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DO WAGES RISE WITH JOB SENIORITY? A REASSESSMENT

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ABSTRACT

We provide new estimates of the return to job seniority using data similar to that used by Abraham and Farber (1987), Altonji and Shakotko (1987) and Topel (1991) as well as a new PSID sample. Topel's use of a wage and a tenure that refer to different years, his use of the Current Population Survey to detrend the PSID, and differences between Altonji and Shakotko's estimator and Topel's estimator explain the fact that Topel obtains much larger estimates. The evidence from the data used by AS and Topel points to an effect of ten years of tenure on the log wage equal to .11, which is above AS's preferred estimate of .066 but far below Topel's estimate. However, this estimate is probably biased upward by the wage measure used in all three studies. We also obtain a modest estimate of the return to seniority using data for 1983-1991.

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1. Introduction

Whether or not seniority has a large effect on wage growth has been the subject of much recent controversy. At stake is the empirical relevance of theories emphasizing a role for worker financed firm specific capital in wage growth and turnover behavior, as well as several models of wages that emphasize the use of deferred compensation as an incentive, insurance, or sorting mechanism. (See Carmichael (1989) and Hutchens (1989)). The size of the returns to seniority are also important in assessing the costs of dislocation from work, a subject of much policy discussion and research over the past 10 years.[1] Perhaps most importantly, the strong relationship between seniority and wage rates in a cross section of workers is a prominent feature of the earnings distribution that needs to be understood.

As data on seniority and large scale panel data sets became available in the 1970s, several researchers, with Mincer and Jovanovic (1981) as one prominent example, concluded that there is a large return to seniority based on the fact that there is a strong positive relationship between tenure and wage rates in cross sectional or pooled cross section-time series data. Several papers in the mid 1980s, with Altonji and Shakotko (1987) (hereafter, AS) and Abraham and Farber (1987) (hereafter, AF) as widely cited examples (see also Topel, 1986; Marshall and Zarkin, 1986; and Williams, 1991) challenged this conclusion, and the literature appeared to be moving towards a new consensus that returns to seniority are relatively small in the U.S. However, an influential paper by Robert Topel (1991) argues that AS and AF reach the wrong conclusions because of inappropriate methods and/or data. He argues that the returns to tenure are large—on the order of what one obtains from a simple OLS regression.

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[1] Recent studies that examine the wage losses from layoffs and discuss the distinction between the value of lost seniority and the job match loss include Altonji and Williams (1996), Hamermesh (1987), Addison and Portugal (1989), Kletzer (1989), Jacobson, LaLonde and Sullivan (1993a and b), Topel (1990), Carrington (1993), Ruhm (1991), and Neal (1995). Jacobson, LaLonde and Sullivan (1993b) survey the literature on dislocated workers.

Topel's results have been widely cited and appear to have been accepted by many researchers.[2] For example, in their recent monograph on earnings, Polachek and Siebert (1993) state, "Apparently the dramatic results of Altonji and Shakotko are in part due to mismeasuring tenure...Thus the specific capital model appears to survive the challenge." Devine and Kiefer (1991) summarize the results from the various studies, including AS, AF, and Topel (1991) and state "The findings have gone full circle and beyond—the most recent results suggest that the early OLS results attributed too small a share of wage growth to tenure and too much to labor market experience." Other researchers, such as Felli and Harris (1996), cite the three studies and state that "Whether wages increase with tenure...is an open question...".

In this paper, we re-examine the evidence. Using primarily a replication of Topel's sample, we explore the role of the treatment of secular trends, the timing of the tenure and wage data, functional form, the measures of tenure, differences in the estimators, and the samples used. In section 2 we present the basic model used by AS, AF, and Topel as well as the econometric methods used. In Section 3 we discuss our replication of Topel's sample and main results. Section 4 shows that the secular trend in wages in Topel's sample is larger than the trend in the CPS based wage index used by Topel to control for economy wide wage growth. Topel's treatment of the secular trend leads to a large positive bias in the AS estimator and a smaller positive bias in his estimator. In Section 5 we present evidence that his use of wages in year t-1 with seniority from year t also leads to a substantial positive bias. In Section 6 we find that differences in the functional form used by AS and Topel are not important. In Section 7 we present new evidence on the issue of downward bias from measurement error and review the impact of measurement error on the two studies. In Section 8 we discuss differences between the estimators and revisit Topel's test of whether his estimator is sensitive to bias from individual heterogeneity.

In Section 9 we summarize our findings and draw conclusions based on estimators and data used by AS and Topel. Our main conclusion is that the returns to seniority are modest, and much closer to the results of AS and AF than Topel. While the increase in the wage from ten years of seniority is probably larger than AS's

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[2] Topel's 1991 paper and the earlier unpublished drafts were cited 65 times between 1987 and 1995. There were 89 citations to AS and 108 to AF during this period.

preferred estimate of 6.7%, it is far below Topel's estimate of 28% and OLS estimates of 35%. We find that the main differences between the studies arise from Topel's use of a time trend that is substantially below the trend in his sample, and his use of year t-1 earnings with year t seniority. However, after one corrects these problems one finds, in contrast to Topel's conclusions, that the estimators used also matter. AS's instrumental variables estimator usually leads to a lower estimate of the return to seniority than the two-step estimator proposed by Topel. This gap narrows when we apply a crude bias correction to the AS estimator. We do not see a compelling case in favor of one approach over the other, but do show that while the estimated tenure effects from both estimators are biased down by job match heterogeneity, the Topel estimator is substantially upward biased by individual heterogeneity. For the replicated Topel data we conclude that 10 years of tenure raises the log wage rate by about .11, and this value is probably biased upward by problems with the hourly wage measured used by AS, AF and Topel. In contrast to Devine and Kiefer's summary of the literature mentioned above, we find that OLS is subject to a large upward bias and should not be used to estimate the return to tenure

The paper continues in Section 10, where we revisit Topel's finding that relaxing certain restrictions in the AF estimator leads to large OLS-like seniority returns. We show that his conclusions are very sensitive to the linear functional form that he (and AF) used and (to a lessor extent) his use of the wage in year t-1 with tenure in year t.

In section 11 we present estimates based on a new PSID extract for 1975-1982 and 1983-1991. We do so because the tenure and wage data are better for these years (particularly from 1981 on) and it is possible, given dramatic changes in the returns to schooling, experience, and ability, that the returns to tenure and the relative biases in the estimators may have changed as well. The results suggest that the return to tenure may have increased, but it is still modest. The estimates for our preferred wage measure point to a return to ten years of tenure of about .08, but are higher for the wage measure used in the earlier studies. In sections 12 and 13 we briefly discuss evidence from other recent studies and summarize our conclusions about the value of job seniority.

2. Background to AS and Topel

2.1 The Wage Model

Many studies of the returns to seniority, including AS, AF, and Topel, work with the basic wage model

$$(2.1) \quad W_{ijt} = \beta_0 t + \beta_1 X_{ijt} + \beta_2 T_{ijt} + \epsilon_{ijt} ,$$

where W_{ijt} is the log real wage of person i in job j in period t, X_{ijt} is total labor market experience, and T_{ijt} is tenure with the employer. We sometimes suppress subscripts where the meaning is clear. All variables are deviations from sample means. The equation abstracts from a set of control variables, and from nonlinear terms in experience and tenure that all three studies add in the empirical specifications. This makes it easier to compare the estimators and analyze biases.

The error term is decomposed as

$$(2.2) \quad \epsilon_{ijt} = \mu_i + \phi_{ij} + \eta_{ijt} + u_{it} ,$$

where μ_i is a fixed individual specific error component, u_{it} is the sum of measurement error in the wage and a person specific component that affects wages at all employers, ϕ_{ij} is a fixed job match specific error component, and η_{ijt} is a time varying job match specific component. AS, Topel and AF all ignore u_{it} on the grounds that it is unlikely to be related to turnover behavior. AS assume movements in η_{ijt} are small or transitory and thus unlikely to have a strong relationship with turnover behavior. Topel argues that his analysis will be insensitive to η if it is a random walk and shows that the data are consistent with this.[3]

The key parameters of interest are β_1 and β_2, where β_1 is the partial effect of an extra year of experience on the wage, and β_2 is the partial effect of tenure. The parameter β_0 is an economy wide trend in real wages. Many studies have used OLS to

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[3] We ignore η in most of the comparison between the AS and Topel estimators. However, modifying AS's estimator in a way that should make it less sensitive to η if it is a random walk has little effect on the results. See Table 5 and footnote 27. Adding heterogeneity in the experience slope β_1 that is uncorrelated with turnover will not affect any of the estimators. We rule out person specific or job match specific heterogeneity in β_2, which is likely to be negatively related to T_{ijt}, and a positive source of bias in all three estimators. Topel presents evidence that this heterogeneity is not important for his analysis. We have not revisited this issue. In constrast, Abowd, Kramarz and Margolis (1994) show that there are differences in tenure slopes among a set of French firms.

estimate these parameters, and they consistently find large returns to seniority. For example, AS and Topel report that 10 years of seniority raises the log wage by .267 and .300 respectively. However, using OLS to estimate β_1 and β_2 is inappropriate since both experience and tenure are likely to be correlated with the unobserved individual and job match heterogeneity. For example, tenure will be positively correlated with μ_i in the likely event that individuals with low productivity (low μ_i) have high quit and layoff propensities.[4] Individual heterogeneity associated with μ_i will bias OLS estimates of the wage-tenure profile upward.

To better understand the biases that arise from unobserved individual and match heterogeneity, we follow Topel and specify auxiliary regressions between the unobserved components and experience and tenure. Consider first the fixed job match error component ϕ_{ij}, and let the auxiliary regression be

$$\phi_{ij} = b_1 X_{ijt} + b_2 T_{ijt} + \xi_{ijt} . \tag{2.3}$$

Both AS and Topel discuss the likely signs of b_1 and b_2. First, matching models and conventional search models (e.g., Burdett, 1978) imply that job shopping over a career will induce a positive correlation between X_{ijt} and ϕ_{ij}, suggesting that b_1 is positive. Second, workers will be less likely to quit high wage jobs than low wage jobs.[5] Furthermore, if firms share in the returns to a good match, ϕ_{ij} will be negatively correlated with the layoff probability. This suggests that tenure is positively correlated with ϕ_{ij} and b_2 is positive. However, Topel notes that the selection induced by voluntary job changes will lead low tenure values to be associated with large values of ϕ_{ij}, so b_2 may be negative. Therefore, the sign of b_2 is ambiguous.

The problem of individual heterogeneity may be analyzed similarly. Consider the auxiliary regression

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[4] See AS for evidence that estimates of μ_i and ϕ_{ij} enter logit models for both quits and layoffs with negative signs. One of AF's key findings is that completed job tenure has a strong positive association with the level of wages on a job.

