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Estimating the return to investments in education: how useful is the standard Mincer equation?

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Abstract

We examine how well the schooling coefficient in standard Mincer equations, estimated on Swedish data for 1968, 1981 and 1991, approximates the marginal internal rate of return to education. We find three cases where inference from the estimated schooling coefficient is misleading. First, the decline in return to schooling from 1968 to 1981 is mainly concentrated to college education, whereas the return to high school education is stable. Second, the rate of return is sensitive to the assumption made about the length of working life, or the retirement decision. Third, both the schooling coefficient and the internal rate of return give misleading information about the value of adult education. By comparing the present value of lifetime earnings between youth and adult education, we find large differences in favor of youth education, even though the schooling coefficient and the internal rate of return are the same.

JEL classification: I21

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1. Introduction

The *Mincer equation*, which relates the logarithm of hourly earnings to years of schooling, years of work experience and years of work experience squared, is one of the most commonly estimated relationships in labor economics. In many studies, economists have also used this equation as the baseline when they have examined other earnings determinants such as working conditions, union membership and sector of employment. When such an approach is used, one can say — as Sherwin Rosen (1992) did in his article in the *Journal of Economic Perspectives* that celebrated the work of Jacob Mincer — that the data were *Mincered*.

There are several reasons for its popularity. The most important one is probably the pragmatic use of results from human-capital theory to derive an estimating earnings equation. Obviously, the goal for labor economists should not only be to estimate the causal effect of schooling on wages, or the *wage premium* for schooling. It is also important to translate the causal wage effect of schooling into a measure of the return on investment in schooling that can be compared with similar measures of the return on other investments in, for example, physical capital. The internal rate of return is one such measure, but the wage premium is not. Thus, another reason for the popularity of the Mincer equation is that the schooling coefficient is closely related to the marginal (and in the linear case, also the average) internal rate of return to education.

In the literature it is often taken for granted that the schooling coefficient can be interpreted as the return to the investment in schooling. However, this interpretation of the coefficient relies on a number of assumptions, all

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of which are seldom discussed in empirical studies. The aim of this study is to investigate how well the schooling coefficients of standard Mincer equations (for Sweden) approximate the rate of return to education. That means that we examine (some of) the assumptions that establish equality between the coefficient and the internal rate of return. We continue in Section 2 by stating these assumptions and presenting the approach of our inquiry. The data used are described in Section 3. Our analysis and results are in Sections 4 and 5. We conclude in Section 6 by discussing and summarizing the findings.

2. The Mincer equation and the internal rate of return to schooling

Willis (1986) shows a general result about the relationship between a statistical earnings function and the marginal internal rate of return to education. Let the earnings function be

$$y=f(s, x), \tag{1}$$

where y denotes earnings, s years of schooling and x years of work experience. The function describes the earnings path across the working life of people with different schooling levels. Under a set of assumptions the marginal internal rate of return to additional schooling equals the derivative of log earnings with respect to years of schooling, or

$$\partial \ln y/\partial s. \tag{2}$$

The assumptions are as follows.

Assumption 1. *The earnings measure captures the full benefits of the investment*. If the purpose is to estimate the social rate of return, this assumption rules out any externalities of education. And if the purpose is to estimate the private rate of return, earnings should be measured net of taxes and transfers, and include non-pecuniary advantages of jobs requiring education.

Further, one must assume that the statistical earnings function measures the causal effect of schooling, i.e., the well-known problem of selection bias must be solved. The basic message in the survey papers on education in the old and the new *Handbook of Labor Economics* (Willis, 1986; Card, 1999) is that cross-sectional earnings functions are quite reliable, so this might be a reasonable assumption to make.[1]

[1] Card (1999, p. 1802) concludes "that the average (or average marginal) return to education is not much below the estimate that emerges from a standard human capital earnings function fit by OLS. Evidence from the latest studies of identical twins suggests a small upward 'ability' bias — on the order of 10%".

Assumption 2. *The only costs of schooling are foregone earnings*. To estimate the social return to schooling, it would be necessary to account for the direct costs for teaching. And in a study of the private returns, the net of students' directs costs of schooling and their financial support would have to be included in a complete analysis.

Assumption 3. *The earnings function is separable in s and x so that $\partial \ln y/\partial s$ is independent of years of work experience*. Obviously, the standard Mincer equation fulfils this assumption, because it contains no interaction between schooling and work experience. Note also that a quadratic in schooling makes the marginal internal rate different from the average rate, but does not change the basic interpretation of the derivative with respect to schooling.

It is important to understand why the standard Mincer equation has this separability property. The equation is derived from an assumption about the accumulation of human capital over the lifetime. The investment behavior is described by means of the investment ratio, or the fraction of earnings capacity that is used for financing the costs of human-capital accumulation. The ratio equals one during the initial period of schooling and declines linearly during working life to reach zero at the time of retirement. The working life is assumed to be fixed, so the derivation of the equation is also based on *A4* (see below). Further, the investment ratio during working life, which determines the accumulation of on-the-job training, is independent of the level of schooling. It is this assumption that generates the separability between schooling and work experience in the earnings equation. But it is possible to use Mincer's approach to derive alternative earnings equations that do not require that the investment ratio is independent of schooling. We also examine such equations.

Assumption 4. *The length of working life is the same independent of the length of schooling*. This means that every additional year of schooling postpones retirement by one year. So, if a person who leaves school at age 19 to start work retires at age 65, we must assume that a person who leaves school at age 20 retires at age 66.

Assumption 5. *Schooling precedes work*. Willis' proof that Eq. (2) equals the internal marginal rate of return is based on the standard case that the individual starts life by going to school and then works a fixed number of years until retirement. In practice, quite a few adults undertake education after having been out in the labor market for several years.

