Labor Demand and Equilibrium Wage Formation
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Chapter IV.2

USING WAGE GROWTH MODELS TO ESTIMATE THE RETURNS TO EXPERIENCE, SENIORITY, AND JOB MOBILITY [1]

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1. INTRODUCTION

The role of labor market experience, job tenure (seniority) and job mobility in determining wage growth is a longstanding and central question in labor economics. There is a substantial literature on these issues, particularly the relationship between experience and wages over a career[2] and the relative contribution of experience, tenure, and job shopping to wage growth.[3] Several papers attempt to estimate the gain from quitting.[4] Other papers focus upon "displaced workers" and examine the relationship between labor market experience, job seniority, industry characteristics and the wage or earnings

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[2] See for example, Mincer's (1974) classic work or the recent paper by Murphy and Welch (1990).

[3] See Borjas (1981), Mincer and Jovanovic (1981), Topel (1986), Altonji and Shakotko (1987), Abraham and Farber (1987), Marshall and Zarkin (1987), Brown (1989), Williams (1991) and Topel (1991), to name just a few of the studies. Devine and Kiefer (1991) survey much of the literature relevant to the present paper.

[4] See Devine and Kiefer (1991).

losses of workers who lose jobs due to layoffs or plant closings.[5] However, despite a substantial amount of research, many of the key empirical questions are still unanswered and a variety of methodological issues are still unresolved.

In Altonji and Williams (1992) (hereafter, AW) we develop and implement a new approach to estimating the wage-tenure profile in the presence of individual heterogeneity and job match heterogeneity. We estimate the returns to seniority, the returns to experience, and the relationship between changes in the match specific component of wages and experience and seniority at the time of a quit or layoff. We also estimate the contribution of general labor market experience, job tenure (seniority) and job mobility to wage growth over a career. But the use of the word "estimate" is a bit misleading, since we show in AW that these returns are not identified in the commonly used regression models relating the wage changes of stayers, quits, and layoffs to tenure and experience. To be more specific, AW investigates the identification of the coefficients on the linear experience and tenure terms in the wage equation and the coefficients on the linear tenure and experience terms in polynomial approximations for the expected change in the job match components in the event of a quit or layoff. AW shows that these parameters are all underidentified by one common parameter.

One way of dealing with the identification problem is to make use of a priori information about the unidentified parameters. We argue that if the effect of tenure on wages is substantial, then the relationship between the change in the job match component and tenure at the time of a quit (layoff) will be positive (negative). With these sign restrictions one can find a range of estimates for all of the unidentified parameters from the regression parameters that are identified.

In this paper, a simple structural model of quits and layoffs provides a theoretical foundation for the sign restrictions on the relationship between tenure and the change in the job match component.[6] These restrictions play an important role in the econometric analysis in AW. We then use artificial data generated from a computable version of the model to examine the sign restrictions. We also explore other issues that arise in using wage growth equations to estimate the returns to experience and seniority and the gains from quits and layoffs. To our knowledge, simulation methods have not previously been used to study

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[5] Recent examples include Hamermesh (1987), Addison and Portugal (1989), Kletzer (1989), Carrington (1990), Topel (1990), and Ruhm (1991). Jacobson, LaLonde and Sullivan (forthcoming) survey the literature on dislocated workers. They also provide a detailed analysis of the earnings losses of job changers using panel data from the unemployment insurance system of the state of Pennsylvania.

[6] Much of the material in this paper and in AW were presented in preliminary form in a much longer paper entitled "Estimating the Effects of Experience, Seniority, and Job Mobility on Wage Growth" (May 1992).

how the parameters of standard wage change regressions are affected by the job match productivity process, the magnitude of the relationship between tenure and productivity, and the division of match specific productivity components between the firm and worker. We take a small first step in this direction and discuss how our model could be expanded into an estimable structural model of wage growth and mobility.

The paper proceeds as follows. In section 2 we present summary statistics on wage growth within and across jobs by experience and tenure level, and by type of separation. The summary of the key empirical patterns provides a useful backdrop for our discussion of the problems with interpreting the patterns. In Section 3 we present the econometric model of wages and the gain from mobility used in AW and summarize our analysis of what is identified and what is not identified in the wage growth equations that are commonly used in the literature. In Section 4 we present a simple theoretical model of mobility and wages and in Section 5 we generate data from a version of the model that can be simulated. We use the models to explore the relationship between changes in the job match wage component and the levels of tenure and prior experience at the time of a quit or a layoff. In the final section we discuss a research agenda.

2. FACTS ABOUT THE LINK BETWEEN WAGES, EXPERIENCE, TENURE, AND MOBILITY

In this section we document the links among wages, experience, tenure, and mobility that must be explained. The results are based upon the 1975-1987 waves of the Panel Study of Income Dynamics and are restricted to white male heads of household. For each year we include persons who were between the ages of 18-60 inclusive, were employed, temporarily laid off, or unemployed at the time of the survey, and were not from Alaska or Hawaii.[7]

The wage measure (WAGE1) is the log of the reported hourly wage for the job held at the time of the survey (deflated by the implicit price

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[7] Individuals who were not household heads in at least 3 years between 1975-1987 are excluded from the analysis entirely, as are individuals who never worked at least 1000 hours or were never employed at the survey date. After an individual retires, any further information is excluded from the analysis. All of the observations from the current job are excluded if the worker reports being self employed or employed by the government.

deflator with a base year of 1982).[8] The PSID does not allow employers to be precisely identified across surveys, so employer tenure, quits and layoffs must be inferred. AW documents the procedures used to infer employer tenure, quits, and layoffs from the information in the PSID.[9] The sample consists of 9883 wage change observations on 1789 individuals and 2686 jobs matches.

Table 1 presents the means and standard deviations for the full sample, for movers, for stayers, for quits, for all layoffs, and for layoffs due to a plant closing. The mean of ΔWAGE1 (the change in the reported wage at the survey) is .0379 for movers and .0235 for stayers. After a quit there is a mean wage increase of .0797, while a layoff reduces wages by -.0489. Interestingly, mean wage growth for layoffs due to plant closings is only -.0036 although its standard error is .0354.[10]. The standard deviation of wage growth is much larger for movers than for stayers.

The quit rate, layoff rate (including plant closings), and layoff rate due to plant closing are .0751, .0366, and .0111. The total separation rate including separations for which reason is unknown is .1237. Stayers have a much higher mean log wage rate than movers (2.32 versus 2.03). This difference may in part reflect a larger difference in experience (17.6 versus 12.1) and in current tenure (8.55 + 1 versus essentially 0) but also may reflect a negative correlation between productivity and the propensity to change jobs.

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[8] The variable WAGE1 is only available for hourly workers in 1975, is truncated at $9.98 prior to 1978 and underestimates wage growth to the extent that paid vacations and holidays rise with tenure and experience. To reduce the influence of measurement error and outliers, we have set the wage rates to missing when they are less than 1.50 in 1982 dollars. We have set the wage changes involving an increase of 800% or a fall to less than 1/8th of the previous years value to missing as well. We have also examined an alternative wage measure that has been used in a number of previous studies based on the PSID. This measure is the log of real labor earnings during the year divided by annual hours (WAGE2). For those who change jobs during the year, average hourly earnings is presumably an average of the wage on each of the jobs weighted by the portion of the year spent in each. For this reason, we prefer WAGE1 to WAGE2.

[9] When the reason for job changes is unavailable or we are unable to classify the job change into a quit or a layoff based on the reason given, we have excluded the observation. Our descriptive statistics understate the combined quit and layoff probability by .012 as a result.

[10] There are some differences between the results for ΔWAGE1 and ΔWAGE2. The low value of the mean of ΔWAGE2 for quits is due in part to the influence of a few very large wage losses.

Table 1 :
Descriptive Statistics

Variable	Sample N :	Overall	Mover	Stayer	Quit	Layoff	Plant Closing
Wage1	MEAN	2.2884	2.0311	2.3208	2.0729	1.9470	2.0832
	STD	0.4614	0.4984	0.4462	0.5005	0.4851	0.5348
ΔWage1	MEAN	0.0251	0.0379	0.0235	0.0797	-0.0489	-0.0036
	STD	0.2071	0.3590	0.1790	0.3462	0.3701	0.3710
ΔWage2	MEAN	0.0270	0.0119	0.0288	0.0487	-0.0661	-0.0632
	STD	0.2565	0.4270	0.2293	0.4057	0.4415	0.4037
EX_{it-1}	MEAN	16.9782	12.0831	17.5957	11.6345	13.0254	15.0048
	STD	10.3574	8.2343	10.4335	7.6687	9.2435	9.9207
$PEX_{ij(t-1)}$	MEAN	8.4234	9.3295	8.3091	9.0985	9.8059	9.8373
	STD	7.7286	7.6508	7.3536	7.3536	8.2345	7.8532
T_{it-1}	MEAN	8.5548	2.7536	9.2866	2.5369	3.2196	5.1675
	STD	8.6351	4.1980	8.7732	3.4632	5.3862	7.8083

* Summary statistics for ΔWAGE1 regression sample. The sample size is 9883. The summary statistics in the table for ΔWAGE2 are for the 8923 cases with nonmissing data that are in the ΔWAGE1 sample.

