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LIFE-CYCLE EARNING CAPACITY AND THE OJT INVESTMENT MODEL*

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After two decades of development, the human capital investment model has been thoroughly incorporated into the language and thinking of labor economists and is central to most analyses of earnings determination. The principal innovation of this development is the focus on earning capacity and human wealth; incomes over time are determined by individuals' choices of investment patterns and by competitive returns on past investments. By this theory, individuals make a series of compensating choices (presumed to be rationally based); these investment choices imply that lifetime labor earnings will be more equally distributed than cross-sectional labor incomes. If such is the case, considerable caution is required in comparing cross-sectional earnings for individuals at different career points or across race and sex groupings.

The empirical usefulness of this theory rests on the ability to characterize parsimoniously the systematic investment patterns of individuals. In the case of formal schooling, where the investigation has been most extensive, empirical analysis utilizing observed data on the quantity of schooling (and, at times, on its quality as well) is fairly straightforward.

Application of the theory to life-cycle differences in earnings, the subject of this paper, is more problematic, because post-school investments are not directly observed and because a wide variety of specific activities might reasonably be construed as "investments." The central role of unobservables and maintained hypotheses about the pattern of individual investments implies that the post-schooling investment model in a fundamental sense cannot be "tested" in full generality. However, the influential work of Jacob Mincer [1974] showed how the model could be applied to life-cycle earnings differences if the optimal investment patterns of individuals could be described in terms of observable characteristics.

Mincer focused on the activity of on-the-job training (OJT). While he considered a variety of possible investment patterns, OJT investment rates that are linear functions of labor market experience have received the most attention. These investment patterns imply that individual (log) earnings are a quadratic function of experience — the "standard" empirical model. More complete

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theoretical analyses giving explicit attention to the derivation of optimal investment patterns have led to only minor differences in the empirical specifications, and Mincer's formulation can be considered as an approximation to these alternative optimal investment patterns. (See, for example, Ben–Porath [1967, 1970], Haley [1973], Polachek [1975], Rosen [1976], Heckman [1976], Brown [1976], and Blinder and Weiss [1976]

However, the testing of this general class of models has been quite indirect. While the economic content of the theory is found in the underlying OJT investment behavior, empirical analyses have concentrated exclusively upon the life-cycle pattern of observed earnings. From age-earnings patterns alone, it is difficult to distinguish this theory from a variety of alternative, noninvestment explanations. Moreover, thee mpirical analysis of OJT investment confronts very difficult measurement problems. Noninvestment factors such as an individual's motivation, ability, or physical health, which are presumably important and perhaps dominant in earnings determination, are seldom accurately measured. Conceptually key information about an individual's past labor force participation and experience is often incomplete or missing. Finally, application of the model has been limited almost exclusively to white males because the assumptions typically made in empirical analysis appear quite implausible for females and minorities. Attempts to amend the empirical model for females (e.g., Mincer and Polachek [1974, 1978], Polachek [1975], Jones and Long [1979], Sandell and Shapiro [1980], Mincer and Ofek [1982]) still leave serious questions about the model's appropriateness.

This analysis refines and extends the basic investment model in an effort to circumvent the most serious empirical problems. An extensive empirical analysis, capitalizing on the unique features of panel data, probes the relationship between wage growth and investments in on-the-job training. However, common specifications of individual investment behavior receive little support when subjected to the more exacting tests of changes in earning capacity developed in this paper.

The use of wage determination models in the interpretation of race or sex differences in earnings is now fairly common (cf. Lazear [1979], Chiswick [1974], Johnson and Stafford [1974], or Sawhill [1976]). In these applications, an attempt is made to distinguish "compensating wage differences", which arise from individual choices, from other sources of earnings variation. This decomposition of earnings differentials is appropriate only if OJT investment patterns are accurately characterized and if they are an important source of systematic life-cycle earnings differences. Our results suggest using extreme caution in applying investment models to the interpretation of earnings differentials by race or sex.

1. EARNING CAPACITY AND ON-THE-JOB TRAINING INVESTMENTS

A wide variety of specific activities may be viewed as augmenting human capital

— schooling, job search, geographic mobility, preventive medicine, even recreation. In this paper, we concentrate on one activity, post-school OJT, because of its perceived dominance in life-cycle wage determination. Human capital investment models vary considerably in both theoretical and empirical specifications. In this section, we extend the "Mincer" version of OJT investment behavior to accommodate intermittant and varying employment patterns and more generalized investment behavior. This is placed within an estimation context which concentrates upon the structural investment parameters.

1.1. *Conceptual Model.* The kernal of the human capital theory of individual earnings is the relationship between investment, productive capacity, and wage rates over the life-cycle. This analysis concentrates exclusively on generalized models of post-school investments in skill acquisition made on-the-job. (The subsequent empirical analysis considers schooling investments only to the extent that they interact with OJT investments).

The potential earning capacity in period t, $\tilde{W}_t^i$, of individual i (that is, earning capacity if it did not include any training) can be written as

$$\tilde{W}_t^i = f(H_t^i;\, X_t^i,\, \eta_t^i), \tag{1}$$

where H_t^i is the accumulated stock of human capital, X_t^i is a vector of other observable, capital augmenting characteristics, η_t^i is a composite of unobserved or unobservable characteristics, and the subscript t indicates years since entry into the labor force. With homogeneity among workers except for human capital stocks, a static competitive market implies

$$\tilde{W}_t^i = rH_t^i \tag{1'}$$

where r is the competitive rate of return to the stock of capital. Earning capacity is taken here to be synonymous with wage rates. This specification clearly limits attention only to "general" worker-financed human capital; cf. Becker [1964]. Human capital that is specific to an individual firm (i.e., nontradable) is ignored, even though such training might have implications for an individual's wages within the given firm. (See, for example, Chapman and Tan [1980]).

