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HUMAN CAPITAL EARNINGS FUNCTIONS:

A Theoretical Introduction

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ABSTRACT: In early studies of the marginal rate of return to education, the functional form of the statistical earnings function was commonly allowed to be unrestrictedly dictated by available data. Using the pioneering theories of investment in education and on-the-job training postulated in the early 1960s, Mincer in 1974 launched an empirical specification of the earnings function which is now widely referred to as the standard human capital earnings function. Since there is a vast literature on the Mincer earnings model, this paper gives only a schematic presentation of the function and the major assumptions underlying the theory. The organization and contents of the paper reflect its primary purpose, viz. to serve as a brief theoretical background for the empirical estimations of human capital earnings functions on Finnish labour force survey data reported in separate discussion papers.

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TIIVISTELMÄ: Varhaisissa koulutuksen tuottoa koskevissa tutkimuksissa estimoitavan palkkayhtälön muoto määräytyi usein käytettävissä olevan aineiston perusteella. 1960-luvun alussa esitettyjä uraauurtavia inhimillisen pääoman teorioita hyödyntäen Mincer esitti vuonna 1974 palkkayhtälön empiirisen muodon, jota nykyään yleisesti kutsutaan inhimillisen pääoman palkkayhtälön perusmalliksi. Koska aiheesta on paljon kirjallisuutta, Mincerin palkkayhtälöä ja sen perusoletuksia on tässä raportissa esitelty varsin lyhyesti ja kaavamaisesti. Käsillä oleva raportti on tarkoitettu lyhyeksi teoreettiseksi johdannoksi niihin empiirisiin tutkimuksiin, joissa on pyritty selvittämään Suomessa esiintyvien palkkaerojen syitä. Näiden tutkimusten tuloksia julkaistaan ETLAn Keskusteluaiheita-sarjassa.

I. INTRODUCTION

The issue that has clearly dominated the human capital literature is that of earnings differentials by age and education. In fact, the premier application of the earnings function is to the study of the effects of investment in schooling and on-the-job training on the level, pattern, and interpersonal distribution of life cycle earnings originating in the pioneering work on human capital by Becker (1964,1967,1975), Becker & Chiswick (1966), Ben-Porath (1967), and, especially, by Mincer (1958,1962,1974).[1]

The basic assumption underlying the human capital methodology is that any increase in educational attainment - accumulation of human capital[2] - creates human capabilities and therefore causes an increase in labour productivity. In particular, education and training are described as investment or production processes that turn unskilled into skilled labour.[3] And with greater knowledge individuals are assumed to be able to act more efficiently in different circumstances including working life, i.e. they will be more productive.

This accumulation of human capital is, in turn, thought to be fully reflected in the market wage received by the worker, which is assumed always to equal the value of the worker's current marginal productivity. The belief underlying the human capital view thus is that the labour market for educated workers operates in accord with the precepts of competitive economic analysis. Accordingly, persons with identical human resources are assumed to be equally paid. Likewise, the allocation of labour is assumed to be determined by the market wages of the different educational categories and the adjustments on the labour market are supposed to take place solely through changes in wage levels. A further implication is that the individuals make all their decisions - including their educational choices - under full information. In other words, education does not provide individuals with more information, it merely improves their human capabilities.

But the human capital view has also been subject to a variety of criticisms. The sceptics most frequently argue that earnings differentials overstate the relative productivity of workers who differ in education. Indeed, the rather extreme screening or filter hypothesis completely disregards the productive value of education. Instead, it is argued that the main (only) role of education is to provide information about the individuals' innate abilities by distilling the talented upwards in the society and award them a quality label, the diploma. This information is in turn used by employers in their hiring policies.

Less extreme in its critique is the sorting hypothesis, the datum of which is that the effect of education on earnings consists of both productivity and signalling components. Hence, according to the sorting argument education both provides information about workers' abilities and affects these abilities. In other words, since individuals are assumed not to have perfect knowledge of their ability, education informs not only the employers but also the individuals themselves about their actual capabilities.

But there is a profound difference between the human capital and sorting theories in the view of the productivity fostering role of education. More precisely, the sorting theory states that the marginal productivity of a worker is linked to the occupation and not to the worker as in the human capital theory; that is, the skill structure of the work force has to be adjusted to fit the (given) job structure, and not vice versa as in the human capital theory. As a consequence, earnings differentials between individuals with identical capabilities may arise from differences in occupational status, leading to differences in productivity, and therefore, in pay.

A further implication of the assumption that productivity and earnings level are linked to the occupation and not to the worker is that educational categories are ranked differently for different occupations; i.e., a high level of education is no self-evident key to any occupation as in the human capital theory. However, this ranking may change if the relative supply of educational categories changes. And since workers compete for jobs mainly with their relative productive characteristics and not with the wage level as in the human capital theory, they have reason to improve continually their capabilities through on-the-job training.

Hence, according to the sorting theory, formal schooling and various background variables are the spring-board to working life, but productive qualifications necessary for a continued career can be achieved only in the labour market through experience and training. This interpretation of on-the-job training is to be compared with the human capital view, according to which on-the-job training gives rise to both general and specific human capital, the latter being productive only in that particular company in which it is obtained and therefore lost when moving to another company. The former, in turn, is seen to be identical with the homogeneous human capital accumulated by investing in education; i.e., it increases the overall productivity of the worker.[4]

Ideally, the direction of causation between investment in human capital and worker productivity would be determined by empirical test. Given the experimental data, the determination of which model is correct is perfectly straightforward. But such data are not available. The consequent difficulty in developing clearcut tests of signalling/screening versus human capital interpretations of human investment therefore partly explains why the empirical literature on this issue is neither large nor very convincive.[5] In fact, current empirical evidence allows no conclusive inferences to be drawn. Nevertheless Freeman (1986), for example, concludes that since no empirical study has found the signalling/screening effects to be a major factor in the demand for education, the findings can be seen to support the human capital view. Similar thoughts are expressed by Willis (1986), who doubts "that the signalling hypothesis will receive a convincing test against the conventional human capital theory because of the inherent identification problem" (p. 598).

The present paper focuses entirely on the human capital theory of wage determination. In Section II, the standard human capital earnings function is reviewed and commented on. However, since there is an extensive literature on the Mincer earnings model, the derviation of the function is presented only schematically and only some major points underlying the theory are pointed to. In Section III, the earnings function is extended to include also investment in specific capital. The organization and contents of the paper reflect its primary purpose, viz. to serve as a brief theoretical background for the empirical estimations of human capital earnings functions on Finnish labour force survey data reported in separate discussion papers.