[5] The existence of differences in match quality across firm-worker pairs (see Jovanovic, 1979; and Johnson, 1978), the presence of noncompetitive elements in the wage structure, and differences across firms in the optimal compensation level for a given type all imply that individual workers face a distribution of wages. See Groshen (1991), Jacobson, LaLonde and Sullivan (1993) and Abowd, Kramarz, and Margolis (1994) for evidence of firm specific wage components.

$$(2.4)\quad \mu_i = c_1 X_{ijt} + c_2 T_{ijt} + \omega_{ijt} .$$

Characterizing c_1 and c_2 requires additional assumptions. Both AS and Topel assume that

$$(2.4a)\quad Cov(\mu_i, X_{ijt}) = 0.$$

Equation (2.4a) embodies two assumptions. First, quality is uncorrelated with year of birth once one conditions on the control variables. Second, high and low wage workers have similar labor force attachment — at least for a sample of white male heads of household. AS investigated the second assumption and found that their results were insensitive to using potential experience as an instrument for actual experience.[6]

To examine the effect of individual heterogeneity on Topel's estimator we will (2.4) and the

auxiliary regression

$$(2.5)\quad T_{ijt} = d_1 \mu_i + d_2 X_{ijt} + v_{ijt}$$

where $d_1 > 0$, $d_2 > 0$, and v_{ijt} is uncorrelated with μ_i and X_{ijt} by definition of an auxiliary regression. Given that $Cov(\mu_i, X_{ijt})=0$, it follows from (2.5) that d_2 is the coefficient γ_{XT} of the least squares regression of T_{ijt} on X_{ijt}. A little algebra establishes that the c_1 and c_2 in (2.4) are

$$(2.6)\quad c_1 = -\gamma_{XT} c_2 < 0 \; ; \quad c_2 = d_1 \frac{Var(\mu_i)}{d_1^2 \; Var(\mu_i) + Var(v_{ijt})} > 0.$$

We now discuss the OLS, AS, and Topel estimators. We consider AF in Section 10.

2.2 <u>The OLS Estimator</u>

Using equations (2.1) to (2.4) it is easy to show that the biases in the OLS estimators of β_1 and β_2 are

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[6] The results in Table 6 for the 1975-1982, 1983-1991, and 1975-1991 are also insensitive to using potential experience as an instrument for actual experience.

$\beta_1^{OLS} - \beta_1 = b_1 + c_1$

$\beta_2^{OLS} - \beta_2 = b_2 + c_2$.

Unfortunately, neither bias can be signed. The bias in experience is ambiguous because the job match (b_1) and individual heterogeneity (c_1) terms are of opposite signs. Similarly, the bias in tenure is ambiguous because the job match heterogeneity (b_2) may either offset or re-enforce the upward bias in β_2^{OLS} from individual heterogeneity (c_2). However, if c_2 is large and positive and b_2 is either positive or small and negative, then the net bias in β_2^{OLS} will be positive, and the estimated effect of seniority on wages will be overstated in OLS wage regressions.

2.3 Altonji and Shakotko's Estimator

Altonji and Shakotko propose an instrumental variables estimator to address the problems of individual and job match heterogeneity in the wage equation. Let $DT_{ijt} = T_{ijt} - \bar{T}_{ijt}$ denote the deviation of T_{ijt} from the mean $\bar{T}_{ijt}$ of the sample observations on job match ij. Abstracting from η_{ijt}, this variable is a valid instrument because it is orthogonal to the error components μ_i and ϕ_{ij}, which are fixed within the job. AS use DT_{ijt}, X_{ijt} and t as instruments. We refer to this estimator as the IV1 estimator. Using the IV1 estimator, they find that 10 years of tenure leads to a wage increase of 2.7 percent, about 1/10th of their OLS estimate.

The IV1 estimator is free of bias from μ_i. However, the likely positive correlation between X_{ijt} and ϕ_{ij}, leads to positive bias in β_1^{IV1} and negative bias in β_2^{IV1}. Topel shows that the bias in β_2^{IV1} induced by ϕ_{ij} is $-b_1 - \dfrac{\gamma_{XT}}{1-\gamma_{XT}}(b_1+b_2)$,

where γ_{XT} is the least squares coefficient in the regression of T on X. AS also recognized this bias, and proposed a modification of the IV1 estimator to correct for it. Let B denote the vector $(\beta_0, \beta_1, \beta_2)$. They note that because ϕ_{ij} is orthogonal to DT_{ijt}, and that correlation between t and ϕ_{ij} arises only because t is correlated with X_{ijt}, this bias can be written as

(2.7) $B_{bias}^{IV1} = \text{plim}\, \Sigma_{ijt}[(t, DT_{ijt}, X_{ijt})'(t, T_{ijt}, X_{ijt})]^{-1}\Sigma_{ijt}[(t, DT_{ijt}, X_{ijt})\phi_{ij}]'$

$= \text{plim}\, \Sigma_{ijt}[(t, DT_{ijt}, X_{ijt})'(t, T_{ijt}, X_{ijt})]^{-1}\, \Sigma_{ijt}[(t\, E(\phi_{ij}|X_{ijt}), 0, X_{ijt}\, E(\phi_{ij}|X_{ijt})]'$.

They estimate $E(\phi_{ij}|X_{ijt})$ as the product of (1) an assumed value of the average change in ϕ_{ij} per quit and (2) the expected number of times a person will quit by experience level X_{ijt} based on a logit model of quits as a function of a cubic in experience. They report results for several assumed values, but also obtain information about the average value of ϕ_{ij} by comparing the average wage change for quits and for layoffs under the conservative assumption that the average change in ϕ_{ij} is zero in the event of a layoff. They ignore the negative effect that layoffs are likely to have on $cov(\phi_{ij},X_{ijt})$. Define the corrected IV1 estimator as

$$B^{IV1*} = B^{IV1} - B_{bias}{}^{IV1}$$

Using the B^{IV1*} estimator AS obtain .066 as their preferred estimate of the effect of ten years of tenure.

Unfortunately, the correction ignores the fact that the gain from quits is likely to vary with the experience level. Furthermore, the rules that are used to discard data on persons with poor tenure and job change information may have a substantial impact on estimates of the experience profile of quits. Finally, it ignores offsetting job match losses associated with layoffs. For these reasons, we make only a limited use of this bias correction below.

2.4 Topel's Estimator

As discussed further below, Topel is reluctant to estimate an economy-wide time trend (β_0) within his PSID sample. Therefore, he first detrends the data using a real wage index constructed from CPS cross sections in an early draft of Murphy and Welsh (1992). This detrending procedure is similar to regressing the Murphy-Welsh index on a time trend using the sample composition to weight the various years, and then using the coefficient estimate $\hat{\beta}_0$ to detrend the data. To estimate β_1 and β_2 Topel proposes a two-stage estimator. Since experience and tenure increase identically within a job, the first step estimates the combined effect of experience and tenure ($\beta = \beta_1 + \beta_2$) by applying OLS to a within job wage growth equation for stayers:

$$(2.8) \quad W_{ijt} - W_{ijt-1} - \hat{\beta}_0 = \beta + \epsilon_{ijt} - \epsilon_{ijt-1} + \beta_0 - \hat{\beta}_0 .$$

After noting that current experience can be written as the sum of the initial experience on the job ($X0_{ijt}$) and T_{ijt}, in the second step Topel estimates the linear experience coefficient (β_1) using OLS on the equation

$$(2.9) \quad W_{ijt} - \hat{\beta}_0 t - \hat{\beta} T_{ijt} = X0_{ijt}\beta_1 + e_{ijt} ,$$

where $e_{ijt} = \epsilon_{ijt} + t(\beta_0 - \hat{\beta}_0) + T_{ijt}(\beta - \hat{\beta})$ and $\hat{\beta}$ is the OLS estimate from (2.8). Finally, the linear tenure slope (β_2) is estimated as $\hat{\beta}$ - $\hat{\beta}_1$. We refer to this estimation method as the "Topel" estimator or as the two-step first difference (2SFD) estimator. When the specification of the tenure and experience effects is linear and an outside estimate of β_0 is used, Topel shows that AS's IV1 estimator is approximately equivalent to using (2.8) to estimate β and estimating (2.9) by instrumental variables with X as an instrument for X0. The approaches are identical in the linear case if one replaces (2.8) with an equation for deviations from job means.

Topel notes that because both μ_i and ϕ_{ij} are included in e_{ijt}, and both may be correlated with X0, his estimator will produce biased results. He shows that job matching produces a downward bias in his estimator of β_2 equal to $-b_1 - \gamma_{X0T}(b_1 + b_2)$, where γ_{X0T} is the least squares coefficient in the regression of T on X0. Comparing this bias to that of the IV1 estimator given above, Topel notes that because γ_{X0T} is about -.25 in his sample and γ_{XT} is .5, the downward bias is larger for the IV1 estimator than Topel's estimator provided that $b_1 + b_2$ is positive. Evidence from Topel and Ward (1992) suggests that $b_1 + b_2$ is positive. However, because Topel's own estimate of $b_1 + b_2$ is only .0020 (page 159), his empirical results suggest that the difference between the estimators due to bias from ϕ_{ij} is small. Topel does not mention AS's attempt to adjust for bias using the IV1* estimator.

The overall bias in Topel's estimator for β_2 also depends on the importance of bias from μ_i. Some algebra establishes that the bias term $\gamma_{X0\mu}$ in Topel's equation (13) is equal to

$\gamma_{X0\mu} = c_2 \frac{Var(T|X)}{Var(T)}$, where c_2 is the coefficient in the auxiliary regression (2.4) for μ_i

above, and Var(T|X) is the variance of T_{ijt} conditional on X_{ijt}.[7] In the replicated sample Var(T|X)/Var(T) is .676, so the bias from individual heterogeneity in the Topel estimator of the linear tenure coefficient is about ⅔ the size of the bias in OLS from this source.

Topel finds that ten years of tenure leads to a log wage increase of .245. This implies a percentage increase in the wage level of 28 percent. When he investigates the importance of the bias from individual heterogeneity by instrumenting X0 in (2.9) with X, he finds that the effect of ten years of tenure on the log wage only declines slightly to about .22. This is substantially larger than AS's IV1 and IV1* estimates of .027 and .066.[8]

Topel makes a serious effort to explain the discrepancy between his findings and those of AS and AF. He argues that AS's estimates are substantially biased down from measurement error in the tenure data, and from their treatment of the time trend as exogenous. The results in Topel's Table 6 as well as his results instrumenting X0 in (2.9) with X, suggest that differences in the estimators explain a relatively small part of the difference in results. In contrast, Topel argues that the difference between his estimates and those of AF arises because AF use an inappropriate methodology. He concludes that the return to seniority is large and that the OLS estimates may even be downward biased.

Most of the remainder of the paper revisits the issue of why the studies differ. Our conclusions differ sharply from Topel's.

3. Replication of Topel's Basic Results

We begin by trying to replicate Topel's basic findings. In performing the replication we started with a working data set covering the 1968-1983 PSID survey years that Topel used. Topel graciously provided a complete and well documented set

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[7] The parameter $\gamma_{X0\mu}$ = Cov(X0,μ)/Var(X0). Cov(X0,μ) = Cov(X-T, μ) = -Cov(T,μ)=-d_1Var(μ). Var(X0)=Var(X-T)=Var(X)-2γ_{XT}Var(X)+Var(T) ≈ Var(T) in Topel's sample because Topel reports that γ_{XT} is .5. Thus, $\gamma_{X0\mu} = -d_1 Var(\mu)/Var(T)$. Using this result, equation (2.6) for c_2 and the fact that (2.5) implies that Var(T|X)=d_1^2 Var(μ) + Var(v_{ijt}) leads to the expression for $\gamma_{X0\mu}$ in the text.

[8] We infer the value of .22 from the fact that Topel reports on page 164 that the estimate is about 3 percent lower when X is used as an instrument for X0 in (2.9).

of programs for the May 1988 draft of his paper, which used a data set covering the 1968-1981 survey years only.[9] The appendix in the published version is very similar to the data appendix in the earlier draft. Consequently, we updated the programs to use the additional sample years.