The human capital stock, with no depreciation, is merely the accumulated flow of past investments. If all investment after leaving school at $\tau = 0$ comes in the form of on-the-job training,[2] then

$$H_t^i = \sum_{\tau=0}^{t-1} \lambda_\tau^i k_\tau^i \tilde{W}_\tau^i \tag{2}$$

where λ_τ^i is the fraction of total time in period τ spent on the job and k_τ^i is the fraction of potential earning capacity devoted to OJT investments. This formulation incorporates explicitly the idea that the amount of on-the-job training

[2] Thoughout this development, "time" begins at entry to the labor force. At that point, an individual has some initial stock of human capital (from previous schooling, experience, etc.) and is able to command some initial wage $\tilde{W}_0^i$.

must be related to the amount of time spent on-the-job. Further, if workers finance training investments through reductions in wages (cf. Becker [1964] or Mincer [1974]), the observed wage, W_t^i, is:

$$W_t^i = \tilde{W}_t^i - k_t^i \tilde{W}_t^i. \tag{3}$$

Combining (1′), (2), and (3), using the recursion relationships, taking the logarithm of both sides, and finally using a Taylor approximation, yields:

$$\log W_t^i \simeq \log \tilde{W}_0^i + r\Big(\sum_{\tau=0}^{t-1} \lambda_\tau^i k_\tau^i\Big) - k_t^i. \tag{4}$$

This equation relates observed wages to investment activities; the observed hourly wage of an individual at t equals the return on the accumulated stock of human capital minus that fraction of productive capacity invested during t.

If other individual factors affecting earnings (both observed and unobserved) augment human capital, equation (1) can be generalized to

$$\tilde{W}_t^i = f(H_t^i, X_t^i, \eta_t^i) = rH_t^i \exp\{X_t^i\beta + \eta_t^i\}, \tag{1''}$$

and equation (4) becomes

$$\log W_t^i = \log \tilde{W}_0^i + r\Big(\sum_{\tau=0}^{t-1} \lambda_\tau^i k_\tau^i\Big) - k_t^i + X_t^i\beta + \eta_t^i. \tag{4'}$$

where $\tilde{W}_0^i$ is the competitive wage rate with no OJT investments at some reference level of individual characteristics.

Equation (4′) describes how an individual's wages throughout the life-cycle are related to past work history (λ_τ^i, $\tau = 0, 1, \ldots, t$), investment patterns (k_τ^i, $\tau = 0, 1, \ldots, t$). and other personal characteristics. The behavioral content of the model is encapsulated in pattern of the k_τ^i, reflecting the rational investment choices of individuals. Since this investment pattern cannot be directly observed, estimation of the model requires the imposition of some structure based upon theoretical considerations. Moreover, the empirical usefulness of the model rests upon the consistency of these investment patterns across individuals, since if "otherwise identical" individuals follow substantially different investment strategies that cannot be readily parameterized in terms of observable characteristics, the model is tautological and lacking of predictive power.

The focus of most empirical analyses of wage determination has been the specification of the underlying investment profiles and/or the stochastic structure of the model. The following section presents a number of generalizations of previous models and considers the identification and estimation of the structural investment parameters.

1.2. *Empirical Implementation.* The typical cross-sectional analysis simultaneously introduces several assumptions to translate the conceptual model into a form amenable to estimation. The k_τ^i are assumed to be some exact functional relationship of observed characteristics such as time out of school (i.e.,

$k_\tau^i=g[\tau]$); work histories are assumed to be time-invariant (e.g., $\lambda_\tau^i\equiv 1$); and, unobserved factors (η_τ^i) are assumed to be distributed independently of the observed determinants of wages.[3] With these assumptions, knowledge of the current value of τ (the time out of school or "potential experience" of an individual) is sufficient to characterize past human capital accumulation, and, when augmented with data about other observable characteristics of individuals (X), the estimation of the wage relationship in Equation 4′ is straightforward.

Given a particular specification of the optimal investment profile, there remain three major difficulties with these cross-sectional analyses. First, if work activity (λ_τ^i) differs over time for individuals, considerable error will be introduced in the estimation of an individual's human capital stock, even when investment plans are adequately characterized. Even white males, historically the demographic group with the most stable employment, show considerable variation in work activity. Second, there are conceptual and empirical reasons to believe that the unobserved determinants of wages may, in fact, be correlated with the observed determinants (cf. Griliches [1977], Hausman [1978]). Finally, even with these assumptions, the rate of return and the parameters of the investment schedule generally are not separately identified. This section develops an integrated solution to these major problems, based in part upon the additional information found in panel data on individuals.

Panel data provide direct observations of the λ_τ^i's, at least for some period of an individual's career, but the estimation of the accumulated human capital stock still requires *a priori* specification of desired, or optimal, investment rates. The pattern of the k_τ^i's, the individual's investment program, presumably incorporates the length of expected working life, the rate of return on investments, the costs of investment, the expected pattern of labor force participation and employment, and the pattern of depreciation of capital. Nevertheless, theory yields few specific insights into the form of investment profiles other than their eventual decline (owing to shortened "pay back" periods and increasing opportunity costs of investments). This analysis begins by adopting a generalization of the "standard" (Mincer) formulation of investment profiles. This is subsequently modified by explicitly incorporating individual specific measures of labor force attachment; ultimately a wide variety of alternative maintained hypotheses about the systematic determinants and functional form of the individual's optimal investment plan are analyzed.