Table 2 :
Separations, Quits, Layoffs, and Layoffs Due to Plant Closing by Experience and Lagged Tenure

Experience Level		Tenure Last Year 0≤T<1	1≤T<3	3≤T<6	6≤T<15	T>=15	All Tenure
$0 \le E_{it} < 5$	Separations	0.3964	0.1276	0.1750	-	-	0.2444
	Quits	0.2308	0.0867	0.1750	-	-	0.1556
	Layoffs	0.1657	0.0408	0.0000	-	-	0.0889
	P Closings	0.0355	0.0102	0.0000	-	-	0.0198
	N	169	196	40	0	0	405
$5 \le E_{it} < 10$	Separations	0.3908	0.1474	0.0913	0.0672	-	0.1752
	Quits	0.2626	0.1066	0.0580	0.0672	-	0.1216
	Layoffs	0.1239	0.0409	0.0333	0.0000	-	0.0527
	P Closings	0.0294	0.0073	0.0101	0.0000	-	0.0124
	N	476	685	690	238	0	2089

Table 2 : Continued

Experience Level		Tenure Last Year 0≤T<1	1≤T<3	3≤T<6	6≤T<15	T>=15	All Tenure
$10 \le E_{it} < 20$	Separations	0.3706	0.1438	0.0962	0.0420	0.0082	0.1150
	Quits	0.2420	0.0647	0.0450	0.0241	0.0051	0.0340
	Layoffs	0.1196	0.0470	0.0218	0.0136	0.0000	0.0353
	P Closings	0.0392	0.0152	0.0038	0.0047	0.0000	0.0110
	N	510	723	780	1691	122	3826
$E_{it} \ge 20$	Separations	0.3607	0.1029	0.0661	0.0449	0.0142	0.0567
	Quits	0.2420	0.0647	0.0450	0.0241	0.0051	0.0340
	Layoffs	0.1187	0.0382	0.0210	0.0208	0.0091	0.0227
	P Closings	0.0274	0.0088	0.0120	0.0099	0.0068	0.0095
	N	219	340	333	913	1758	3563
all E_{it} category	Separations	0.3792	0.1363	0.0906	0.0450	0.0138	0.1120
	Quits	0.2504	0.0936	0.0651	0.0303	0.0053	0.0751
	Layoffs	0.1266	0.0427	0.0255	0.0148	0.0085	0.0366
	P Closings	0.0335	0.0108	0.0076	0.0060	0.0064	0.0111
	N	1374	1944	1843	2842	1880	9883

Notes :
The first row of each experience category is the total separation rate excluding observations that we could not classify into quits or layoffs. The second row is the quit rate. The third row is the total layoff rate, including plant closings. The fourth row is the layoff rate due to plant closings. N is the number of observations.

Quits and Layoffs by Experience Level

It is also important to get a feeling for the distribution of quits and layoffs. In Table 2 we present the overall separation rate excluding observations that we cannot classify into quits or layoffs, the quit rate, the total layoff rate, and the rate of layoff due to plant closings. As is well known from previous studies, the quit and layoff rates have strong negative relationships to tenure, although this relationship is probably overstated by individual heterogeneity in turnover probabilities. The negative relationship between turnover and tenure is evident in the all experience category.

In the last column, we observe that turnover, quit, and layoff rates all decline with experience. Perhaps less well known is the fact that the relationship between labor market experience and the separation variables is less dramatic when tenure is held constant.[11] Within tenure categories, the quit probability falls only modestly. There is little relationship in the 0 to 1 tenure category, although the relationship is negative in the other categories and strong in the 3 to 5 category and 6 to 14 category. Layoffs have little relationship with experience within tenure categories. Layoffs due to plant closing are also weakly negatively related to tenure. This may reflect heterogeneity across firms in the plant closing probability, and the possibility that individuals with a propensity to change jobs sort into firms that are relatively unstable.[12]

[11] See Mincer and Jovanovic (1981) and Topel and Ward (1992).

Wage Levels

We regressed WAGE1 against a cubic in EX_{it}, T_{it}, T_{it}^2, a dummy variable OJ_{it} equal to 1 if $T_{it} > 1$, and a set of control variables.[13] The tenure and experience coefficients imply that 10 years of tenure lead to an increase in the log wage of .26, while 10 and 30 years of experience lead to increases in the log wage of .315 and .430 respectively.[14] The finding of a strong positive effect of both tenure and experience on the conditional mean of the wage is standard in the literature.

Wage Growth

In Tables 3a-3e we present the means and standard deviations of the change in the log wage, ΔWAGE1, by experience and tenure category for stayers, movers, quits, and layoffs. Standard errors of the means are also presented.

Consider first wage growth for stayers in Table 3a. Holding lagged tenure constant between 0 and 1, the wage growth for stayers falls from .057 when experience is between 0 and 5 to .011 for experience greater than 20. This is consistent with a strong effect of experience on wages that diminishes with time in the labor market. The pattern is similar in the 1-3 and 3-6 tenure categories. In

[12] We have computed the quit, layoff and layoff due to plant closings rates broken down by the 1 digit industry of the job held in the previous period. The quit rates varied from a low of .0429 (.0058) in the Transportation, Communications and other Public Utilities to a high of 0.1354 (.0105) in Services. The quit rate in manufacturing was .0463 (.0032). Similarly, the layoff rate varied from .0186 (.0038) in Transportation, Communications and other Public Utilities to a high of .0848 (.0218) in Agriculture, Forestry and Fisheries. The layoff rate in manufacturing was .0312 (.0026). Standard errors are in parentheses.

[13] These consist of education, education squared, union membership, the product of experience and education, city size and region controls, a control for a health limitation and year dummies.

[14] The effect of 10 years of tenure is .335 and the effect of 30 years of experience is .385 when WAGE2 is used as the dependent variable. As noted earlier, this is the variable used in Topel (1991) and Altonji and Shakotko (1987).

contrast, wage growth within jobs has only a weak relationship to tenure when labor market experience is held constant. These results are potentially consistent with a substantial but relatively constant return to each year of additional tenure. However, they are inconsistent with the view that a large effect of tenure on wages in the early years on a job is responsible for the drop in quits with tenure discussed above. Assuming the effect of experience is substantial, then the effect of tenure would seem to be much smaller than the effect implied by the wage level regressions discussed above.

Looking at job changers in Table 3b, we observe that for all movers there is a sharp drop in wage growth with years in the labor market, holding tenure constant. The drop is most dramatic when tenure is less than 1. For quits in Table 3c, wage growth drops dramatically with experience when tenure on the previous job is less than 1 but does not vary much with experience in the higher tenure categories relative to the sampling errors of the cell means. For layoffs in Table 3d there is also a substantial drop in wage growth at higher experience levels within each tenure category (with the exception of the 3 to 6 category). In sum, tables 3a-3e reveal that wage growth within and across jobs tends to fall as experience increases, holding tenure constant.

Holding experience constant and reading across the rows, we observe that mean wage growth for job changers drops with tenure on the previous job. Table 3b shows that for all movers in the 5 to 10 year experience category, wage growth is .100 if tenure on the previous job is less than 1 and .008 if tenure is between 6 and 15 years. These results are consistent with a seniority effect on wages. The same general pattern is present for quits, layoffs and plant closings. However, the standard errors of the means in the tables are quite large. Overall, the evidence is consistent with a modest positive return to tenure, although the large standard errors, differences in the detailed results by type of separation, and failure to hold constant the job match term make it dangerous to infer too much from the tables. In particular, our theoretical discussion and simulations below suggest that the relationship between tenure and the wage gains following quits are likely to understate the returns to tenure. They also suggest that the relationship between tenure and wage gains following layoffs is likely to overstate the return to tenure.

It is also important to note that the standard deviation of wage changes is much larger for both quits and layoffs than for stayers even when experience and tenure last year are held constant. This implies that changes in match specific error components are quantitatively important and underlie the basic fact in Table 1 that wage growth is much more variable for movers than stayers.

In sum, wage levels are strongly related to both tenure holding experience constant and experience holding tenure constant. The descriptive statistics indicate a drop in turnover with tenure. Turnover also declines sharply with experience, but the relationship is weak once tenure is held constant. There is a decline in wage growth with experience holding tenure constant. Within jobs there is modest wage growth within jobs which declines with experience holding tenure constant, but is only weakly related to tenure when experience

is held constant. We also find a negative relationship between wage changes for movers and tenure prior to the move. The results are potentially consistent with a role for experience, tenure, and job match gains via mobility in wage growth over a career. The fact that wage changes are more variable across jobs suggests that job specific error components are an important feature of the data. We now turn to the formal econometric analysis.

