the extent that such turnover is significant (and little evidence is available to support its significance), it may produce nonmonotonic effects on $s(t, X, z)$ for young workers as t and X increase.

Next, define

$$H(t, X, z) \equiv \int_0^t h(\tau \mid X, z)\, d\tau \geq 0 \tag{9}$$

so that $H(0, X, z) = 0$ and $H(X, X, z) = F(X \mid 0, z)$. Then, integrating by parts in (7) and (8), one obtains

$$a(X, z) = s(X, X, z) - \int_0^X s_t\,(t, X, z)\, H(t, X, z)\, dt \tag{10}$$

and

$$y(X, z) = w(X, X, z) - \int_0^X w_t\,(t, X, z)\, H(t, X, z)\, dt \tag{11}$$

Equations 10 and 11 should be compared for their identical structure.

The following results follow directly from equations 10 and 11, and are presented in theorem 1:

Theorem 1: Let $s_t < 0$ and $w_t > 0$ for all values of the arguments. Then

$$a(0, z) = s(0, 0, z) \text{ and } y(0, z) = w(0, 0, z)$$
$$a_X(0, z) = s_X(0, 0, z) + s_t(0, 0, z)$$
$$y_X(0, z) = w_X(0, 0, z) + w_t(0, 0, z)$$
$$a(X, z) > s(X, X, z)$$
$$y(X, z) < w(X, X, z) \text{ for any } X > 0$$

Proof: The assertions follow from the observation that

$$H(t, X, z) > 0 \text{ for any } t > 0 \text{ and from } H(0, 0, z) = 0$$

Next, consider the special case in which $s_X = 0$, as would be true if turnover was a pure renewal process. We then have the following theorem:

Theorem 2: Let $s(t, X, z)$ be independent of X. Then if $s_t < 0$ for all (X, t, z) then $a_X < 0$ for all (X, z).

Proof: Differentiating with respect to X in equation 10 and applying the assumption that $s_X = 0$ yields

$$a_X(X, z) = s_t(X, X, z)\,[1 - F(X \mid 0, z)] - \int_0^X s_t(t, X, z)\, H_X(t, X, z)\, dt$$

and since, by assumption, $s_t < 0$, it is sufficient to prove that $H_X < 0$ for all (t, X, z). But since s does not depend on X, neither does F. Therefore, $H_X(t, X, z) = \int_0^t a_X(X-y, z)\,[1 - F(y \mid X - y, z)]\, dy$. Therefore, $H_X(t, X, z) < 0$ if $a_X(X-y, z) < 0$ for all $y \varepsilon (0, X)$. But then, $a_X(\mathrm{X}, z) < 0$ for all X if there exists an $\varepsilon > 0$, no matter how small, such that $a_X(X, z) < 0$ for $X \varepsilon (0, \varepsilon)$. But such an ε must exist if $a_X(X, z)$ is continuous at zero, because by theorem 1, $a_X(0, z) = s_t(0, 0, z) + s_X(0, 0, z) < 0$. (The last inequality follows by the assumptions of the theorem.) This completes the proof of the theorem.

Intuitively, one expects that theorem 2 should extend to the case where $s_t < 0$ *and* $s_X < 0$, that is, to the case where the separation propensity declines with both tenure and market experience, and that the decline in the separation propensity considered as a function of market experience alone $[a(X, z)]$ should, if anything, be reinforced. While this conjecture may be true, an attempt at proving it along the lines of the proof of theorem 2 fails, because H_X cannot be signed.

Theorem 2 asserts that the renewal density declines monotonically if the interevent waiting time distribution possesses a monotonically decreasing hazard rate. Note that a parallel result for monotonically increasing hazard rate distribution does not hold. That is, $s_t > 0$ everywhere does not imply that $a_X > 0$ for all X, and an attempt at a proof along the lines of the proof of theorem 2 is quickly seen to fail (a counterexample is given in Brown 1940).

It should be noted that $y(X, z)$ is the wage experience profile for a homogeneous group of type z. By differentiating in equation 8, conditions may be derived under which the wage experience profile will be increasing and concave ($y_X > 0$, $y_{XX} < 0$) for each homogeneous group. These conditions involve restrictions on both $w(t, X, z)$ and $s(t, X, z)$. For example, one set of *sufficient* conditions for a monotonically increasing wage experience profile ($y_X > 0$) is: $s_X = 0$, $s_t < 0$, $w_t > 0$, $w_X > 0$ and $w_{tX} > 0$, as may be verified by direct differentiation in (8) (and by applying the result of theorem 2 which states that $s_t < 0$ and $s_X = 0$ jointly imply $a_X < 0$ everywhere). Assuming that $s_X = 0$ is theoretically consistent with assuming that $w_X > 0$, that is, the accumulation of purely general on-the-job training raises the worker's productivity in all firms by an equal amount, and it raises his wage (hence $w_X > 0$), but it is not expected to have any effect on his separation propensity (hence $s_X = 0$). Sufficient conditions for concavity of the wage experience profile may also be derived but turn out to be much more complicated.