The replication sample has 9,315 within job wage change and 11,374 wage level observations, while Topel reports 13,138 observations in the text (page 154). However, Topel also reports a sample of 8,683 within job wage change observations in the note to his Table 2, and 10,685 observations in the note to his Table 3. We suspect that these latter values are the actual sample sizes, because the ratio of the within job wage changes to wage level observations of .8126 corresponds closely to the ratio of .8190 in the replicated sample. We do not know the source of the discrepancies between Topel's sample and our replication.[10]

In Table 1 we report the sample means of the variables used in the analysis. Column 1 is reproduced from Table A1 in Topel. Column 2 reports the sample means for the replicated Topel sample. The remaining columns refer to other samples that we will discuss below. The means of education (Educi), marital status (Mrdnow), union membership (Unm), residence in an SMSA (SMSA), and a disability affecting work (Dsablh) match almost exactly. There is a substantial discrepancy in the mean of Topel's earnings measure, Realearn, but this appears to be due to a difference in the base of the price deflator used rather than to differences in the samples.[11] However, we doubt if this is important because the mean of the change in Realearn in the

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[9] The 1968-1983 extract was supplied to Topel by Altonji and Nachum Sicherman. The wage data refer to the 1967-1982 calendar years. It is a superset of an extract for the 1968-1981 surveys created by AS and used by AF. We were able to replicate a number of the results in the earlier draft. In private communication Topel indicated that the files for the published version were misplaced during a change in computing systems.

[10] The figure .8190 is 9315/11374. In the second paragraph on page 174, Topel states that he deleted some additional jobs in which there were ambiguities about starting and ending dates. An earlier draft of his paper makes the same statement, and we implemented the checks in the programs that Topel supplied to us corresponding to that draft. It is possible that some additional checks were put into place when Topel extended the sample to take advantage of the data from 1982 and 1983. Topel states that "these deletions had very minor effects on the results and none on the conclusions."

[11] As will be discussed further below, Logearn is the log of real annual earnings divided by annual hours, while Realearn adjusts this further by subtracting the log of the real wage index constructed by Murphy and Welch.

replication sample is identical to Topel's reported value of .026. The means of experience are close—20.02 versus 19.82. The one somewhat worrisome difference is that the mean of tenure is 9.98 in Topel's sample and 10.659 in our replication, a difference of .68 years.

In Table 2 we directly compare estimates reported by Topel to those obtained using our replicated sample. (Some of Topel's estimates are not shown because they were not reported in his study.) In columns 1 and 4 we report the OLS estimates.[12] Our replicated estimate of the effect of 5 years of tenure is .1863, which is substantially below Topel's estimate of .2313. However, at ten years of tenure the estimates are .2702 versus .3002, and are almost identical at the higher levels of tenure. In columns 2 and 5 we report the IV1 estimates when we include an exogenous time trend. The estimates for the replication sample are almost identical to Topel's. In columns 3 and 6 we present Topel's estimator. The replicated results show a slightly higher effect of tenure at 5 years, almost exactly the same effect at ten years, and a slightly lower effect at 15 and 20 years. We have also replicated many other results reported in Topel's paper. The comparison between columns 2 and 5, and between 3 and 6 is typical of what we found.

While the above discrepancies in the sample sizes and summary statistics is cause for some concern, the multivariate results are very close. We conclude that our replication sample is close enough to Topel's to give reliable information. Throughout the paper, whenever we present results for our replicated Topel sample that are also reported by Topel, we have checked that the two correspond closely.

4. Controlling for Economy Wide Time Trends and Changes in Sample Composition

4.1 Introduction

AS and AF included a time trend in their models to control for an economy-wide trend in real wages. Topel argues against the use of a time trend on two grounds. The first is that time will be correlated with ϕ_{ij} because it is correlated with experience

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[12] Unless otherwise noted, we report White standard errors that account for individual specific heterogeneity and serial correlation in the error terms as well as for the fact that the Topel estimator is a two-step estimator.

and persons who have been in the labor market longer will have had more time to locate better jobs.[13] The second is that time may be correlated with the mean of μ_i because of changes in the sample over time. Since the time trend is correlated with both seniority and experience, any bias in the time trend may affect the other parameters. Topel's alternative to including a time trend or year dummies in the wage equation is to subtract the log of the Murphy and Welch (1992) real wage index from the PSID wage variable prior to estimation. In the tables below we call this trend-adjusted real wage measure Realearn.

In section 4.2 we consider the seriousness of the two sources of bias that Topel emphasizes and then discuss fixing the problem by instrumenting the time trend. In Section 4.3 we present the results of our experiments with alternative treatments of the trend, and then in section 4.4 explain the consequences of using the wrong time trend.

4.2 Will treating time as exogenous lead to serious bias?

Topel is correct that t may be positively correlated with ϕ_{ij}. The correlation would arise if there is a positive relationship between time and average experience. However, the simple correlation between t and ϕ_{ij} is likely to be weak, because the relationship between time and average experience is very weak in both our Topel replication sample and in the original sample used by AS.[14]

In any case, the covariance between t and ϕ_{ij} will not lead to bias in the tenure and experience coefficients of the OLS and IV1 estimators. The covariance between t and ϕ_{ij} arises because t is correlated with the amount of time a given cohort of workers has been in the labor market, not because of the passage of time per say. Consequently, the covariance is 0 conditional on X_{ijt}, T_{ijt} and X_{ijt}, or T_{ijt} and $X0_{ijt}$. That is,

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[13] This issue is also mentioned by AS (page 450).

[14] In the replicated Topel sample, the coefficient on X_{ijt} in the auxiliary regression of t on X_{ijt} is actually negative (-.0018) and is not statistically significant. The relationship is weak primarily because much of the variation in X_{ijt} is cross sectional but also because the PSID is a self replicating sample. The male children in the original PSID families enter the regression sample when they set up separate households, and original members of the sample leave when they retire, die, or reach the age 60 cutoff used by AS and Topel. Furthermore, the Topel and AS samples include nonsample men who marry members of original PSID sample households. The splitoffs and persons who marry into the sample tend to enter the sample early in their careers, while the heads in 1968 were a cross section of the population.

$$Cov(t, \phi_{ij}|X_{ijt}) = Cov(t, \phi_{ij}|T_{ijt}, X_{ijt}) = Cov(t, \phi_{ij}|T_{ijt}, X0_{ijt}) = 0.$$

It follows that whether or not t is positively correlated with ϕ_{ij} has no effect on the probability limit of the OLS estimator or the IV1 estimator. However, inclusion of a time trend in the second step of the Topel estimator is likely to have an effect because T_{ijt} is omitted from (2.9) and t is correlated with T_{ijt} conditional on $X0_{ijt}$.

Topel's second concern is that changes in sample composition induce a positive correlation between t and μ_i. Bechetti et al (1988) and Moffit and Gottschalk (1996) do find that attrition is higher among low income individuals. However, the AS sample is drawn from persons who were heads of household in 1981, and Topel's sample is drawn from heads of household in 1981, 1982, or 1983.[15] Sample attrition does not lead to an upward trend in μ_i because persons who left the PSID prior to 1981 are excluded in all years. Some of the observations in the later years are contributed by persons who married into PSID families or who split off from the original households. The observations in the early years might even be more select than those in the late years, because they are contributed by persons who remained in the sample until at least 1981.[16] (This comment does not apply to the 1975-1982, 1983-1991, and 1975-1991 samples we analyze in section 11, because these use the available data on persons who later become nonrespondents.)

In any event, one can easily deal with correlation between t and μ_i by treating time as endogenous and using $\tilde{t}_i$, the deviation of t from its mean for person i, as an instrument for time. This variable is uncorrelated with μ_i by construction and is uncorrelated with ϕ_{ij} conditional on T_{ijt} and $X0_{ijt}$.[17]

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[15] Topel states that his sample is limited to persons who were respondents in the 1983 survey. However, the extract he used includes persons who were respondents in 1981 and/or 1982 even if they were nonrespondents in 1983. We suspect that these 1983 nonrespondents were included in his analysis because the fractions of the sample from 1983 and 1982 is lower than 1981.

[16] In footnote 11 Topel indicates he found that real wage growth in the PSID sample as a whole exceeds real wage growth implied by the CPS, but real wage growth in the PSID and the CPS is the same in the subsample of persons who entered the data in 1968-1969. We could not confirm this result. In the replicated sample, we obtain a time trend of .00945 for the 1968-1969 entrants when we follow Topel and use the period t-1 wage with period t tenure. The value in Table 3, column 4 for the full sample is .0088.

[17] Biases in the tenure and experience coefficients from other factors could contaminate the time trend coefficient even if the time trend is unrelated to the error term. However, the correlations between t and X_{ijt} and T_{ijt} are too weak for this to be a serious issue, as evidenced by the fact that the

4.3 Results

In Panel A of Table 3 we report results for the OLS, IV1 and Topel estimators for various treatments of the time trend. All of the models include 4th order polynomials in both tenure and experience and the other control variables used by Topel. In columns 1-3 we follow Topel and use Realearn as the dependent variable and exclude the time trend from the equation. The IV1 and Topel estimators both imply a return to ten years of tenure of about .25. The implied effect of 20 years of tenure is larger for the IV1 estimator than for the Topel estimator (.40 versus .31).

In columns 4-6 we follow AS and most other studies of earnings and add an exogenous time trend to the model with Logearn as the dependent variable. The estimates of the time trend parameter β_0 are .0088 in the case of OLS and .0085 in the case of IV1. In implementing the Topel estimator in column 6, we detrended the data using the estimate of the OLS estimate from column 4. The OLS estimator is virtually unaffected. However, the IV1 estimate declines by half—from .246 to .121. There is also a small decline in the Topel estimator from .255 to .227.

In columns 7-9 we report results assuming an endogenous time trend and using $\tilde{t}_i$ as an instrumental variable. The estimated time trends rise slightly when t is treated as endogenous. The IV estimator underlying column 7 is the counterpart to OLS but treats time as endogenous. The counterparts to OLS and the Topel estimator in columns 7 and 9 are very similar to those in columns 4 and 6, while the IV1 estimate actually declines to .0789. Finally, in columns 10-12 we replace the time trend with a set of year dummies and use the deviations of the dummies from their time means as instrumental variables. The results are similar to those obtained with the endogenous time trend.

In sum, these results suggest that controlling for economy-wide real wage changes using the Murphy-Welch wage index vis a vis an estimated time trend has no effect on OLS, makes a substantial difference in the IV1 estimator, and has some effect on the Topel estimator. To gain some insight into this result, we estimated (but do not report) regressions where Realearn is used as the dependent variable and a time trend is included. Treating the trend as exogenous yielded an OLS estimate of the

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estimated time trend is nearly the same for OLS and IV1 despite the large difference in the tenure and experience effects.

trend as .0062 and an IV1 estimate of .0059. For the same specification with time endogenous, the IV-tenure exogenous trend coefficient is .0064 and the IV1 estimate is .0077. Thus, it is clear that the Murphy-Welch time trend is different from the trend in the replicated Topel sample. One cannot explain this with an appeal to correlation between t and ϕ_{ij} because this correlation is zero conditional on T_{ijt} and X_{ijt}. The insensitivity of the trend estimate to the use of $\tilde{t}$ as an instrumental variable for t would seem to rule out changes over time in sample composition as an explanation. (See also footnote 14). We are not sure why the time trend for the male household heads we study differ from the CPS as a whole. However, we wish to point out that CPS cross sections involve different sample frames and variable definitions. There is also a large nonresponse rate to questions about earnings in the CPS that has increased over time, as well as problems with the top coding of earnings.