TABLE 3A :
Log Wage Change (ΔWAGE1) by Tenure and Experience, STAYERS

Experience Level		Tenure Last Year				
		0≤T<1	1≤T<3	3≤T<6	6≤T<15	T≥15
$0 \le E_{it} < 5$	Mean	0.0575	0.0795	0.0525	-	-
	Std.Error	0.0167	0.0128	0.0340	-	-
	Std.Dev.	0.1687	0.1667	0.1950	-	-
$5 \le E_{it} < 10$	Mean	0.0461	0.0671	0.0303	0.0061	-
	Std.Error	0.0126	0.0065	0.0062	0.0121	-
	Std.Dev.	0.2150	0.1578	0.1557	0.1810	-
$10 \le E_{it} < 20$	Mean	0.0223	0.0226	0.0283	0.0196	-0.0172
	Std.Error	0.0128	0.0077	0.0069	0.0046	0.0195
	Std.Dev.	0.2290	0.1910	0.1819	0.1851	0.2146
$E_{it} \ge 20$	Mean	0.0113	0.0233	0.0219	0.0071	0.0113
	Std.Error	0.0183	0.0108	0.0094	0.0056	0.0039
	Std.Dev.	0.2167	0.1881	0.1664	0.1646	0.1633

TABLE 3B :
Log Wage Change (ΔWAGE1) by Tenure and Experience, QUITS AND LAYOFFS

Experience Level		Tenure Last Year				
		0≤T<1	1≤T<3	3≤T<6	6≤T<15	T≥15
$0 \le E_{it} < 5$	Mean	0.1635	-0.0223	0.0325	-	-
	Std.Error	0.0377	0.0736	0.1188	-	-
	Std.Dev.	0.3087	0.3679	0.3143	-	-
$5 \le E_{it} < 10$	Mean	0.1004	0.0767	-0.0276	0.0083	-
	Std.Error	0.0292	0.0330	0.0450	0.0726	-
	Std.Dev.	0.3985	0.3321	0.3575	0.2904	-
$10 \le E_{it} < 20$	Mean	0.0540	0.0281	-0.0109	0.0076	0.0055
	Std.Error	0.0294	0.0326	0.0360	0.0380	-
	Std.Dev.	0.4048	0.3326	0.3119	0.3283	-
$E_{it} \ge 20$	Mean	0.0238	-0.0273	0.0077	-0.1081	-0.1210
	Std.Error	0.0373	0.0482	0.0427	0.0597	0.0767
	Std.Dev.	0.3317	0.2852	0.2003	0.3824	0.3832

TABLE 3C :
Log Wage Change (ΔWAGE1) by Tenure and Experience, QUITS

Experience Level		Tenure Last Year				
		0≤T<1	1≤T<3	3≤T<6	6≤T<15	T≥15
$0 \le E_{it} < 5$	Mean	0.2614	-0.0085	0.0325	-	-
	Std.Error	0.0371	0.1051	0.1188	-	-
	Std.Dev.	0.2318	0.4334	0.3143	-	-
$5 \le E_{it} < 10$	Mean	0.1453	0.1084	0.0444	0.0083	-
	Std.Error	0.0353	0.0393	0.0526	0.0726	-
	Std.Dev.	0.3948	0.3354	0.3328	0.2904	-
$10 \le E_{it} < 20$	Mean	0.0494	0.0737	0.0426	0.0436	0.0055
	Std.Error	0.0346	0.0389	0.0374	0.0422	-
	Std.Dev.	0.3903	0.3255	0.2849	0.2924	-
$E_{it} \ge 20$	Mean	0.0853	0.0707	0.0504	-0.0668	-0.0557
	Std.Error	0.0458	0.0495	0.0552	0.0879	0.1058
	Std.Dev.	0.3333	0.2323	0.2137	0.4124	0.3175

TABLE 3D :
Log Wage Change (ΔWAGE1) by Tenure and Experience, LAYOFFS

Experience Level		Tenure Last Year				
		0≤T<1	1≤T<3	3≤T<6	6≤T<15	T≥15
$0 \le E_{it} < 5$	Mean	0.0273	-0.0516	-	-	-
	Std.Error	0.0666	0.0645	-	-	-
	Std.Dev.	0.3523	0.1824	-	-	-
$5 \le E_{it} < 10$	Mean	-0.0029	-0.0059	-0.1528	-	-
	Std.Error	0.0514	0.0594	0.0774	-	-
	Std.Dev.	0.3946	0.3140	0.3714	-	-
$10 \le E_{it} < 20$	Mean	0.0668	-0.0659	-0.1934	-0.0673	-
	Std.Error	0.0562	0.0570	0.0823	0.0812	-
	Std.Dev.	0.4388	0.3321	0.3395	0.3893	-
$E_{it} \ge 20$	Mean	-0.1014	-0.1931	-0.0838	-0.1559	-0.1577
	Std.Error	0.0581	0.0826	0.0528	0.0801	0.1053
	Std.Dev.	0.2963	0.2978	0.1398	0.3493	0.4210

TABLE 3E :
Log Wage Change (ΔWAGE1) by Tenure and Experience, PLANT CLOSINGS

Experience Level		Tenure Last Year				
		0≤T<1	1≤T<3	3≤T<6	6≤T<15	T≥15
$0 \le E_{it} < 5$	Mean	0.0542	-0.0110	-	-	-
	Std.Error	0.0353	0.2083	-	-	-
	Std.Dev.	0.0865	0.2945	-	-	-
$5 \le E_{it} < 10$	Mean	0.1172	-0.0464	-0.0634	-	-
	Std.Error	0.0892	0.1746	0.1820	-	-
	Std.Dev.	0.3339	0.3905	0.4816	-	-
$10 \le E_{it} < 20$	Mean	0.1075	-0.0807	-0.1564	0.1149	-
	Std.Error	0.1240	0.0860	0.1043	0.0881	-
	Std.Dev.	0.5546	0.2853	0.1806	0.2492	-
$E_{it} \ge 20$	Mean	-0.0377	0.1426	-0.1227	-0.1462	-0.1478
	Std.Error	0.0797	0.0480	0.0838	0.1048	0.1193
	Std.Dev.	0.1952	0.0832	0.1677	0.3144	0.4133

3. USING WAGE GROWTH EQUATIONS TO IDENTIFY THE SOURCES OF WAGE GROWTH

The wage change equation below provides a convenient framework for thinking about the factors that underlie relationships between wage changes, tenure, experience, and mobility documented in the previous section:

$$(3.1)\quad \Delta W_{it} = \Delta Z^*_{it}\,\Gamma^* + b_0\Delta EX_{it} + b_1\Delta EX^2_{it} + b_2\Delta T_{it} + b_3\Delta T^2_{it} + \Delta\epsilon_{ij(t)} + \Delta u_{it} + \Delta\nu_{ijt}\,.$$

In (3.1) W_{it} is the log real wage of person i who is in job j at time t, where Z^*_{it} is a set of observed wage determinants that change over time, EX_{it} and EX^2_{it} are labor market experience and its square, T_{it} and T^2_{it} are tenure with the employer and tenure squared, $\epsilon_{ij(t)}$ is a fixed job match specific error component, u_{it} is an individual specific transitory error component, and ν_{ijt} is a stochastic job match error component that is uncorrelated with u_{it}.[15] Variable $\Delta\epsilon_{ij(t)}$ is nonzero only if worker i quits or is laid off.
The terms involving experience EX_{it} are the return to general labor market experience. The terms involving T_{it} reflect growth of wages with seniority in a firm. These may arise from shared investments in firm specific training. However, the return to tenure may also arise

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15 We abstract from a secular time trend and economy-wide wage disturbances for simplicity. One may use panel data or a series of cross sections to identify this trend. The wage level formulation corresponding to (3.1) includes a fixed individual specific error component that further complicates the estimation of the effect of tenure using wage level data.

because employers use wage profiles as a device to attract workers who are likely to stay on the job, or as an incentive mechanism[16].

Wage changes from job to job and growth over a career may also be due to changes in the fixed job match component $\epsilon_{ij(t)}$. Table 3 establishes that persons often experience large wage changes when they change jobs regardless of tenure on the job. These changes across firms may reflect the presence of noncompetitive elements in the wage structure, and differences across firms in the optimal compensation level for a given type. They also may arise because the productivity of a particular worker differs across employers. (See Jovanovic (1979), Johnson (1978) and Flinn (1986)).

Wages will grow over a career as workers quit jobs with relatively low values of $\epsilon_{ij(t)}$. (See Topel and Ward (1992)). However, the upward movement of $\epsilon_{ij(t)}$ over a career may be weakened by layoffs. To analyze the gains (and losses) from quits and layoffs, one must know not only the value of tenure that is given up but also the relationship between tenure and experience at the time of the change and the expected value of $\Delta\epsilon_{ij(t)}$. In AW we mainly concentrate on the effect of changes in $\epsilon_{ij(t)}$, while here we also address issues related to the effect of changes in the stochastic job specific error ν_{ijt}. Changes within and across jobs in ν_{ijt} affect wage growth over a career and the gains and losses from quits and layoffs.[17] Job specific changes in product demand or production technology as well as personnel shifts may induce serially correlated shifts in the job specific component of the worker's marginal product. Also, the firm may gradually learn about the match specific component of productivity.[18] One might expect ν_{ijt} to increase over a career. Job matches in which negative changes in ν_{ijt} occur will be more likely to end in a quit or a layoff. This suggests that the expected value of ν_{ijt} will tend to be positive *for stayers*. However, Bull and Jovanovic (1988) note that if workers tend to enter firms during periods of strong demand, ν_{ijt} may be expected to revert toward its mean value as time goes on. In this case the expected value of ν_{ijt} for stayers could be negative.[19] Furthermore,

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[16] See Hutchens (1989) and Carmichael (1989) for lucid discussions of the literature.