Let $T(X, z)$ be the mathematical expectation of current tenure. The latter is distributed according to (4), and, therefore,

$$T(X, z) = X[1 - F(X|0, z)] + \int_0^X th(t|X, z)dt \tag{12}$$
$$= X - \int_0^X H(t, X, z)dt$$

The second equality follows after integration by parts. Since $H > 0$, $T(X, z)$ cannot exceed X. Differentiating with respect to X,

$$T_X(X, z) = 1 - F(X|0, z) - \int_0^X H_X(t, X, z)dt \tag{13}$$

so that $T_X(0, z) = 1$. If turnover is a pure renewal process, with $s_t < 0$ everywhere, then, from theorem 2, $H_X > 0$, and $T_X > 0$ for all X. In other words, the average current job tenure will always be increasing for a cohort of workers as their market experience increases under these assumptions.

Let $t_1, t_2, \ldots$ be the sequence of completed job durations. Then the distribution function for the length of the nth job episode is $F(t_n | \sum_{j=1}^{n-1} t_j, z)$. The t_j are therefore neither independent nor identically distributed random variables so long as the aging effect (s_X) is not zero. If there is no aging effect, then each job episode has the same distribution, and if, in addition, one assumes that the job episode durations are independently distributed, then turnover is a pure renewal process. Let $n(X, z)$ be the number of job changes (the number of completed episodes or the number of "prior moves") on the experience interval $(0, X)$. Then

$$E\,n(X, z) = \int_0^X a(t, z)\,dt \tag{14}$$

To see this, note that $a(X, z)\,\Delta X + 0\,[(\Delta X)^2]$ is the probability that exactly one job change will occur in the interval $(X, X + \Delta X)$. The expression in equation 14 is the sum of these probabilities over such disjoint intervals as Δt tends to zero. Dividing both sides of (14) through by X, taking the limit as X tends to infinity, and applying L'Hôpital's rule, one obtains

$$\lim_{X\to\infty} a(X, z) = \lim_{X\to\infty} \frac{E\,n(X, z)}{X}$$

Of course, $(\partial/\partial X\,[E\,n(X, z)] = a(X, z)$, and $(\partial^2/\partial X^2)\,[E\,n(X, z)] = a_X(X, z)$. Therefore, a monotonically decreasing experience profile of turnover implies concavity of the expected number of moves treated as a function of experience.

1.9.1 Example: A Pure Renewal Process

Let F be the mixed exponential distribution:

$$F(t \mid X, z) = 1 - \frac{1}{2}\,[e^{-zt} + e^{-(z+b)t}]$$

so that no aging effects exist. Then

$$f(t \mid X, z) = \frac{1}{2}\,[ze^{-zt} + (z+b)e^{-(z+b)t}]$$

and

$$s(t, X, z) = z + \frac{b}{1 + e^{bt}}$$

$$s_t(t, X, z) = -\frac{b^2 e^{bt}}{(1 + e^{bt})^2}$$

The slope of the separation function is in this case independent of z. If $b = 0$, then $s_t = 0$, and so b is a parameter denoting the extent of duration dependence. Then let

$$\hat{T}(X, z) = \frac{1}{2}\left(\frac{1}{z} + \frac{1}{z+b}\right) < \frac{1}{z}$$

The renewal equation (5) has for this case explicitly been solved by Bartholomew (1972) to yield

$$a(X, z) = [\hat{T}(X, z)]^{-1} + (z + \tfrac{b}{2} - [\hat{T}(X, z)]^{-1})e^{-(z+\frac{b}{2})X}$$
$$= \frac{2(z+b)z}{2z+b} - \frac{b^2}{2(2z+b)}e^{-(z+\frac{b}{2})X}$$

so that

$$a_X(X, z) = -\frac{b^2}{4}e^{-(z+\frac{b}{2})X}$$

If there is no duration dependence with tenure ($b=0$), then separations also do not decline when considered as a function of age. Notice also that

$$a_{Xz}(X, z) = -X\, a_X(X, z) > 0$$

so that although the $s(t, X, z)$ curves are parallel in z, that is, ($s_{tz} = 0$), the age curves are not—they diverge. The relationship between the tenure and age curves is depicted in figure 1.1.