4.4 Explaining the Sensitivity of the Results to Treatment of the Time Trend

What does theory predict about the consequences of using the wrong trend? In the case of OLS, the consequences should be small because both the simple and partial correlations between t and X_{ijt}, and t and T_{ijt} are small. This underlies the fact that the results in columns 1, 4, and 10 in Panel A of Table 3 vary little. However, the consequences are very serious for the IV1 estimator and significant for the Topel or 2SFD estimator. To see why, redefine the wage measure W_{ijt} as the real wage net of the Murphy-Welch wage index and rewrite the wage equation (2.1) as

$$W_{ijt} = \beta_0^* t + \beta_1 X_{ijt} + \beta_2 T_{ijt} + \epsilon_{ijt}$$

where β_0* is the difference between the actual time trend (β_0) and the coefficient ($\hat{\beta}_0$) from a regression of the Murphy-Welch wage index on t. In the linear case Topel shows that the IV1 estimators of $\beta = \beta_1 + \beta_2$ and β_1 are

$$\beta^{IV1} = (DT'DT)^{-1}\ DT'DW \quad \text{and} \quad \beta_1^{IV1} = (X'X0)^{-1}X'(Y - T\beta^{IV})$$

where we use obvious matrix notation and DT and DW are vectors of deviations from job means of T_{ijt} and W_{ijt}. From the first equation it is easy to show that

$$plim\,\hat{\beta}^{IV1} = plim\,\hat{\beta}^{2SFD} = \beta_1 + \beta_2 + \beta_0^* .$$ [18]

From the second equation it is easy to show that bias in the experience coefficient is

$$\hat{\beta}_1^{IV1} - \beta_1 = b_1 + \frac{\gamma_{XT}}{1-\gamma_{XT}}[b_1 + b_2] - \frac{\gamma_{XT}}{1-\gamma_{XT}}[\beta_0^*] + \frac{\gamma_{Xt}}{1-\gamma_{XT}}\beta_0^*$$

where γ_{Xt} is the coefficient in the auxiliary regression of t on X_{ijt}. Since $\hat{\beta}_2^{IV1} = \hat{\beta}^{IV1} - \hat{\beta}_1^{IV1}$, the bias in the tenure coefficient contributed by the terms involving β_0^* is

$$\beta_0^* + \frac{\gamma_{XT}}{1-\gamma_{XT}}[\beta_0^*] - \frac{\gamma_{Xt}}{1-\gamma_{XT}}\beta_0^*$$

We can evaluate the bias from using the wrong time trend by substituting the estimates γ_{XT}, γ_{Xt}, and β_0^* obtained from using the replicated Topel sample. In that sample, γ_{XT} is about .5 and γ_{Xt} is only -.0018 so the bias implied by the above expression is about $-2\beta_0^*$. Setting β_0^* to the value of .0062 obtained when the time trend is treated as exogenous and evaluating the above expression implies that the IV1 estimate of the effect of ten years of seniority will decline by about .122 when one replaces Realearn with Logearn and adds a time trend to the analysis. This is almost exactly what happens. In the case of an endogenous time trend the results in columns 2 and 8 indicate that the actual reduction is a bit larger than the reduction implied by the formula. We conclude that the use of the Murphy-Welch index to control for the time trend leads to a large downward bias in the IV1 estimator.

A similar analysis of the Topel estimator implies that using the wrong time trend biases $\hat{\beta}_2$ by

$$\beta_0^* + \frac{\gamma_{X0T}}{1-\gamma_{X0T}}[\beta_0^*] - \gamma_{X0tij}\beta_0^*$$

where γ_{X0tij} is the coefficient in the auxiliary regression of the job match start date t_{ij} on $X0_{ijt}$. Since in the replicated Topel sample, γ_{X0T} is -.25 and γ_{X0tij} is only -.014, the implied downward bias in the effect of ten years of tenure is about .8 * .0062 *10=.0496, which is larger than but reasonably close to the decline of .028 that we

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[18] The expression for $\hat{\beta}^{IV1}$ is simply the mean wage growth within jobs after adjusting for the Murphy- Welsh trend estimate. This is $\beta_1 + \beta_2 + (\beta_0 - \hat{\beta}_0)$

obtain when we replace Realearn with Logearn and set β_0 to the estimate from the specification with T and X exogenous and t endogenous.[19]

We conclude that the use of the Murphy-Welch wage index to detrend real wages in the replicated Topel sample leads to a large upward bias in the IV1 estimator and to a smaller upward bias in the Topel estimator. It has little effect on the OLS estimates, so the net result is to move the Topel estimator closer to OLS and the IV1 estimator closer to both the Topel and OLS estimators.

5. Consistency between the Dating of the Tenure and Earnings Measures.

In the PSID, employer tenure, union status, and other job specific variables refer to the survey date (typically March, April or May), while the wage measure is annual earnings divided by annual hours in the previous calendar year. Consequently, AS and AF use the wage measure from the survey in year t and tenure and union status from the survey in t-1. In contrast, Topel takes both the wage and the tenure and union status measures from the year t survey. He excludes observations if $T_{ijt}<1$ because "wages refer to average hourly wages in the year preceding the survey."

Topel's choice of dating could lead to bias for two reasons. The first is a bit subtle and has to do with the fact that all of the estimation methods suggest that the return to seniority declines sharply after the first year or two. When the returns are nonlinear, adding a constant of .75 or 1 to the tenure variable affects the interpretation of the coefficients. For example, if Topel's measure of tenure is equal to $T_{ijt} + 1$, then one would compute the effect of the first ten years of tenure as the effect of an increase in the tenure measure from 1 to 11 rather than from 0 to 10. Topel uses an increase from 0 to 10 to arrive at the conclusion that ten years of tenure lead to a log wage increase of .246. If one uses 1 to 11, his parameter estimates imply an increase of about .19. Of course, the survey date is typically March, April or May so the average overstatement of tenure is smaller than 1.

The second reason stems from the fact that, as noted by both AS and Topel, both Realearn and Logearn are mixtures of the wage on the old and new job when a job change occurs. Topel's timing convention may affect the bias that results from this

[19] Our analytic results are for the case of linear tenure and experience specifications rather than the quartic specifications that used. This may be a partial explanation for the discrepancy.

in ways that are hard to sign a priori.[20]

In Panel B of Table 3 we analyze the empirical importance of this issue for the various estimators by reporting estimates using year t wages with year t tenure. In columns 13-15 we include observations with $T_{ijt} < 1$, use Realearn as the wage measure, and exclude the time trend. Comparison of columns 2 and 14 shows that when one uses year t wages with year t tenure the IV1 estimate of the effect of ten years of tenure declines from .246 to .177. Comparison of columns 3 and 15 reveal that the Topel estimate of this effect declines from .255 to .186.

The results in columns 16 and 17 are also based on the use of year t wages with year t tenure but use Logearn as the dependent variable and include an endogenous time trend. They may be compared to columns 8 and 9 in Panel A of Table 3, which use year t-1 wages and year t tenure. Both the IV1 estimates and the Topel estimates decline substantially. For example, Topel's estimate of the effect of ten years of tenure declines from .223 (column 9) to .161 in column 17.

The problem that Logearn is a mixture of wages on the old and new jobs when a job change occurs remains even when one uses the average hourly wage with tenure from the same year. For this reason, we exclude observations with $T_{ijt}<1$ in columns 18 and 19. This reduces the estimates of the effect of ten years of tenure by about .05. In columns 20 and 21 we exclude observations if $T_{ijt} < 1$ or if the job ended between the survey in t and the survey in t+1. This IV1 estimate of the effect of ten years of tenure is .007 and the Topel estimate is .118. Excluding the first year would tend to bias downward the estimated return if a large part of the return occurs in the first year or two.

As a further check and to get around the problem posed by the fact that the average hourly wage may be a mixture from different jobs, in Table 4 we report results using Logwage as the wage measure, where Logwage is the log of the reported hourly wage at the survey date for persons paid by the hour and is based on the salary per week, per month, or per year reported by salary workers. Unfortunately, Logwage

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[20] If the tenure effect is nonlinear, the use of a time aggregated wage measure may affect the interpretation of the tenure coefficients even when the wage and tenure measures refer to the same year. However, our major concern about the use of wages that are an average of the wage on the old job and the new job is that wage growth in the first year on the job may be overstated. This would bias the returns to tenure upward.

is unavailable prior to 1970, is limited to hourly workers prior to 1976 and is capped at \$9.98 per hour prior to 1978. The results in Table 4 are based on an endogenous time trend. Observations with $T_{ijt} < 1$ are included since the reported wage refers to the job held at the survey, which is when tenure is measured. The IV1 estimate of the effect of ten years of tenure is .023. The Topel estimate is .090, which is far below the comparable estimate of .223 (Table 3, Panel A, column 9) based on Topel's dating convention. It is a bit lower than the results obtained using tenure and the wage from the same year and excluding wage observations that are likely to be a mixture of two jobs (Table 3, Panel B, columns 19 and 21).[21]

We conclude that the use of the period t-1 wage with period t tenure leads to a large upward bias in Topel's results for both the IV1 and Topel estimator.

6. Functional Form

Although not discussed by Topel, the AS and Topel papers used different functional forms.[22] AS use a dummy for whether $T_{ijt} > 1$ and a quadratic in T_{ijt}. Topel excludes the indicator variable (which would always be 0 given his sample selection rules and the fact that he uses tenure at the survey date with the wage from the previous year) but includes a quartic in T_{ijt}. AS includes an interaction between X_{ijt} and years of schooling and a cubic in X_{ijt}, while Topel excludes the interaction but includes a quartic in X_{ijt}.

In Appendix Table B-1 we report OLS, IV1, and 2SFD estimates using both Topel's functional form and the AS functional form. The results in columns 1-3, and 7-9 are based on Topel's functional form and columns 4-6, and 10-12 are based on AS's functional form. We use Logearn with an endogenous time trend and take tenure and wages from the same calendar year. The estimates are not very sensitive to the functional form used, regardless of whether the observations with tenure less than 1 are included. We conclude that functional form assumptions explain little of the

[21] In the analysis in Section 11 we replace the top coded values for 1975-1977 with imputed values from a regression of the nominal values of Logwage on Logearn in 1978 for the sample in which the nominal value of Logwage exceeds the topcode value of \$9.98.

[22] In an earlier version of his paper Topel did report results for a functional form similar to AS's.

differences in the results of the two studies.

7. Measurement Error in Tenure

As noted earlier, Topel considers measurement error in the AS tenure measure to be a major factor leading to the differences in the conclusions of the two studies. Topel (Table 7) reports that the estimated effect of tenure rises from .074 at ten years of tenure to .122 when he uses the IV1 estimator with an exogenous time trend and replaces AS's tenure measure with his tenure measure, a ratio of .607. The difference at 20 years of tenure is .052 versus .161. AS were aware of problems with the tenure data and performed several experiments to check on the seriousness of the problem.[23] They found that eliminating the effects of bracketing of tenure values in the early years and unusual changes in tenure or smoothing the tenure variable increased their basic estimate from .027 to about .044, a ratio of .61. They concluded on the basis of these calculations and other results that measurement error is important but has little effect on their substantive conclusions.[24]

How can AS's and Topel's results about effects of measurement error be reconciled? As the numbers provided above suggest, the bias from measurement error seems similar in the two samples in percentage terms. The difference between the studies in the absolute magnitude of the bias from measurement error reflects the fact that Topel's use of period t tenure information with period t-1 wage information leads to a larger value in the IV1 estimator. A similar bias in percentage terms leads

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[23] AS used a complicated procedure to identify job matches and separations and to measure T. They included programming checks to make sure that tenure refers to the employer rather than the job and to try to guard against cases in which persons left an employer and then returned. However, they chose not to smooth tenure during the years 1968-1974 when it is bracketed and did not require tenure to increase by 1 for each year on the job. These were bad decisions.

