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Age, Experience, Earnings, and Investments in Human Capital

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This paper explores the distinction between physical age and experience within the context of the human capital model of earnings determination. We extend the human capital model to distinguish the investment behavior of age-experience cohorts and to incorporate the effects of calendar time. Several alternative models are developed which are empirically tested based on a unique body of data (on Swedish engineering graduates) reflecting the earnings of cohorts with identical educational qualifications cross-classified by age and experience for a 10-year period. The results clearly indicate the necessity for distinguishing between experience and age in analyses of investment in human capital and are consistent with the interpretation that younger members of the same experience cohort are more efficient in producing human capital. The analysis also indicates the sensitivity of investment profiles to a priori restrictions on functional form and detects an inflection point in earnings increases consistent with Becker's original formulation of human investment theory.

Most studies of the human capital investment process relate cross-sectional earnings profiles to schooling levels and years of experience, usually measured by calendar age. In this paper we analyze the conceptual distinction between calendar age and years of experience in explaining investment behavior and in interpreting earnings profiles.

This distinction was first noted by Mincer (1970) in his classic review article; it is also an integral part of his most recent work (Mincer 1974), where he shows that identical experience profiles of investment can lead

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to substantial differences in age-earnings profiles if individuals receive unequal amounts of schooling.

Our analysis goes one step further in considering the investment decisions of individuals who receive identical amounts of schooling but complete their schooling at different ages. Variations in the age at which schooling is completed are substantial, at least for graduate education. For example, Harris (1972, p. 89) reports that the mean time elapsed between baccalaureate and doctorate degrees in the United States is about 10 years, with a standard deviation of 6 years. Harris also presents separate estimates of the mean and standard deviation of time elapsed between baccalaureate and doctorate degrees for 13 fields of study. The coefficients of variation range between .45 (for physics) and .56 (for mathematics). There is also evidence of considerable variation in the age at which bachelor degrees are awarded.¹

In this paper we indicate, by extending Mincer's analysis of the human capital model, how investment behavior and capital depreciation depend on both age and years of experience even for individuals with identical quantities of education. A general model is developed (Sec. I), distinguishing between cohort and cross-sectional earnings profiles, which relates observed earnings to investment and disinvestment in human capital, to returns from the human capital stock, and to those secular increases in productivity which are unrelated to investment behavior.

By making alternative assumptions about these factors, we derive two specific models for subsequent testing (Sec. II). The models differ in generality, making possible an assessment of the realism of several underlying assumptions.

In Section III the models are estimated separately for two populations using annual cross sections of earnings classified by age, years of experience, and calendar year. For several reasons described below, the data (obtained from annual surveys of all engineering graduates in Sweden) are particularly well suited to testing the theoretical model.

In the analysis of Sections IV and V, the estimated earnings profiles are first presented, followed by an analysis of the implied human capital investment behavior. The framework also allows an investigation of the differentiation of starting salaries for cohorts which enter the full-time labor market at different ages.

I. The Economic Model

According to human capital theory, individuals make conscious or unconscious decisions to invest in their own productive capacity. Indi-

¹ E.g., a sample of U.S. graduate students analyzed by Davis revealed that more than one-third were not between the ages of 21 and 23 when they completed their undergraduate education. The mean age was 23 years, with a standard deviation of 3 years, and 4 percent of the sample received bachelor degrees at age 20 or younger (Davis 1962, p. 183).
individuals invest first in length and type of schooling. After entering the labor market, they make additional investments in training, health care, and possibly additional formal schooling. These human capital investments and their rates of return are important determinants of individuals' earnings profiles.

In its simplest form, the human capital model postulates that

\[ E_j = E_{j-1} + r_{j-1} C_{j-1}, \]

where \( E_j \) is potential earnings of an individual with \( j \) years of experience, that is, the earnings obtainable if no resources are used for investment in human capital in the \( j \)th year; \( C_{j-1} \) is the amount by which potential earnings are reduced by human capital investment in the \( j - 1 \)th year of experience; and \( r_{j-1} \) is its corresponding marginal rate of return.

The postulate of diminishing returns to the production of human capital in any period implies that gross investment in human capital will be spread out over the working life. In addition, even if the marginal cost-of-investment curve facing an individual were identical during each period of possible investment activity, the finiteness of working life would ensure that the marginal revenues of later investments were lower than those of earlier investments. Taken together, these considerations imply that the profile of human capital investments throughout the working life will generally be declining.

Several factors complicate this simple relationship between earnings and human capital investment, including: (1) the depreciation of human capital; (2) the complex dependence of human capital investment on “ability” and physical age as well as years of experience; and (3) the presence of physical capital.

1. As an analogue to physical capital, human capital is subject to deterioration. The existence of retirement alone points to this conclusion, but the precise level of age-related depreciation probably varies with an individual’s occupation or industry. For example, it is widely observed that piece-rate output declines for older workers, and we may expect mental abilities to decline at some point in analogous fashion. Knowledge and skills may also become obsolete. Thus, depreciation may be related to the vintage of the human capital stock.

2. In the “naive” formulation of equation (1), physical age and experience are used interchangeably. But even if we consider a population with given educational qualifications, the “naive” formulation would only be appropriate \((a)\) if all individuals were continuously employed in the labor force after completing schooling and \((b)\) if all individuals completed schooling and entered the labor force at the same age.

The well-known problems of applying the human capital model to females illustrate the first qualification. For females, the clouded relationship between physical age and years of experience, coupled with our
ignorance of human capital investment behavior during periods of non-participation in the labor market, makes the "naive" model inapplicable.\(^2\)

However, even if all individuals were continuously employed after completing schooling, variations in the age at which schooling is completed will still complicate the analysis.

For postsecondary education, real variations exist in the age at which training is completed and individuals enter the full-time labor market. Variation in graduation age is most pronounced for holders of advanced degrees, but there also exists variation in the age of completion of most educational qualifications. Individuals may "drop out" for long or short periods on the way to their degrees, their training programs may be interrupted by military service, or circumstances may necessitate their taking part-time jobs on the way to completing their educational qualifications.

Figure 1 presents a hypothetical frequency distribution of age at graduation for a cohort of workers. If we stratify the distribution in figure 1 into, say, three groups—a "quick" group, composed of those who are younger than "normal" at graduation; a "normal" group, who graduate at the "normal" age; and a "slow" group, composed of those who are older than "normal" at graduation—we may roughly characterize the individuals in each group in the following way. The "quick" group is made up of students who are more efficient in learning than average but who graduate with no previous labor market experience; the "normal" group contains students of average ability who graduate with no (or very little) previous labor market experience; and the "slow" group contains those who are perhaps less efficient in learning than average but are often those with additional labor market experience. In general, one would expect that students who are efficient in learning are also efficient in productive work. For this reason their potential starting salaries would tend to be high. However, previous labor market experience would also increase their potential starting salaries.