The divergence of age profiles therefore can be explained not only by divergences in levels of specific human capital (as argued in part 1) but also as a purely statistical phenomenon.

In this case, convexity of $s(t, X, z)$ implies convexity of $a(X, z)$ in X. As b (the duration-dependence parameter) tends to zero, both $a(z, z)$ and $s(t, X, z)$ tend to a constant, z.

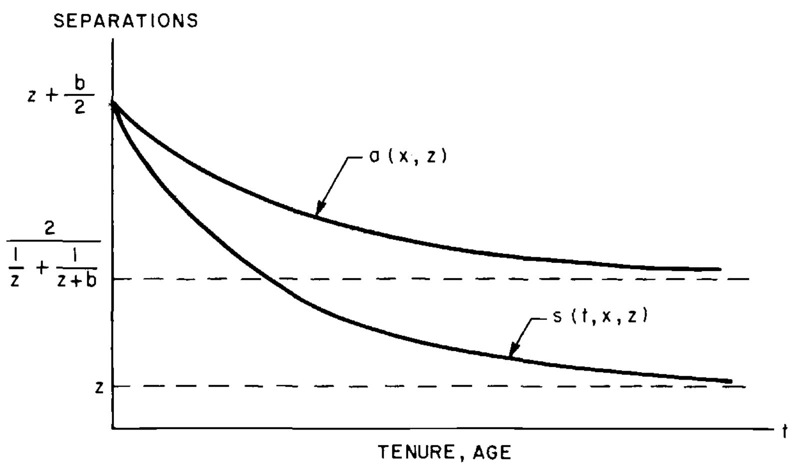

Figure 1.1 Separations by age and by tenure.

1.10 Group Relationships

The individual-specific parameter z is by assumption unobservable. It is an "incidental parameter." The population distribution of z is assumed to be $p(z)$ with mean μ and variance σ. The nondegeneracy of this distribution gives rise to the dynamic version of the sample selection problem studied below.

Upon entering the labor market, a worker is assumed to be a random drawing from the distribution $p(z)$. On the other hand, a worker who is starting out on a job *other* than his first, at a market experience level $X>0$, is *not* representative of the entire population in the sense that he cannot be considered a random drawing from the distribution $p(z)$.

Although $p(z)$ is interpreted to be an unmeasured personal characteristic, it is likely to be correlated with measured personal characteristics such as years of schooling, race, sex, and so on. The unmeaured variability in separation propensities decreases as the number of personal characteristics held constant increases, which is another way of saying that part of the variance of z is "explained" by the variance of a set of personal characteristics. (Note that this is quite different from the statement that the variance of the conditional distribution is never greater than the variance of the marginal distribution. The latter statement is false.)

The objective now is to characterize the distribution of z conditional upon X and t. Let $p(z \mid X)$ be the distribution of z which applies to workers who are just *starting* a new job at experience level X. Applying Bayes's theorem,

$$(15) \qquad p(z \mid X) = \begin{cases} \dfrac{a(X,z)\,p(z)}{\int a(X,z)\,p(z)dz} & X>0 \\[2ex] p(z) & X=0 \end{cases}$$

It follows that $p(z \mid X)$ is a continuous function of X except at $X=0$. [The continuity of $p(z \mid X)$ at $X>0$ follows if $a(X, z)$ is continuous.]

Now let $\hat{p}(z \mid X_0, t)$ be the probability density that the worker is of type z, given job tenure t and experience X_0+t. At the time he joined his current firm, the worker was drawn from the population $p(z \mid X_0)$. Applying Bayes's theorem again,

$$(16) \qquad \hat{p}(z \mid X_0, t) = \frac{[1-F(t \mid X_0, z)]p(z \mid X_0)}{\int [1-F(t \mid X_0, z)]\,p(z \mid X_0)dz}$$

Equation 16 follows because $1-F(t \mid X_0, z)$ is just the probability that the worker of type z will attain tenure t in a job which he started at experience level X_0.