[17] If ν_{ijt} is serially uncorrelated, then this variable will not have much effect on earnings over a career or mobility decisions, since it has a small effect on the present value of the earning stream associated with a particular job. Here we focus on persistent change in ν_{ijt}.

[18] See Bishop (1990), who analyzes the relationship between productivity and turnover.

[19] They do not provide evidence on the quantitative significance of the issues. The assumptions about productivity underlying our simulations imply that ν_{ijt} is either 0 or a random walk with initial condition 0 at the start of the job, so there is no reversion to the mean.

Altonji and Shakotko (1987) note that the size of the decline in ν_{ijt} necessary to induce a quit (holding the value of the alternative offer fixed) increases with tenure if wages rise with tenure. Therefore, the expected value of $\Delta\nu_{ijt}$ conditional on continuation of the job may decline with T_{it}. Consequently, if the effect of tenure on wages and productivity is large, the expected value of $\Delta\nu_{ijt}$ for stayers may decline with tenure on the job.

The accumulation of returns to seniority and changes in $\epsilon_{ij(t)}$ and ν_{ijt} do not operate independently. Workers must make tradeoffs between remaining in the same job and accumulating returns to seniority, and moving across jobs and experiencing changes in $\epsilon_{ij(t)}$ and ν_{ijt}. This has two implications. First, while it is meaningful to estimate the mean contribution of accumulated experience, tenure, and growth in $\epsilon_{ij(t)}$ and ν_{ijt} to wage growth over a career for a sample of workers, a reduction in mobility might increase the contribution of accumulated tenure to career wage growth while reducing accumulation of $\epsilon_{ij(t)}$ and ν_{ijt}. The second implication is closely related to the first---the fact that workers are trading off alternative sources of wage growth in their mobility decisions leads to econometric difficulties in estimating the parameters of the wage equation (3.1) and in estimating the gains and losses from quits and layoffs. The selection problems are further complicated by the fact that firms are also weighing their share of the return to tenure against their share of the fixed and stochastic match specific components of productivity. Unfortunately, to provide a full accounting of the sources of career wage growth and the gains and losses from mobility, we need to separately identify (1) the value of experience and tenure holding $\epsilon_{ij(t)}$ and ν_{ijt} constant and (2) the relationship between changes in $\epsilon_{ij(t)}$ and ν_{ijt} and tenure and experience at the time of a quit or layoff.

These econometric difficulties are noted in many of the papers cited in the introduction. In AW we show what is and is not identified from wage growth equations. We summarize the main points here. Let $E(\Delta\epsilon_{ij(t)}|Q_{it},PEX_{ij(t-1)},T_{it-1})$ be the expected value of $\Delta\epsilon_{ij(t)}$ conditional on T_{it-1}, the level of experience prior to job j $(PEX_{ij(t-1)})$,[20] and a quit between t-1 and t (Q_{it}=1). Let $E(\Delta\epsilon_{ij(t)}|L_{it},PEX_{ij(t-1)},T_{it-1})$ be the corresponding expectation for a layoff (L_{it}=1). Approximating the expectation functions and noting that $\Delta\epsilon_{ij(t)}$ is 0 for stayers implies the following equation for $\Delta\epsilon_{ij(t)}$:

$$\begin{aligned}\Delta\epsilon_{ij(t)} = {} & d_0Q_{it}PEX_{ij(t-1)} + d_1Q_{it} + d_2Q_{it}T_{it-1} + d_3Q_{it}T^2_{it-1} + d_4Q_{it}OJ_{it-1} \\ & + g_0L_{it}PEX_{ij(t-1)} + g_1L_{it} + g_2L_{it}T_{it-1} + g_3L_{it}T^2_{it-1} + g_4L_{it}OJ_{it-1} \\ & + Q_{it}\eta_{ij(t)} + L_{it}\xi_{ij(t)} .\end{aligned} \quad (3.2)$$

where the first two lines are $E(\Delta\epsilon_{ij(t)}|Q_{it},PEX_{ij(t-1)},T_{it-1})$ and

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[20] $PEX_{ij(t-1)} = EX_{it-1} - T_{it-1}$.

$E(\Delta\epsilon_{ij(t)} | L_{it}, PEX_{ij(t-1)}, T_{it-1})$ (respectively) and $Q_{it}\eta_{ij(t)} + L_{it}\xi_{ij(t)}$ is an error term that is uncorrelated with $PEX_{ij(t-1)}$, T_{it-1}, Q_{it}, and L_{it}. (One may add additional nonlinear terms in T_{it-1} and or $PEX_{ij(t-1)}$ to (3.2)). The term OJ_{it-1} is a dummy variable which is one if T_{it-1} is greater than one, and equal to zero otherwise. Since the change in the tenure variables are a function of past tenure, particularly for those who separate, and since the change in EX^2_{it} will be correlated with past experience and tenure, one will obtain biased estimates of the tenure and experience slopes using equation (3.1) unless one accounts for the fact that the expectation of $\Delta\epsilon_{ij(t)}$ is a function of past tenure and experience for those who experience a quit or layoff. Furthermore, the relationship between $\Delta\epsilon_{ij(t)}$ and tenure and experience at the time of a quit or layoff is of central interest and cannot be discovered from estimation of (3.1).
To see what is identified, AW use (3.2) to substitute out for $\Delta\epsilon_{ij(t)}$ and the identity

(3.3) $$\Delta T_{it} = [1 - Q_{it} - L_{it}] + [Q_{it} + L_{it}][\underline{T} - T_{it-1}] + [Q_{it} + L_{it}][T_{it} - \underline{T}] ,$$

to substitute out for ΔT_{it} in (3.1), where $\underline{T}$ is the mean of T_{ijt} conditional on a job change in the preceding year. After simplification this leads to

(3.4)

$$\Delta W_{it} = \Delta Z^*_{it}\Gamma^* + (b_0 + b_2) + b_1\Delta EX^2_{it} + b_3\Delta T^2_{it} + d_0 Q_{it} PEX_{ij(t-1)} + d_3 Q_{it} T^2_{it-1}$$
$$+ d_4 Q_{it} OJ_{it-1} + g_0 L_{it} PEX_{ij(t-1)} + g_3 L_{it} T^2_{it-1} + g_4 L_{it} OJ_{it-1}$$
$$+ [d_1 - b_2(1-\underline{T})]Q_{it} + [g_1 - b_2(1-\underline{T})]L_{it} + (b_2 - d_2)(-Q_{it}T_{it-1})$$
$$+ (b_2 - g_2)(-L_{it}T_{it-1}) + Q_{it}\eta_{ij(t)} + L_{it}\xi_{ij(t)} + \Delta u_{it} + \Delta v_{ijt}$$
$$+ b_2(Q_{it} + L_{it})(T_{it} - \underline{T}) .$$

The term $b_2[(Q_{it} + L_{it})(T_{it} - \underline{T})]$ is best treated as part of the error term because the variation in $[T_{it} - \underline{T}]$ is too unreliable given measurement error for $[T_{it} - \underline{T}]$ to be used in estimation. The linear experience slope b_0, the linear tenure slope b_2 and coefficients d_2 and g_2 on $Q_{it}T_{it-1}$ and $L_{it}T_{it-1}$ in (3.4) are not identified. Note, however, that the nonlinear tenure and experience terms are identified and that coefficients on $-Q_{it}T_{it-1}$ and $-L_{it}T_{it-1}$ provide estimates of (b_2-d_2) and (b_2-g_2), respectively, where d_2 and g_2 are the coefficients of the linear tenure term on the expected value of $\Delta\epsilon_{ij(t)}$ in the event of a quit and in the event of a layoff, respectively.
Equations similar to (3.4) have frequently been estimated on samples of job losers, quits and in some cases combined samples, and the coefficients relating the wage gain to tenure and experience prior to the job change have been used to draw inferences about the returns to tenure.[21] However, the above discussion makes clear that one cannot use wage change equations to decompose wage changes associated with layoffs into the effect of lost human capital, losses in the value of general human capital, the change in the value of the match specific component, etc.. One must have a model of quits and layoffs to identify the wage parameters needed to draw conclusions about what is responsible for the wage changes associated with job mobility, or about the extent to which the coefficients b_2-d_2 and b_2-g_2 will be biased as estimates of the linear component of the return to tenure.
In AW we use a priori restrictions to help break the identification problem. We argue that the expected value of $\Delta\epsilon_{ij(t)}$ is an increasing function of tenure at the time of a quit and a decreasing function of tenure at the time of a layoff, controlling for experience at the start of the job (PEX). This would imply that $d_2 \geq 0$ and that $g_2 \leq 0$ and that $(b_2 - d_2) \leq b_2 \leq (b_2 - g_2)$. AW exploit the fact that in this case, coefficients for $-Q_{it}T_{it-1}$ and $-L_{it}T_{it-1}$ provide lower and upper bounds, respectively, for b_2. Since the other parameters are identified conditional on an estimate of b_2, we then compute a range of estimates for the other underidentified parameters as well.
In the next two sections, we investigate the sign of d_2 and g_2 and the form of (3.2) by first analyzing a simple model of quits, layoffs, and wages, and then simulating a version of the model. We also consider the likely relationship between ν_{ijt} and tenure at the time of a quit or layoff, which was ignored in the discussion of (3.4) above.