\(^2\) See, e.g., Mincer and Polachek (1974) for an application of the theory to female earnings.
The quick group should thus have a relatively high potential starting salary. But it is more difficult to say anything about their observable starting salaries, since, with greater efficiency in learning, they should invest more in human capital than the others. The slow group may also receive relatively high potential and actual starting salaries as a result of their previous labor market experience.

Figure 2 illustrates how physical age also influences postschool investment behavior. The diagram indicates that depreciation of human capital and variations in age and experience can affect analyses of human capital investment profiles by altering the marginal cost-of-investment curve and/or the marginal revenue curve facing different cohorts of individuals.

At the same level of experience, there are at least three factors which may cause the marginal cost curve facing an older worker to lie above the curve facing a younger worker. First, if the age of an individual is an input in the production function for human capital and its marginal product is negative, then ceteris paribus the cost of human capital will be greater for older workers. Second, if age at graduation measures efficiency in learning, then the marginal cost curve for older workers will lie above the curve for younger workers. Third, if the production function for human capital includes the current capital stock as an input (see Ben-Porath 1967, 1970), then any age-related depreciation will reduce the current stock more for older than for younger workers.
The effect on the marginal revenue curve is more straightforward. At a
given level of experience, the marginal revenue curve is lower for older
workers. If all individuals retire from employment at a common age, the
marginal return from any investment is lower for older workers. However,
even if the age of retirement is variable, the marginal revenue curve for
older workers will be below that for younger workers if depreciation is an
increasing function of age. In addition, if those with more "ability," as
measured by age at which schooling is completed, have lower depreciation
rates, this is another reason for expecting lower marginal revenue curves
for older members of an experience cohort.

All of these factors suggest that investment ratios decline with experience
and with age. But this tendency for declining investment ratios need not
logically exist for all intervals in the range of age and experience for all
individuals. For example, if there are intervals where productivity in
learning grows faster than productivity in earning, investment ratios may
increase. Presumably, these intervals occur during the early years in the
labor market, if at all (see Mincer 1974, pp. 13–16).

3. For individuals who enter the labor market in different calendar
years, we may expect starting salaries to vary, causing shifts in earnings
profiles. In the short run, these variations in starting salaries are responsive
to supply and demand conditions in particular labor markets. In the long
run, however, the systematic increases in starting salaries accruing to
those entering the labor force later but with the same embodied human
capital reflect economic growth, that is, increases in physical capital, its
productivity and organization, and other factors distinct from human
capital investments. Similarly, the increases in earnings received after
entering the labor force depend on net investments in physical capital
as well as the returns to human capital investment.

We now extend the human capital model to confront these issues. First,
we develop a formal framework to incorporate depreciation of human
capital, variations in experience and physical age, and variations in
initial salaries. By making a number of specific assumptions, we derive
two estimable models which are investigated below in several variants.

The general model is developed by describing several definitional
relationships among potential starting salaries, potential earnings, and the
actual observable earnings received by individuals in the labor market.

Define the potential starting salary (i.e., the starting salary obtainable if

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3 Only in the special case where depreciation is at a constant rate and retirement age
is variable would the marginal revenue curves coincide.

4 Since the theory implies that there is a secular but not necessarily monotonic decline
in investment ratios with age and experience, empirical analyses which impose some
"convenient" functional form (e.g., linear in experience) throughout the age or experience
range are unlikely to detect intervals where investment ratios are increasing, if they exist
at all. Indeed, the empirical results reported in Sec. IV allow an investigation of this
question.
no resources are expended in human capital investment) for individuals who entered the labor force in year $b$ at the age of $k_0$ as

$$E_{bko} = E_{0ko} \exp \left( \sum_{t=1}^{b} \beta_{tko} \right),$$

(2)

where $E_{0ko}$ is a function of $k_0$ and $\beta_{tko}$ is simply the rate of increase of the starting salary between year $t - 1$ and $t$.

Define the potential earnings (i.e., the salary obtainable if no resources are expended in human capital investment) at time $b + j$ after $j$ years of experience for those who entered the labor force at age $k_0$ as

$$E_{bkoj} = E_{bkoj-1}[1 + \beta_{bkoj} + r_{j-1}(c_{bkoj-1} - d_{bkoj-1})],$$

(3)

where $\beta_{bkoj}$ is the rate of increase in potential earnings independent of investments in human capital; $r_{j-1}$ is the rate of return to the previous year’s investments; $c_{bkoj-1}$ is the investment ratio (i.e., the ratio between the previous year’s investment in human capital and potential earnings for that year); and $d_{bkoj-1}$ is the corresponding depreciation ratio.

Since by definition human capital investment in any year is the difference between potential earnings and observable income,

$$Y_{bkoj} = E_{bkoj}(1 - c_{bkoj}),$$

(4)

the basic model can be stated simply as

$$Y_{bkoj} = E_{0ko} \exp \left( \sum_{t=1}^{b} \beta_{tko} \right)(1 - c_{bkoj})$$

$$\times \prod_{i=1}^{j} [1 + \beta_{bkoi} + r_{i-1}(c_{bkoi-1} - d_{bkoi-1})].$$

(5)

By taking the natural logarithm of both sides of equation (5), the following approximate expression is obtained:

$$\log Y_{bkoj} = \log E_{0ko} + \sum_{t=1}^{b} \beta_{tko} + \sum_{i=1}^{j} \beta_{bkoi}$$

$$+ \sum_{i=1}^{j} r_{i-1}(c_{bkoi-1} - d_{bkoi-1}) - c_{bkoj}.$$  

(6)

Equation (6) expresses in a general form the relationship among the observed incomes obtained by individuals, their starting salaries, their human capital stocks, and the rates of return to their human capital investments.

5 The terminology and the formulation of investment and depreciation ratios are due to Becker and Chiswick (1966).
II. Alternative Specifications

To derive an estimable model from equation (6), we must impose specific assumptions about the functional relationships implied by $\beta$, $c$, $d$, and $E$. Assumptions 1–5 below yield two specific and plausible forms of the general model.

*Assumption 1*: rates of return, $r$:

$$r_j = r.$$  \((7.1), (7.2)\)

For both models we assume that the rate of return to human capital investment is the same for all years of experience; equivalently, there exists a market for human capital. This assumption is commonly and almost uniformly adopted in empirical applications of the human capital approach.