Writing $\hat{s}(t \mid X_0, z)$ instead of $\hat{s}(t, X_0, z)$ (thereby emphasizing the nature of the conditioning), let

$$\hat{s}(t, X_0) \equiv \int \hat{s}(t \mid X_0, z)\, \hat{p}(z \mid X_0, t)\, dz \tag{17}$$

be the probability that the worker will experience a separation at tenure t given X_0 and t. We then have

Theorem 3

$$\hat{s}_t(t, X_0) = \int \hat{s}_t(t \mid X_0, z)\, \hat{p}(z \mid X_0, t) dz - \sigma^2(\hat{s} \mid X_0, t)$$

(18) and

$$\hat{w}_t(t, X_0) = \int \hat{w}_t(t \mid X_0, z) \hat{p}(z \mid X_0, t) dz$$
$$- \operatorname{Cov}(\hat{s}, \hat{w} \mid X_0, t)$$

where $\hat{w}(X_0, t)$ is the mathematical expectation of the wage given X_0 and t, where $\sigma^2(\hat{s} \mid X_0, t)$ is the variance of $\hat{s}(t \mid X_0, z)$ in the population $\hat{p}(z \mid X_0, t)$, and where $\operatorname{Cov}(\hat{s}, \hat{w} \mid X_0, t)$ is the covariance of $\hat{s}(t \mid X_0, z)$ and $\hat{w}(t \mid X_0, z)$ in the population $\hat{p}(z \mid X_0, t)$. Before proving this theorem, we elaborate on the meaning of its assertions. When t is increased by one unit while X_0 is held constant, tenure and experience both increase by one unit. Therefore, s_t is the sum of the tenure effect and of the pure age effect, and similarly for w_t. In words, the first assertion of the theorem may be expressed as: The slope of the average separation rate is equal to the average of the individual slopes, minus the variance of the separation rates in the *current* population $\hat{p}(z \mid X_0, t)$. This result is an extension of an earlier result of Barlow, Marshall, and Proschan (1963). Their result states that mixtures of decreasing hazard rate distributions also possess decreasing hazard rates.

Suppose that there are no true age or tenure effects on separations, so that $\hat{s}_t(t \mid X_0, z) = 0$ everywhere. Then, $\hat{s}_t(t, X_0) = -\sigma^2(\hat{s} \mid X_0, t)$, so that the group separation rate declines although the individual separation rates are constant. Furthermore, $\hat{s}(t, X_0)$ would in this special case be convex in t (which would be consistent with the evidence presented in table 1.2), if $\sigma^2(\hat{s} \mid X_0, t)$ declines monotonically with t. For a wide class of distributions $p(z \mid X_0)$, one would expect such a monotonic decline because the selection out of the sample as t increases is such that "movers" are (on average) selected out leaving behind only "stayers," so that the sample of those left behind becomes increasingly more homogeneous. But σ^2 need not decline monotonically, as is demonstrated by the following example. Assume that at any X_0, $p(z \mid X_0)$ is such that z takes on only two values, say 1 and 0, and that the $z = 1$ workers have a higher separation propensity than do the $z = 0$ workers. Assume that the initial ($t = 0$) sample is such that nine-tenths of the workers are $z = 1$ types and that the remaining one-tenth are $z = 0$ types. Then the initial variance of z is $(1 - .9).9 = .09$.

As tenure increases, the population proportions shift toward the stayers, and the variance of z increases steadily up to .25, at which point the population proportions are equal. Thereafter, the variance declines monotonically to zero.[17] Of course, a monotonic decline would occur even in this example if the initial proportions happened to be equal, or were weighted in favor of stayers.

According to the first part of equation 18, the change in the group separation rate is always an overstatement (in the negative direction) of the average of the individual changes. However, the same is not true of the group wage change, because the covariance term in the second part of equation 18 may be either positive or negative. The relevant question is whether a "mover" [for whom $\hat{s}(t, X_0) - \hat{s}(t \mid X_0, z)$ is negative] would expect to receive higher or lower wages than a "stayer" at a certain tenure level *given that it was optimal for both to remain in the firm up to that time*. A theory which predicts that a worker will separate from a job on which wages paid to him were low relative to his prior expectations implies nothing about this question.

The implications of human capital theory for the sign and magnitude of $\mathrm{Cov}(\hat{w}, \hat{s} \mid X_0, t)$ are ambiguous. In part 1 we emphasized the role of firm-specific human capital in generating a wedge between the worker's productivity in his current firm and his productivity elsewhere. Consider the polar case in which the ratio of general to firm-specific training is fixed and constant across workers, but in which workers differ in the total amount of training that they undertake. Suppose that z is an index inversely related to the worker's propensity to invest in on-the-job training. Under these assumptions, a higher propensity to invest also implies a higher investment in specific training, so that $\hat{s}_z(t \mid X_0, z) > 0$. Assume that z is not correlated with unmeasured ability components. Then, since investment in training involves foregone earnings early on in return for higher earnings later, this implies that $w_z(t \mid X_0, z) > 0$ for young workers (for whom X_0 and t are small), and $w_z(t \mid X_0, z) < 0$ for older workers. Therefore, $\mathrm{Cov}(\hat{w}, \hat{s} \mid X_0, t)$ is *positive* for the young and *negative* for the old workers.