For expositional purposes, we concentrate upon investment schedules described by investment ratios (k_τ^i) that decline linearly with the individual's potential

[3] Note that $\lambda_\tau^i\equiv 1$ is stronger than actually needed for empirical implementation. If, for example, the λ_τ^i's differ across individuals but are constant over each individual's lifetime (i.e., $\lambda_\tau^i=\lambda^i$), cross-sectional information about individuals' potential experience and actual labor market experience is sufficient to characterize total investments (cf. see Hanushek and Quigley [1978]). The analysis of part-week work of women by Jones and Long [1979] is essentially an adaptation of the "lambda constant" model.

experience (τ):[4]

(5) $$k_\tau^i = \gamma_0 + \gamma_1 \tau \quad \text{where} \quad 0 \leq \gamma_0 < 1 \quad \text{and} \quad -1 < \gamma_1 \leq 0.$$

The parameters of this schedule (γ_0 and γ_1) are assumed constant across a particular class of individuals; for example, in the subsequent empricial analysis the parameters are allowed to vary freely across race, sex, and schooling groups but are assumed constant within groups. With continuous employment, or $\lambda_\tau^i = 1$, this leads to the familiar model that log wages are a quadratic function of potential experience.

Such a formulation is neither the only nor even the most plausible specification of individual investment behavior. Yet, because of its convenience and usefulness in empirical analysis, particularly when direct measurement of work activity is unavailable, this implied investment pattern has dominated statistical estimation of earnings and wage models. Further, while seldom made explicit, it is central to many comparisons of black-white or male-female earnings differences. Subsequent discussion will focus both on the interpretation and on various modifications of this specification, but it is useful to indicate some of the key assumptions at this point. Individuals are presumed to make optimal investment plans that are independent of the specific occupation, industry, or firm of their employment, and the plan is not readjusted based upon realized employment records.[5] This formulation thus contains a number of obvious assumptions about individual foresight, the functioning of capital markets, and the availability of training opportunities.

The actual pattern of capital accumulation is dependent upon both the planned work-training division (k_τ^i) and the realized work (λ_τ^i) in each period; therefore, annual investment will not be linear —indeed it will not necessarily be monotonically decreasing— when employment varies over time. Nevertheless, the implied life-cycle pattern of investment plans in Equation 5, since it does not directly incorporate individual variations in expected labor force activity, is probably least plausible for individuals who have in the past or might expect in the future to move in and out of the labor force — for example, some women and minorities. At this point, no attempt is made to derive independently any new specification of investment behavior. Instead, the thrust of this effort is to

[4] Also for expositional convenience, the investment profile is specified as deterministic. However, the analytical development is consistent with a more general random coefficients specification:

(N–1) $k_\tau^i = \gamma_0^i + \gamma_1^i \tau + \psi_\tau^i$.

where γ_0^i, γ_1^i, and ψ_τ^i are i.i.d. random variables with $E(\gamma_0^i) = \gamma_0$, $E(\gamma_1^i) = \gamma_1$, and $E(\psi_\tau^i) = 0$. The major impact of this specification is the introduction of serial correlation in the individual errors (i.e., the ξ_t^i below); we test for this below.

[5] Human capital investment at any point in time —in a particular firm, occupation, and job— is portrayed as perfectly substitutable for any other training investment. Chapman and Tan [1980] and Polachek [1981] concentrate upon training differences in different industries or occupations, although is is difficult to distinguish between differing quantities and qualities of training across industry or occupation.

concentrate upon the direct interaction between investment and employment experiences while exploiting the relatively parsimonious investment characterization common to most previous empirical analyses.

The other major consideration in the empirical implementation of the model is the precise specification of the stochastic structure of wages. Virtually all past wage investigations can be cast in terms of a simple error components structure, where η_t^i is the sum of a systematic, time invariant component (ω^i) and a pure white noise term (ξ_t^i) such that: $E(\omega^i, \omega^j)=0$ for $i \neq j$; $E(\xi_t^i)=0$ for all i, t; and, $E(\xi_t^i, \xi_p^j)=0$ for all $i \neq j$ and $p \neq t$. In general, no additional distributional assumptions are made about the ω^i, but the ξ_t^i are assumed to be drawn independently of the observed variables.

Most past attention has been directed at the systematic, individual differences (ω^i) — generally labelled "ability." As is well recognized, the parameter estimates for the wage relationships will be biased and inconsistent when ability differences (whether reflecting physical, mental, motivational or informational differences) are related to the measured determinants of wages.

The common thrust of this past research has been the introduction, either explicitly or implicitly, of assumptions about the omitted or unobserved abilities, so that any correlations with the included exogenous variables could be presumed small. In cross-sections, where disentangling the components of the η_t^i is not possible, direct measures of ability (generally cognitive test measures) have been introduced directly (e.g., Hause [1972]) or in conjunction with instrumental variables techniques that recognize measurement errors (e.g., Griliches and Mason [1972], Griliches [1977], Chamberlain and Griliches [1975]).[6] Data for more than a single cross-section allow estimation that more fully incorporates the error structure; for example, data on siblings (cf. Griliches [1977] or Taubman [1976]) or on the same individual over time (cf. Lazear [1976] or Brown [1980]) permit consistent estimation in the presence of unmeasured ability factors. These latter analyses are essentially fixed effects models where ω^i may be correlated with the observed variables. Hausman and Taylor [1981] further develop an instrumental variables approach that allows estimation of time invariant individual factors such as schooling, even with fixed unobservable components. However, this technique requires orthogonality of the unobserved component and some of the observed variables, and this condition is difficult to meet, given the composition of the fixed components discussed below. Other analyses (e.g., Lillard and Willis [1978]) employ a random effects model where the ω^i are assumed to be drawn from a common distribution and independent of the observed variables. With these assumptions, generalized least squares provide efficient estimation. However, the results of Hausman [1978] and Hausman and Taylor [1981] strongly reject the random effects model.

[6] The assumption of the first is that, once ability is directly measured, $\omega^i=0$. The assumption of the second is that ω^i reflects measurement errors in ability; instrumental estimation purges measured ability of these errors and thus eliminates (asymptotically) the correlation of ω^i and X.