*Assumption 2*: rates of earnings increase unrelated to investment, $\beta$:

$$\beta_{tkoj} = \beta, \quad \text{for all } t, k_0, \text{ and } j > 0, \quad \text{(8.I)}$$

$$\beta_{tkoj} = \beta(k_0), \quad \text{for all } t \text{ and } j > 0. \quad \text{(8.II)}$$

For model I we assume that the rate of increase in earnings independent of investment in human capital is constant. Thus we abstract from changes in the growth rate of the economy cyclical changes in the rate of earnings increase or particular features of narrowly defined labor markets. This simplification may seem unrealistic, but no bias will be introduced into estimates of cohort age-earnings profiles as long as $\beta_{tkoj}$ is independent of years of experience, $j$.

For model II we allow the rate of increase to vary systematically with graduation age. This extension is included because, as we noted above, graduation age may be an indication of "ability"; more able individuals are more efficient in utilizing new capital equipment, new methods of production, and so forth.

*Assumption 3*: investment profiles, $c$:

$$c_{bkoj} = c_1(j) + c_2(k), \quad k = k_0 + j, \quad \text{(9.I)}$$

$$c_{bkoj} = c(j, k). \quad \text{(9.II)}$$

For model I we assume that the investment ratio can be expressed additively as two separable functions, one relating experience and one relating age to investment behavior. This implies that the difference in gross investment ratio between two workers of the same age but at different levels of experience does not systematically depend on their age, and vice versa. Figure 3 illustrates this property of model I in the case of linearly declining investment ratios. The $C_1C_1$ in the figure represents the profile of investment ratios as a function of experience. To this we add the profile of investment as a function of physical age. The three dashed
Fig. 3.—Alternative models of capital investment

lines represent the resulting profiles of investment ratios for three hypothetical groups of individuals, those who graduate when they are younger than the normal age ("quick"), at the normal age ("normal"), and older than the normal age ("slow"). The profiles are all parallel; if the difference in graduation age between the quick and normal groups is the same as between the normal and slow groups, the profiles are also
equidistant. If the investment ratios are nonlinear functions of experience and age, respectively, the profiles will no longer be parallel, but the difference between any two profiles will still be independent of experience.

For model II, we allow for interactions between age and experience. This is illustrated in figure 3 for the case of linear functions. In this hypothetical figure, those who graduate relatively younger have a higher initial investment ratio than those who graduate at an older age, and their profiles have a smaller slope. Our theory suggests that the first group invests more than the second. This, however, does not necessarily imply that the investment rate is higher, since the potential starting salary may well be higher for those who graduate when they are younger.

**Assumption 4**: depreciation profiles, \( d \):

\[
d_{bkoj} = d_1(j) + d_2(k), \quad (10.I)
\]

\[
d_{bkoj} = d(j, k). \quad (10.II)
\]

Human capital may depreciate in several ways, due to the obsolescence of skills or the deterioration of mental and physical capacity. Both models recognize deterioration by relating annual depreciation to physical age. In addition, since much of postschool investment is made during the first years in the labor market, years of experience reflect the obsolescence of capital of a given vintage, that is, it measures the elapsed time since schooling and most of postschool investments were made.

We expect the profile of depreciation rates to be nondecreasing; the functional relationships for models I and II parallel those described for the investment profile.

**Assumption 5**: potential starting salaries, \( E \):

\[
\log E_{bko0} = \alpha + \beta b + r \sum_{k=0}^{k_0-1} [e_2(k) - d_2(k)], \quad (11.I)
\]

\[
\log E_{bko0} = E(k_0) + [\beta(k_0)]b. \quad (11.II)
\]

For model I the assumption implies that cross-sectional log earnings profiles will exhibit a parallel shift between any two years.\(^6\) Model I emphasizes the possibility of labor market activity (and human capital investment) prior to graduation; the specification assumes that those who are older when they graduate have invested more in human capital than those who are younger and thus receive higher starting salaries.

For model II the rate of increase in starting salaries is a function of graduation age. The assumption implies that potential and observable starting salaries may vary quite generally with graduation age, \( k_0 \).

\(^6\) In other words, the rate of increase in salary due to factors other than investments in human capital is the same for each year of experience and age and is the same as the rate of increase in starting salaries.
The two models of human capital investment behavior imply observed earnings profiles:

\[
\log Y_{bkoj} = \alpha + \beta(b + j) + r \sum_{i=0}^{j-1} [c_1(i) - d_1(i)] + r \sum_{i=0}^{k_0 + j-1} [c_2(i) - d_2(i)] - c_1(j) - c_2(k_0 + j),
\]

(12.I)

\[
\log Y_{bkoj} = E(k_0) + [\beta(k_0)](b + j) + r \sum_{i=0}^{j-1} [c(i, k_0 + i) - d(i, k_0 + i)] - c(j, k_0 + j).
\]

(12.II)

The shape of the earnings profiles implied by the two models is revealed by the following expressions for the rate of increase in earnings between the \(j-1\) and the \(j\)th year of experience for those starting to work in year \(b\) at \(k_0\) years of age, say, \(\gamma_{bkoj}\):

\[
\gamma_{bkoj} = \beta + r[c_1(j-1) + c_2(k_0 + j-1) - d_1(j-1) - d_2(k_0 + j-1)] - [c_1(j) + c_2(k_0 + j) - c_1(j-1) - c_2(k_0 + j-1)],
\]

(13.I)

\[
\gamma_{bkoj} = \beta(k_0) + r[c(j-1, k_0 + j-1) - d(j-1, k_0 + j-1)] - [c(j, k_0 + j) - c(j-1, k_0 + j-1)].
\]

(13.II)

As noted above, increasing investment ratios are conceivable for some intervals in an individual’s career, but they must ultimately decline with age or experience; depreciation rates may increase. Equations (13) indicate the implications for earnings profiles more generally; an increase in earnings will be observed as long as the investment ratio does not increase more than the return to the previous year’s investment.

Consideration of equations (13) leads to the following conclusions: (i) If investment ratios decline at a constant rate or at a decreasing rate, the rate of increase in earnings decreases. (ii) If investment ratios decline at a rapidly increasing rate of change (greater than the rate of return), the rate of increase in earnings increases. (iii) If investment ratios decline at a moderately increasing rate of change (less than the rate of return), the rate of increase in earnings decreases. For example, in model I, if investment and depreciation ratios are all linear functions, it follows that those who graduate at a younger age will always have larger increases in earnings than those who graduate at an older age. However, if \(c_2\) is not a linear function, this is not necessarily true.\(^7\) In contrast to this

\(^7\) E.g., if the investment ratio is large for young people but levels off rapidly with physical age (a step function is the limiting case), it is possible that those who graduate at younger ages will experience a smaller increase in earnings during their first years in the labor force than those who graduate at older ages. After some years of experience, however, the reverse should be true.
specification, model II is more general; no specific results can be obtained a priori from a comparison by age at graduation.