Suppose instead, however, that the total amount of training across individuals (with given X_0 and t and other observable characteristics) is constant while only the ratio of general to specific training varies positively with z. Now, high-z workers have higher separation propensities because their training is general in nature rather than firm specific. In view of the well-known argument (see Becker 1975) that general training is financed by the workers, such workers earn lower wages initially, and higher wages later on, than do "stayers" whose training is more firm specific in nature. (Again, this conclusion depends on the assumption that the preference for the type of training is not related to unmeasured ability differences.) The implication now is that $\mathrm{Cov}(\hat{s}, \hat{w} \mid X_0, t)$ is *negative* for the young, and *positive* for the old workers.

Neither polar case is expected to obtain in practice. Both the total amount and the composition of the training may be expected to vary systematically with z. But which dominates? The wage function estimates reported in table 1.6 strongly suggest that the dominant variation is in the total amount of training. This inference is made by comparing the second row with the fourth row in panel A, and the second row with the third in panel B. The variables PM and NIM are indexes of past mobility and are correlated with $\hat{s}(t \mid X_0, z)$. By definition, z is the unmeasured component of heterogeneity, and the inclusion of PM and NIM therefore has the effect of reducing the *absolute value* of $\mathrm{Cov}(\hat{w}, \hat{s} \mid X_0, t)$. In both panels, there appears to be an effect of this reduction. The wage growth, measured as the sum of the coefficients on X and T, *increases* for the young men when NIM is included, and *decreases* for the older men when PM is included in the regression, and these changes are consistent with the first polar case, but not the second, as is clear from equation 18.

Proof: Substituting for $\hat{p}$ into (17),

$$\hat{s}(t, X_0) = \frac{\int f(t \mid X_0, z)\, p(z \mid X_0) dz}{\int [1 - F(t \mid X_0, z)]\, p(z \mid X_0) dz} \tag{19}$$

Differentiating with respect to t in equation 16,

$$\begin{aligned} \hat{p}_t(z \mid X_0, t) &= \frac{-f(t \mid X_0, z)\, p(z \mid X_0)}{\int (1-F)\, p dz} \\ &+ \frac{[1 - F(t|X_0, z)] p(z|X_0) \int f(t|X_0, z)\, p(z|X_0) dz}{[\int (1-F)\, p dz]^2} \\ &= [-\hat{s}(t \mid X_0, z) + \hat{s}(t, X_0)]\, \hat{p}(z \mid X_0, t) \end{aligned} \tag{20}$$

Multiplying both sides by $\hat{s}(t \mid X_0, z)$ and integrating both sides over z,

$$\begin{aligned} \int \hat{s}(t|X_0, z)\, \hat{p}_t(z \mid X_0, t) &= \hat{s}(t, X_0)^2 - \int \hat{s}(t|X_0, z)^2\, \hat{p} dz \\ &= [E(\hat{s})]^2 - E(\hat{s}^2) = -\sigma^2(\hat{s} \mid X_0, t) \end{aligned} \tag{21}$$

and differentiating with respect to t in equation (17) and using equation 21, one obtains the first assertion of the theorem which has therefore been proved. Next,

$$\hat{w}(X_0, t) = \int \hat{w}(t \mid X_0, z)\, \hat{p}(z \mid X_0, t) dz$$

and differentiating with respect to t,

$$\begin{aligned} \hat{w}_t(X_0, t) &= \int \hat{w}_t\, \hat{p} dz + \int \hat{w} \hat{p}_t\, dz \\ &= \int \hat{w}_t\, \hat{p} dz + \int \hat{w}(t|X_0, z)\, [\hat{s}(t, X_0) \\ &\quad - \hat{s}(t \mid X_0, z)]\, \hat{p}(z \mid X_0, t) dz \end{aligned}$$

where the second equality follows in view of equation 20, and this completes the proof of the theorem.