Note that the fixed individual error component includes not only ability but also a variety of measurement errors related to the quantity and quality of the human capital stock. Consider, for example, estimation from panel data where typically the complete employment histories of all invididuals (i.e., the complete set of λ_τ^i's) are unavailable. Say we observe an individual over some time period, p to t. The capital stock terms from Equation 4′ can be written as:

$$\sum_{\tau=0}^{t-1} \lambda_\tau^i k_\tau^i = h_p^i + \sum_{\tau=p}^{t-1} \lambda_\tau^i k_\tau^i$$

where h_p^i represents the sum of investments prior to observation at p and whose magnitude depends upon the unobserved employment history $(\lambda_1^i, \ldots, \lambda_{p-1}^i)$. The last term is the accurately measured part of the capital stock, and, while h_p^i might be estimated from the observed data (cf. Hanushek and Quigley [1978]), it is unlikely that errors in measurement of h_p^i will be uncorrelated with the observed portion of the human capital stock. In general, any other measurement errors, say those resulting from quality differences in schooling (where schooling is included in the X's), will also be included in the individual specific errors.

Define $\hat{h}_p^i$ as an estimate of the human capital stock prior to the beginning observation where $\hat{h}_p^i = h_p^i + v^i$. Then, given the investment specification of Eq. (5), we can write the wage relationship of Eq. (4) in terms of observable variables plus stochastic terms:

$$\text{(6)} \qquad \log W_t^i = (\log \tilde{W}_0^i - \gamma_0) + r\{\hat{h}_p^i + \gamma_0(\sum_{\tau=p}^{t-1} \lambda_\tau^i)\} + r\gamma_1(\sum_{\tau=p}^{t-1} \lambda_\tau^i \tau)$$
$$- \gamma_1 t + X_t^i \beta + (\omega^i - rv^i + \xi_t^i).$$

Equation 6 is a straightforward generalization of standard earnings generating functions such that, when $\lambda_\tau^i \equiv 1$, it reduces to the familiar cross-sectional wage relationship in terms of t and t^2. In this form, however, the problems noted at the beginning of this section can be explicitly considered. To begin with, it is unlikely that the composite error term $(\omega^i - rv^i + \xi_t^i)$ is independent of the observed variables (see Hausman [1978]). Further, the biases in the estimation will be an increasing function of the variance of work activity. Finally, the relevant human capital parameters (r, γ_0, and γ_1) are not identified in the standard cross-sectional model. With $\lambda_\tau^i \equiv 1$, the two parameters of t and t^2 are nonlinear functions of the three structural parameters, and in general no solution is possible. (One approach to identification is to set the return to OJT equal to the return to years of schooling, but such an assumption is clearly questionable).

The advantages of panel data are also clear from Equation 6. First, the fixed error component for any individual (i.e., $\omega^i - rv^i$) can be dealt with in estimation since it enters as a constant into individual wages observed at two or more different times. Second, if λ_τ^i varies across individuals or time and can be directly observed, experience accumulation can be distinguished from simple aging, and the underlying human capital parameters can be identified and separately estimated.

However, to use panel data the specification must be amended to incorporate the effects of intertemporal differences in wages. Exogenous factors — such as the availability of capital and its organization, inflation, short run demand fluctuations, and so forth — could lead to unequal wages for otherwise identical workers observed in different years. While our complete empirical analysis considers alternative specifications of time differences, each leads to qualitatively similar conclusions, and the results reported here simply normalize for annual inflation.[7]

Consider the growth in real wages (nominal wages deflated by price levels) between any two years (p and t) of an individual's working life. From Eq. (6), we have that the logarithmic change in observed real wages ($\Delta \log RW^i$) is

$$\underset{p,t}{\Delta \log} RW^i = r\gamma_0\Big(\sum_{\tau=p}^{t-1} \lambda_\tau^i\Big) + r\gamma_1\Big(\sum_{\tau=p}^{t-1} \lambda_\tau^i \tau\Big) - \gamma_1(t-p) + (X_t^i - X_p^i)\beta + (\xi_t^i - \xi_p^i). \tag{7}$$

In this, real wage growth is related by the structural investment parameters to the accumulated experience over the period of observation, ($\sum \lambda_\tau^i$), to an interaction between labor force activity and the point in the working life of the individual, ($\sum \lambda_\tau^i \tau$), and to the elapsed time of the observational period ($t-p$).

If data are available for only two points in time, Equation 7 is consistently and efficiently estimated with OLS. However, with more than two periods, efficient parameter estimates are obtained by incorporating data on the wage growth for each individual between the first year of observation and each succeeding year through the last. Thus, for example, if an individual is observed for six consecutive years, five observations are created consisting of the growth between the first and second years, the growth between the first and third years, and so forth. While using all of the independent information from the panel, this procedure introduces one minor complication. The error terms (from Equation 7) for each individual will contain a common element, ξ_p^i. When the ξ_t^i's are i.i.d. random variables, this is an error components structure with random individual effects, and generalized least squares provides completely efficient parameter estimates. This error components structure is, however, merely an artifact of the form of the estimation equation, since individual heterogeneity has been treated directly by the differencing procedure. If the ξ_p^i's are i.i.d., the intraclass correlation (ρ) should be exactly .5, since $\rho = \mathrm{var}(\xi_p)/[\mathrm{var}(\xi_t) + \mathrm{var}(\xi_p)]$, which in turn reflects the common term across observations for each individual. There are several alternative estimation forms that could be used; however, the alternatives do not have any more desirable statistical properties, are generally more difficult