II. THE STANDARD HUMAN CAPITAL EARNINGS FUNCTION[6]

In early studies of the marginal internal rate of return to education, the functional form of the statistical earnings function was commonly allowed to be unrestrictedly dictated by available data. In fact, when micro-level data were used, simply that regression specification was chosen which best fitted to the data.

Using the theories of investment in education and on-the-job training pioneered by Becker (1964) and Mincer (1958,1962) in an attempt to restrict the functional form of the human capital earnings function, Mincer in 1974 launched an empirical specification of the earnings function which is now widely referred to as the standard human capital earnings function. Moreover, the Mincer earnings function was intended as an approximation to the mostly unknown, precise functional form for the life cycle earnings path implied by optimal human capital investment models initiated by Ben-Porath (1967).[7]

The basic econometric specification of human capital earnings functions developed by Mincer (1974) implies the following relationship between the natural logarithm of earnings (EARN) and the human capital productivity proxies of years of schooling (S) and labour force experience (EXP):[8]

$$(1) \qquad \ln EARN_i = \alpha_0 + \alpha_1 S_i + \alpha_2 EXP_i + \alpha_3 EXP_i^2 + \varepsilon_i \qquad i = 1, \ldots, n$$

where the schooling coefficient (α_1) provides a direct estimate of the average level of the internal rate of return to education in a population of n individuals. In this particular regression specification, the marginal rate of return to schooling is assumed to be constant; i.e., each additional year of schooling is assumed to yield the same pecuniary return. The quadratic experience term is included to capture the concavity of observed experience-earnings profiles, implying that a priori $\alpha_2 > 0$ and $\alpha_3 < 0$.

However, lack of data on the actual work experience of employees forced Mincer to use a transformation of the employees' age as a proxy for their experience. Specifically, using Mincer's transformation the length of an employee's total work experience can be defined as

$$(2) \quad EXP_i = AGE_i - S_i - PRES$$

where the years of schooling (S) are assumed to begin at the age of school start, PRES (typically at age 6, in Finland at age 7). The proxy in eq. (2) is based on the assumption that the individuals enter the labour force immediately after having completed schooling (at age S + PRES) and are continuously employed.

The Mincer earnings function has been used in a large number of studies of educational wage differentials and the life cycle pattern of earnings. The strength of the function is reflected, inter alia, by the fact that practically all these studies reveal important empirical regularities in educational wage differentials and the life cycle pattern of earnings despite the considerable differences between the societies investigated and the various time periods considered. But it is actually quite remarkable that the Mincer earnings function works so well, considering the rather strong assumptions on which it is based. The most decisive of these assumptions are briefly commented on in the following derivation of the basic earnings function in eq. (1) above.[9]

To start, Mincer makes the simplifying theoretical assumption that the employees acquire solely homogeneous human capital through their investments in education and on-the-job training. In other words, an employee who has acquired a given amount of skills is assumed to be equally productive as any employee holding the same stock of human capital; i.e., their stocks of accumulated human capital consist of an equal number of homogeneous efficiency units of labour.[10] All employees can consistently be regarded as perfect substitutes in production at rates proportional to their endowment of efficiency units. The assumption implies that the acquired human capital as well as any increase in it will influence the employee's productivity by the same amount irrespective of the type of work done or the employer for whom it is done.

Following Becker's (1962,1964) pioneering distinction between general and firm-specific skills[11], this assumption abstracting from occupational skills has two interdependent implications when, as in the human capital theory, the labour market is assumed to be characterized by perfect competition. First, the employee will have to pay all the costs of his/her training. If the firm is to finance the training, the employee has to accept that his/her wage is reduced below his/her marginal product during the training period. The firm thus implicitly charges the employee for the costs of the training, and the employee is willing to pay that price, because the increase in his/her stock of human capital following from the investment will increase his/her productivity and therefore also future earnings. Secondly, the competitive labour market guarantees that the employee alone receives the returns from his/her accumulated investment in training. If the firm tried to capture some of the returns from the employee's training investment, there is always another firm willing to hire the employee at a wage which reflects the full value of his/her stock of homogeneous human capital.

For simplicity Mincer further treats the rate of return to investment in human capital as a constant for the individual, implying that a change in the individual's investments does not affect his/her marginal and thus also not his/her average rate of return. Put differently, any additional investment in human capital is seen to have the same proportional effect on the individual's earnings at all experience levels. Graphically, the profiles of log earnings against experience are taken to be approximately vertically parallel for all schooling groups. This assumed independence between schooling and experience allows the human capital earnings function to be written in the weakly separable form.[12]

In deriving the human capital earnings function in eq. (1) above, Mincer combines this key assumption of a constant individual-specific rate of return with an assumption about the time path of human capital investment over the individual's life cycle similar to that in models of optimal human capital accumulation. However, these models commonly assume that faced with a given market interest rate, the individual will choose to invest in schooling and post-school training so as to maximize the present value of lifetime earnings. Mincer, on the other hand, treats the individual's investment in human capital as determined exogenously, which Willis (1986) argues to be definitely inconsistent with the above maximization hypothesis.[13]

Specifically, Mincer assumes that the individual begins with an exogenously given stock of human capital at the age of school entry.[14] Let HC(0) denote the initial human capital embodied in the individual when entering school. Schooling is regarded as a full-time activity; i.e., the individual devotes all his/her time and capacity to investment in education, the reasoning being that, because of the high rate of return and the long payoff period, it pays for the individual to specialize completely in accumulating human capital. From each year of schooling the individual reaps a constant rate of return (r).[15] When this ith individual leaves school after S years of schooling, his/her earnings capacity will, as a consequence, amount to[16]

$$(3) \quad HC(S) = HC(0)\exp^{rS}$$

Provided that the individual makes no further investment in human capital after leaving school, his/her earnings capacity will equal actual - net - earnings, i.e. HC(S) = EARN(S). In other words, disregarding the possibility of human capital depreciation the individual's life cycle earnings profile will be horizontal at a value of EARN(S). Taking natural logarithms of eq. (3) gives the log-linear schooling-earnings relationship often referred to as the Mincer schooling model

$$(4) \quad \ln EARN(S) = \ln HC(0) + rS$$

It is worth noting in this context that underlying eq. (4) is the assumption of potential earnings forgone being the only cost (= the assumed value) of education to the individual.[17] This simplifying assumption commonly dictated by data limitations with respect to individual schooling costs goes, in effect, back to the early studies of the internal rate of return to education in the 1960s.