1.11 An Estimation Procedure

The following estimation procedure exploits the property of $p(z \mid X)$ (defined in equation 15) of having two different functional forms, implying, in turn, two different functional forms for $\hat{s}(t, X_0)$ in (17). We demonstrate below how identification of the parameters may be secured by subdividing the sample of all workers into two subsamples: one for which $X_0 = 0$ (workers on their first job ever), and the other for which $X_0 > 0$. In fact, in the following illustration for an *additive* fixed effect parametrization of $s(t, X, z)$, the parameters are overidentified, which suggests that identification may be secured for more complex functional forms which we hope to consider in future work. The following additive fixed effect formulation is perhaps inadequate in capturing the individual differences, but it is adequate as an illustration of the estimation method. Let

$$s(t, X, z) = z + S(t, X) \tag{22}$$

where, without loss of generality $S(0, 0) = 0$. One possible way to proceed is to take first differences in equation 22 and eliminate z, thereby also eliminating the selection bias. There are two problems with this approach. First, using differences in separation probabilities as the dependent variable leads to coefficients that are not significant. Secondly, there is then no possibility of estimating σ^2, the variance of z. We have therefore chosen a different procedure, which is based on deriving two separate relationships associated with equation 22.

Let $z(t, X)$ be the conditional expectation of z, and $s(t, X)$ the conditional expectation of the separation rate, given t and X. Then, taking conditional expectations in equation 22,

$$s(t, X) = z(t, X) + S(t, X) \tag{23}$$

where

$$z(t, X) = \int z\hat{p}(z \mid X - t, t)dz$$

Then since

$$F(t \mid X - t, z) = 1 - \exp\left[-zt - \int_0^t S(y, X - t + y)\, dy\right]$$

application of (16) and (15) leads to

$$z(t, X) = \frac{\int ze^{-zt}\, a(X - t, z)\, p(z)dz}{\int e^{-zt}\, a(X - t, z)\, p(z)dz} \text{ for } X > t \tag{24}$$

$$z(X, X) = \frac{\int ze^{-zX}\, p(z)dz}{\int e^{-zX}\, p(z)dz} \text{for } X = t$$

(Workers with $X = t$ are on their first job.) Assume now that $p(z)$ is the normal distribution. Then a straightforward calculation yields

$$z(X, X) = \mu - \sigma^2 X$$

where μ and σ^2 are the mean and variance of z.

So that (for workers on their first job)

(25) $$s(X, X) = \mu + S(X, X) - \sigma^2 X$$

The discontinuity of the $\hat{p}$ distribution at $X = 0$ carries over to $z(t, X)$. It is seen from (24) that

$$z(0, 0) = \mu$$

while taking the limit in (24) and observing (7),

$$\lim_{X \to 0} z(0, X) = \mu + \frac{\sigma^2}{\mu}$$

To obtain a closed form approximation to $z(t, X)$ for $X > t$, a first-order Taylor's expansion is performed in equation 24 around the point ($t = 0$, $X = \varepsilon$) where $\varepsilon > 0$. Then

$$z(0, \varepsilon) = \frac{\int za(\varepsilon, z)\, p(z)dz}{\int a(\varepsilon, z)\, p(z)dz}$$

$$z_t(0, \varepsilon) = -\frac{[\int z^2 a(\varepsilon, z) p(z)dz + \int z\, a_X(\varepsilon, z)\, p(z)dz]}{\int a(\varepsilon, z)\, p(z)\, dz}$$

$$+ \frac{[\int z\, a(\varepsilon, z)p(z)dz + \int a_X(\varepsilon, z)\, p(z)dz] \int za(\varepsilon, z)p(z)dz}{[\int a(\varepsilon, z)\, p(z)\, dz]^2}$$

and

$$z_X(0, \varepsilon) = \frac{\int z\, a_X(\varepsilon, z)\, p(z)dz}{\int a(\varepsilon, z)\, p(z)dz} - \frac{\int a_X(\varepsilon, z)\, p(z)dz}{\int a(\varepsilon, z)\, p(z)dz} z(0, \varepsilon)$$

For any $X > t$, and any $\varepsilon > 0$ no matter how small,

(26) $$\begin{aligned} z(t, X) &= z(0, \varepsilon) + z_t(0, \varepsilon)t + z_X(0, \varepsilon)\, (X - \varepsilon) \\ &\quad + \text{higher order terms} \\ &= \lim_{\varepsilon \to 0} z(0, \varepsilon) + [\lim_{\varepsilon \to 0} z_t(0, \varepsilon)]\, t \\ &\quad + [\lim_{\varepsilon \to 0} z_X(0, \varepsilon)]\, X \\ &\quad + \text{higher order terms} \end{aligned}$$