4. WAGE CHANGES ASSOCIATED WITH QUITS AND LAYOFFS : THEORETICAL CONSIDERATIONS

Let PV_{ijt} denote the present value of earnings for a worker currently in job j and ignore the effects of the stochastic component ν_{ijt}.

(4.1) $$PV_{ijt} = PV(PEX_{ij(t)}, T_{it}, \epsilon_{ij(t)}) .$$

The wage level equation corresponding to (3.1) implies that PV is a positive function of T_{it} and $\epsilon_{ij(t)}$. Let the utility U_{ijt} of job j be

$$U_{ijt} = PV_{ijt} + v_{ijt},$$

where v_{ijt} summarizes the value of nonwage aspects of job j for person i. Assuming for simplicity that v_{ijt} does not depend upon $\epsilon_{ij(t)}$ and is a nondecreasing function of T_{ijt}, then U_{ijt} is an increasing function of both T_{ijt} and $\epsilon_{ij(t)}$. A person quits if he receives an offer j' which provides a higher utility level than j

[21] Recent examples include Carrington (1990), Addison and Portugal (1989), and Topel (1990).

after allowing for mobility costs M.[22] That is

(4.2)

$$Q_{it} = 1 \quad \text{if } PV(PEX_{ij'(t)}, 0, \epsilon_{ij'(t)}) + v_{ij't} - PV(PEX_{ij(t)}, T_{it}, \epsilon_{ij(t)}) - v_{ijt} > M$$

$$Q_{it} = 0 \quad \text{otherwise}$$

In the above equation $PEX_{ij'(t)} = PEX_{ij(t)} + T_{it}$.
The expected value of $\Delta\epsilon_{ij(t)}$ in the event of a quit depends upon the joint distribution of $\epsilon_{ij(t)}$ and $\epsilon_{ij'(t)}$ conditional on the inequality above and $PEX_{ij(t)}$. Assume that the new offer distribution does not depend on the tenure level. Note that the left-hand side of the inequality is a negative function of T_{it} if tenure has a positive effect on the wage in the current job. It is a positive function of $\epsilon_{ij'(t)} - \epsilon_{ij(t)}$. As a result, the expectation of $\Delta\epsilon_{ij(t)}$ conditional on a quit is likely to be a positive function of T_{it}, since the quit condition is likely to be satisfied at high values of tenure only if $\Delta\epsilon_{ij(t)}$ is large. The relationship between the values of T_{it} and $\Delta\epsilon_{ij(t)}$ that lead to a quit depends positively on the effect of T_{it} on W_{it}.[23]
This is not the whole story however. Since the probability that a worker will have received a better offer by tenure level T_{it-1} is negatively related to $\epsilon_{ij(t-1)}$ for all tenure levels even if the true tenure effect on wages is 0, the distribution of $\epsilon_{ij(t-1)}$ given PEX_{it} and survival of the job through T_{it-1} periods is stochastically increasing in T_{it-1}. To see the implication of this, suppose that $(\epsilon_{ij(t-1)} | PEX_{it}, T_{it-1})$ has a log concave distribution and stochastically dominates $(\epsilon_{ij(t-1)} | PEX_{it}, T'_{it-1})$ if $T_{it-1} > T'_{it-1}$. Both are distributed independently of new offers $\epsilon_{ij'}$. Then

$$E\left\{ [(\epsilon_{ij(t-1)} | PEX_{it}, T_{it-1}) - \epsilon_{ij'}] \mid [(\epsilon_{ij(t-1)} | PEX_{it}, T_{it-1}) > \epsilon_{ij'}] \right\} >$$

$$E\left\{ [(\epsilon_{ij(t-1)} | PEX_{it}, T'_{it-1}) - \epsilon_{ij'}] \mid [(\epsilon_{ij(t-1)} | PEX_{it}, T'_{it-1}) > \epsilon_{ij'}] \right\}.$$

Consequently, the fact that jobs with high $\epsilon_{ij(t-1)}$ tend to last and are hard to improve upon means that T_{it-1} could be *negatively* related to $E(\Delta\epsilon_{ij(t)} | Q_{it}, PEX_{ij(t-1)}, T_{it-1})$.[24] A net positive relationship will arise when the true tenure effect on wages or the link between mobility costs and tenure is sufficiently positive. This is because the requirement that $\epsilon_{ij'}$ exceed $\epsilon_{ij(t-1)}$ plus the tenure related wage component is more stringent at higher tenure levels and will offset the above negative relationship induced by the outward shift in the distribution of $\epsilon_{ij(t-1)}$ among the surviving jobs.
The implications for the coefficient on the $Q_{it}T_{it-1}$ interaction terms in (3.2) and (3.4) are as follows. The linear term d_2 must be greater than 0 to insure a positive, monotonic relationship between $T_{ij(t)}$ and $E(\Delta\epsilon_{ij(t)} | Q_{it}, PEX_{ij(t-1)}, T_{it-1})$. The value of d_3, d_4, etc., may further constrain d_2. For example, if the coefficient d_3 on the quadratic term is sufficiently negative then the lower bound on d_2 that insures a monotonic relationship over the relevant range of tenure may be positive. However, if tenure has a negligible relation to wages and mobility costs, then tenure could have a negative relationship to $E(\Delta\epsilon_{ij(t)} | Q_{it}, PEX_{ij(t-1)}, T_{it-1})$ and d_2 could be negative.
We also have some comments on the relationship between $\Delta\epsilon_{ij(t)}$ and $PEX_{ij(t-1)}$. Since individuals with more experience prior to the start of the current job had more years in which to locate jobs in the right tail of the job offer distribution, the expected value of $\epsilon_{ij(t)}$ is a positive function of $PEX_{ij(t-1)}$, and one would expect that $PEX_{ij(t-1)}$ will have a negative partial effect on the expectation of $\Delta\epsilon_{ij(t)}$. However, job change costs may rise with total experience if a geographic move is involved. In this case, $PEX_{ij(t-1)}$ might have a positive partial effect on the expectation of $\Delta\epsilon_{ij(t)}$. Overall, the sign of the effect of $PEX_{ij(t-1)}$ on $\Delta\epsilon_{ij(t)}$ is ambiguous. We would expect it to be negative.[25]
We now turn to the relationship between $E(\Delta\epsilon_{ij(t)})$ and tenure and experience in the event of a layoff. We use a simple layoff model that is motivated by Hashimoto and Yu (1980) and Hall and Lazear (1984). Let V_{ijt} denote the value of worker i to firm j. This is a function of the discounted expected value of current and future

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22 The worker's value function should incorporate the options of future quits and the likelihood of a firm initiated layoff. Similarly, the firm's value function depends on the value of current productivity and wages and the expected future profits from the match, where future profits depend upon expectations about future wages and productivity, the option of laying off the worker in the future, and expected quit behavior. One implication is that the time varying productivity component, e_{ijt} (introduced below) should enter (4.1) even if the firm bears all of the productivity risk, with $\nu_{ijt} = 0$.

23 The relationship is re-enforced if mobility costs rise with total experience in a given geographic location. In this case, EX_{it} might have a positive partial effect on the expectation of $\Delta\epsilon_{ij(t)}$ in the event of a quit. The tenure term will pick up the effect on the expectation of $\Delta\epsilon_{ij(t)}$ of any increase in mobility costs with tenure or with experience. This is because we control for initial experience rather than actual experience which increases one for one with tenure.