A definitely more realistic assumption about the individual's post-school investment behaviour would, however, be to presume that the individual continues to invest in human capital after having completed school. In other words, when entering the labour force the individual will most probably allocate his/her earnings capacity between further investment in human capital, i.e. on-the-job training, and earning. Suppose that in the first year of work experience, the individual devotes a fraction of I(0) of his/her earnings capacity to training investment, leaving only 1 - I(0) to earning. Accordingly, costless learning is ruled out. Assuming for the moment that the rate of return to post-school investment is the same as that to schooling, the immediate growth in the individual's earnings capacity due to this investment would be rI(0). With equal amounts of on-the-job investment in each year, the individual's potential earnings would after EXP years of work experience since the completion of school amount to

$$(5) \quad HC(EXP) = HC(S) + \sum_{t=1}^{EXP} rI(t)$$

and, when translated into continuous time, to

$$(6) \quad HC(EXP) = HC(S) \exp\left[\int_{0}^{EXP} rI(t)\, dt\right]$$

However, it seems unlikely that the individual continues to invest the same fraction of his/her earnings capacity in human capital throughout working life, the main reason being that human capital investments undertaken later in life have a shorter payoff period. Hence, if the individual can be assumed to choose to invest in human capital so as to maximize the present value of lifetime earnings, then there is most certainly a tendency of the amount of investment to decline over time. Specifically, Mincer assumes that the amount invested tends to decline linearly over the individual's working life from the initial value of I(0) at the beginning of the work career to a value of zero at the end of the career[18], i.e. at retirement. Accordingly, instead of treating the time path of post-school investment as a constant as in eqs. (5) and (6), it is written in the linear form

$$(7) \quad I(EXP) = I(0) - \frac{I(0)}{y} EXP$$

where y is the length of the individual's working life. For simplicity, y is not related to the individual's years of education. The shrinking fraction of earnings capacity invested in human capital is reflected in a slower growth in the individual's human capital stock and thereby also in a slower rate of growth of potential earnings. Specifically, rewriting eq. (6) using eq. (7) yields

$$(8) \quad HC(EXP) = HC(S)\ \exp\left[r\int_0^{EXP}[I(0) - (\frac{I(0}{y})\ t]\ dt\right]$$

which after integration gives

$$(9) \quad HC(EXP) = HC(S)\ \exp\left[rI(0)\,EXP - \frac{rI(0)}{2y}EXP^2\right]$$

Subtracting the costs of human investment, i.e. the fraction of potential earnings forgone, C(EXP) = I(EXP)HC(EXP), from the individual's earnings capacity as defined in eq. (9) gives his/her actual disposable earnings after a total of EXP years of labour force experience

$$(10) \quad EARN(EXP) = HC(EXP) - C(EXP) = [1 - I(EXP)]\,HC(EXP)$$

Finally, inserting eqs. (3) and (9) into eq. (10) and taking natural logarithms yields

$$(11) \quad \ln EARN(EXP) = \ln[1 - I(EXP)] + \ln HC(0) + rS + rI(0)\,EXP - \frac{rI(0)}{2y}EXP^2$$

If the individual's rate of return parameter on schooling investments, r_s, is allowed to differ from the corresponding parameter on post-school investments, r_e, then eq. (11) may be written in the form

$$(11') \quad \ln EARN(EXP) = \ln[1 - I(EXP)] + \ln HC(0) + r_s S + r_e I(0)\,EXP - \frac{r_e I(0)}{2y}EXP^2$$

When the first term on the right-hand side of eq. (11) is further approximated by a second-order Taylor expansion, i.e. by

$$(12) \quad \ln[1 - I(EXP)] \approx -I(EXP) - \frac{I(EXP)^2}{2}$$

the earnings function, with the indicies referring to the ith individual still suppressed, may be written

$$(13)\quad \ln EARN(EXP) = \ln HC(0) + rS - I(0) - \frac{I(0)^2}{2} + [rI(0) + \delta + I(0)\delta]\,EXP - \frac{(r\delta + \delta^2)}{2}EXP^2$$

where δ = I(0)/y, that is, the rate at which the post-school investment ratio is supposed to decline over the individual's working career.[19]

Also in eq. (13), a distinction between the rate of return to schooling and the rate of return to on-the-job training similar to that in eq. (11') above can, of course, be undertaken. But this method does not provide a direct estimate of r_e. On the contrary, if some kind of estimate of the average rate of return to a year of labour force experience is to be obtained using that approach, specific assumptions need to be made about the time path of post-school investment in eq. (7).[20] The obtained estimate of r_e may, as a consequence, be incorrect. But the estimate should be interpreted with caution not only because it can be criticized for being based on more or less uncertain assumptions. More important, as pointed out earlier, the standard human capital earnings function disregards the possibility of a relationship between schooling and the amount of and rate of return to on-the-job training. Below a less restrictive approach to estimating the rate of return to post-school investment is briefly discussed.

The human capital earnings function given in eq. (1) is the widely-used econometric approximation of the life cycle earnings profile of the ith individual portrayed in eq. (13). However, comparison of eqs. (1) and (13) reveals an important shortcoming of the empirical model specification: it treats the rate of return to human capital, r, the individual's initial earnings capacity, HC(0), the fraction of capacity invested in post-school human capital, I(0), and thus also δ as unobservable individual-specific constants. Put differently, the earnings function in eq. (1) is written as if everyone had the same values of these parameters. Hence, to the extent that the parameters differ across individuals because of differences in ability or family background (or any other unobservable variable affecting human capital investment behaviour), the effects are captured by the error term, ϵ.