Although our theory suggests the shape of the investment and depreciation profiles, labor market transactions do not provide direct observations on human capital investment and depreciation. We therefore postulate alternative profiles consistent with the theory, estimate their parameters (from annual earnings data cross-classified by physical age and years of experience), and compare the results. In particular, we investigate three representations of the investment and depreciation ratios as a function of years of experience: the linear profile (profile A), the exponential profile (profile B), and a more general step function (profile C). We expect that the results in each case will support a declining profile of investment ratios.  

In the experience dimension, model I is estimated separately for the linear investment and depreciation profile, for the proportional (exponential) investment and depreciation profile, and for the step function. The profile used in the physical age dimension is the step function.

The linear investment profile implies that experience-earnings profiles are parabolic. The exponential investment profile implies an asymptote in experience-earnings profiles, while the step function imposes only a general polygon on experience-earnings profiles.  

From eqn. (13) note that earnings increases depend on investments in an accelerator mechanism. Increases in earnings may be sensitive to small changes in investment ratios, and the imposition of a particular functional form on the investment ratios for the entire experience range may be a rather strong assumption. It is quite possible, e.g., that seemingly reasonable estimates of the age-earnings profile based on one functional form may be consistent with systematic increases in investment ratios with years of experience, while estimates of another (more general) function may be consistent with decreases in investment ratios.

For model I, the linear form for investment and depreciation ratios,

\[ c_1(i) = A + Bi, \]
\[ d_1(i) = a + bi, \]

implies (by summing an arithmetic series) an experience-earnings profile,

\[ r \sum_{i=0}^{j-1} [c_1(i) - d_1(i)] - c_1(j) = -A + \left[ r(A - a - \frac{B - b}{2}) - B \right] j + \frac{r(B - b)}{2} j^2 \]

\[ = H_1 + H_2 j + H_3 j^2. \]

The exponential form assumes that investment ratios are in fixed proportion to one another,

\[ c_1(i) = Ue^{-\nu i} + W, \]

and that the depreciation rate, \( d \), is constant. This implies (by summing a geometric series) an experience-earnings profile,

\[ r \sum_{i=0}^{j-1} [c_1(i) - d(i)] - c_1(j) = U \left( 1 + \frac{r}{1 - e^{-\nu}} \right) (1 - e^{-\nu j}) \]

\[ + r(W - d) j - (W + U) \]

\[ = N_1 + N_2 j + N_3 (1 - e^{-\nu j}). \]
dimension, the step function similarly implies that the age-earnings profile is a general polygon.

The estimated equations for the three variants of model I are

\[
\log Y_{bkoj} = (\alpha + H_1) + \beta b + (H_2 + \beta)j + H_3j^2
\]
\[+ \sum_{m=1}^{p-1} P_m(k_m - k_{m-1}) + P_p(k - k_{p-1}) + Z_{bkoj}, \quad (14.A)
\]

\[
\log Y_{bkoj} = (\alpha + N_1) + \beta b + (N_2 + \beta)j + N_3(1 - e^{-vj})
\]
\[+ \sum_{m=1}^{p-1} P_m(k_m - k_{m-1}) + P_p(k - k_{p-1}) + Z_{bkoj}, \quad (14.B)
\]

\[
\log Y_{bkoj} = \alpha + \beta b + \sum_{m=1}^{p-1} (X_m + \beta)(j_m - j_{m-1})
\]
\[+ (X_p + \beta)(j - j_{p-1}) + \sum_{m=1}^{p-1} P_m(k_m - k_{m-1})
\]
\[+ P_p(k - k_{p-1}) + Z_{bkoj}, \quad (14.C)
\]

where \( p \) is the number of intervals in the step function within which earnings change and \( P_m \) and \( X_m \) are constant. Thus, \( X_m \) is a constant defined on the interval \( j_{2-1} < j < j_m \) and \( P_m \) is a constant defined on the interval \( k_{2-1} < k < k_m \). The quantity \( Z_{bkoj} \) is a composite random error,

\[
Z_{bkoj} = U_{bko0} + \sum_{i=1}^{j} U_{bkoi},
\]

where \( U_{bko0} \) is the random error of the initial earnings and \( U_{bkoi} \) is the random error of the increase in earnings, \( \gamma_{bkoi} \).

Model II exists in two variants corresponding to functional forms A and C. In the first variant of model II, we assume that for a given age of graduation \( k_0 \) the investment ratio and the depreciation ratio are linear functions of years of experience. The age-earnings profile thus becomes a parabola, but the parameters may vary by the age of graduation. When model II is estimated using profile C, each step in the earnings function depends on \( k_0 \). Thus, the experience-earnings profiles are all polygons which may differ in shape depending on age at graduation. Model II is estimated by stratifying the sample by \( k_0 \).

The stochastic properties which apply to both models are specified below. The expectation of the error term is zero. However, drawing on some earlier results (Klevmarken 1972), we assume that the variance of logarithmic earnings is a linear function of years of experience and that all covariances are zero:

\[
E(Z_{bkoj}) = E(U_{bko0}) + \sum_{i=1}^{j} E(U_{bkoi}) = 0, \quad (16)
\]

\[
\text{var}(Z_{bkoj}) = \text{var}(U_{bko0}) + \sum_{i=1}^{j} \text{var}(U_{bkoi}) = (1 + j)\sigma^2. \quad (17)
\]
The data to be used are geometric average salaries; thus, the model should be stated in average form. Since we assume that individual earnings are independent, this is easily accomplished:

$$\text{var} \left( \bar{Z}_{bkoj} \right) = \frac{(1 + j)\sigma^2}{n_{bkoj}},$$  \hspace{1cm} (18)

where $\bar{Z}_{bkoj}$ represents the mean logarithmic error and $n_{bkoj}$ is the number of individuals comprising the geometric averages.

For all specifications except those involving profile B, the models are estimated by generalized least squares. However, when model I is estimated using profile B, the exponential investment function (eq. [14.B]), the equation contains a nonlinear parameter. Equation (14.B) has therefore been estimated by the golden-section search method (Flanagan 1969), that is, by minimizing the residual sum of squares over a range of values for the nonlinear parameter $V$.