24 See Burdett and Ondrich (1985) for the use of log concavity in a related context.

25 Also, more experienced workers are closer to retirement and thus when comparing jobs may give more weight (than younger workers) to wage losses from lost tenure relative to a given increase in $\epsilon_{ij(t)}$. Note that the discussion of the firm's layoff decision ignores the fact that time until retirement may affect the value of a worker to a firm even after tenure and the quality of the job match are controlled for.

productivity net of wage payments to the worker. The discount factor depends on the interest rate and the probability that the firm or the worker will terminate the match in the future. Productivity depends on EX_{it} and T_{it} as well as an individual specific productivity factor p_i, a match component $\omega_{ij(t)}$ and a time varying component e_{ijt}. Competition among firms implies that the general productivity components p_i and EX_{it} are fully reflected in wage rates and to a first approximation do not affect V_{ijt}. Workers and firms share in the returns to the match component. The wage component $\epsilon_{ij(t)}$ is the worker's share s_ω of $\omega_{ij(t)}$, with

$$\epsilon_{ij(t)} = S_\omega \omega_{ij(t)} .$$

We sometimes write $\omega_{ij(t)}$ as ω_{ij} for simplicity. Consequently, V_{ijt} is a positive function of ω_{ij}. In general workers may also share in the returns to the time varying component e_{ijt}, and this sharing may be reflected in ν_{ijt}. However, we assume that because of risk aversion or costs of re-contracting and information (see Hall and Lazear and Hashimoto) firms bear most of the risk associated with e_{ijt}. This implies that V_{ijt} is a positive function of e_{ijt}. (In the simulations below we vary our assumptions about how much of the time varying component is shared.) Finally, assume that firms have a share in the costs and returns to specific capital investments, so V_{ijt} is a positive function of T_{it}. This discussion suggests that the value of the worker to the firm may be written as

$$V_{ijt} = V(\omega_{ij}, T_{it}, e_{ijt}) .$$

The partial derivatives of V with respect to all three arguments are positive.

The firm lays off the worker if V_{ijt} falls below the cost of terminating the worker.[26] Given that V_{ijt} increases with T_{it} and V_{ijt} must be positive at the time the worker is hired, a layoff occurs in t only if (1) e_{ijt} falls sufficiently below its value at the time the worker is hired and (2) the match had not already ended due to a quit or layoff in an earlier period. The probability that a layoff occurs at time t is a negative function of ω_{ij} regardless of the value of tenure at t. The distribution of ω_{ij} and $\epsilon_{ij(t)}$ is increasing in prior experience, but we hold that constant. For any tenure value the quit probability is also a negative function of $\epsilon_{ij(t)}$ and, therefore, a negative function of ω_{ij}. Consequently both quit and layoff behavior tends to select out the lower values of ω_{ij} and $\epsilon_{ij(t)}$ from the distribution of these variables conditional on initial experience. It

[26] Termination costs include severance pay and unemployment insurance and other factors. However, the layoff cost is not necessarily equal to the shadow price such that layoffs occur only if they maximize the joint utility of the worker and the firm.

follows that the distribution of ω_{ij} and thus $\epsilon_{ij(t)}$ conditional on $PEX_{ij(t)}$ and T_{it} is increasing in T_{it} for the subsample of jobs which end in a layoff in t as well as for the subsample which survive additional periods.

Layoffs occur if e_{ijt} falls sufficiently given the values of $\epsilon_{ij(t)}$ and T_{it}. Following the layoff the worker locates a new job j'. Under the assumption (mentioned previously) that the offer distribution does not depend on T_{it} the above discussion suggests that $E(\epsilon_{ij'(t)} - \epsilon_{ij(t)} | L_{it}, PEX_{it}, T_{it})$ is a negative function of T_{it}.

The above discussion is not complete under the standard assumption that firms share in the returns as well as the costs of specific capital investment. In this case, productivity net of wages will be increasing in tenure holding everything else constant. Consequently, the higher tenure, the lower ω_{ij} and e_{ijt} must be for profits on the worker to become negative. Since $\epsilon_{ij(t)}$ is positively related to ω_{ij}, the implication is that for a given value of e_{ijt} the critical value of $\epsilon_{ij(t)}$ below which a layoff occurs will fall with tenure. The value of $\epsilon_{ij(t)}$ may be such that a job match is marginal from the point of view of the firm in the first few years. If the match survives the first few years due to a set of positive or 0 shocks to productivity, the accumulation of firm specific capital will make it unlikely that the match will end in a layoff later. This tends to induce a positive relationship between tenure and $E(\Delta\epsilon_{ij(t)} | L_{it}, PEX_{ij(t-1)}, T_{it-1})$. To the extent that the distribution of e_{ijt} spreads out with tenure, as more relatively permanent shocks accumulate, this selection effect is mitigated. Further, it is limited because job matches with values of $\epsilon_{ij(t)}$ that would result in a layoff after tenure has been accumulated are unlikely to survive the first few years of the match. Consequently, we expect based on this discussion that $E(\Delta\epsilon_{ij(t)} | L_{it}, PEX_{ij(t-1)}, T_{it-1})$ will be negatively related to T_{it-1}. The implication for the parameters g_1, g_2, g_3, etc., in the approximation (3.2) is that they should be consistent with a negative monotonic relationship. This implies that g_2 will be negative.

The partial effect of prior experience $PEX_{ij(t)}$ is likely to be negative because of job search. To see this, note that job shopping over the course of a career implies that at every tenure level the expected value of $\epsilon_{ij(t)}$ is a positive function of $PEX_{ij(t)}$, for reasons discussed earlier. However, in the event of a layoff the value of $\epsilon_{ij'(t)}$ associated with the job accepted by the worker does not rise with experience. Following a layoff the worker takes the best offer received during the period of job search even though it may be dominated by the ϵ_{ij} that are associated with jobs held by the worker in the past but are no longer available to him.

Variation in ν_{ijt}

Changes in e_{ijt} may induce wage changes reflected in productivity shifts which are shared between the firm and worker. One may add ν_{ijt} to the value function PV_{ijt} and use (4.2) to argue that the expected value of $\Delta\epsilon_{ij(t)} + \Delta\nu_{ijt}$ is an increasing function of T_{it-1} in the event of a quit when the tenure slope of wages is substantial. The basic idea is that for any given value of $\Delta\epsilon_{ij(t)}$ the critical value of $\Delta\nu_{ijt}$

needed to make a quit worthwhile is an increasing function of T_{it-1}. These wage changes are induced by shifts in e_{ijt} that are partially passed on to W_{it}.
In the case of layoffs we do not have a clear intuition about the relationship between $\Delta\nu_{ijt}$ and T_{it-1}. First, to the extent that wages are heavily influenced by firm specific shocks to productivity, layoffs are unlikely to result from them. Second, to the extent that firms provide wage insurance against shocks which affect productivity of workers not only in the current firm but in other firms, $E(\Delta\nu_{ijt})$ could be a negative function of tenure, as wages in the spot market for new hires are not protected from a shift in product demand or productivity affecting an industry or occupation.[27]
One may reinterpret the parameters d_2 and g_2 in equation (3.4) as measuring the effect of T_{it-1} on the conditional expectation of $(\Delta\epsilon_{ij(t)} + \Delta\nu_{ijt})$ in the event of a quit and in the event of a layoff. If the combined effect of T_{it-1} on the two variables is positive for a quit and nonpositive for a layoff, then one may still obtain bounds on b_2 from the coefficients on $-Q_{it}T_{it-1}$ and $-L_{it}T_{it-1}$. The simulations support this view.
Since $\Delta\nu_{ijt}$ is not constant within the job, it may bias the combined return to a year of tenure and experience if the mean of $\Delta\nu_{ijt}$ is not zero for stayers. It may also bias estimates of the nonlinear tenure and experience terms in (3.4) if $E(\Delta\nu_{ijt})$ varies systematically with tenure. Above we argued that $E(\Delta\nu_{ijt})$ is likely to be positive for stayers but may decline with tenure. We explore the issue below.

5. A SIMULATION MODEL

In this section we present a simple simulation model of productivity, wages, and turnover that is in the spirit of the model sketched above. We then simulate the model for various parameter values and draw conclusions about the form of $E(\Delta\epsilon_{ij(t)}|Q_{it},PEX_{ij(t-1)},T_{it-1})$, $E(\Delta\epsilon_{ij(t)}|L_{it},PEX_{ij(t-1)},T_{it-1})$, $E(\Delta\nu_{ijt}|Q_{it},PEX_{ij(t-1)},T_{it-1})$ and $E(\Delta\nu_{ijt}|L_{it},PEX_{ij(t-1)},T_{it-1})$. We also examine the relationship between $\Delta\nu_{ijt}$ and tenure for stayers.
Assume the marginal product of worker i in firm j in year t is

(5.1) $$P_{ijt} = Z_{ijt}\Gamma + B_0EX_{it} + B_2T_{it} + B_4OJ_{it} + \epsilon_i + \omega_{ij(t)} + u_{it} + e_{ijt},$$

where ϵ_i is a fixed individual specific productivity component. We consider the case in which e_{ijt} is a random walk with initial condition 0 on any new job match and an innovation that is $N(0,\sigma_e^2)$. We assume that the fixed job specific productivity component ω_{ij} is drawn from a normal distribution with mean μ_ω and variance σ_ω^2 that is truncated at 0.
Assume that wages are determined according to

[27] Our simulation model does not allow for this possibility.