[24] They obtained the .044 value when they restricted the sample to 1975-1981, which excludes the years in which tenure is bracketed and eliminated observations in which the change in tenure is less than .9 or greater than 1.1 (unless a separation took place between surveys). Second, they experiment with a procedure to smooth the tenure data and impose the restriction that tenure grow by 1 for each year on a job. This lead to an estimate of .04. (See AS, Tables 2 and 3.) As a final check on measurement error bias and as a general specification test, they computed the mean of predicted wage growth by level of tenure in the previous year for job stayers, quits, and layoffs (using the cell means of tenure) and compared the predictions to actual growth. Random measurement error in tenure should have little effect on these sample means. Tthe IV1 estimator performs well in these prediction tests. The OLS estimator performs miserably, with a pattern of errors that suggests that the OLS estimator has a strong positive bias.

to a larger bias in absolute terms.[25] [26]

8. Differences in the Estimators

Although Topel finds little difference between the IV1 estimator and his estimator, our results show that when the trend in the PSID is accounted for and earnings and tenure are taken from the same year, Topel's estimator is consistently larger than the IV1 estimator, although both are much smaller than OLS. In the replicated Topel sample the gap between IV1 and the Topel estimator is about .10 at ten years of tenure and .15 at twenty years of tenure. As discussed above in sections 2.3 and 2.4, both the IV1 and Topel estimators are biased down by job match heterogeneity, and the Topel estimator is biased up by individual heterogeneity. In this section we investigate the relative importance of these biases in the IV1 and Topel estimators.

As noted above, Topel shows that the downward bias from correlation with the job component ϕ_{ij} is likely to be larger for IV1 than for his estimator. The IV1*

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[25] It would be useful to show how the results in the replicated Topel sample change as one alters the dating the wage and tenure and treatment of the time trend, but we are unable to closely replicate Topel's results in column 1 of his Table 7 that use AS's tenure measure. We obtain estimates of the effects of 10 and 20 years of tenure of .106 and .129 when we replicate that column, while Topel's estimates are .074 and .052. We are able to replicate column 2 and the other columns of his table, which uses his tenure measure, quite closely. In replicating Topel's results in column 1 that use AS's tenure we assume that he excluded observations for which this measure is less than 1 since he made this exclusion with his own measure of tenure. However, AS's measure is missing for a substantial number of observations for which Topel's tenure measure is available, and vice versus. Consequently, the samples underlying column 1 and the other columns in Topel's Table 7 are probably different. (Topel does not report sample sizes.) We suspect that the differences between our replication and Topel's results in column 1 of his table are due to minor differences in the samples that we use and Topel used. We also re-analyzed the issue of measurement error using the AS sample after imposing the constraint that tenure within a job increases by 1 per year and eliminating all jobs in which the implied starting value of tenure is negative and eliminate all jobs that start in the sample and have an implied starting value of tenure that is greater than 1.25. In this data set we find that the absolute value of the effect of measurement error on IV1 rises when uses a treatment of the time trend or the timing of wages and tenure that leads to a large IV1 estimate. For example, when we estimate that model with Realearn rather a time trend in the AS sample, the estimated effect of 10 years of tenure is .0936 using AS's tenure measure and .172 using the smoothed tenure measure.

[26] Brown and Light (1992) provide a thorough and somewhat harrowing account of the quality of the data on job seniority and job mobility from the PSID, although they also emphasize the many advantages of this data set. It is important to note that they obtaining results similar to AS for various treatments of the tenure data, although they criticize AS's methodology. Our conclusions about measurement error seem quite consistent with theirs.

estimator is an attempt to correct IV1 for the effects of ϕ_{ij} under alternative assumptions about the gain from quits. We follow AS and compute the IV1* estimator, which incorporates a crude adjustment for the correlation between X_{ijt} and ϕ_{ij}. We assume a job match gain per quit of .05, which was consistent with AS's data. Because we ignore layoffs, which tend to reduce the growth in ϕ_{ij} with X_{ijt}, we overstate the relationship between ϕ_{ij} with X_{ijt} and overstate the size of the bias. The $IV1^*$ estimate of the effect of ten years of tenure is .12 (not shown), while the comparable IV1 and Topel estimates are .031 and .161 (Table 3, Panel B, columns 16 and 17.) We conclude that the IV1 estimator is biased downward by job match heterogeneity, although we wish to stress that the adjustment in the IV1* estimator is not rigorous.

The Topel estimator is also biased down by job match heterogeneity, although to a lessor degree than the IV1 estimator. This downward bias is offset by an upward bias from individual heterogeneity. In section 2.4 we showed that this upward bias in the Topel estimator is about ⅔ of the bias in tenure in the OLS or IV-exogenous tenure estimators. If the upward bias is small, however, the Topel estimator might be more accurate than IV1. As noted previously, Topel investigated this issue by instrumenting X0 with X in the second step of his estimator, and concluded that unobserved individual heterogeneity did not substantially bias his estimates upward.

In columns 1, 5, and 9 of Table 5 we use X as an instrument for X0 for alternative treatments of the time trend and the timing of wages and tenure. When we use Realearn and measure wages at t-1 and tenure at t, the estimate of the value of ten years of tenure is .223 (column 1). This is close to the value for the Topel estimator (with X0 exogenous) of .255 in column 3 of Table 2. These results closely replicate those reported by Topel and are the basis of his conclusion that upward bias from correlation between μ_i and X0 is not much of a problem. However, when one corrects the dating of W_{ijt} and T_{ijt} so that they are from the same calendar year, the estimate drops from .223 to .126 (column 5), which compares to .186 (Table 3, Panel B, column 15) using the Topel estimator with X0 exogenous. When we replace Realearn with Logearn, estimate the time trend and instrument X0 with X, the effect of ten years of tenure falls to .044 (column 9), which compares to .161 (Table 3, Panel B, column 17) when X0 is treated as exogenous. From the facts that the instrumenting

X0 with X is similar to the IV1 estimator and that the Topel estimator is also biased downward by job match heterogeneity and the fact that correcting IV1 for job match heterogeneity closes only a small part of the gap between IV1 and OLS, we conclude that individual heterogeneity is important. We also conclude that much of the reduction in the tenure estimates that results when X is used as an instrument for X0 in the second step of Topel's estimator is due to a reduction in bias from individual heterogeneity.[27]

Taken together, the evidence suggests the downward bias in the Topel estimator from job match heterogeneity is more than offset by an upward bias from individual heterogeneity. However, the difference between the IV1 and IV1* estimators and the Topel estimator is minor compared to the difference between these estimators and OLS.

9. Conclusions about AS and Topel's Analyses

The two main sources of the difference between AS and Topel's results are Topel's use of the t-1 wage with year t tenure and his detrending procedure. In addition, the differences between the IV1 estimator and Topel's 2SFD estimator is partially responsible for the gap. Using 2SFD leads to higher estimates in the replicated Topel sample. When the trend in the PSID is properly accounted for and the timing of the wage and tenure measures are consistent, Topel's testing procedure suggests that the upward bias from individual heterogeneity in his estimator is substantial. On the other hand, the IV1 estimator is biased downward by job match heterogeneity. Given this fact we think weight of the evidence for the samples and wage data used by AS and Topel points to an intermediate value for the effect of ten years of tenure of perhaps 11 percent. This is above AS's IV1* estimate of .066 but far

[27] Columns 2, 6, and 10 of Table 5 are the Topel estimator with the first difference equation (2.8) replaced by an equation for the deviation of the wage from the mean for the job. The estimates are basically similar to the estimates for the corresponding specifications in columns 3, 15 and 17 of Table 3. Columns 3, 7, and 11 of Table 5 are analogous to columns 2, 14 and 16 of Table 3 but treat experience as endogenous. The difference in the estimated effects of ten years of tenure when the time trend is included and the correct dating is used is about .10. The results are very similar to the IV1 estimator in all cases, which is shown in columns 4, 8, and 12 of Table 5. As Topel notes, consideration of the effects of the time varying error component η_{ijt} might lead one to prefer the use of first differences, particularly if it is a random walk. On the other hand, the use of deviations from job means might be less sensitive to minor misdating of job start and end dates.

below Topel's results. Our results in table 4 for the reported wage measure at the survey date, which is preferred to average hourly earnings over the year, imply a return to 10 years of tenure of about .06.

10. Topel's Analysis of the Abraham and Farber estimator

AF add an estimate of the expected completed tenure T^*_{ij} of each job to (2.1) as a control for heterogeneity and obtain estimates of the return to tenure by estimating the equation

$$(10.1)\quad W_{ijt} = \beta_0 t + \beta_1 X_{0ij} + (\beta_1+\beta_2)T_{ijt} + \psi T^*_{ij} + \epsilon^1_{ijt} \quad .$$

OLS estimation of (10.1) leads to estimates of the returns to seniority well below estimates that exclude T^*_{ij}. Partly on the basis of this evidence AF conclude that the returns to tenure are relatively small. Topel notes (10.1) is equivalent to estimating

$$(10.2)\quad W = \beta_0 t + \beta_1 X_0 + (\beta_1+\beta_2)(T-\bar{T}) + (\beta_1+\beta_2)\bar{T} + \psi T^* + \epsilon^1$$

by OLS with the coefficients on $\bar{T}$ and $T - \bar{T}$ restricted to be same. He notes that $\bar{T}$ may be correlated with the unobservables conditional on T^* in a sample that includes incomplete longitudinal histories. Imposing the parameter restrictions implicit in (10.1) on (10.2) will lead this bias to be transmitted to the coefficient on $T - \bar{T}$. When Topel estimates (10.2) he strongly rejects the restrictions implicit in (10.1) and obtains estimates of the tenure parameter that are similar to the OLS value that he obtains when using the linear specification of the tenure effect. Note that the OLS estimate of .138 for the linear specification if far below the estimate of .302 that Topel obtains using a 4th order polynomial for tenure. In Appendix 1 we confirm Topel's findings, although we also show that they are somewhat sensitive to his use of the period t-1 wage with period t tenure. More importantly, we show that when one relaxes the linear specification of the tenure effect in (10.1) and (10.2) by using parameter estimates from a within job wage growth equation to remove the nonlinear tenure and experience effects prior to estimation of these two equations, the OLS estimates rise dramatically, but the estimates of the tenure effect based on (10.2) rise only slightly. The use of an estimate of job duration to control for heterogeneity yields an estimate of the return to ten years of tenure between .06 and .13 even if one uses the unrestricted version of AF estimator that Topel advocates. These values are between ¼ and ½ of the OLS estimates for the Topel's 4th order polynomial specification.

11. Results for a More Recent Sample

It is possible given dramatic changes in the returns to schooling and experience documented by Murphy and Welch (1992) and others that the returns to tenure have changed. Furthermore, the quality of the tenure data and the data on the survey wage (Logwage) are better after 1975 and there are further improvements in the tenure data in the 80s. For all of these reasons, we examine a more recent period.

In Table 6 we present estimates for calendar years 1975-1982 (panel A), which overlaps Topel's sample period of 1967-1982, for 1983-1991 (panel B), and for the combined sample (panel C).[28] In columns 2-4 of Table 6 we present results for the various estimators using Logwage as the dependent variable for the two sample periods. The specifications are the same as those in Table 4. (The results with endogenous year dummies are almost identical, and we exclude them from the tables.) The estimator that instruments time with $\tilde{T}$ but treats tenure as exogenous yields a return to ten years of tenure of .234 in the first period and .292 in the latter period. In contrast, the IV1 estimate of the value of ten years of tenure is .013 in the first period and .043 in the second period. As was noted earlier, these estimates are probably downward biased by job shopping. They are consistent with a small increase in the return to tenure. The Topel estimates of the effect of ten years of tenure are .114 for 75-82 and .120 for 83-91. These latter estimates are slightly larger than the estimate of .090 in Table 4 obtained using Logwage in the replicated Topel sample. Since the

[28] We use the algorithms developed in Altonji and Williams (1996) and Devereux (1996) to create the experience and tenure measures, which we believe to be superior to both AS's and Topel's. Our computer programs and data are available on request. Both the Logwage sample and the Logearn samples use data that refer to the calendar years 1975 to 1982 and 1983 to 1991.

analysis in section 8 suggests that the Topel estimates are upward biased by individual heterogeneity, we would take a value of .09, which lies between the IV1 and Topel estimates for 1983-1991, as our point estimate of the return to ten years of tenure based on this wage measure.