III. Results

The two models are tested empirically using salary data obtained from the Swedish Association of Graduate Engineers. These data include geometric average salaries by age, year of graduation, and calendar year for separate populations of electrical and mechanical engineers. The data cover the 10-year period 1961–70 and are obtained from an annual survey of all engineering graduates in Sweden.\(^{10}\) The data thus refer to those with identical educational qualifications belonging to well-defined professions; this makes the assumption of identical rates of return to human capital investments slightly less heroic than in other studies. Moreover, the data measure wages and salaries (not total income) in a society where, for all practical purposes, individual variations in health-care investment can be neglected.

The dependent variable is the logarithm of average monthly salaries in constant (1949) Swedish kronor. We assume that the year of entering the labor force ($k_0$) is the same as the year of graduation, that is, years of experience equal the number of years elapsed since graduation.\(^{11}\) For profile C, there are nine experience variables for electrical engineers,

\(^{10}\) The response rate for these surveys varied between 76 and 94 percent during the period (see Klevmarken [1972, chap. 2] for a discussion of the underlying data). A total of 1,130 observations on (geometric) average salaries is available for electrical engineers; the sample size is 1,042 for mechanical engineers. In 1965, e.g., the averages were obtained from surveys of 1,462 electrical engineers and 1,416 mechanical engineers.

\(^{11}\) The underlying populations during this period were approximately 99 percent male, and the unemployment rate for engineers was about 0.5 percent.
reflecting the number of years in each interval. In particular there is one interval for each of the first 4 years of experience. For mechanical engineers, the data allowed 10 experience variables to be defined. Again, there is one interval for each of the first 4 years of experience. Seven physical age intervals are included for electrical engineers, and eight are included for mechanical engineers.

For model I, the coefficient estimates are presented in tables 1 and 2. For each profile A, B, and C, two sets of results are presented, one including the estimated coefficients of the physical age variables and one based simply on the experience variables.

For each of the three profiles, the magnitudes of the coefficients of the experience variables change when physical age is excluded, implying a less steep earnings profile in the experience dimension. The physical age variables explain an additional 5 percent of the variance for both samples.

The general pattern of the estimated coefficients is the same for both samples, but a minor difference in the pattern of the physical age coefficients occurs in the age interval 55–59 years for mechanical engineers, where the estimates are larger than expected.

For electrical engineers, the real increase in starting salaries is estimated to be about 1.5 percent. When the physical age variables are omitted, the estimates decrease to about 1.2 percent. The estimates for mechanical engineers are only slightly lower.

Tables 1 and 2 indicate that the best fit to the data is obtained for profile C, but the differences are very small. In the physical age dimension, salaries increase up to the age of 45 years and decrease thereafter. There are only minor differences in the estimates between the three variants of model I.

In principle, model II states that the investment profile may differ for each age of entry, $k_0$. We have estimated the models for three intervals of $k_0$ corresponding to those who completed schooling: at ages younger than the normal age (quick), at the normal age (normal), and at ages older than the normal age (slow).\footnote{The average matriculation age for Swedish engineers varied between 25.9 and 26.5 years during the period 1961–70, with a variance of 3.6–7.8 years. Neither figure exhibits a trend. Accordingly, the data were divided into three groups: the "quick" group, who completed their degrees at or below 23 years of age; the "normal" group, who completed their degrees at ages 24–26 years of age; and the "slow" group, who completed their degrees at or above 27 years of age.}

Coefficients for model II are presented in tables 3 and 4. Table 3 presents separate estimates of the parameters of profiles A and C for the three groups of electrical engineers, and table 4 presents the estimates for mechanical engineers.

Stratification of the sample into three groups reduces the degrees of
freedom and the variation in the variables, making the estimates less certain. In all cases, however, the covariance tests reported in tables 3 and 4 indicate that stratification is appropriate. The adjusted $R^2$ is .96 for the entire sample of electrical engineers and .97 for mechanical engineers.

The estimates for profile C generally indicate that salary increases are higher at given levels of experience for the quick group than for the

| TABLE 1 |
| Estimates of Alternative Investment Profiles for Swedish Electrical Engineers from Model I (Standard Errors in Parentheses) |
| Profile A: Linear |

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Equation (14.A)</th>
<th>Excluding Age</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\beta$</td>
<td>.0146 (0.006)</td>
<td>.0122 (0.009)</td>
</tr>
<tr>
<td>$x + H_1$</td>
<td>-26.15 (1.25)</td>
<td>-21.31 (1.75)</td>
</tr>
<tr>
<td>Experience ($j$):</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$H_2 + \beta$</td>
<td>.0635 (0.015)</td>
<td>.0896 (0.017)</td>
</tr>
<tr>
<td>$H_3 \times 10^3$</td>
<td>-0.9848 (0.0754)</td>
<td>-1.728 (0.0788)</td>
</tr>
<tr>
<td>Age ($k$):</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$P_m$ for $k =$</td>
<td></td>
<td></td>
</tr>
<tr>
<td>-29 years</td>
<td>.0268 (0.0017)</td>
<td>...</td>
</tr>
<tr>
<td>30-34 years</td>
<td>.0240 (0.0017)</td>
<td>...</td>
</tr>
<tr>
<td>35-39 years</td>
<td>.0164 (0.0034)</td>
<td>...</td>
</tr>
<tr>
<td>40-44 years</td>
<td>.0024 (0.0059)</td>
<td>...</td>
</tr>
<tr>
<td>45-49 years</td>
<td>-.0040 (0.0090)</td>
<td>...</td>
</tr>
<tr>
<td>50-54 years</td>
<td>-.0365 (0.0150)</td>
<td>...</td>
</tr>
<tr>
<td>$55+$ years</td>
<td>-.0082 (0.0380)</td>
<td>...</td>
</tr>
<tr>
<td>$R^2$</td>
<td>.9457</td>
<td>.8929</td>
</tr>
</tbody>
</table>

| Profile B: Exponential |

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Equation (14.B)</th>
<th>Excluding Age</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\beta$</td>
<td>.0145 (0.006)</td>
<td>.0121 (0.009)</td>
</tr>
<tr>
<td>$x + N_1$</td>
<td>-26.01 (1.25)</td>
<td>-21.29 (1.75)</td>
</tr>
<tr>
<td>Experience ($j$):</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$V$</td>
<td>.1116</td>
<td>.0079</td>
</tr>
<tr>
<td>$N_2 + \beta$</td>
<td>.4255 (0.0315)</td>
<td>59.310 (2.707)</td>
</tr>
<tr>
<td>Age ($k$):</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$P_m$ for $k =$</td>
<td></td>
<td></td>
</tr>
<tr>
<td>-29 years</td>
<td>.0249 (0.0017)</td>
<td>...</td>
</tr>
<tr>
<td>30-34 years</td>
<td>.0248 (0.0017)</td>
<td>...</td>
</tr>
<tr>
<td>35-39 years</td>
<td>.0188 (0.0034)</td>
<td>...</td>
</tr>
<tr>
<td>40-44 years</td>
<td>.0021 (0.0058)</td>
<td>...</td>
</tr>
<tr>
<td>45-49 years</td>
<td>-.0076 (0.0087)</td>
<td>...</td>
</tr>
<tr>
<td>50-54 years</td>
<td>-.0369 (0.0149)</td>
<td>...</td>
</tr>
<tr>
<td>$55+$ years</td>
<td>-.0057 (0.0138)</td>
<td>...</td>
</tr>
<tr>
<td>$R^2$</td>
<td>.9469</td>
<td>.8932</td>
</tr>
</tbody>
</table>
### Table 1 (Continued)