[7] In addition to the real wage specification, three alternative specifications were analyzed. First, exogenous shifts in nominal wages were parameterized as being proportional to changes both of price level and real GNP. Second, exogenous shifts were estimated to occur at a constant annual rate. Third, year specific exogenous changes were estimated with dummy variables. These alternative specifications yielded only minor and inconsequential differences in the results, although the latter two imply that identification of the investment parameters is conditional upon exogenous information about annual wage profile shifts.

to estimate, and make it difficult to include individuals observed for less than the full sample period.[8]

Finally, this formulation can be contrasted with other wage analyses, which are generally interpreted as providing strong support for the OJT investment formulation. Such support has relied upon agreement with only a weak and partial set of the restrictions implied by the model — namely, in the standard cross-sectional form, the concavity of wages in potential experience (i.e., the coefficient on linear potential experience is positive while that on squared potential experience is negative). We consider the empirical validity of the more specific restrictions implied by the model — restrictions on the pattern of wage growth as related to the pattern of experience accumulation and the career point of the individual. These implications can be considered only if the underlying parameters can be identified, distinguished from non-investment influences, and separately estimated.[9]

2. ESTIMATION RESULTS

2.1. *Basic Models.* Equation (7) is estimated from observations on changes in earning capacity for similar workers (first by race and sex and later by schooling class) during differing time intervals between 1968 and 1974. Data come from the Panel Study on Income Dynamics. Hourly wages,[10] computed from annual labor income and reported hours worked, and actual experience accumulated (normalized such that full time, or $\lambda_\tau^i = 1$, is assumed to be 1750 annual hours) are

[8] One alternative would be estimation of a covariance model through introduction of individual dummy variables in Equation 6. This is equivalent to subtracting an individual's means for wages and the exogenous variables from each year's observation (cf. Brown [1980]). This does provide direct estimates of fixed individual terms, but there is little inherent interest in these because unmeasured ability factors, measurement errors in the capital stock, and all time invariant factors such as level of schooling are combined together in a single term. Further, when individuals are observed over periods of differing lengths, heteroskedasticity is introduced by the covariance procedure.

Yet another alternative is the use of successive first differences of log wages (i.e., one year growth rates) as the basis for estimation. However, since adjoining growth rates have a common white noise term, a particular type of negative serial correlation is induced by this, and correction is difficult given conventionally available estimation packages.

[9] Contrast this, for example, with Lazear's [1979] analysis of black-white wages. While his empirical analysis employs a somewhat similar specification in terms of actual experience, he neither specifies explicitly the investment behavior nor estimates the underlying investment parameters. His conclusions about employment discrimination are based upon a particular interpretation of composite OJT parameters and upon the assumed validity of his (unspecified) individual investment behavior.

[10] Wages do not take into account any fringe benefits. While it would be desirable to incorporate fringes, reliable data on these benefits are unavailable. The absence of such information would cause estimation problems if fringes varied over time for each individual and were correlated with the measured exogenous variables. To the extent that fringes were approximately proportional to wage rates within the sample period for an individual, the estimation technique eliminates any biases.

directly observed for each year 1968–1974. All differences in variables are calculated relative to the first year an individual was observed. Individuals were eliminated from the sample if they were not between 16 and 55 years of age in 1968, if their calculated wage was less than $1/hour, or if they did not work at least 25 percent (i.e., 438 hours) of a year in at least two of the seven years between 1968 and 1974. For each individual in the sample, specific years were excluded if the individual did not have positive earnings, was employed in the military, or was classified as having a primary activity of schooling. For each individual, up to six wage changes for periods of varying length (each taken relative to the first year of observation) are included. Two measures of temporally varying individual characteristics, health status and region of residence, are explicitly included in the empirical specification. These are assumed exogenous, although it is quite possible to characterize each as a kind of investment (e.g., "health capital").[11] By stratification, sex, race and education level are all held constant (and the remaining parameters are allowed to vary with these characteristics). No explicit consideration is given to job changes which are viewed as a possible mechanism by which the returns to investment are obtained (as opposed to an exogenous event).[12]

Table 1 displays separate GLS estimates of Equation (7) by race and sex. Although allowed to vary freely in the estimation, the estimate of ρ (the intra-class correlation coefficient) is, in each case, numerically close to, and insignificantly different from, 0.5. From Equation (7), this implies that intertemporal variations in the effects of exogenous factors, such as ability, are unimportant and that the more general random coefficients investment model adds little.[13]

The estimates suggest that changes to bad health status reduce wage growth in their year of occurrence by one percent for white males and eight percent for black males. Movement into the South reduces the wage growth of black women by seven percent and of white women by nine percent. For black males the estimate reaches 15 percent, while for white males relocation into the South appears to have no effect upon wage growth.

The parameters of the investment schedule and the rate of return on investments are presented in the bottom panel of Table 1; t ratios for the parameters γ_0, γ_1, and r are estimated by a Taylor series expansion. In no case is the estimated rate of return significantly different from zero at the .05 level for a one-tailed test. For white males the point estimate of the real rate of return is a plausible 5.2

[11] In each year, "bad health" is coded as one for self-reported health limitations and zero otherwise. (This variable is unavailable for females). Residence is coded as one for workers in the 13 states of the Old Confederacy and zero otherwise. Thus $+1$ indicates movement into the South (or bad health status), 0 indicates no change, and -1 indicates movement from the South (or bad health).

[12] As discussed below, if investment differs by occupation, industry, or job, the entire model would require substantial modification.

[13] When there is serial correlation of the ξ_t^i's, the calculation of ρ will contain a covariance term, and its expected value will no longer be 0.5. Similarly, individual variance in the parameters of the investment schedule will induce serial correlation.