Evaluating the limits, and using theorem 1,

$$\lim_{\varepsilon\to 0} z(0, \varepsilon) = \frac{\int z\, a(0, z)\, p(z)dz}{\int a(0, z)\, p(z)ds}$$

$$= \frac{\int z\, s(0, 0, z)\, p(z)ds}{\int s(0, 0, z)\, p(z)dz}$$

$$= \frac{\int z^2\, p(z)dz}{\int z\, p(z)dz} = \mu + \frac{\sigma^2}{\mu}$$

$$\lim_{\varepsilon\to 0} z_t(0, \varepsilon) =$$

$$= \frac{[\int z^2 s(0, 0, z)\, p(z)dz + \int z[s_X(0, 0, z) + s_t(0, 0, z)]\, p(z)dz]}{\int s(0, 0, z)\, p(z)dz}$$

$$+ \frac{\int z\, s(0, 0, z)\, p(z)dz + \int [s_X(0, 0, z) + s_t(0, 0, z)]\, p(z)dz}{[\int s(0, 0, z)\, p(z)dz]^2}$$

$$= -\mu^{-1}[\int z^3\, pdz + \mu(\alpha + \gamma)] + \mu^{-2}(\int z^2\, pdz + \alpha + \gamma)$$

where $\alpha \equiv S_X(0, 0)$ and $\gamma = S_t(0, 0)$.

If $p(z)$ is a symmetric distribution so that the third order moment about the mean is equal to zero, then one obtains $\int z^3 pdz = \mu^3 + 3\sigma^2\mu$, and therefore

$$\lim_{\varepsilon\to 0} z_t(0, \varepsilon) = (\mu^{-2} - 1)\ (\alpha + \gamma) + 1 - 3\sigma^2 - \mu^2 + \frac{\sigma^2}{\mu}$$

Also,

$$\lim_{\varepsilon\to 0} z_X(0, \varepsilon) = -\frac{\sigma^2}{\mu^2}(\alpha + \gamma)$$

Taking an expansion in (23),

$$s(t, X) = \alpha X + \gamma t + z(t, X) + \text{higher order terms}$$

But making the substitution into (26),

$$z(t, X) = \mu + \frac{\sigma^2}{\mu} + [(\mu^{-2} + 1)(\alpha - \gamma) + 1 - 3\sigma^2 - \mu^2 + \frac{\sigma^2}{\mu^2}]t$$

$$-\frac{\sigma^2}{\mu^2}(\alpha + \gamma)X + \text{higher order terms}$$

Therefore for $t < X$,

(27) $$s(t, X) = \mu + \frac{\sigma^2}{\mu} + [(\mu^{-2} - 1)\alpha + \mu^{-2}\gamma + 1 - 3\sigma^2 - \mu^2 + \frac{\sigma^2}{\mu_2}]t + [\alpha - \frac{\sigma^2}{\mu^2}(\alpha + \gamma)]X$$
$$+ \text{higher order terms}$$

Also, expanding in (25)

(28) $$s(X, X) = \mu + (\alpha + \gamma - \sigma^2)X + \text{higher order terms.}$$

Equations 27 and 28 are the two basic relationships estimated.

The separation propensity is of course unobservable. All that is observed is whether or not an individual has changed jobs within a particular period. Let $y = 1$ if the worker has changed jobs within the period $(X, X + \Delta X)$, and zero otherwise.

$$\text{Prob } (y = 1) = 1 - \exp\{-\int_0^{\Delta X} s(t + y, \text{X} + y, z)dy\}$$
$$= s(t, \text{X}, z)\ \Delta X + 0\ [(\Delta X)^2]$$

Similarly

$$\text{Prob } (y = 0) = 1 - s(t, X, z)\ \Delta X + 0\ [(\Delta X)^2]$$

Therefore y_X has a mean equal to $s(t, X, z)\ \Delta X + 0\ [(\Delta X)^2]$

Ignoring the $0[(\Delta X)^2]$

$$y_X = [z + S(t, X)]\ \Delta X + u$$

where u is a disturbance with zero mean. In the data, ΔX was equal to two years. The regressions for the separation equations are reported in the first two columns of table 1.7. (Separate regressions were also run for quits and for layoffs, and they are reported in the table, although they do not have an interpretation within the mathematical structure presented above.) The three linear coefficients and the two constant terms provide five restrictions on the four parameters so that the parameters are over-identified. However, the relative magnitude of the two constant terms is reversed from that implied by the theory, leading to an estimate of σ^2 which is negative, which may mean that the additive fixed effect formulation is inadequate. In future work, we intend to experiment with different functional forms for the separation and wage equations, focusing on the question of the best way to model the individual differences, and to organize the data so that the time interval ΔX is shortened, one year rather than two.