**Profile C: Step Function**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Equation (14.C)</th>
<th>Excluding Age</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\beta$</td>
<td>.0146 (.0006)</td>
<td>.0123 (.0009)</td>
</tr>
<tr>
<td>$\alpha$</td>
<td>-26.08 (1.24)</td>
<td>-21.63 (1.73)</td>
</tr>
</tbody>
</table>

**Experience ($j$):**

- $X_m + \beta$ for $j =$
  - 1 year ................. .0491 (.0058) .0504 (.0082)
  - 2 years ................. .0689 (.0062) .0877 (.0085)
  - 3 years ................. .0708 (.0074) .0940 (.0104)
  - 4 years ................. .0759 (.0079) .0995 (.0110)
  - 5–9 years ............... .0436 (.0024) .0646 (.0032)
  - 10–14 years ............. .0393 (.0043) .0511 (.0056)
  - 15–19 years ............. .0314 (.0072) .0279 (.0096)
  - 20–24 years ............. .0335 (.0113) .0252 (.0149)
  - 25– years ............... .0281 (.0228) .0080 (.0311)

**Age ($k$):**

- $P_m$ for $k =$
  - 29 years ............... .0234 (.0018) ... ...
  - 30–34 years ............ .0250 (.0018) ... ...
  - 35–39 years ............ .0202 (.0035) ... ...
  - 40–44 years ............ .0101 (.0061) ... ...
  - 45–49 years ............ - .0082 (.0094) ... ...
  - 50–54 years ............ - .0372 (.0153) ... ...
  - 55– years .............. - .0049 (.0377) ... ...

$R^2$ .................. .9437 .8952

normal group and are higher for the normal group than for the slow group. This is not true for each experience interval, however, and for several intervals the standard errors are quite large.

### IV. Implications

The empirical results provide insights into several of the theoretical issues posed in the previous sections—issues related to “ability,” starting salaries, and investment profiles.

First, it is worth pointing out that for both models and for both samples the estimates of profile C suggest that salary increases peak at about 3 or 4 years of experience. The initial rise in salary increments early in the career implies that earnings curves have an inflection point consistent with Becker’s original (1962) theoretical insight (but not heretofore observed).

As noted above (assumption 5), both models permit starting salaries to differ by age at graduation. Model I is constrained so that variations in starting salaries depend only on prior labor market experience—previous human capital investment and depreciation. The results of model I indicate that starting salaries increase monotonically with age at grad-
uation, that is, prior net investment is positive. This result is illustrated in table 5, which presents estimated starting salaries for the three groups of engineers.

In contrast, the more general formulation (model II) permits starting salaries for each group to vary by efficiency in learning (or "ability," as measured by \( k_0 \)) as well as by prior labor market experience. The parameters estimated from the more general model suggest that the starting salary is smaller for the normal group than for the other two groups.

\[
\begin{align*}
\text{TABLE 2} \\
\text{ESTIMATES OF ALTERNATIVE INVESTMENT PROFILES FOR} \\
\text{SWEDISH MECHANICAL ENGINEERS FROM MODEL I (STANDARD ERRORS IN PARENTHESES)} \\
\text{PROFILE A: LINEAR} \\
\hline
\text{Parameter} & \text{Equation (14.A)} & \text{Excluding Age} \\
\hline
\beta & .0019 & .0103 \\
\alpha + H_1 & -20.93 & -17.76 \\
\text{Experience (j):} & & \\
H_2 + \beta & .0611 & .0885 \\
H_3 \times 10^3 & -.9437 & -1.6313 \\
\text{Age (k):} & & \\
P_m \text{ for } k = & & \\
-29 \text{ years} & .0322 & \ldots \\
30-34 \text{ years} & .0220 & \ldots \\
35-39 \text{ years} & .0169 & \ldots \\
40-44 \text{ years} & .0011 & \ldots \\
45-49 \text{ years} & .0129 & \ldots \\
50-54 \text{ years} & -.0317 & \ldots \\
55+ \text{ years} & .0577 & \ldots \\
R^2 & .9538 & .9200 \\
\hline
\end{align*}
\]

\[
\begin{align*}
\text{PROFILE B: EXPONENTIAL} \\
\hline
\text{Parameter} & \text{Equation (14.B)} & \text{Excluding Age} \\
\hline
\beta & .0119 & .0104 \\
\alpha + N_1 & -21.03 & -17.90 \\
\text{Experience (j):} & & \\
V & .0806 & .0304 \\
N_2 & .6866 & 5.0416 \\
N_2 + \beta & .0144 & -.0590 \\
\text{Age (k):} & & \\
P_m \text{ for } k = & & \\
-29 \text{ years} & .0293 & \ldots \\
30-34 \text{ years} & .0225 & \ldots \\
35-39 \text{ years} & .0195 & \ldots \\
40-44 \text{ years} & .0022 & \ldots \\
45-49 \text{ years} & .0125 & \ldots \\
50-54 \text{ years} & -.0422 & \ldots \\
55+ \text{ years} & .0581 & \ldots \\
R^2 & .9548 & .9208 \\
\hline
\end{align*}
\]
<table>
<thead>
<tr>
<th>Parameter</th>
<th>Equation (14.C)</th>
<th>Excluding Age</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\beta$</td>
<td>.0118 (.0007)</td>
<td>.0101 (.0009)</td>
</tr>
<tr>
<td>$\alpha$</td>
<td>$-20.63$ (1.31)</td>
<td>$-17.20$ (1.71)</td>
</tr>
</tbody>
</table>

Experience ($j$):
- 1 year: .0457 (.0077), .0549 (.0099)
- 2 years: .0641 (.0078), .0871 (.0001)
- 3 years: .0778 (.0089), .1042 (.0115)
- 4 years: .0581 (.0089), .0855 (.0116)
- 5–9 years: .0450 (.0026), .0648 (.0030)
- 10–14 years: .0431 (.0042), .0554 (.0050)
- 15–19 years: .0122 (.0068), .0172 (.0083)
- 20–24 years: .0430 (.0100), .0389 (.0123)
- 25+ years: .0207 (.0150), $-.0005$ (.0187)

Age ($k$):
- $P_m$ for $k = -29$ years: .0290 (.0024), ...
- 30–34 years: .0224 (.0022), ...
- 35–39 years: .0174 (.0037), ...
- 40–44 years: .0083 (.0058), ...
- 45–49 years: .0057 (.0078), ...
- 50–54 years: $-.0425$ (.0099), ...
- 55+ years: .0582 (.0104), ...