TABLE 1

GENERALIZED LEAST SQUARES ESTIMATES OF WAGE CHANGE MODELS BY RACE AND SEX

(Coefficients Times Ten)[a]

Parameter	Males		Females	
	White	Black	White	Black
$r\gamma_0$	0.274 (1.97)	−0.353 (1.69)	0.165 (1.69)	0.280 (2.04)
$r\gamma_1$	−0.011 (9.61)	−0.003 (1.26)	−0.002 (1.18)	0.000 (0.27)
$-\gamma_1$	0.220 (1.64)	0.763 (3.83)	0.123 (1.80)	0.005 (0.05)
ΔSouth	0.173 (0.70)	−1.552 (2.81)	−0.686 (1.97)	−0.874 (1.22)
ΔHealth	−0.088 (0.60)	−0.772 (2.92)	*c*	*c*
ρ	0.563 (0.31)[b]	0.568 (0.32)[b]	0.592 (0.41)[b]	0.500 (0.00)[b]
R^2	0.021	0.031	0.008	0.013
Number of Observations	9078	3083	4776	2493
Number of Individuals	1751	645	1148	650
Post School Investment Parameters				
γ_0	0.532 (8.21)	*d*	0.841 (1.65)	*d*
γ_1	−0.022 (1.64)	−0.076 (3.83)	−0.012 (1.80)	−0.000 (0.05)
r	5.16% (1.63)	0.36% (1.22)	1.97% (0.95)	*d*

Notes:

a. t-statistics in parentheses

b. t-statistics for null hypotheses that $\rho = 0.5$

c. not available

d. estimated parameter has wrong sign

percent, and the investment profile is quite flat; investment ratios decline by two percentage points per year, and there is positive net investment for 25 years. For black males the estimated real rate of return is very small, with investment ratios declining more sharply; however, the initial level of investment γ_0 has the wrong sign. For females, the investment parameters are quite implausible. Point estimates of the investment parameters and the associated t ratios do vary somewhat with the specification of exogenous economic forces. However, none of the alternative estimates yields more plausible results for female workers.

Part of the divergence in results across groups could reflect interactions between investment profiles and schooling levels (coupled with differences in schooling

TABLE 2

GENERALIZED LEAST SQUARES ESTIMATES OF WAGE CHANGE MODELS BY EDUCATION LEVEL AND SEX FOR WHITE WORKERS (Cofficients Times Ten)[a]

Parameter	Males			Females		
	Elementary School	High School	College	Elementary School	High School	College
$r\gamma_0$	−0.434 (1.49)	0.193 (0.91)	0.770 (3.15)	0.464 (1.04)	0.172 (1.43)	0.035 (0.19)
$r\gamma_1$	0.001 (0.38)	−0.012 (7.42)	−0.017 (6.76)	0.002 (0.20)	0.001 (0.40)	−0.008 (1.97)
$-\gamma_1$	0.496 (1.77)	0.344 (1.65)	−0.196 (0.84)	−0.274 (1.05)	0.015 (0.18)	0.417 (3.20)
ΔSouth	0.065 (0.05)	−0.541 (1.66)	1.088 (2.53)	1.657 (1.19)	−0.435 (0.98)	−1.469 (2.39)
ΔHealth	−0.027 (0.08)	−0.086 (0.45)	−0.170 (0.95)	*c*	*c*	*c*
ρ	0.484 (0.08)[b]	0.548 (0.26)[b]	0.594 (0.46)[b]	0.740 (1.15)[b]	0.574 (0.33)[b]	0.584 (0.38)[b]
R^2	0.005	0.029	0.025	0.018	0.004	0.030
Number of Observations	1323	4495	3260	345	3101	1330
Number of Individuals	244	877	630	87	745	316
Post School Investment Parameters						
γ_0	16.785 (0.34)	0.530 (2.01)	*d*	07.546 (0.16)	*d*	0.171 (0.21)
γ_1	−0.050 (1.77)	−0.034 (1.65)	*d*	*d*	−0.002 (0.18)	−0.042 (3.20)
r	*d*	3.64% (1.65)	*d*	0.61% (0.19)	*d*	2.03% (1.60)

Notes:

a. t-statistics in parentheses

b. t-statistics for null hypothesis that $\rho = 0.5$

c. not available

d. estimated parameter has wrong sign

distributions by groups).[14] Table 2 presents estimates of the same model for white workers stratified by sex and three schooling levels. The most striking finding is again the differences across the population groups. For white workers, the F-ratios (F = 2.78 for males and F = 2.68 for females) suggest heterogeneity

[14] It may be anticipated that the capital investment patterns differ for demographic groups with identical work histories due to unobserved differences in expected future breaks in employment. In Equation 7, earnings growth is independent of stocks of human capital (consistent with the Blinder and Weiss [1976] formulation.) Weiss and Gronau [1981] have shown that, for this formulation, the rate of growth of earnings will be lower for those with expected future employment breaks. The differences between males and females or between whites and blacks in Table 1 are not consistent with this theoretical result.

across the three schooling levels: 8 or fewer years of education; 9 through 12 years; and more than 12 years. This also holds for black workers ($F=7.52$ for males and $F=1.86$ for females). Except perhaps for males with nine to twelve years schooling and females with some college, the results are again implausible; the signs on the relevant human capital parameters are consistently incorrect according to the theoretical model. Only for the male high school group does one find the estimated rate of return significantly different from zero at the .05 level, but just barely so by a one-tailed test.

Another possible explanation of these results is that pooling observations over the different lengthed intervals (and, in particular, including the shorter time intervals) makes it difficult to detect the effects of changes in the human capital stock because of reduced signal to noise ratios. Further, the time periods of the observations are set somewhat arbitrarily at one year, even though the actual dynamics of wage adjustment may take place over longer periods or periods that do not correspond completely to the annual survey.[15] These possibilities are considered by estimating the basic model separately for the one year through six year differences,[16] since both possible conditions would have less effect on the statistical results when observations refer to longer periods of time. Such stratification yields no additional support for the underlying model. Specifically, there is no apparent improvement in results from those stratifications based on longer time intervals. Thus, it does not appear that the weak results simply reflect "data problems" inherent in the differencing of fixed time observations.