Thus the omission of interpersonal ability differences indicates a possibility that the basic human capital earnings function does not measure correctly the opportunity set faced by the individual. If ability differences are likely to influence the marginal internal rate of return to human investment, then also the choice of schooling will vary across individuals. In particular, high ability individuals will on average choose higher levels of schooling because of their larger capacity to translate investments in human capital into higher productivity compared with low ability individuals. The estimated rate of return to education will, as a consequence, be upward biased, and the residual, ϵ, positively correlated with S. Hence, the estimated earnings function will be subject to an ability bias caused by self-selection, which overstates the incremental earnings an individual of certain ability would gain through additional investment in schooling.[21]

Also family background factors have frequently been regarded as important determinants of the distribution of investments in education across individuals. But it has also been hypothesized that where there is widespread public subsidisation of education evening up the educational opportunities of children from different home environments, family background should not have much impact on educational decisions. The logic then is that with equal educational opportunities, observed differences in education are due only to differences in the demand for education, which may in turn be explained by varying ability.[22] All in all, adjustment for this potential selectivity bias problem requires that the individual's educational choices can be determined endogenously, that is, on the basis of expected income and other relevant explanatory factors (e.g. Maddala, 1983). Because of lack of appropriate data, this approach is mostly of necessity abandoned in empirical work.[23]

But in contrast to what would be expected from the theoretical arguments given above, empirical evidence clearly indicates that simple human capital earnings functions allowing only for exogenously given investment in human capital, thus omitting ability and family background factors and the consequent selectivity bias problem, do contribute to the explanation of interpersonal earnings variance. Indeed, average rates of return to education adjusted for ability have been found to largely fall within the same range (some 5 to 10 per cent) as unadjusted rates of return. In fact, it has been argued that allowing for ability can be expected to reduce the rate of return by at most 50 per cent.[24] Hence, as concluded by Siebert (1990), "the main role of ability is in determining the acquisition of education, not in influencing the rate of return to education once it has been acquired" (p.35). Likewise, home environment has also not been found to have a decisive effect on individuals' earnings after school.

A further question closely related to ability is whether it is reasonable to assume, as in the Mincer earnings function, that the rate of return to post-school investment is independent of the rate of return to schooling. Suppose that individuals with more education gain more from post-school investment than less educated individuals, i.e. they have a higher rate of return on their on-the-job investments. This would occur if ability were positively correlated with education so that individuals on a higher educational attainment level learned more quickly also on the job. Indeed, empirical evidence does seem to indicate that post-school returns tend to increase with schooling (e.g. Psacharopoulos & Layard, 1979).

In that case, forcing the regression to have exactly the same profile with respect to post-school investment for all schooling groups, except for a vertical shift, would give an incorrect estimate of the returns to on-the-job investment and an overestimation of the returns to schooling. One simple way of approaching this problem would be to allow post-school investment to depend on schooling by supplementing the standard human capital earnings function with an interaction term, $S \cdot EXP$. Indeed, Psacharopoulos & Layard (1979) augmented the Mincer earnings function with a whole set of interaction terms, viz. $S \cdot EXP$, $S^2 \cdot EXP$, $S \cdot EXP^2$, $S^2 \cdot EXP^2$. From their "basic" model they were then able to compute the average rate of return to training investment and simultaneously check if the rate of return to education does equal the rate of return to post-school investment.

Before turning to the next section it might be appropriate to point to some further aspects not yet discussed, which may also give rise to difficulties when interpreting estimated rates of return to schooling. First, the above analysis is made only in pecuniary terms, thereby omitting the eventual impact of the non-pecuniary benefits and disbenefits associated with different jobs. This may bias the obtained estimates of the rate of return to education. Specifically, the average returns will be underestimated if there are compensatory payments for working conditions but no allowance made in the regression for such compensating differentials. There is, in fact, already good evidence on the existence of differentials both as regards physical working conditions and with respect to fringe benefits.

The problem, however, is that the data bases available rarely comprise information allowing such aspects to be taken into account.[25]

In addition to this, there is the question of the difference between the rate of return to investment in education reaped by the individual and the rate of return received by the society from that very same investment. Social returns will differ from private returns if there are differences between the private and social costs of schooling due to public subsidisation of education and/or between the private and social benefits of schooling because of the taxation of earnings. Generally when calculating the private rate of return, earnings are net of taxes and, because of public subsidies of direct schooling costs, forgone earnings the only costs of education individuals are seen to incur.[26] Contrary to this, the social rates of return include all direct costs of schooling and use before-tax earnings.

But in comparing estimated private and social rates of return to education for different countries, Psacharopoulus (1981) found that the impact of the tax system is generally more or less negligible; the estimated tax rates tend to be approximately proportional. Instead, most of the difference between the two rates of return could be ascribed to the direct costs of schooling. This implies that by computing social rates of return to education the analysis can be extended to issues raised by public subsidisation of education in general and to the correct amount and composition of the subsidy in particular.

However, by making the simplifying assumptions that a) forgone earnings are the only costs of schooling, b) the individual enters the labour force immediately after completing school at age PRES + S, and c) the individual's years of schooling do not influence his/her working life of y years, the obtained estimates can be taken to reflect both the private and the social rates of return to schooling. As indicated above, these assumptions, among others, play a crucial role in deriving the standard human capital earnings function. Indeed, the use of these simplifying assumptions is still today commonly dictated by the limitations set by available micro-level data bases.

Finally it may be noted that since the human capital model treats the costs of forgone earnings as an investment, the estimates of the private rate of return to education can be broadly compared with the rates of return on comparably risky physical investments (as well as with the market interest rate).

But in comparing rates of return to schooling with returns on equally risky physical capital due allowance should be made for the fact that, as pointed out earlier, the estimated returns to formal education may be subject to various biases.[27] Therefore, estimates slightly exceeding or deceeding this comparison standard are generally to be regarded as being of a plausible order of magnitude and thus to corroborate the model. If, on the other hand, the estimated rates turn out to be much lower than the returns on physical capital, there is likely to be a tendency of overinvestment in education. This may be due in part to consumption aspects and in part to screening effects involved in the individuals' educational decisions.

III. THE SEGMENTED HUMAN CAPITAL EARNINGS FUNCTION

As pointed out earlier, one of the key assumptions underlying the Mincer human capital earnings function is the employees' acquisition of solely general human capital. And since any general capital will by definition raise the potential productivity of workers to the same extent in all firms, including the firm providing it, the acquired skills will be fully transferable across jobs. In a labour market characterized by perfect competition, the workers will, as a consequence, both pay the costs and reap the returns from the investment. A further implication is that there is no reason for the workers to change their investment behaviour when moving to another job.

Opposite to this, specific human capital raises the worker's potential productivity only within the firm providing the training. Hence, in contrast to the general human capital approach, the individual's decisions on post-school investment and thus his/her life cycle earnings will be influenced also by the conditions within the given firm. This joint dependency of the productivity of specific capital on both the worker and the firm implies that the two agents should agree on sharing costs as well as returns so that each would suffer a loss if the employmentship ended. However, as pointed out by Willis (1986), "Becker was unable to provide a theory of the factors that determine the worker's and the firm's shares...[and thus]...to derive the implications for the life cycle pattern of worker earnings" (p. 594).