$R^2$: .9549, .9216

Our analysis suggests that the U-shaped relation between starting salary and age of graduation is the result of two factors—the relatively greater ability of those who are youngest at graduation and the relatively greater labor market experience of those who are oldest at graduation. Some indirect evidence supports this interpretation. For example, a negative correlation between course grades and elapsed time to matriculation is reported for one Swedish engineering school (Rubenowitz 1962); another study indicates that a major reason for delayed graduation among Swedish engineers is some parallel participation in the labor market (Håstad, Högberg, and Johansson 1974).

Differential access to capital markets could provide an alternative interpretation of these results, especially if those with access to funds also had “connections” leading to better-paying jobs. However, public grants and loan guarantees, available to all students, together with tuition-free higher education in Sweden make this interpretation somewhat less plausible. It is estimated that 50 percent of Swedish university students subsist exclusively on public grants and loans and that another 36 percent depend “mostly” on such assistance (Statens Offentliga Utredningar 1970, p. 20). Another study estimated that only 5 percent of those students who interrupt their graduate careers do so because of financial difficulties (Håstad et al. 1974).
<table>
<thead>
<tr>
<th>Parameters Estimated</th>
<th>Profile A: Linear Investment and Depreciation Rates</th>
<th>Profile C: Step Function</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Quick</td>
<td>Normal</td>
</tr>
<tr>
<td>$\beta(k_0)$ ..........</td>
<td>.0171 (.0015)</td>
<td>.0134 (.0007)</td>
</tr>
<tr>
<td>Intercept ..........</td>
<td>-31.06 (3.00)</td>
<td>-23.77 (1.37)</td>
</tr>
<tr>
<td>Profile A:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Years ..........</td>
<td>.0924 (.0031)</td>
<td>.0956 (.0013)</td>
</tr>
<tr>
<td>Years$^2$ ..........</td>
<td>-.0015 (.0001)</td>
<td>-.0018 (.0001)</td>
</tr>
<tr>
<td>Profile C:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1 year ............</td>
<td>...</td>
<td>...</td>
</tr>
<tr>
<td>2 years ............</td>
<td>...</td>
<td>...</td>
</tr>
<tr>
<td>3 years ............</td>
<td>...</td>
<td>...</td>
</tr>
<tr>
<td>4 years ............</td>
<td>...</td>
<td>...</td>
</tr>
<tr>
<td>5–9 years ..........</td>
<td>...</td>
<td>...</td>
</tr>
<tr>
<td>10–14 years .......</td>
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<td>...</td>
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<tr>
<td>15–19 years .......</td>
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<tr>
<td>20–24 years .......</td>
<td>...</td>
<td>...</td>
</tr>
<tr>
<td>25–years ..........</td>
<td>...</td>
<td>...</td>
</tr>
<tr>
<td>$R^2$ ...............</td>
<td>.9437</td>
<td>.9833</td>
</tr>
<tr>
<td>No. of observations</td>
<td>195</td>
<td>319</td>
</tr>
<tr>
<td>F-ratio for stratification</td>
<td>$F(1,126, 1,118) = 2.718$</td>
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</tr>
<tr>
<td>$R^2$ overall .......</td>
<td>.9606</td>
<td></td>
</tr>
</tbody>
</table>
### TABLE 4

Estimates of Model II for Mechanical Engineers (Standard Error in Parentheses)

<table>
<thead>
<tr>
<th>Parameters Estimated</th>
<th>Profile A: Linear Investment and Depreciation Rates</th>
<th>Profile C: Step Function</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Quick</td>
<td>Normal</td>
</tr>
<tr>
<td>$\beta(k_0)$</td>
<td>.0175 (.0021)</td>
<td>.0126 (.0009)</td>
</tr>
<tr>
<td>Intercept</td>
<td>-31.89 (4.06)</td>
<td>-22.23 (1.84)</td>
</tr>
<tr>
<td>Profile A:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Years</td>
<td>.0895 (.0037)</td>
<td>.0945 (.0017)</td>
</tr>
<tr>
<td>Years$^2$</td>
<td>-.0012 (.0001)</td>
<td>-.0017 (.0001)</td>
</tr>
<tr>
<td>Profile C:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1 year</td>
<td>...</td>
<td>...</td>
</tr>
<tr>
<td>2 years</td>
<td>...</td>
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</tr>
<tr>
<td>3 years</td>
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<tr>
<td>4 years</td>
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<tr>
<td>5–9 years</td>
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<tr>
<td>10–14 years</td>
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<tr>
<td>15–19 years</td>
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<tr>
<td>20–24 years</td>
<td>...</td>
<td>...</td>
</tr>
<tr>
<td>25–years</td>
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</tr>
<tr>
<td>$R^2$</td>
<td>.9276</td>
<td>.9739</td>
</tr>
<tr>
<td>No. of observations</td>
<td>179</td>
<td>322</td>
</tr>
<tr>
<td>$F$-ratio for stratification &amp; $R^2$ overall</td>
<td>$F(1,038, 1,040) = 2.925$, $R^2 = .9726$</td>
<td>$F(1,030, 1,008) = 2.918$, $R^2 = .9731$</td>
</tr>
</tbody>
</table>
TABLE 5
ESTIMATED STARTING SALARIES BY YEAR OF GRADUATION
(1960 SWEDISH KRONER)

<table>
<thead>
<tr>
<th>Model/Group</th>
<th>Electrical Engineers</th>
<th>Mechanical Engineers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Quick</td>
<td>1,819</td>
<td>2,125</td>
</tr>
<tr>
<td>Normal</td>
<td>1,906</td>
<td>2,228</td>
</tr>
<tr>
<td>Slow</td>
<td>2,045</td>
<td>2,390</td>
</tr>
<tr>
<td>Model II:†</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Quick</td>
<td>2,119</td>
<td>2,525</td>
</tr>
<tr>
<td>Normal</td>
<td>1,937</td>
<td>2,240</td>
</tr>
<tr>
<td>Slow</td>
<td>2,140</td>
<td>2,499</td>
</tr>
</tbody>
</table>

* Coefficients from tables 1 and 2 for age at graduation: \( k_0 = 23 \) years (quick); \( k_0 = 25 \) years (normal); and \( k_0 = 28 \) years (slow).
† Coefficients from tables 3 and 4 for age at graduation: \( k_0 \leq 23 \) years (quick); \( 24 \leq k_0 \leq 26 \) (normal); and \( k_0 \geq 27 \) years (slow).