Table 1.7 NLS Young Men's Sample, 1967–73

	Separations		Quits		Permanent Layoffs	
	$X=T$	$X>T$	$X=T$	$X>T$	$X=T$	$X>T$
Constant	.78	.64	.5583	.4439	.103	.1999
X	−.1805 (23.22)	.0137 (1.13)	−.1112 (14.55)	.0051 (.4)	−.0692 (12.51)	.0086 (.844)
X^2	.0098 (15.38)	−.0012 (1.27)	.0057 (9.02)	−.0005 (.524)	.0042 (9.09)	−.0006 (.862)
T		−.1819 (10.03)		−.0996 (5.28)		−.0822 (5.38)
T^2		.0069 (3.02)		.0032 (1.34)		.0037 (1.92)
XT		.0037 (1.65)		.0016 (.696)		.0021 (.924)
R^2	.305	.246	.167	.106		.148
n	1,877	1,985	1,877	1,984	1,877	1,984

Notes

1. The subject of women's labor mobility is reserved for separate study.

2. For analysis of geographic mobility see Bartel (1978) and Mincer (1978).

3. This is in contrast to the BLS data of Table 1.1 and may be peculiar to the NLS sample.

4. In his work, Jovanovic (1978b) has shown that job-matching processes produce downward sloping tenure-separation functions and upward sloping tenure-wage functions. Investments of employers and workers in their mutual association are a corollary. We use the language of specific capital to cover the combined phenomena.

5. We may note that even if returns to specific capital accumulation, and in particular W_s, did not decelerate with tenure, but grew in a linear fashion, the resulting growth of the reservation wage in job search would nevertheless lead to decelerating declines in the probability of quit, given a declining upper tail of the wage-offer distribution.

6. We must be careful, however, not to assert the converse: by itself, inertia does not bring about specific investments.

7. The deterministic treatment is for expository convenience only. See part 2 for a more formal and more specialized analysis of the stochastic process.

8. Perhaps a simple way of illustrating the conclusion that dT/dX is larger with than without tenure dependence is to consider a case in which we go from none to some tenure dependence. Let the mean tenure in the group be T_{av} and the overall turnover rate s. Then, after a passage of a year, the $(1-s)$ stayers have increased tenure by one year, while the s movers, without tenure dependence, have lost on average T_{av} years of tenure. The net change dT/dX is therefore $(1-s)-sT$, which approaches zero since T approaches $[(1/s)-1]$. Now, let s remain the same, but the process become tenure-dependent. In this case, the average tenure lost by movers is $T_{mav} < T_{av}$ since proportionately more of them are drawn from low-tenure classes. Consequently the net gain in tenure $dT/dX = (1-s)-sT_m > (1-s)-sT$.

9. Cf. theorem 3 in part 2. Such a decline in the variance need not be inconsistent with a widening of differences in mobility rates.

10. For those men whose current tenure started before the initial year of reported prior mobility (1965 for the older men and 1966 for the young men in NLS, and 1968 for MID), no information on PM is available (12% of young men and 62% of the old men in NLS, and about 50% in MID). As a check on the results in table 1.5 which implicitly assigns a value of PM = 0 to those whose tenure is too long, we used dummy variables on the complete samples, and we also replicated the regressions of table 1.5 on the subsamples which contained information on prior mobility. The results were quite similar to those in table 1.5 with one interesting feature: the tenure coefficients for the old men in NLS (with short tenure in the subsample) were as steep as for the young, and the inclusion of PM reduced the slope by a relatively small amount as it did for the young.

11. The longitudinal evidence is less familar. See Borjas and Mincer (1978) reporting Coleman-Rossi data, and Anderson, Balcer, and Diamond (1976) on the Continuous Work History Sample.

12. Dollar wage equations, not shown here, show similar patterns, but weaker predictive power.

13. This is true also in the sample with $T \leq 8$, in contrast to the short-tenure mobility equation (see note 10).

14. Supporting evidence is shown in the Bartel and Borjas paper in this volume, as well as in previous research by Borjas. Borjas (1975) classified the older NLS men into movers and stayers. The latter were defined by the fact that their current job was the longest ever. Education and experience were only slightly different in the two groups. The movers had lower wages (about 25%) and flatter experience profiles.

15. See Freeman (1978), Borjas (1978), and others. The flatter union tenure slopes have been analyzed as effects of union policy. We suggest that they may also reflect lesser heterogeneity in the union compared with the nonunion sector.

16. See Burdett (1973), Sorensen (1975). Jovanovic (1978a) is an adaptation of Burdett, which allows for on-the-job human capital accumulation. It is doubtful, however, that the assumption of a fixed wage-offer distribution can be maintained for workers whose skills are growing and changing over the life cycle.

17. This example was supplied by R. Shakotko.

18. Helpful comments by J. Heckman on an earlier version of this paper have led to considerable improvement of this section.

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