Therefore, a widely-used approach within the general human capital framework to assessing empirically the influence on earnings growth of investment in specific capital has been to simply introduce into the standard human capital earnings function the employee's length of employment with the current employer, i.e. his/her seniority (tenure). In other words, the years of experience at the same employer are assumed to reflect the specific human capital acquired by the employee.

However, this simple way of extending the standard human capital earnings function to include also specific capital tells little about the work history of the individual. In particular, Holmlund (1984), among others, underlines that since firm-specific training is by definition non-transferable, it may be expected that the returns to on-the-job training outside the current job are lower than to human investment undertaken at the current job. Discontinuities in the employee's life cycle earnings due to job switches are therefore most likely to occur.

Moreover, it has been suggested that, because of individual optimizing decisions, the amount the individual is willing to invest in (specific) human capital at each job will depend on the expected duration of the job (Borjas, 1981). Specifically, given that the job offers suitable training opportunities, the individual will realize his/her investment plans only when the job is considered to be of some duration. Even older employees could therefore be expected to invest in human capital if they have recently changed jobs. Hence, the individual's investment activities need not necessarily decline monotonically over the life cycle, as assumed in the Mincer earnings function.

Instead, the typical employee's human investment path can be assumed to have a saw-tooth pattern; the individual's accumulation of specific capital declines as the expected remaining time at the job approaches zero, but moves upwards when the individual enters a new job. The amount of the jump is, in turn, most likely related to the expected duration of the new job. However, with increasing age job shifts tend to become less frequent and expected remaining time at the job shorter. Siebert (1990) therefore argues that the investment behaviour of the employee may nonetheless have a declining age profile.

In the following, the standard human capital earnings function is modified to take account of this kind of arguments. Specifically, both specific training and job mobility effects are introduced into the earnings function by incorporating the work history of the individual into the equation. But instead of supposing that the individual's working life comprises a total of j jobs, the earnings function that is to be derived makes a distinction between two segments only: one corresponding to current job experience and the other to all previous labour force experience. The main reason for restricting the model to just two segments is the labour force survey data employed in the empirical analysis; the Finnish labour force survey merely provides information on total years of work experience and years of experience with the current employer.

Following Holmlund (1984), the expression for the individual's earnings capacity in eq. (6) above may now be written

$$(14) \quad HC(EXP) = HC(S)\exp\left[r_c\int_0^{SEN} I_c(t)\,dt + r_p\int_0^{PREEXP} I_p(t)\,dt\right]$$

where I_c and I_p reflect the fractions of the employee's earnings capacity invested in human capital in the current job (SEN) and prior to the current job (PREEXP = EXP - SEN), respectively. The rates of return corresponding to these investment ratios are given by r_c and r_p.

Eq. (14) thus offers a possibility to determine to what extent the individual's earnings capacity depends on the amount of and the returns to human capital accumulated within the current job, on the one hand, and prior to the current job, on the other. As before, it is assumed that there is a tendency of the initial amount of post-school investment, I(0), to decline linearly over time. This assumption is thought to hold not only over the life cycle but also within jobs. Specifically,

$$(15)\quad I_p = I_p(0) - \frac{I_p(0)}{y} PREEXP = I_p(0) - \delta_p PREEXP$$

$$(16)\quad I_c = I_c(0) - \frac{I_c(0)}{y} SEN = I_c(0) - \delta_c SEN$$

where the initial post-school investment ratio at the current job, $I_c(0)$, is seen to be a decreasing function of work experience acquired prior to this job, i.e.

$$(17)\quad I_c(0) = \sigma - \phi PREEXP$$

The definition of $I_c(0)$ in terms of previous work experience implies an investment behaviour consistent with optimal human capital models. In particular, eq. (17) indicates that for persons with a continuous labour market participation, initial human investment ratios are lower for jobs started at higher ages. Moreover, by using the definition in eq. (17) no assumptions are needed about the actual investment opportunities associated with each job. If investment opportunities vary across jobs, the employee can still obtain the desired initial investment ratio by simply choosing that job which offers the most suitable training characteristics.

Inserting eqs. (15)-(17) into eq. (14) gives

$$(18)\quad HC(EXP) = HC(S)\exp\Big[r_c\int_0^{SEN}(\sigma - \phi PREEXP - \delta_c t)\,dt + r_p\int_0^{PREEXP}(I_p(0) - \delta_p t)\,dt\Big]$$

which after integration takes the form

$$(19)\quad HC(EXP) = HC(S)\exp\Big[r_c\sigma SEN - r_c\phi PREEXP\cdot SEN - \frac{r_c\delta_c}{2}SEN^2 + r_pI_p(0)\,PREEXP - \frac{r_p\delta_p}{2}PREEXP^2\Big]$$

The employee's actual earnings are obtained after subtracting the costs of post-school investments at the current job, i.e.

$$(20)\quad EARN(EXP) = (1 - I_c)\,HC(EXP)$$

Inserting eqs. (3) and (19) into eq. (20) and taking natural logarithms yields

$$(21)\quad \ln EARN(EXP) = \ln(1 - I_c) + \ln HC(0) + rS + r_c\sigma SEN - \frac{r_c\delta_c}{2}SEN^2 + r_pI_p(0)\,PREEXP - \frac{r_p\delta_p}{2}PREEXP^2 - r_c\phi\,PREEXP\cdot SEN$$

When further using a second-order Taylor expansion to approximate $\ln(1 - I_c)$[28], we arrive at

$$(22)\quad \ln EARN = \ln HC(0) + rS - \sigma - \frac{\sigma^2}{2} + (r_c\sigma + \delta_c + \sigma\delta_c)\,SEN - \frac{(r_c\delta_c + \delta_c^2)}{2}SEN^2 + (r_pI_p(0) + \phi + \sigma\phi)\,PREEXP - \frac{(r_p\delta_p + \phi^2)}{2}PREEXP^2 - (r_c\phi + \phi\delta_c)\,PREEXP\cdot SEN$$

It is evident from eq. (22) that estimates of this segmented human capital earnings function will not allow the rates of return and investment ratios with respect to the individual's work history to be readily identifiable. Some interesting tests may nevertheless be undertaken. Thus, in deriving eq. (22) it was assumed, inter alia, that the initial investment ratio at the current job is a decreasing function of experience acquired on previous jobs. If such a relationship does not exist, i.e. $\Phi = 0$, then the coefficient of the interaction term, PREEXP·SEN, will not be significantly different from zero.