2.2. *Some Extended Tests.* Two other possible explanations for the results relate to the specification of the optimal investment patterns and to the pattern of labor supply. First, while the general investment model may be appropriate, the specific functional form of the profiles may not be. Second, while the focal point is wage determination, individuals also make some choices about the amount of time to spend working; this implies that labor market experience is endogenous and the coefficients may be biased.[17]

A wide variety of maintained hypotheses about optimal investment plans were investigated. Because an individual's investment strategy may be related to the degree of commitment to the labor force (cf. Weiss and Gronau [1981]), the parameters of the linear function (γ_0 and γ_1) were allowed to vary with the individual's average, or permanent, labor force activity, and the desired investment profile was related to actual accumulated experience as opposed to potential experience. These variations seemed particularly reasonable for females where there is more variation in labor force attachment, although the specifications still

[15] For example, if significant portions of the wage dynamics are related to job changing, the adjustments are less likely to be observed in the shorter periods as opposed to the longer periods.

[16] Estimation was conducted for white male workers with 9–12 years of schooling, the largest race/sex/schooling group stratum. While the previous analyses pooled observations of different length, this analysis divides them into six separate samples.

[17] See, for example, MaCurdy [1981] on labor force behavior.

rely upon observed data and therefore cannot account for any planned labor force withdrawal that hasn't yet occured. In addition, exponentially declining functions in potential experience, with and without depreciation, were considered. Further, while the linearly declining schedules were generally not constrained to positive values (thus leading to a net investment interpretation), estimation that constrained investment to be nonnegative was also conducted. The results from each of these formulations were qualitatively similar to those reported: there were wide variations across groups, but the relevant parameters often had incorrect signs or were implausible.[18]

Clearly, however, the range of investment specifications that have been investigated remains limited. For example, all of the investment plans (incorporated in the pattern of the k_t^i) call for monotonic declines throughout the worklife (except for some effects of updating based upon realized participation rates). This need not be the case, particularly for individuals planning a temporary withdrawal from the labor force — say to raise a family. Theoretical analyses, nonetheless, provide little guidance when labor force participation plans are unknown; even when known, precise predictions are available only with quite strong assumptions. It does seem that the samples of male workers or college educated workers would be less affected by such considerations of intermittant paticipation; yet the estimation results are no better for these stratifications. To the extent that one must alternatively consider different investment strategies for many different subgroups in the population, the appeal of the elegant and simple OJT model is considerably lessened.

The statistical complications might occur because work in any year may be affected by the wage obtained in that year and, importantly, might be related to the stochastic term in the wage equations (ξ_t^i). In Equation (7), the work effort in the first period (λ_p^i) is the only term that appears with the contemporaneous error. To investigate possible simultaneity, an instrument for λ_p^i was formed, based upon future labor force experience, and used in each of the wage growth models; the results were unaffected by this instrumental procedure.

2.3. *Comparison with Previous Analyses.* This estimation provides little support for the human capital investment model even though the investment model — tested elsewhere in a wide variety of forms — has been quite generally accepted. The conflict in evidence may, however, be more apparent than real.

This analysis has simultaneously made several modifications to the typical analysis of wage determination. It has generalized the "standard" investment models to incorporate the interaction between work behavior and on-the-job training. It has developed an estimation strategy that avoids the confounding effects of "ability" and other individual-specific unobservables. And, it has formulated an earnings determination model in which the relevant investment parameters are separately identified (without further assuming that the rates of

[18] Summaries of the extended tests are available from the authors.

return to schooling and on-the-job training are the same). This last difference —the identification and estimation of the investment parameters — changes the nature of the tests of the model and appears to lead to the largest discrepancy between the evidence here and that developed elsewhere. Without identification of the investment parameters, the only "test" of the basic model has been the concavity of age-earnings profiles, an empirical regularity that is consistent with a wide variety of underlying explanations.

Some indication of the importance of these differences is obtained by comparing results to those of the standard "fulltime work" cross-sectional wage model using the *same data set* but relying upon undifferenced observations. (This formulation assumes $\lambda_\tau^i = 1$ and reduces to a quadratic function of potential experience). In all but one of the 12 race/sex/schooling stratifications, estimates pass routine "tests" of the OJT model — i.e., log wages are found to be concave in potential experience.[19] This ability to reproduce "standard" cross-sectional results offers further confirmation that the results here are not an artifact of sample peculiarities or measurement errors in the wage rates.

The wage formulation of Hanushek and Quigley [1978], which incorporates observed experience accumulation, goes one step further by providing direct parameter estimates if labor force activity is constant over the worker's lifetime (i.e., $\lambda_\tau^i = \lambda^i$). Again, using the same samples, the results are quite consistent with previous cross-sectional results in terms of explained variance, concavity of profiles, and so forth.[20]

But the investment theory has stronger implications for the relationship among aging, the accumulation of experience, on-the-job training investments, and the growth of earnings. Further, by concentrating upon wage growth —the appropriate focus of attention for investment returns— OJT effects can be separated from "ability" and other unobservables. In this growth formulation, however, the OJT model gets only weak support. The apparently strong support for the OJT model in more conventional formulations comes *only because log wages are concave in potential experience and in accumulated experience.* Without identification of the separate investment parameters, the "tests" are simply very weak, amounting to certain regularities in the signs of composite parameters.

It should be stressed that only a few of the "dynamic" analyses of human capital and earnings relationships in the literature actually analyze the evolution of individual wages. Typically, earnings levels are related to cumulative measures of experiences or to measures of historical intervals of activities (e.g. Mincer and Polachek [1974, 1978], Sandell and Shapiro [1978, 1980], Jones and Long [1979]).