When we use Logearn in columns 6-8, the estimates for all 3 estimators are larger and increase between periods. When tenure is treated as exogenous the estimate of the effect of ten years of tenure rise from .336 to .406. The IV1 estimate rises from .054 to .139 between periods, and the Topel estimate rises from .143 to .219. [29] These are subject to the problem that Logearn is a mixture of wages from two jobs, and the results based on the survey wage rate should be preferred a priori.[30] [31]

There is a large literature showing that much of the rise in inequality has been within education/experience cells, and there is some evidence that the return to aptitude and achievement measures have risen over time.[32] There is also evidence that the relationship between unobserved personal characteristics and wages has changed.

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[29] The IV-exogenous tenure estimator produced estimates of .334 in the first period and .4054 in the second, but overstates the combined effect of the first ten years of experience and tenure by .22 for the years 1975-1983.

[30] There are minor differences in the samples for the two wage measures that stem primarily from the fact that persons must be employed or on temporary layoff to have a survey wage. We re-estimated the models on the set of observations for which both wage measures are available and obtained results that are similar to those in Table 6. The differences between the results for the two measures have to do with the division of returns between experience and tenure, because the two wage measures yield similar estimates of the total return to experience when we exclude tenure from the model. These results are in Appendix Table A-2 and suggest that the total return to experience from general skill accumulation, accumulation of tenure, and the returns to job shopping are higher in the later period.

[31] The IV1 estimator produces larger estimates for the 1975-1991 period than for either subperiod and is not simply an average of the results for the two subperiods. We have investigated this and determined that it is related to the fact that $T_{ijt} - \bar{T}_{ijt}$ is constructed using all of the data on job match ij to compute $\bar{T}_{ijt}$. Consequently, the IV1 estimator puts more weight on long jobs when we use the 1975-1991 period. When we literally pool the observations on the variables in the wage equation and the instrumental variables, we obtain results that are intermediate between those for the subperiods. This raises the possibility that there is heterogeneity in the tenure and/or experience slopes, and persons who move less often have higher slopes. When we replace (2.8) with a deviation from job means equation, the Topel estimator for the pooled sample moves closer to the estimate for the 83-92. When we implement Topel's 2SFD estimator but instrument X0 with X, the effects of ten years of tenure of .045 for log wage and .041 for Logearn for the 75-1991 period, and these estimates lie between the estimates for the two subsamples.

[32] See the survey by Levy and Murnane (1992).

This would imply that the market price on the individual heterogeneity component μ_i and/or the variance in the distribution of μ_i has increased. Secular increases or decreases in the distribution of the job match heterogeneity component or its relationship with experience and tenure will affect all three estimators.

One way to isolate the change in the return to tenure and experience from the above changes is to compute the combined return to ten years of experience and tenure using the within job wage change equation (2.8) for different periods because these estimates are not affected by μ_i.[33] We use the estimate of the time trend obtained using the IV-exogenous tenure estimator to remove the effect of secular growth. The within job estimates for Logwage in column 1 of Table 6 imply a combined return to ten years of tenure and experience of .522 for 1975-1982, and .497 for 1983-1991. The corresponding results for Logearn are .551 and .580. Thus, the change in the sum of the effects of tenure and experience appears to have been small and may even have been negative.

12. Other Evidence

Because of space considerations we do not provide a comprehensive survey of other studies of the return to seniority that have been conducted since Topel (1991). Much of the recent work examines displaced workers. (See footnote 1). Topel (1991) presents evidence that wage losses rise with seniority of workers at the time of displacement, but Topel (1990) finds little relationship between wage losses and seniority prior to a layoff. Carrington (1993) reports wage growth equations for displaced workers using several panels of the Displaced Worker Survey. His models are parameterized in terms of experience and tenure at the time of displacement rather than prior experience and tenure, but for purposes of comparison we used his estimates to evaluate the effect of tenure holding prior experience constant. His estimates imply that the wage loss is about .16 larger for a person with ten years of seniority than a person with 0 years. (See his Table 7, column 1.) This number is not directly comparable to ours, because it represents the combined effect of ten years of

[33] We normalize μ_i to have a mean of 0 in the sample, but if the mean of μ_i is higher for stayers than movers, an increase in the factor loading relating wages to μ_i could lead to an increase in the estimate of within job wage growth that has nothing to do with the return to experience or seniority.

tenure and experience on the wage level given the job match component plus the effects of tenure and experience on the change in the job match component. Neal (1995) examines industry stayers and industry changers with the same data. His finding that the value of tenure before and after a dislocation is about the same is consistent with only a small return to firm seniority. In contrast, he finds that industry specific returns may be important, a result that is consistent with the work of Carrington and Parent (1995). Using French data on individuals matched to firms, Abowd, Kramarz, and Margolis (1994) obtain relatively small estimates of the average return to seniority. Finally, Altonji and Williams (1996) use a different estimation method to obtain lower and upper bounds on the returns to seniority of .06 and .14 using the PSID and obtain similar results using the NLSY. In summary, most of the other recent studies point to a modest return to job seniority that is consistent with the evidence we present.

13. Conclusion

Our main conclusion is that the data used by both AS and Topel imply a return to ten years of tenure of about .11, which is much closer to AS's preferred estimate of .066 than Topel's estimate of .245 or the OLS estimates. Use of the survey wage rate in place of average hourly earnings leads one to revise this estimate back downward to about .06. The OLS type estimators lead a large overestimate of the return to tenure and should not be used.

The return to tenure is probably a bit larger over the 1983-1991 period than over the period analyzed by AS and Topel, but our estimate of the size of the return is sensitive to the choice of wage measure. For the later period we are able to perform a more complete analysis using the survey wage rate, which is the preferred wage measure because it does not average wages across jobs. Using this measure we obtain a return of .043 using IV1, which is probably downward biased, and a return of .120 using Topel's estimator, which is probably upward biased. We would choose an intermediate value of .08 or .09 as our estimate based on this wage measure. We would revise this estimate upward to perhaps .13 because the IV1 and Topel estimates are both substantially higher for the problematic average hourly earnings meausure of wages. We conclude that the return to job seniority plays only a modest role in the determination of wages.

Appendix 1. Topel's Analysis of the Abraham and Farber estimator: Empirical Results

Topel reports estimates of (10.1) and (10.2) based on a somewhat different sample than that used elsewhere in his paper. In these models he used year dummies to control for the secular time trend rather than the Murphy-Welsh wage index. The analysis uses data from the 1968-1981 surveys rather than 1968-1983.[34] To improve comparability with AF, he reports estimates of a model that includes only a linear and quadratic in experience and only a linear effect of tenure. He used period t-1 tenure with period t wages for this analysis. In panel A of Table A-1 we present the estimates of the return to ten years of tenure and thirty years of experience implied by the estimates Topel reports in his Table 7. The first column is OLS applied to equation (2.1) with a linear tenure specification and quadratic experience specification. The second column and fourth columns are based on versions of (10.1). The second column replaces T* with observed completed duration T_1^*, and the interaction between T_1^* and the indicator JC for whether the job was censored at the end of the panel. The fourth column sets T* to T_2^* for jobs that end in the sample and the sum of T_1^* and an estimate of the predicted residual life of the job that is based on a proportional hazards model (See Topel, footnote 24). Columns 3 and 5 are estimates of the "unrestricted" model (10.2) corresponding to columns 2 and 4. The estimates in the replication sample (for the years 1968-1981) are reported in panel B. They tend to be a bit higher, particularly in column 5, but are close to those reported by Topel.

In panel C we report results using period t tenure with period t wages. The restricted estimates in columns 2 and 4 are already small and do not fall by very much. The unrestricted estimate of the value of 10 years of tenure is still .113 when the estimate of T* based on the proportional hazards model is used (column 5), which is not that much smaller than the OLS estimate of .131 in column 1. On the other hand, the estimate is only .055 in column 3, which is close to the corresponding IV1 estimate of .062 (not reported). Consequently, the results for Topel's unrestricted version of the AF estimator become sensitive to the specific job duration control once one corrects the timing of the data.

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[34] Topel's article does not mention this, but he provided us with the computer printout underlying his Table 7.

The fact that the OLS estimates are so low in this analysis raises the possibility that the use of a linear tenure specification plays a role in these results. We investigated this by implementing 2-step versions of the restricted and unrestricted AF estimators in which we use within job variation to estimate the nonlinear tenure and experience coefficients (based on quartic specifications for both tenure and experience) in the wage level equation and then subtract these terms from the wage prior to estimation of 10.1 and 10.2. The results are in Panel D of Table A-1. As expected given our other results, the OLS estimate of the value of 10 years of tenure in column 1 rises substantially, from .131 to .268. However, the restricted AF estimators in columns 2 and 4 rise only slightly---to .030 and .053 respectively. Furthermore, the unrestricted estimates are only .092 in column 3 and .126 in column 5---much closer to the IV1 estimate of .06 for this sample and specification than to the OLS estimate. (If we add the second, third, and fourth powers of T^* to the restricted model in column 4 and the unrestricted model in column 5 the estimates are .109 and .103)[35]

In summary, after one relaxes Topel's functional form assumptions and uses wages and tenure from the same period, the use of an estimate of job duration to control for heterogeneity yields an estimate of the return to tenure between .06 and .13 even if one uses the unrestricted version of the AF estimator that Topel advocates. These values are between ¼ and ½ of the OLS estimate.

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[35] We use the 2-step version on the pragmatic grounds that it is difficult to think about how biases from individual heterogeneity and job match heterogeneity work out after one adds the means and the deviation from job means of the second, third, and fourth powers of tenure to the equation. The one step estimates of the restricted model are very close to the two step estimates after one includes the higher powers of t^*. The unrestricted 1-step estimates corresponding to the estimate in column 4 do not make much sense. They imply a large negative return to 30 years of experience equal to -.559 along with a return to ten years of tenure of .681.

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TABLE 1: Summary Statistics

	Topel (1991) Sample	Replicated Topel Sample Tenure <1 Excluded	Samples Using Year t Wage, Year t Tenure Tenure <1 Included	Tenure <1 Excluded	Tenure <1 Excluded Omit Last.Job
	(1)	(2)	(3)	(4)	(5)
Realearn	1.131 (0.497)	1.529 (0.442)	1.496 (0.462)	1.553 (0.434)	1.566 (0.429)
ΔRealearn	0.026	0.026 (0.229)	0.026 (0.235)	0.019 (0.224)	0.020 (0.221)
Logearn		1.636 (0.443)	1.604 (0.462)	1.659 (0.436)	1.672 (0.430)
Δlogearn		0.030 (0.229)	0.030 (0.235)	0.023 (0.224)	0.024 (0.221)
Experience	20.021 (11.045)	19.817 (10.592)	18.187 (10.656)	19.495 (10.375)	19.785 (10.343)
Tenure	9.978 (8.944)	10.659 (8.966)	8.989 (8.904)	10.576 (8.749)	10.870 (8.782)
Educi	12.645 (2.809)	12.675 (2.837)	12.660 (2.812)	12.648 (2.851)	12.642 (2.852)
Mrdnow	0.925 (0.263)	0.925 (0.264)	0.919 (0.273)	0.932 (0.252)	0.933 (0.250)
Unm	0.344 (0.473)	0.335 (0.471)	0.322 (0.465)	0.340 (0.472)	0.344 (0.474)
SMSA	0.644 (0.478)	0.635 (0.482)	0.646 (0.478)	0.645 (0.478)	0.647 (0.478)
Dsablh	0.074 (0.262)	0.074 (0.261)	0.069 (0.253)	0.070 (0.255)	0.070 (0.255)
Wage Change Observations	86831	9315	9831	8765	8441
Wage Level Observations	10685	11374	12499	10620	10134

Notes: Standard deviations in parentheses. Topel (1991) reports the number of wage change observations in the notes to his Table 2 (page 157) and the number of wage level observations in the notes to Table 3 (page 158).