Holmlund (1984) also points to the possibility of testing whether the rate of return to human investment on the current job really exceeds the rate of return received in previous jobs. However, in order to test this hypothesis it has to be further assumed that job mobility does not influence the individual's investment behaviour. In other words, we are forced to reintroduce the simplifying assumption of eq. (7) used in deriving the standard human capital earnings function.[29] In that case, eq. (22) is modified to the form

$$(23)\quad \ln EARN(EXP) = \ln HC(0) + rS - I(0) - \frac{I(0)^2}{2} + (r_c I(0) + \delta + I(0)\delta)\,SEN - \frac{(r_c\delta + \delta^2)}{2}SEN^2 + (r_p I(0) + \delta + I(0)\delta)\,PREEXP - \frac{(r_p\delta + \delta^2)}{2}PREEXP^2 - (r_c\delta + \delta^2)\,PREEXP\cdot SEN$$

From eq. (23) it is obvious that the hypothesis $r_c > r_p$ is verified if the coefficient on seniority exceeds the coefficient on previous work experience and if the absolute value of the coefficient on seniority squared exceeds the absolute value of the coefficient on previous experience squared.

Thus, in analysing earnings and earnings differentials not only total labour force experience but also seniority and, when possible, the number of job moves should be incorporated in the regression function. From the above it is apparent that the omission of specific human investments may bias the estimates of the return to general post-school investment. The direction of this bias may, however, differ between young and old workers (Siebert, 1990). In particular, for old workers longer seniority is likely to imply more accumulated human capital and higher earnings for given levels of experience compared with old-age job movers. This would result in an overestimation of the return to experience for old workers. Among young workers, on the other hand, the more able tend to shift jobs more frequently (job shopping) than their less able counterparts. Given such ability effects, the return to experience would be downward biased.

Given that some kind of information on job moves is available, the effect of labour turnover can be captured by simply adding a job mobility variable to eq. (23). In the two segment case, for example, the occurrence of labour mobility could be approximated by means of a dummy variable taking a value of one if the total years in the labour market exceed the years with the present employer (EXP > SEN), and a value of zero otherwise.

A strong, positive effect of job seniority accumulation on earnings growth has been reported in empirical studies by, among others, Bartel & Borjas (1981), Borjas (1981), Mincer & Jovanovic (1981), Mincer (1986,1988,1989), and Mincer & Higuchi (1988). Moreover, these empirical results are seen to clearly support the human capital interpretation of longer length of employment at the same employer or firm as resulting in more accumulated specific skills and thus in higher productivity and earnings.

There are, however, also more recent, competing theories of compensation and productivity offering alternative explanations for the strong, positive link between job seniority and earnings growth observed in empirical analyses based on survey data. A common feature of these theories is that companies use a strong seniority-earnings profile to affect the behaviour of workers.[30] But it has also been argued that the estimated effect of seniority on earnings and labour turnover is the result of inconsistent estimates produced by unobserved heterogeneity across individuals and job matches. More precisely, since job duration is a strong negative function of past quits and layoffs, longer tenure is likely to be positively correlated with characteristics of individuals and jobs which explain fewer quits and layoffs. These same characteristics are taken to be positively associated with employee productivity and thus with earnings.

Hence, long spells of job seniority and high earnings levels may be associated with one another even if earnings do not increase with time employed at the same employer; higher productivity and earnings are simply the result of a good job match.[31] In that case, omission of individual and job heterogeneity in the empirical estimation of earnings functions will produce a disturbance term which partly reflects job-match quality and therefore is positively correlated with seniority. The estimated earnings effect of seniority will, as a consequence, be positive but upward-biased.

Recently, several studies have been concerned with consistent estimation of the effect of seniority (tenure) on earnings in the presence of job matching. Topel (1986), Abraham & Farber (1987), Altonji & Shakotko (1987), Marshall & Zarkin (1987), Mortensen (1988), and Ruhm (1990), among others, all find a strong inverse relationship between earnings and turnover rates and, consequently, a small earnings effect of job seniority. In other words, most of the acquired skills are interpreted as general and thus fully transferable across jobs, implying small turnover and unemployment costs for employees. If this evidence is correct, it will without doubt have far-reaching implications for the theoretical work in the employment relationship literature as well as for labour market policies.

But recent empirical studies, even when based on the same data set, also provide strong evidence in support of the hypothesis that specific capital accumulation is an important ingredient of employment relationships. In particular, the findings of Garen (1989) imply correlation between seniority and the disturbance term consistent with the job-matching model. But contrary to the job-match hypothesis, the estimates obtained by Garen indicate that the earnings effect of seniority is understated if the heterogeneity bias problem is overlooked in the estimations. Garen consistently concludes that the observed inverse correlation between the residual and seniority is evidently not explained by the matching model. Instead, the results are seen to be more supportive of models suggested by Lazear (1986) and Topel (1986).

A substantial earnings effect of seniority not explained by either heterogeneity across individuals or across jobs is also reported by Topel (1991). He argues that by disregarding job quality, the estimated effects of seniority will be understated and not overstated as commonly assumed in the basic theory of job search and matching. According to Topel "the overestimation argument ignores the fact that persons who change jobs gain, on average, from their move, and they are included in the data at low job tenures" (p. 151). These largely diverging findings on the effects of specific capital imply that the importance of productivity versus other factors in explaining earnings growth will remain at issue.

Footnotes:

1. In a somewhat different vein is the study by Habrison & Meyers (1964), which initiated cross-country comparisons of education and economic well-being, and Krueger (1968).

2. The term "human capital" has come to refer to the knowledge, skills, and other physical and mental capabilities contributing to productivity that individuals have acquired by investing in education, training, health, and so on. Specifically, human resource development involves investment principally in education and training, with secondary contributions from health and labour mobility.

3. Following Miyagiwa (1989), the educational process can, in effect, be represented by a production function where the total output of skills emerges from the input of the number of students and the units of educational input. Cf. also Aulin-Ahmavaara (1987,1989,1990) who has developed a complete dynamic input-output model, which along with the production of goods and services also includes the production of human capital and of different kinds of labour.

4. The notion of general and specific skills was introduced by Becker (1962,1964). General skills were thought to be acquired in school and could be transferred from one job to another; i.e. were useful to several firms or in several industrial sectors. Specific skills, on the other hand, were developed on the job through on-the-job training and lost when the employee moved. To this may, however, be added that Eliasson (1988), for example, underlines that Becker's distinction is not consistent with the prevailing situation in modern highly specialized industrial societies. Today, the formal educational system teaches a variety of skills with extremely limited applications, whereas work life is full of specialized skills acquired on the job that can be transferred to many jobs.