(5.2) $$W_{ijt} = Z_{ijt}\Gamma + B_0EX_{it} + S_T[B_2T_{it} + B_4OJ_{it}] + \epsilon_i + S_\omega\omega_{ij(t)} + u_{it} + S_e e_{ijt},$$

where S_T is the worker's share of the returns to seniority, S_ω is the worker's share of the returns to the job match component of productivity, and S_e is the worker's share of the time varying match specific component of productivity. The term ν_{ijt} in (3.1) is equal to $S_e e_{ijt}$.
We assume that wages fully reflect changes in productivity associated with labor market experience EX_{it}, the person specific productivity component ϵ_i, observed person specific variables in Z_{ijt} and the unobserved person specific component u_{it}.[28] Each period (including the first period) workers costlessly receive an outside offer with job match component $\epsilon_{ij'}$, where $\epsilon_{ij'} = S_\omega\omega_{ij'}$ and the ω are distributed as discussed above. Since the effect of tenure on wages is linear after the first year and the expected value of the innovations in the random walk components on the two jobs is 0, it follows that after the first year on the alternative job the expected difference in wages on the current job and the alternative job is

(5.3) $$\epsilon_{ij'} - \epsilon_{ij} - S_e e_{ijt} - S_T B_2 T_{it}$$

We assume that the worker quits if

$$\epsilon_{ij'} - \epsilon_{ij} - S_e e_{ijt} - S_T B_2 T_{it} - (1-\delta)S_T B_4 > 0$$

where the discount parameter δ on the increment in wages following the first year on the job is included because the worker may not remain on the new job to experience the increase. This quit rule is only an approximation, as we discuss below.
The firm lays off the worker if productivity in the current period minus the wage rate becomes negative:

$$P_{ijt} - W_{ijt} = (1-S_T)[B_2T_{it}+B_4OJ_{it}] + (1-S_\omega)\omega_{ij(t)} + (1-S_e)e_{ijt} < 0 .$$

In addition, we also allow for exogenous layoffs that occur with probability .019 if a layoff or a quit does not occur for other reasons. We think of these as business failures and assume that they are independent of P_{ijt}. If the firm plans a layoff and the worker plans a quit, we treat this as a quit. The quit rule is only an approximation to the rule that maximizes expected income given the possibility of a future quit or layoff on the current job or on the alternative job. For example, suppose S_e is 0. A worker with a high

[28] This may not be the case if firms provide insurance against health related or other changes in productivity or if the firm has private information about the worker's general productivity.

value of $\epsilon_{ij(t)}$ who knows that a layoff is likely because e_{ijt} is very negative may accept an offer that is above the mean for $\epsilon_{ij(t)}$, but below $\epsilon_{ij(t)}$ rather than run the risk that a layoff will occur later at a time when he does not have a good outside offer.[29]

Simulation Results

We simulated the model for various sets of parameter values.[30] The results are presented in Table 4. Columns 1 to 5 list the parameter values of each experiment. S_ω is the worker's share of the returns to the job match component of productivity, and S_e is the worker's share of the time varying match specific component of productivity. We set S_T to .5 and δ=.85 in all of the simulations. Column 6 and 7 report the estimated quit rate and the estimated layoff rate. Cases in which both a quit and a layoff are indicated are counted as quits but not layoffs. Column 8 reports the endogenous layoff rate, including cases in which the model implies that the worker would quit. The exogenous layoff rate is set to .019 in all of the simulations. The numbers in bold in columns 9-18 are the mean of $\Delta\epsilon_{ij(t)} + \Delta\nu_{ijt} = S_\omega\Delta\omega_{ij(t)} + S_e\Delta e_{ijt}$. The second set of numbers in columns 9-18 are the job match gain, $\Delta\epsilon_{ij(t)} = S_\omega\Delta\omega_{ij(t)}$. When S_e is 0, $\Delta\epsilon_{ij(t)} + \Delta\nu_{ijt}$ reduces to $\Delta\epsilon_{ij(t)}$, and therefore the first 8 models contain only one row each.

Our main results are as follows. First, when the effect of tenure on productivity is 0 so that wages do not rise with seniority, (model 1, 5, 9, 13), there is a negative relationship between tenure at the time of a quit and $\Delta\epsilon_{ij(t)} + \Delta\nu_{ijt}$ in all instances and between tenure and $\Delta\epsilon_{ij(t)}$ in all instances except model 13, where the relationship is strongly negative when tenure is between 0 and 10 but turns positive when tenure is between 10 and 20. These results are basically consistent with the theoretical argument above for the case in which mobility costs and wages are unrelated to tenure. We have also estimated the 16 specifications with S_T set to .25 (instead of .5), so that the effect of tenure on wages is small even in the case in which B_4 is .1 and B_2 is .02. (Recall that $b_2 = S_T B_2$.) In this case the relationship between tenure and the expected wage gain associated with a quit is small in absolute value and often negative.

Second, when the effect of tenure on productivity is positive, so that wages do rise with seniority, the overall gain $\Delta\epsilon_{ij(t)} + \Delta\nu_{ijt}$ is a positive function of tenure at the time of a quit once tenure is greater than 0. The same is true of the fixed job match component $\Delta\epsilon_{ij(t)}$ in all cases except row 14, where the relationship is initially negative and then turns up. The magnitude of the relationship between $\Delta\epsilon_{ij(t)} + \Delta\nu_{ijt}$ is positively related to the effect of tenure on the wage rate, which is determined by S_T times B_2 and S_T times B_4. For example, the mean of the job match gain for a quit with 10 years of seniority is between .06 and .10 when the effect of tenure is 0, between .17 and .23 when the product of S_T and the linear tenure slope B_2 is .01 and the product of S_T and first year increase in productivity (B_4) is .05. The gain is between .38 and .44 when S_T times the linear tenure slope is .03 and S_T times the effect of the first year on the job is .05. The increase is approximately equal to the increase in the value of tenure that is given up in a quit. The relationship between $\Delta\epsilon_{ij(t)}$ and tenure is also positively related to the effect of tenure on the wage rate.[31]

The other main result is that the expected values of both $\Delta\epsilon_{ij(t)}$ and $\Delta\epsilon_{ij(t)} + \Delta\nu_{ijt}$ in the event of a layoff are negatively related to tenure on the previous job for all of the specifications through ten years of seniority, although there is a slight increase in the gain between 10 years of seniority and 20 years for several of the models. We do not understand the reason for this up turn, but suspect that it is related to the mix of endogenous and exogenous layoffs at the various tenure levels. Relatively few endogenous layoffs occur at high tenure levels. Not surprisingly, the endogenous layoff rate and the quit rate are strongly affected by the sharing parameters and the tenure parameters.

The simulation model could be generalized in many ways. However, the basic finding for the cases that we have examined is that the relationship between wage growth and tenure understates the returns to tenure in the event of a quit except when the return to tenure is close to 0. The return to the first year of tenure may be overstated. The relationship between wage growth and tenure will overstate the returns to tenure in the event of a layoff, except possibly at high tenure levels. These conclusions are basically consistent with the theoretical arguments made above about the sign of d_2 and g_2. They provide support for our use of these sign restrictions in AW to compute a range of estimates for all of the unidentified parameters from parameters of (3.4) that are identified directly.

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29 We have been able to get closed form solutions to the optimal quit and layoff rules only in the case in which careers last at most 3 periods. We suspect that closed form solutions will be difficult to obtain in multiperiod cases unless the distributions of the random variables are severely restricted. A more promising approach is to use numerical methods to solve for the layoff and quit rules in the multiperiod case, but we leave this formidable undertaking to future research. Note that we are ignoring nonpecuniary preferences for jobs and assuming mobility costs and layoff costs are 0. These assumptions should be relaxed in future work.

30 For each set of parameter values we use the model to generate data on 37 year careers for 5,000 individuals. The results in columns 9 to 18 of the table are based on separate regressions for quits and layoffs of the generated data on $\Delta\epsilon_{ij(t)}$ and $\Delta\nu_{ijt}$ on an intercept, a cubic in T_{it-1}, a cubic in $PEX_{ij(t-1)}$, and OJ_{t-1}.

31 An increase in the worker's share S_ω of the match specific error component from .5 to .8 tends to increase the gain in $\Delta\epsilon_{ij(t)} + \Delta\nu_{ijt}$ from quitting as well as the gain in $\Delta\epsilon_{ij(t)}$, which is not surprising. (Compare models 1-4 with 5-8 and 10-12 with 13-16). However, the tenure profile of the job match gain is not very sensitive to S_ω.

Table 4 :
Simulation Results

S_T=.5, ω_{ij} drawn from N(.25,.25) truncated at 0 for all models.