TABLE 2: OLS, IV1 and Topel 2-Stage Estimators on Replicated Topel Sample (Dependent Variable is Realearn)

	Replicated Topel Sample			Topel (1991)		
	OLS	IV1	Topel	OLS	IV1	Topel
	(1)	(2)	(3)	(4)	(5)	(6)
Linear Tenure Coefficient	0.0529 (0.0079)	0.0343 (0.0063)	0.0623 (0.0078)		0.032 (0.006)	0.0545 (0.0079)
Linear Experience Coefficient	0.0479 (0.0119)	0.0458 (0.0124)	0.0634 (0.0169)			0.0713 (0.0181)
2 Years of Tenure	0.0918 (0.0124)	0.0565 (0.0102)	0.1040 (0.0126)			
5 Years of Tenure	0.1863 (0.0214)	0.1048 (0.0190)	0.1975 (0.0227)	0.2313 (0.0098)	0.098 (0.017)	0.1793 (0.0235)
10 Years of Tenure	0.2702 (0.0245)	0.1296 (0.0270)	0.2545 (0.0274)	0.3002 (0.0105)	0.122 (0.024)	0.2459 (0.0341)
15 Years of Tenure	0.3147 (0.0256)	0.1354 (0.0356)	0.2712 (0.0286)	0.3203 (0.0110)	0.131 (0.028)	0.2832 (0.0411)
20 Years of Tenure	0.3564 (0.0280)	0.1582 (0.0471)	0.3065 (0.0304)	0.3563 (0.0116)	0.161 (0.035)	0.3375 (0.0438)
5 Years of Experience	0.2028 (0.0395)	0.2088 (0.0409)	0.2502 (0.0571)			
10 Years of Experience	0.3391 (0.0515)	0.3723 (0.0535)	0.3931 (0.0769)			
30 Years of Experience	0.4480 (0.0507)	0.5680 (0.0607)	0.4779 (0.0748)			

Notes: White standard errors in parentheses for the OLS, IV with tenure exogenous, and IV1 estimators. Standard errors for the "Topel" or 2SFD estimator account for the fact that it is a 2-step estimator and for person specific heteroscedasticity and serial correlation in the error terms. Columns 1 through 3 use the replicated Topel sample, while columns 4 through 6 contain estimates reported by Topel (1991). The specifications in column 1 and 3 do not contain a time trend. The specification in column 2 contains an exogenous time trend. Columns 4 and 6 are taken from Table 3 of Topel. Column 5 is taken from Table 6, column 2 of Topel. All specifications include a quartic in tenure, a quartic in experience, years of education, marital status, a union membership variable, current disability, residence in an SMSA, residence in a city with a population of more than 500,000 and eight Census regions.

TABLE 3: The Effects of Time Trend and Dating of the Wage and Tenure in the Replicated Topel Sample.

Panel A: Year t-1 wage, Year t tenure, Tenure < 1 excluded

	Realearn No Time Trend			Logearn Exogenous Time Trend			Logearn Endogenous Time Trend			Logearn Endogenous Year Dummies		
	OLS	IV1	Topel	OLS	IV1	Topel	Tenure Exo.	IV1	Topel	Tenure Exo.	IV1	Topel
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Time Trend				0.0088 (0.0011)	0.0085 (0.0011)		0.0093 (0.0011)	0.0106 (0.0012)				
2 Yrs. Tenure	0.0918 (0.0124)	0.0771 (0.0103)	0.1040 (0.0126)	0.0920 (0.0124)	0.0520 (0.0102)	0.0972 (0.0126)	0.0920 (0.0124)	0.0445 (0.0101)	0.0966 (0.0126)	0.0923 (0.0123)	0.0505 (0.0100)	0.0980 (0.0126)
10 Yrs. Tenure	0.2702 (0.0245)	0.2462 (0.0277)	0.2545 (0.0274)	0.2717 (0.0246)	0.1209 (0.0270)	0.2265 (0.0273)	0.2719 (0.0243)	0.0789 (0.0251)	0.2231 (0.0273)	0.2730 (0.0243)	0.0930 (0.0249)	0.2197 (0.0273)
20 Yrs. Tenure	0.3564 (0.0280)	0.4048 (0.0471)	0.3065 (0.0304)	0.3579 (0.0279)	0.1634 (0.0474)	0.2566 (0.0306)	0.3580 (0.0279)	0.0745 (0.0402)	0.2499 (0.0306)	0.3587 (0.0279)	0.0834 (0.0396)	0.2323 (0.0302)
10 Yrs. Exper.	0.3391 (0.0515)	0.3528 (0.0540)	0.3931 (0.0769)	0.3036 (0.0517)	0.3668 (0.0534)	0.3662 (0.0763)	0.3019 (0.0516)	0.3738 (0.0537)	0.3649 (0.0763)	0.3072 (0.0516)	0.3710 (0.0537)	0.3613 (0.0763)
30 Yrs. Exper.	0.4480 (0.0507)	0.3882 (0.0663)	0.4779 (0.0748)	0.4191 (0.0510)	0.5541 (0.0607)	0.4258 (0.0744)	0.4176 (0.0511)	0.6189 (0.0563)	0.4217 (0.0744)	0.4221 (0.0511)	0.6159 (0.0561)	0.4144 (0.0745)

(continued)

TABLE 3—Continued

Panel B: Year t Wage, Year t Tenure

	Realearn, No Time Trend Tenure < 1 included			Logearn, Endogenous Time Trend Tenure < 1 Included		Tenure < 1 Excluded		Tenure < 1 and Last Obs on Job Excluded	
	OLS	IV1	Topel	IV1	Topel	IV1	Topel	IV1	Topel
	(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20)	(21)
2 Yrs. Tenure	0.0959 (0.0095)	0.0574 (0.0081)	0.0802 (0.0097)	0.0281 (0.0078)	0.0728 (0.0097)	-0.0008 (0.0102)	0.0319 (0.0118)	0.0088 (0.0104)	0.0377 (0.0115)
10 Yrs. Tenure	0.2630 (0.0203)	0.1767 (0.0247)	0.1857 (0.0223)	0.0311 (0.0220)	0.1611 (0.0225)	-0.0287 (0.0252)	0.1052 (0.0252)	0.0070 (0.0267)	0.1182 (0.0242)
20 Yrs. Tenure	0.3391 (0.0274)	0.3134 (0.0469)	0.2413 (0.0287)	0.0316 (0.0403)	0.1962 (0.0290)	-0.0284 (0.0418)	0.1786 (0.0298)	0.0276 (0.0446)	0.1994 (0.0292)
10 Yrs. Exper.	0.2967 (0.0396)	0.3482 (0.0413)	0.3793 (0.0658)	0.3632 (0.0410)	0.3514 (0.0652)	0.3491 (0.0513)	0.3926 (0.0646)	0.3099 (0.0528)	0.3998 (0.0634)
30 Yrs. Exper.	0.3906 (0.0418)	0.4082 (0.0577)	0.4311 (0.0628)	0.6007 (0.0478)	0.3850 (0.0626)	0.5897 (0.0548)	0.4099 (0.0642)	0.5165 (0.0573)	0.4175 (0.0629)

Notes: Standard errors in parentheses—see Table 2. The specification is as described in the notes to Table 2. The sample sizes are 11374 for cols. 1, 2, 4, 5, 7, 8, 10, and 11 and for the second stage of the Topel 2-step estimator (equation 2.9) in cols. 3, 6, and 9. The sample for first stage of the Topel 2-step model (2.8) in cols. 3, 6, and 9 contains 9315 wage change observations. The samples for cols. 13, 14, 16, and 17 and for the 2nd stage of the Topel 2-step estimator in cols. 15 and 17 contain 12499 observations, and the 1st stage in cols. 15 and 17 contains 9831 wage change observations. The sample for col. 18 and for the 2nd stage of the Topel estimator in col. 19 contains 10620 observations, and the 1st stage in col. 19 contains 8765 wage change observations. The sample for column 20 and for the 2nd stage of the Topel estimator in col. 21 contains 10134 observations, and the 1st stage in col. 21 contains 8441 wage change observations.

TABLE 4: Logwage Regressions

	Endogenous Time Trend Year t Wage, Year t Tenure T < 1 Included		
	IV, Tenure Exogenous	IV1	Topel
	(1)	(2)	(3)
2 Years of Tenure	0.0675 (0.0103)	0.0224 (0.0079)	0.0454 (0.0100)
5 Years of Tenure	0.1362 (0.0176)	0.0343 (0.0149)	0.0814 (0.0182)
10 Years of Tenure	0.1957 (0.0215)	0.0226 (0.0226)	0.0903 (0.0234)
20 Years of Tenure	0.2539 (0.0277)	0.0072 (0.0423)	0.0733 (0.0302)
5 Years of Experience	0.1589 (0.0315)	0.1876 (0.0328)	0.1863 (0.0414)
10 Years of Experience	0.2639 (0.0393)	0.3312 (0.0406)	0.2734 (0.0568)
30 Years of Experience	0.3651 (0.0415)	0.5447 (0.04485	0.3111 (0.0541)

Notes: Standard errors in parentheses—see Table 2. The specification is as described in the notes to Table 2. The mean of logwage is 1.48. The first stage of the Topel two-step estimator uses 6462 within job first differences, while the IV with tenure exogenous, IV1, and second stage of the Topel estimator uses 9183 observations.

TABLE 5: Estimator Investigation

	Realearn No Time Trend Year t-1 Wage, Year t Tenure Tenure < 1 excluded				Realearn No Time Trend Year t Wage, Year t Tenure Tenure < 1 included				Logearn Endogenous Time Trend Year t Wage, Year t Tenure Tenure < 1 included			
	2SFD	2SDEV	2SDEV	IV1	2SFD	2SDEV	2SDEV	IV1	2SFD	2SDEV	2SDEV	IV1
	X0 Endo	X0 Exo	X0 Endo	X Exo	X0 endo	X0 exo	X0 endo	X exo	X0 endo	X0 exo	X0 endo	X exo
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
2 Yrs. Tenure	0.0976 (0.0139)	0.0679 (0.0093)	0.0709 (0.0116)	0.0771 (0.0103)	0.0683 (0.0116)	0.0577 (0.0072)	0.0564 (0.0095)	0.0574 (0.0081)	0.0497 (0.0113)	0.0451 (0.0071)	0.0269 (0.0090)	0.0281 (0.0078)
10 Yrs. Tenure	0.2225 (0.0491)	0.2099 (0.0208)	0.2248 (0.0418)	0.2462 (0.0277)	0.1260 (0.0781)	0.1801 (0.0169)	0.1738 (0.0368)	0.1767 (0.0247)	0.0438 (0.0408)	0.1289 (0.0169)	0.0380 (0.0339)	0.0311 (0.0220)
20 Yrs. Tenure	0.2424 (0.0774)	0.3165 (0.0260)	0.3463 (0.0778)	0.4048 (0.0471)	0.1218 (0.0523)	0.2882 (0.0248)	0.2757 (0.0705)	0.3134 (0.0469)	-0.0354 (0.0766)	0.2022 (0.0248)	0.0203 (0.0649)	0.0316 (0.0403)
5 Yrs. Exper.	0.2662 (0.0592)	0.2626 (0.0379)	0.2552 (0.0416)	0.2106 (0.0411)	0.2814 (0.0523)	0.2339 (0.0325)	0.2370 (0.0355)	0.2039 (0.0320)	0.2954 (0.0515)	0.2115 (0.0321)	0.2570 (0.0345)	0.1955 (0.0322)
10 Yrs. Exper.	0.4251 (0.0828)	0.4140 (0.0514)	0.3991 (0.0615)	0.3528 (0.0769)	0.4390 (0.0722)	0.3645 (0.0432)	0.3707 (0.0519)	0.3482 (0.0413)	0.4672 (0.0708)	0.3277 (0.0427)	0.4187 (0.0495)	0.3632 (0.0410)
30 Yrs. Exper.	0.5741 (0.1208)	0.5151 (0.0540)	0.4704 (0.1155)	0.3882 (0.0748)	0.6103 (0.1131)	0.4435 (0.0461)	0.4622 (0.1004)	0.4082 (0.0577)	0.7324 (0.1089)	0.3763 (0.0459)	0.6491 (0.0911)	0.6007 (0.0478)

Notes: Standard errors in parentheses—see Table 2. The specification is as described in the notes to Table 2. When X0 is treated as endogenous, it is instrumented with current experience, X. The sample size is 9315 for the 1st stage in column 1 and 11374 for the 2nd stage. The sample size for the first stage, 2nd stage, and IV estimates in columns 2-4 is 11374. The sample size for the 1st stage in columns 5 and 9 is 9831 and 12499 for the 1st stage. The sample size for the 1st stage, 2nd stage and IV estimates in columns 6-8 and 10-12 is 12499.