5. For a brief survey of the screening and sorting theories, see e.g. Asplund (1991) and the literature referred to.

6. The chapter is based mainly on the surveys of the standard human capital earnings function in Holmlund (1984), Willis (1986), and Siebert (1990).

7. In the Ben-Porath (1967) model of optimal human capital accumulation, the individual is assumed to allocate his or her time between work and education/training so as to maximize the present value of lifetime income. But the model has also been generalized to include leisure as a third activity to which time can be allocated, whereby utility rather than income is

maximized (Heckman, 1976). Siebert (1990), though, argues that the two models do not, in the last resort, yield very different conclusions. For a comprehensive survey of optimal human capital investment models, see e.g. Weiss (1986).

8. It may be noted that Mincer (1974) estimated and reported results also for two other specifications of the earnings function, viz.

$$(1') \quad \ln EARN_i = \alpha_0 + \alpha_2 S_i + \varepsilon_i \qquad (\text{"the schooling model"})$$

$$(1'') \quad \ln EARN_i = \alpha_0 + \alpha_1 S_i + \alpha_2 S_i^2 + \alpha_3 EXP_i + \alpha_4 EXP_i^2 + \alpha_5 S_i \cdot EXP_i + \varepsilon_i$$

9. For criticisms of the assumptions underlying the human capital theory, see e.g. Blaug (1976).

10. The concept of efficiency units of labour is widely used in the growth accounting framework. See e.g. Asplund (1991).

11. See footnote 4 above.

12. It is, however, worth pointing out that parallel log-earnings-experience profiles are a necessary but not a sufficient condition for there to be no relationship between education and post-school investments. Hence, the fact that the profiles of log earnings with respect to experience, when drawn from real-world data for different schooling groups, often turn out to be approximately parallel does not imply per se that the coefficient on schooling is an unbiased estimator of the rate of return to education (cf. Psacharopoulos & Layard, 1979).
In this context it may further be noted that for the sake that the assumption of all individuals having the same human capital investment profile would not hold, Mincer (1974) offered an alternative approach to estimating the return to education, viz. the so-called "short-cut" approximate method. In brief, the method involves the use of the conventionally-calculated rate of return to education in order to identify for each schooling group the so-called overtaking level of experience, i.e. the year when actual earnings equal potential earnings had no (employee-financed) training investment been undertaken. The average log earnings corresponding to the overtaking experience level are estimated, and the rate of return to each level of schooling is evaluated by simply comparing the earnings levels for consecutive schooling groups. The problem, however, is that the overtaking experience year for each schooling group cannot

be computed unless also the rate of return to training investments is known. It is, therefore, assumed that the rate of return to training is the same as that to schooling. If this is not so, then the method is clearly incorrect. This is also the reason why Psacharopoulos & Layard (1979) argue that Mincer's short-cut method should be discarded.

13. Willis (1986) further argues that much of the difficulty that arise when trying to interpret the Mincer earnings function within the wealth maximization context can, in effect, be traced to one of the key assumptions underlying the model, i.e. that of homogeneous human capital. He therefore reinterprets the earnings function in terms of heterogeneous human capital, whereby the Mincer-type earnings function emerges as a special case. Drawing on the work of Willis, de Beyer & Knight (1989) derive and test a theory of occupation-specific productivity and earnings which is seen to be consistent with the competitive framework of the human capital theory. Empirical evidence on the importance of occupational status in explaining earnings dispersion in Finland are reported in Asplund (1992).

14. According to Leibowitz (1974,1977), the individual's initial human capital can be seen to be determined by genetic factors and mother's care.

15. In measuring schooling in years it is implicitly assumed that each year is homogeneous. Not only are interpersonal ability differences omitted, as will be discussed below. All variation in schooling quality is ignored as well. Yet, empirical evidence indicates a positive correlation between education quality and earnings resulting from the fact that those with more years of schooling also tend to have high-quality years. Hence, ignoring the quality aspect will result in an overstatement of the estimated average rate of return to an additional year of education. But apparently individuals also tend to compensate less satisfactory quality of their schooling with a larger quantity of schooling, which will weaken the observed positive correlation between the quantity and quality of schooling. Indeed, this is seen to be one of the reasons why, in practice, omitting schooling quality from the estimated earnings function has been found to have a negligible effect on the estimated rate of return to schooling. See further e.g. Siebert (1990).
Rivera-Batiz (1990), however, argues that since persons with an equal number of years of education may have widely diverging skills due, for example, to differences in schooling quality, some kind of measure of the individuals' literacy skills should be incorporated in the regression in addition to the years of schooling variable. He therefore supplements the earnings function with a literacy skills variable constructed from test-based reading proficiency scores. The coefficient on the literacy skills variable is found to clearly indicate that, given the level of education, an improvement in literacy skills would have a notable effect on earnings not least for persons on

lower readings levels. This inclines Rivera-Batiz to conclude that education and reading proficiency are correlated but no perfect proxies for each other. But on the other hand, the statistical significance of his skills variable may be largely due to the investigated sample, which comprises solely adults in their early twenties.

16. For ease of exposition, the index referring to the earnings, education and work experience of the ith individual considered is suppressed in the subsequent theoretical presentation of human capital earnings functions. Alternatively, the earnings function may be thought of as derived for a "representative" individual.

17. Specifically, the private internal rate of return to one year's education is assumed to be

$$r = \frac{HC(S) - H(S-1)}{HC(S-1)}$$

while the true rate of return is

$$r = \frac{[HC(S) - HC(S-1)](1-m)}{HC(S-1)(1-t) + FC - Y}$$

where m is the marginal income tax rate, t is the average income tax rate, FC is possible private direct costs of education such as tuition fees, and Y is, for instance, scholarship or part-time earnings of students. It is evident that the use of pre-tax or post-tax earnings does not affect the rate of return to education, provided that the tax system is proportional and that there are no fixed costs of schooling to the individual (these are covered by public subsidies and/or paid out of scholarship or part-time earnings). The reason why the rate of return to education will be totally unaffected by the proportional tax system is that the reduction in the opportunity cost of schooling caused by a tax increase will be offset by a simultaneous reduction in the benefits from schooling. Cf. Psacharopoulos & Layard (1979) and Willis (1986).
In sum, for the coefficient on the schooling variable to be an unbiased estimator of the average private rate of return to a year's education three assumptions would have to be fulfilled: (1) the individual faces no private direct costs of schooling, (2) there is no relationship between education and work experience, and (3) the age-experience profiles are flat. Cf. Psacharopoulos (1982).