Model	Share[a,b] Params. S_ω 1	S_e 2	σ_e [c] 3	Tenure[d,e] Params. OJ B_4 4	T B_2 5	Turnover Rates[f] Quit 6	Layoff 7	Layoff Endog. 8
1	.5	.0	.09	.0	.00	.126	.034	.028
2	.5	.0	.09	.1	.02	.123	.028	.031
3	.5	.0	.09	.1	.06	.062	.023	.012
4	.5	.0	.03	.1	.02	.119	.017	.002
5	.8	.0	.09	.0	.00	.170	.086	.107
6	.8	.0	.09	.1	.02	.143	.048	.056
7	.8	.0	.09	.1	.06	.082	.031	.024
8	.8	.0	.03	.1	.02	.120	.017	.002
9	.5	.5	.09	.0	.00	.126	.017	.003
10	.5	.5	.09	.1	.02	.128	.017	.008
11	.5	.5	.09	.1	.06	.068	.018	.002
12	.5	.5	.03	.1	.02	.120	.017	.000
13	.8	.5	.09	.0	.00	.123	.032	.033
14	.8	.5	.09	.1	.02	.124	.018	.008
15	.8	.5	.09	.1	.06	.077	.018	.002
16	.8	.5	.03	.1	.02	.120	.017	.000

a) S_ω is the worker's share of the returns to the job match component of productivity.
b) S_e is the worker's share of the time varying match specific component of productivity.
c) σ_e is the standard deviation of the time varying productivity shock.
d) S_T is the worker's share of the return to tenure.
e) B_2 is the effect of tenure T on productivity. The wage parameter b_2 is $S_T B_2$. B_4 is the effect of OJ (tenure greater than 1) on productivity. The wage parameter $b_4 = S_T B_4$.

Table 4 : Continued

Mean of $\Delta\epsilon_{ij(t)} + \Delta\nu_{ijt}$ [f]
Mean of $\Delta\epsilon_{ij(t)}$

Quits: Tenure on Previous Job 0 (9)	1 (10)	5 (11)	10 (12)	20 (13)	Layoffs: Tenure on Previous Job 0 (14)	1 (15)	5 (16)	10 (17)	20 (18)
.11	.09	.08	.07	.07	-.02	-.06	-.12	-.16	-.18
.17	.14	.16	.20	.30	.08	-.07	-.13	-.17	-.18
.18	.17	.27	.40	.68	.07	-.08	-.11	-.12	-.12
.17	.14	.16	.20	.30	-.02	-.10	-.14	-.17	-.17
.17	.14	.11	.10	.11	-.04	-.14	-.23	-.29	-.31
.24	.19	.19	.22	.34	.01	-.14	-.24	-.30	-.29
.25	.22	.30	.44	.83	.04	-.11	-.18	-.22	-.21
.24	.18	.19	.23	.33	-.08	-.15	-.22	-.26	-.27
.10	.08	.07	.06	.06	-.10	-.12	-.19	-.24	-.31
.11	.09	.06	.04	.04	-.08	-.10	-.12	-.13	-.14
.16	.12	.13	.17	.28	-.06	-.12	-.19	-.24	-.27
.16	.12	.10	.09	.10	-.04	-.09	-.12	-.14	-.15
.17	.15	.24	.38	.61	-.04	-.11	-.15	-.17	-.16
.17	.15	.17	.19	.22	-.03	-.09	-.11	-.12	-.11
.17	.13	.15	.19	.30	-.05	-.10	-.15	-.18	-.18
.17	.13	.14	.18	.23	-.04	-.09	-.15	-.16	-.16
.17	.14	.11	.09	.10	-.06	-.10	-.19	-.26	-.34
.17	.15	.12	.11	.13	-.04	-.11	-.19	-.24	-.24
.24	.17	.18	.21	.31	-.10	-.15	-.23	-.30	-.35
.24	.17	.16	.15	.17	-.08	-.14	-.21	-.25	-.24
.24	.20	.29	.42	.71	-.09	-.16	-.21	-.25	-.24
.24	.21	.24	.30	.40	-.08	-.15	-.17	-.19	-.19
.24	.18	.19	.23	.33	-.10	-.16	-.24	-.28	-.29
.24	.18	.19	.22	.31	-.09	-.15	-.22	-.27	-.27

f) Columns 6-8 report the estimated quit rate, overall layoff rate, and endogenous layoff rate. The exogenous layoff rate is set to .019 for all models. The numbers in bold in columns 9-18 are the mean of $\Delta\epsilon_{ij(t)} + \Delta\nu_{ijt} = S_\omega\Delta\omega_{ij(t)} + S_e\Delta e_{ijt}$. The second set of numbers in columns 9-18 for models 9-16 are the job match gain, $\Delta\epsilon_{ij(t)} = S_\omega\Delta\omega_{ij(t)}$. When S_e is 0 (models 1-8), $S_\omega\Delta\omega_{ij(t)} + S_e\Delta e_{ijt} = \Delta\epsilon_{ij(t)} + \Delta\nu_{ijt} = \Delta\epsilon_{ij(t)}$, so we display only one set of numbers.

We also examined the effect of $\Delta\nu_{ijt}$ on within job wage growth to get at the issue of whether there is likely to be upward or downward bias in the intercept of wage growth for stayers and in the nonlinear tenure parameters. The intercept provides an estimate of the sum $b_0 + b_2$ of the linear experience and tenure slopes. One can examine the implications for bias in estimates of the return to tenure for estimation procedures that allocate most of the upward bias in $b_0 + b_2$ to the tenure parameter b_2.[32] The basic result is that the return to tenure tends to be overstated. The intuition is that large negative innovations in ν_{ijt} tend to lead to quits or layoffs. This sample selection induces a positive bias in wage growth within jobs. The combined effect is to overstate the return to 10 years of tenure by a small amount. For example, in model 11 the actual return to 10 years of tenure is .35, and the upward bias is .04. For this model $E(\Delta\nu_{ijt})$ is negatively related to tenure, as suggested by the discussion above. In model 9, the actual return 10 years of tenure is 0, and the upward bias is .04. The fact that magnitudes of the bias are relatively small suggests that failure of AW and other studies to deal with time varying job specific error components may not be a serious problem. However, a much more exhaustive simulation study that considers alternative processes for ν_{ijt} such as those discussed by Bull and Jovanovic will be required before conclusions should be drawn.

6. DISCUSSION AND CONCLUSIONS

In this paper we discuss the problems of identifying the role of the tenure, experience, and mobility in determining wage growth in the context of an empirical summary of the patterns of within job wage growth by experience, tenure and wage growth, and the patterns of across job wage growth by experience, tenure, and the type of job change. We note in section II that the wage changes of those who quit or are laid off reflect the combined influence of lost seniority and the difference across jobs in the match specific components of wages. Consequently, one needs a model of mobility to identify the returns to seniority and the relationship between "job match gain" from mobility, and tenure and experience at the time of the job change.

A priori information about the relationship between "job match gain" and tenure and experience is helpful in breaking the identification problem inherent in wage growth equations such as (3.4). To this end we analyze a simple structural model of wages, quits and layoffs. The analysis suggests that if the effect of tenure on wages is substantial, then the relationship between the change in the job match component and tenure at the time of a quit will be positive, while the relationship between the change in the job match component and tenure at the time of a layoff will be negative. With these sign restrictions one can find a range of estimates for all of the unidentified parameters from the regression parameters that are identified.

There is a long research agenda. We believe that simulation models are a very fruitful way to analyze the complicated selection problems that arise in studies of wage dynamics and mobility. The prototype model can be modified in several directions. The model should incorporate mobility costs and both fixed and time varying nonpecuniary job characteristics. Quit and layoff rules that are optimal given the wage and productivity processes should replace the ad hoc rules that we work with. One might also experiment with simulations based on alternative theories of separations such as Mortensen (1988) or McLaughlin (1991). The model should also be modified to allow for heterogeneity in experience and tenure slopes. Such variation has been emphasized in both formal and informal discussions of earnings dynamics.[33] Finally, the matching literature and recent papers by Gibbons and Katz (1989) and Farber and Gibbons (1991) stress the role of information revelation in wage growth within firms, and the wage gains associated with layoffs.

The most interesting and ambitious extension would be to formally estimate a greatly expanded version of the simulation model of wages and mobility by choosing parameters that fit the empirical distribution of quits, layoffs, wages, tenure, and experience documented in the paper.

In AW we have already pursued the most obvious project, which is to estimate (3.4) and then analyze the implications of the estimates for the returns to tenure and experience, job match gains as a function of experience and tenure, and the relative contribution of experience, tenure, and job match gains to wage growth over a career. We close with a brief summary of the results. First, we find a large return to general labor market experience that is independent of job shopping. Second, we conclude effect of 10 years of tenure on the log wage that is probably above the .07 estimate suggested by Altonji and Shakotko (1987) but far below OLS estimates for our sample and Topel's (1991) estimate of .246. Third, our preferred estimates suggest that quits result in substantial job match gains when prior experience is less than 10. They also imply that layoffs are associated with substantial job match losses for workers who have been on the job over a year.

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[32] Both Altonji and Shakotko's (1987) estimator and Topel's (1991) estimator would tend to allocate the bias to b_2, because they use cross person and cross job variation in experience to identify b_0 and within job variation in tenure to identify b_2. We are less clear about the estimator used by Abraham and Farber (1987).

[33] See, for example, Mincer and Jovanovic (1981), Jovanovic (1979) and Bartel and Borjas (1981).

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