TABLE 6: Estimates for 1975-1982, 1983-1991, and 1975-1991

	Panel A: 1975-1982							
	Dependent Variable: log wage				Dependent Variable: log earnings			
	Within Job Wage Growth	IV, Tenure Exogenous	IV1	Topel	Within Job Wage Growth	IV, Tenure Exogenous	IV1	Topel
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
10 Years of Tenure	Not Identified	0.2335 (0.0226)	0.0134 (0.0000)	0.1136 (0.0000)	Not Identified	0.3363 (0.0237)	0.0542 (0.0303)	0.1427 (0.0366)
30 Years of Experience	Not Identified	0.4817 (0.0471)	0.7404 (0.0657)	0.5327 (0.0538)	Not Identified	0.4305 (0.0507)	0.7598 (0.0717)	0.4650 (0.0729)
10 Years of Tenure and Experience	0.5220 (0.0479)	0.5542 (0.0426)	0.4631 (0.0438)	0.5220 (0.0479)	0.5507 (0.0479)	0.6265 (0.0463)	0.5088 (0.0480)	0.5507 (0.0479)
	Panel B: 1983-1991							
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
10 Years of Tenure	Not Identified	0.2923 (0.0214)	0.0427 (0.0267)	0.1202 (0.0263)	Not Identified	0.4060 (0.0223)	0.1391 (0.0271)	0.2189 (0.0308)
30 Years of Experience	Not Identified	0.5853 (0.0510)	0.8058 (0.0611)	0.4639 (0.0550)	Not Identified	0.5243 (0.0309)	0.7419 (0.0628)	0.4553 (0.0743)
10 years of Tenure and Experience	0.4964 (0.0491)	0.6846 (0.0503)	0.5420 (0.0503)	0.4964 (0.0491)	0.5801 (0.0759)	0.7817 (0.0499)	0.6385 (0.0533)	0.5811 (0.0759)

(continued)

TABLE 6—Continued

	Panel C: 1975-1991							
	Dependent Variable: log wage				Dependent Variable: log earnings			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
10 Years of Tenure	Not Identified	0.2740 (0.0167)	0.1077 (0.0183)	0.1184 (0.0191)	Not Identified	0.3812 (0.0175)	0.1634 (0.0190)	0.1818 (0.0219)
30 Years of Experience	Not Identified	0.5231 (0.0369)	0.6384 (0.0416)	0.4980 (0.0404)	Not Identified	0.4677 (0.0385)	0.6342 (0.0436)	0.4444 (0.0507)
10 years of Tenure and Experience	0.5120 (0.0332)	0.6196 (0.0308)	0.5399 (0.0312)	0.5120 (0.0332)	0.5651 (0.0495)	0.7056 (0.0335)	0.6040 (0.0335)	0.5651 (0.0495)

Notes: Standard errors in parentheses—see Table 2. The specification is as described in the notes to Table 2, except that the eight Census region dummies have been replaced by three area dummies. In all panels, the dependent variable is the log wage in columns 1-4, and log earnings in columns 5-8. The log wage samples for 1975-1982, 1983-1991, and 1975-1991 contain 8582, 11514, and 20096 observations. The samples for column 1 and for the first stage of the Topel estimator in column 4 contain 5782, 7297, and 14056 wage change observations. The log earnings samples for 1975-1982, 1983-1991, and 1975-1991 contain 9782, 12776, and 22558 observations. The samples for column 5 and for the first stage of the Topel estimator in column 8 contain 6771, 8198, and 16056 wage change observations. The sample periods are the calendar year that the wage and earnings data refer to, rather than the years of the PSID survey. For example, the log earnings in 1991 are from the 1992 survey, and log wage in 1991 is from the 1991 survey.

TABLE A-1: Topel's Analysis of Abraham and Farber's Estimator

	OLS	AF (10.1)	Unrestricted AF (10.2)	AF (10.1)	Unrestricted AF (10.2)
	(1)	(2)	(3)	(4)	(5)
Controls for Duration	None	$T_1^*, JC^*T_1^*$	$T_1^*, JC^*T_1^*$	T_2^*	T_2^*
	Panel A: Results based upon Topel (1991), Table 7. Linear Tenure, Linear and Quadratic Experience, Year t-1 Wage, Year t Tenure				
10 Years of Tenure	0.138 (0.052)	-0.015 (0.015)	0.137 (0.038)	0.060 (0.007)	0.163 (0.067)
30 Years of Experience	0.543	0.516	0.387	0.525	0.546
	Panel B: Results based upon Replication Sample, 1968-1981. Linear Tenure, Linear and Quadratic Experience, Year t-1 Wage, Year t Tenure				
10 Years of Tenure	0.1423 (0.0050)	0.0016 (0.0147)	0.1557 (0.0366)	0.0212 (0.0091)	0.2102 (0.0366)
30 Years of Experience	0.5046 (0.0159)	0.4881 (0.0159)	0.3514 (0.0744)	0.5049 (0.0157)	0.3712 (0.0731)

(continued)

TABLE A-1— Continued

	Panel C: Replication Sample, 1968-1981. Linear Tenure, Linear and Quadratic Experience, Year t Wage, Year t Tenure				
10 Years of Tenure	0.1309 (0.0051)	-0.0108 (0.0149)	0.0554 (0.0369)	-0.0024 (0.0095)	0.1146 (0.0369)
30 Years of Experience	0.4085 (0.0155)	0.3967 (0.0158)	0.4175 (0.0758)	0.4023 (0.0157)	0.3929 (0.0744)
	Panel D: 1968-1981 Replication Sample, 1968-1981 Fourth Order Polynomials in Tenure and Experience, Year t Wage, Year t Tenure				
10 Years of Tenure	0.2678 (0.0306)	0.0295 (0.0306)	0.0921 (0.0294)	0.0529 (0.0236)	0.1262 (0.0285)
30 Years of Tenure	0.3661 (0.0482)	0.4503 (0.0482)	0.4434 (0.0478)	0.4675 (0.0478)	0.4637 (0.0478)

Notes: Standard errors in parentheses have not been corrected for correlation over time in the errors for each persons or for the fact that the estimates in column 4 and 5 of Panel B and C and the estimates in columns 2-5 of Panel C are based on 2-step estimators. Following Topel (1991), in Panels A-C, columns 3 and 5 also include the deviation of squared experience from its job mean, and the job mean of squared experience. The other variables in the equations correspond to Topel (1991), and include controls for education, marital status, disability status, union status, region, and city size. All equations contain a set of year dummies. In Panel D, we implement a 2-step version of the Abraham and Farber estimator. In the first step we use within wage changes to estimate nonlinear tenure and experience coefficients in the wage level equation. We subtract these terms from the wage prior to estimation of equations 10.1 and 10.2 by OLS.

TABLE A-2: Experience Effects When Tenure is Excluded (IV with endogenous time trend)

	Dependent Variable					
	Logwage			Logearn		
	1975-1982	1983-1991	1975-1991	1975-1982	1983-1991	1975-1991
	(1)	(2)	(3)	(4)	(5)	(6)
10 Years Experience	0.469	0.530	0.497	0.496	0.568	0.532
30 Years Experience	0.710	0.826	0.769	0.772	0.859	0.818
Time Trend	0.0094	-0.0082	-0.0018	0.0093	-0.0052	0.0006

Notes: The dependent variable is Logwage in columns 1-3 and Logearn in columns 4-6. The sample sizes are given in Table 6. The estimation method is IV with the time trend treated as endogenous with $\tilde{t}_i$, and the estimation method and specification of the wage equations are identical to columns 2 and 6 of Table 6 except that all terms involving tenure are excluded from the wage equation and instrumental variables set.

TABLE B-1: Functional Form Investigation

Logearn, Endogenous Time Trend
Year t Wage, Year t Tenure

	Tenure < 1 excluded Topel's functional form			Tenure < 1 excluded AS' functional form			Tenure < 1 included Topel's functional form			Tenure < 1 included AS' functional form		
	IV, Tenure Exo	IV1	Topel	IV, Tenure Exo	IV1	Topel	IV, Tenure Exo	IV1	Topel	IV, Tenure Exo	IV1	Topel
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
2 Years Tenure	0.0599 (0.0088)	-0.0008 (0.0119)	0.0318	0.0415 (0.0027)	-0.0107 (0.0052)	0.0241	0.0953 (0.0060)	0.0281 (0.0090)	0.0728	0.1126 (0.0092)	0.0386 (0.0123)	0.0521
10 Years Tenure	0.2055 (0.0160)	-0.0286 (0.0262)	0.1051	0.1805 (0.0102)	-0.0375 (0.0215)	0.1063	0.2632 (0.0108)	0.0311 (0.0208)	0.1595	0.2431 (0.0094)	0.0207 (0.0194)	0.1767
20 Years Tenure	0.3047 (0.0143)	-0.0284 (0.0356)	0.1785	0.2928 (0.0132)	-0.0354 (0.0352)	0.1775	0.3395 (0.0114)	0.0316 (0.0320)	0.1958	0.3494 (0.0114)	0.0361 (0.0315)	0.2580
10 Years Experience	0.2559 (0.0325)	0.3491 (0.0102)	0.3927	0.2761 (0.0213)	0.3752 (0.0237)	0.3113	0.2627 (0.0246)	0.3632 (0.0269)	0.3516	0.2927 (0.0177)	0.3953 (0.0199)	0.3568
30 Years Experience	0.3483 (0.0308)	0.5897 (0.0404)	0.4101	0.3646 (0.0212)	0.6143 (0.0327)	0.3351	0.3635 (0.0236)	0.6007 (0.03334	0.3855	0.3895 (0.0173)	0.6313 (0.0282)	0.3799

Notes: Standard errors in parentheses have not been corrected for correlation over time in the errors for each person. Columns 1-3 and 7-9 include a quartic in tenure and experience. The specifications in columns 4-6 and 10-12 contain a quadratic in tenure, a dummy for tenure equal to or exceeding one year, a cubic in experience, and the interaction of experience and education.