Model I also requires that the relative differences in starting salaries be the same in each calendar year, while model II does not. As tables 3 and 4 show, the estimate of the rate of increase in starting salary is higher for the quick group than for the other two groups. This is also highlighted by the starting-salary estimates in table 5. This may reflect a secular increase in the variance of both the distribution of ability and the distribution of human capital accumulated before graduation. This phenomenon is a likely result of the expansion of the education system during the period, an expansion which seems to have motivated students with relatively lower efficiency in learning to undertake higher education.\(^{13}\)

The empirical results support the importance of considering both age and years of experience in analyzing returns to human capital investments. However, even with these highly disaggregated data, the results provide little basis for distinguishing between a linear representation of net investment ratios and a more complex proportional representation.

As we have noted, the recognition that human capital both deteriorates (with elapsed time) and becomes obsolete (with successive vintages) makes it impossible to derive gross investment profiles without indepen-

\(^{13}\) During the period 1955–70, the number of new students admitted to engineering schools expanded from 600 to 3,000, and it appears that the quality of entering students declined. For instance, in 1961, 61 percent of those admitted to the program in mechanical engineering at the largest engineering school had the top grade in high school mathematics and 1 percent had the lowest qualifying grade; in 1972, only 7 percent of those admitted had the top grade and 63 percent had the lowest grade (Lindberg et al. 1974). Based on these trends, we might expect the proportion of slow graduates to increase. There is, however, no such tendency in our data, probably because the share of students with parallel labor market activities declined.
Fig. 4.—Estimates of gross investment profiles from model I for workers graduating at age 25 ($r = .13; d = .02$).

dent information. With a few additional assumptions, however, it is possible to estimate the relationship between gross investment and years of experience. Consider, for example, the parameters estimated by profile C. If we assume that the depreciation rate is constant, knowledge of the retirement age and the rate of return are sufficient to estimate a gross investment profile consistent with any depreciation rate. Moreover, since gross investment can never be negative, for any rate of return it is possible, at least in principle, to estimate the minimum rate of obsolescence consistent with nonnegative gross investment.

Figure 4 presents such gross investment profiles estimated from model I. We assume that for all workers the age of retirement is 65; an independent estimate of the return to education among Swedish engineers is 13 percent (Klevmarken 1972, p. 128). The investment profile is drawn for a depreciation rate of 2 percent.\textsuperscript{14} For any cohort, the age of retirement determines the year of experience at which the gross investment ratio goes to zero, and this allows gross investment in all previous periods to be

\textsuperscript{14} Because it was not possible to define steps in the estimated-earnings functions after 34 years of experience, an investigation of the minimum rate of obsolescence is not possible. Indeed, for mechanical engineers, the low estimates (essentially zero) for gross investment after 30 years of experience are attributable to a single coefficient ($-.0066$, table 2) with a large standard error (.0256).
solved by successive substitution.\textsuperscript{15} As the figure suggests, if these assumptions are reasonable, the gross investment ratios early in the career are quite substantial. Gross investment rates decline rather rapidly throughout the working life; they decline by 50 percent after about 12 years experience.

Figure 5 shows the gross investment ratios estimated from model II under the same assumptions. The figure indicates that the experience profile of gross investment differs among cohorts. At any year of experience, the quick group invests more than the normal group and the normal group invests more than the slow group. The rate of decrease of investment is also less for the quick group than for the other two cohorts.

As indicated in figures 4 and 5, the estimated gross investment ratios increase in the interval containing the first year of experience. This finding is consistent with the so-called corner solution implied by Ben-Porath's original analysis (1967), in which it is assumed that the production function for human capital includes the current capital stock as an argument.\textsuperscript{16}

Although these estimates of gross investment profiles are subject to a generous margin of error, the differences among cohorts are just what we would expect based on the theoretical analysis (see figs. 1 and 2):

\textsuperscript{15} The quantity $c(j)$ is greater than or equal to zero for all years of experience before retirement. If the "scrap value" of human capital is realized at retirement (either because a functioning market exists or, more realistically, because the human capital remaining at retirement provides satisfaction), gross investment will continue up to retirement. In figs. 4 and 5 above, we have assumed that gross investment goes to zero at retirement. Thus, knowledge of the retirement age, $K$, allows us to calculate the years of experience, $J = K - k_0$, for which $c(J) = 0$ for any cohort. The other values are found from the expression

$$c(J - 1) = \frac{X_j + c(J) - rd}{(1 + r)}.$$  \hspace{1cm} (6N)

If, on the other hand, the "scrap value" of human capital is not realized at retirement, gross investment will cease before retirement. In this case, it can be shown that the year of experience, $J^\ast$, at which gross investment goes to zero is

$$J^\ast = J - \frac{\log [1 - (1 - Q)/rQ]}{\log Q}, \quad Q \neq 1,$$

$$J^\ast = J - \frac{1}{r}, \quad Q = 1,$$  \hspace{1cm} (7N)

where $J = K - k_0$, $Q = (1 - d)/(1 + \rho)$, and $\rho$ is the rate of return on riskless securities. The qualitative results, in particular the comparisons among the models and cohorts, are similar to those presented above if human capital has no "scrap value." In fact, the reported comparisons among cohorts hold for either assumption for all the rates of return and depreciation rates we investigated (.08 \leq r \leq .15, 0 \leq d \leq .05, .05 \leq \rho \leq .15).\textsuperscript{16}

\textsuperscript{16} If the initial stock of human capital is small, it is possible that even large amounts of other inputs (e.g., all available time) produce small quantities of human capital. Under these conditions, output of human capital will increase until an optimum is reached, with input levels less than total available resources. After this point, investment ratios decline (see Ben-Porath 1967; Mincer 1974).
Fig. 5.—Estimates of gross investment profiles for mechanical engineers for three cohorts ($r = .13; d = .02$).

Younger cohorts with the same education and experience invest more resources in the production of human capital throughout their careers. Not only do they invest more absolutely, but their human capital investments as a proportion of potential earnings are higher. In terms of calendar age, by age 40 the investment ratio for the quick group is about twice as high as those for the other two groups.

These results suggest that age and experience are both important determinants of human capital investment profiles. They also suggest that the elapsed time to the completion of graduate training is related to "ability" in ways postulated by the theory of human capital.

References