[19] In this, log wages were regressed upon an ability test measure, dummy variables indicating calendar year, school completion within aggregate category, and quadratic potential experience. All estimation employed a random components error structure, but estimation that ignores any individual specific differences yields the same qualitative conclusions.

[20] Explained variance was approximately 25 percent lower for the potential experience formulation, indicating that actual experience measures contain valuable additional information. The models were again estimated with GLS assuming a random components error structure.

Correspondingly, the error structures, if they have a dynamic component, are not considered in relation to the evolution of investment activities (e.g., Lillard and Willis [1978]). When earnings or wage growth is considered, it is frequently related to measures of the stock of experience or to interruptions without extracting the investment parameters (e.g., Mincer and Ofek [1982]).

Only a few previous analyses have considered truly dynamic wage relationships (Lazear [1976, 1979], Brown [1980], Hausman [1978]). However, none of these models is derived from the underlying investment behavior, making such an interpretation very difficult.

In virtually all previous estimation, the estimated experience coefficients have been interpreted as *either* the return to training *or* the rate of investment in training, ignoring the fact that the coefficient is actually a composite of *both factors*. Indeed, while we have stressed the difference between our results and those of previous analyses, the results are very consistent in terms of standard interpretations. For example, except for black males, the results in Table 1 indicate a concave relationship between wages and experience. It is only when an attempt is made to judge the magnitude and curvature of this relationship that the support for the investment model withers.

3. CONCLUSIONS

On-the-job investments are quite commonly accepted as an important explanation for systematic variations in earnings over the life-cycle, but this acceptance has not come from detailed examinations of OJT activities themselves. Instead, it has come from the logically consistent conceptual framework based upon individual maximizing behavior, coupled with very indirect empirical support found in the concavity of age-earnings profiles. As developed in this paper, the more precise empirical implications of the OJT model involve the relationship between the wage growth patterns of individual workers and their work histories. The models presented isolate the labor market returns that are associated with on-the-job investment activities, while allowing in a very general manner for the influences of such concurrent explanatory factors as "ability," "motivation," quality of schooling, and differential labor force attachment.

The empirical analysis involves explicit estimation of investment profiles and the returns on investments for different race, sex, and schooling groupings. The investment specifications include the linear form due to Mincer as well as a wide variety of alternatives, including those with random individual differences, systematic differences related to individual labor force attachment, and nonlinear forms with and without depreciation. The estimation methodology incorporates the error components structure dictated by the specification and considers the possibility of simultaneity between wages and work effort.

There are two basic ways to judge the results. First, does the underlying conceptual framework provide a reasonable characterization of the observed earnings differences across broad groupings of the labor force? Second, is the implied investment behavior plausible? Judged in either way, there is only modest support for the theory.

The major conclusion of this analysis is that the restrictions imposed on wage gorwth by the broad classes of OJT investment plans investigated are suspect. The empirical results are simply implausible for substantial portions of the work force. While there are scattered results that are more plausible, the estimated investment behavior is found to differ significantly by sex, race, and schooling group. To the extent that different models are required for finely categorized subgroups of the work force, the elegant and parsimonious model loses much of its appeal and usefulness.

This empirical analysis, of course, does not (and simply cannot) "disprove" the validity of the OJT investment model, and our analysis says nothing about other activities which can be characterized as human investment. Alternative explanations, based upon shortcomings of the empirical specifications, of the data, or of the methodology, could lead to other conclusions. For example, the assumed OJT investment behavior imposed might not be "correct," and better characterizations might indeed provide more support. Or, measurement errors might have a dominant influence.

On the other hand, a wide variety of investment specifications have been investigated. Importantly, each of the specifications involves only the characteristics of workers and their market experiences — in the tradition of past human capital analyses. Interactions of desired investment with OJT opportunities, related to occupations, industries, and so forth, might be important in determining the equilibrium investment patterns of individuals (cf. Rosen [1972] or Polachek [1981]). In such a case, the systematic components of such investments could not be characterized simply in terms of individual characteristics. Incorporating such ideas in the wage determination models would then require simultaneously modeling the choices of occupation or industry by individuals. Further, the stratification by time periods and the estimation of the error components does not suggest that measurement error biases or other data problems are the explanation of the results.

This analysis leads us to conclude that more attention should be devoted to non-investment models of life-cycle variations in earnings. Detailed consideration of alternatives is beyond the scope of this paper; however, three distinct possibilities seem worthy of investigation. First, workers could be paid the value of their marginal product, but the age-experience pattern of productivity might be governed by non-investment considerations. For example, relative cohort sizes coupled with experience substitutability in production (Welch [1979]) may drive age-earnings profiles, or interactions with demands for trained individuals (see above) may set equilibrium wage profiles. Second, wages may not equal marginal productivity in the short run. For example, with either long-term employment contracts and income smoothing or employer-employee sharing of the costs and returns of specific training, the relationship of contemporaneous wages and general productivity would be broken (see, for example, Hall [1980]). Finally, variations in wage growth across race or sex groups could reflect complex forms of wage discrimination. Nevertheless, the detailed life-cycle wage implications of these alternatives have yet to be developed fully.

The familiar quadratic age-earnings specification has proven to be a useful descriptive device. This analysis indicates, however, that attempts to impute added validity to this characterization by appealing to underlying structural investment models is unwarranted. Furthermore, interpreting the results from such analyses in structural terms —as is typical in earnings comparisons between blacks and whites (e.g., Chiswick [1974] or Lazear [1979])— may be misleading. Such comparisons and projections require knowledge of the underlying structural relationships to distinguish purely compensating differences arising from individual choices from differences in rates of return or in other factors affecting wage determination. The preceeding analysis suggests that the commonly employed specifications do not accurately characterize the underlying behavioral relationships. Therefore, they can hardly provide a solid basis for the desired comparisons.

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