18. Mincer (1974) also suggested other possible assumptions about the time path of employees' investments in human capital after leaving school. However, the alternative functional forms of the earnings function corresponding to these assumptions have

not been found to be preferable to the quadratic function of the standard human capital earnings function. But irrespective of the pace at which the employee's human investments are supposed to decline, the wealth maximization hypothesis clearly suggests that the use of work time on human capital accumulation towards the end of working life cannot be regarded as an investment but is rather showing that the employee enjoys studing, i.e. treats education as a consumption good.

19. Following Mincer (1974), the expression for the individual's actual earnings in eq. (10) may alternatively be approximated by

$$(10') \quad EARN(EXP) = HC(EXP)\,[1 - I(EXP)] \approx HC(EXP)\,\exp[-I(EXP)]$$

which yields a somewhat simpler expression than that in eq. (13), viz.

$$(13') \quad \ln EARN(EXP) = \ln HC(0) + rS - I(0) + \left[rI(0) + \delta + \frac{r\delta}{2}\right]EXP - \frac{r\delta}{2}EXP^2$$

The fundamental idea is nevertheless maintained: in both cases, the coefficients are estimated by regressing log earnings on years of schooling, experience and experience squared.

20. Siebert (1990) makes a rough estimation of the rate of return to post-school investment, r_e, by using the expression for the coefficient on EXP in eq. (13') in footnote 19. He assumes that I(0) is approximately 50 per cent (the overtaking year approximation suggested by Mincer) and that $\delta = -0.013$ (I(0) is thereby assumed to be close to zero after 40 years in working life). The estimated coefficient on EXP is given the value 0.1, which he finds to be a reasonable average of estimates obtained in various studies. From these assumptions, Siebert calculates r_e to be about 0.23 on average, which is considerably higher than the estimated rate of return to education. To this may be added that the corresponding, slightly different expression for EXP in eq. (13) in the text yields a value of r_e of 0.24.

21. The self-selection problem will, of course, be present in any situation where the full opportunity set of each economic agent is not observed and opportunities are known to vary across agents. However, it has also been suggested that some individuals can be thought of as possessing "mechanical ability" as opposed to the "academic ability" possessed by other individuals. This mechanical ability is seen to partly explain why some individuals finish their formal education early. Their earnings will, as a consequence, overstate the earnings forgone by those who continue their studies. The implication is that the estimated rate of return to schooling will be downward biased thereby counteracting the upward bias following from the

omission of ability differences. Siebert (1990) notes, though, that "this is probably rather a minor point" (p. 11).

22. It may, nevertheless, be of interest to note that empirical schooling functions for the UK and US imply that parental schooling has the strongest effect on children's schooling decisions. The strong family background effect observed for the UK and US in combination with the considerable contribution of schooling to earnings differences has resulted in much concern about so-called intergenerational transmission of inequality. See e.g. Siebert (1990) and the literature referred to.
Simple correlation tests based on Finnish Population Census data for 1985 suggest that the relation between parental and children's schooling is notable also in Finland (Kivinen & Rinne, 1991). But so far, no empirical evidence on the order of magnitude of this relationship compared with other influencing factors has been reported. Preliminary results for Sweden (Björklund, 1992) based on Level of Living Survey data suggest that there is weak support for the comparative advantage hypothesis, that is, a higher marginal rate of return to education for individuals with high-schooling family background. But the estimation results also provide support for the financing hypothesis, i.e. a slightly lower marginal rate for those with a highly educated father.

23. In a recent study of education and earnings in the Netherlands, Oosterbeek (1990) estimates not only a standard earnings model in which the educational variables are exogenous but also two other models which treat education as an endogenously determined variable, that is, take account of the fact that individuals do choose their optimal amount of education.

24. For more details on measured effects of ability, see e.g. the survey in Siebert (1990).

25. Lucas (1977), for instance, has estimated the understatement due to equalizing differences, i.e. to not allowing for non-pecuniary effects, to amount to some 15-30 per cent of the measured rate of return to schooling. A further consequence of performing the analysis in pecuniary terms may also be noted in this context, although its relevance is disregarded in the investment-based human capital approach. Suppose that education is regarded not only as an investment but is also seen to comprise consumption aspects. In that case, pecuniary costs will overstate true investment costs. Similarly, if higher education also brings "status", pecuniary returns will most likely understate true returns to schooling investment. It is argued that the combined effect of these two aspects tends to push the measured rate of return below the true rate. (Cf. e.g. Siebert, 1990.)

26. Cf. footnote 17 above.

27. In making this comparison, it should be remembered that the estimated rate of return to education is an average rate. If the dispersion in rates of return to education can be assumed to be wide, then the estimated average rate of return may not give a correct picture. Apart from individual preferences and available funds, also occupational licensing restrictions will contribute to this dispersion. Hence, as pointed out by Siebert (1990), by analysing the dispersion of returns also the fundamental assumption of competitive labour markets underlying the human capital theory may be evaluated. Available empirical results do not, however, seem to reject the use of the theory.

28. The second-order Taylor expansion is of the form

$$(12') \quad \ln(1 - I_c) \approx -I_c - \frac{I_c^2}{2} = -\sigma - \frac{\sigma^2}{2} + (\phi + \sigma\phi)\,PREEXP - \frac{\phi^2}{2}PREEXP^2 + (\delta_c + \sigma\delta_c)\,SEN - \frac{\delta_c^2}{2}SEN^2 - \phi\delta_c\,PREEXP \cdot SEN$$

after inserting eqs. (16) and (17) given in the text.

29. Specifically, eqs. (15) and (16) now take the form

$$(15') \quad I_p = I(0) - \delta PREEXP$$

$$(16') \quad I_c = I(0) - \delta PREEXP - \delta SEN$$

i.e. it is assumed that $\sigma = I_p(0) = I(0)$ and that $\Phi = \delta_c = \delta_p = \delta$.

30. See the survey in e.g. Parson (1986) for a review of the theory of specific human capital as well as of competing theories explaining within-firm earnings growth without appealing to contemporaneous productivity growth, such as the agency and other contracting models and adverse selection models.

31. The formal development of the model of job matching under imperfect information goes back to Jovanovic (1979).

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