Intuitively, it seems reasonable that — for a given wage premium — the payoff to schooling is higher, the earlier it is undertaken. But the mathematics of the internal rate of return implies that the internal rate of return to schooling that is undertaken at the age of 50 is the same as the one that is undertaken at the age of 20, as long as *A3* and *A4* are fulfilled. But the present value of an investment that is done at a younger age is higher, again assuming that the wage premium is the same. Our interpretation of this fact is that the internal rate of return is an inappropriate measure to compare the return to education at different ages. So we compare the return from adult and youth education by using the present value criterion.

Assumption 6. *The economy is in a steady state without any wage and productivity growth*. In general, it is more realistic to account for some overall wage and productivity growth. If the purpose is to estimate the expected (ex ante) returns to schooling, the earnings function is supposed to represent the expected earnings paths conditional upon alternative schooling choices.[2]

Many economists might find assumptions *A1* to *A6* as reasonable approximations to reality, even though it is unlikely that they are exactly fulfilled in the real world. It is also likely that the assumptions are more realistic for some specific purposes (and for some countries) than for others. Our purpose is to examine the impact of relaxing some of these assumptions. We emphasize *A3* to *A6*, which we think have been neglected in previous research. We ignore *A1*, i.e., we assume that the schooling coefficient in a before-tax hourly earnings function captures the full benefits of schooling.[3] We also ignore *A2*. This means that we address the following question: How well does the standard Mincer equation approximate the social return to schooling, if direct schooling costs are small? As explained above, our neglect of the selection bias issue should not be considered a severe limitation. Those who think so should keep in mind that our analysis is useful for all who use a "selection-bias controlled" equation relating the logarithm of earnings to years of schooling and work experience to the log of earnings in order to infer the marginal internal rate of return to schooling.

We start by focusing on the most appropriate functional form, i.e., *A3*. This analysis gives us a preferred functional form. We then examine how sensitive the results are to assumption *A4* and continue by examining the consequence of postponing schooling, i.e., *A5*. Finally, we discuss the implications of *A6*. But first we present the data set.

3. The data

We use the Swedish Level of Living Surveys from 1968, 1981 and 1991.[4] This data set is the most commonly used one in previous studies of the return to education in Sweden; see, e.g., Björklund and Kjellström (1994), Edin and Holmlund (1995) and Palme and Wright (1998). A consistent finding in the previous studies is that the schooling coefficient declined markedly from 1968 to 1981 and was quite stable from 1981 until 1991. A natural task for us is to examine whether the internal rate of return to schooling follows the same pattern, even when the assumptions that the use of the Mincer equation are based on are relaxed.

The Level of Living Survey is representative for the Swedish population (ages 15 to 75, except in 1991 when the lower age limit was age 18). The data set has the panel design, but we do not use this property in this study. We impose some restrictions on the samples that we use for estimations. We use the 16–65 age interval in 1968 and 1981 and the 18–65 age interval in 1991. In 1968 and 1981, quite a large number of youths left school and entered the labor market at the age of 16, whereas in 1991, the normal length of schooling had been extended to age 18. Further, we only use observations on employed persons, the reason being that we do not have accurate measures of the hourly earnings for self-employed persons. Another major restriction is that we only include men in our study. One reason for this choice is that the labor market behavior of women, over the period for which we have data, does not correspond to the assumptions that the Mincer equation is based on: many women made interruptions in their work careers and often worked part-time. So it is rather natural that conclusions on the internal rate of return of education for women from a simple Mincer equation are misleading. Finally, we only include persons who reported that they lived in Sweden when they grew up.

The survey asks direct questions about earnings, years of schooling and work experience and we use these variables. Table 1 contains the means and standard deviations of these variables. The table shows the well-known decline of wage dispersion in Sweden during the 1970s; from 1968 to 1981, the standard deviation of the log of hourly earnings declined from 0.447 to 0.308. Further, the level of schooling increased by three years from 1968 to 1991, whereas years of work experience declined by almost two years.

[2] The distinction between returns to schooling ex ante and ex post is seldom made in the literature.

[3] On Swedish data, Björklund and Kjellström (1994) and Edin and Holmlund (1995) compute private returns to schooling and account for taxes and financial student support.

[4] Erikson and Åberg (1987) present the first three waves, and Fritzell and Lundberg (1994) the 1991 wave.

Table 1
Means and standard deviations (within parentheses) of variables used

	1968	1981	1991
Log of hourly earnings	2.41 (0.447)	3.67 (0.308)	4.45 (0.310)
Years of schooling	8.69 (2.91)	10.74 (3.52)	11.64 (3.20)
–6	0.20 (0.40)	0.07 (0.25)	0.01 (0.11)
7	0.28 (0.45)	0.15 (0.36)	0.08 (0.27)
8	0.13 (0.34)	0.08 (0.28)	0.07 (0.26)
9	0.10 (0.30)	0.12 (0.33)	0.10 (0.30)
10	0.10 (0.29)	0.08 (0.27)	0.07 (0.25)
11	0.05 (0.22)	0.13 (0.34)	0.22 (0.41)
12	0.04 (0.19)	0.10 (0.30)	0.13 (0.33)
13	0.03 (0.17)	0.07 (0.26)	0.09 (0.29)
14	0.02 (0.15)	0.05 (0.22)	0.05 (0.22)
15	0.01 (0.12)	0.03 (0.17)	0.05 (0.21)
16	0.01 (0.12)	0.03 (0.16)	0.04 (0.20)
17	0.01 (0.09)	0.03 (0.17)	0.04 (0.20)
18	0.01 (0.08)	0.02 (0.13)	0.02 (0.14)
19–	0.01 (0.11)	0.03 (0.18)	0.03 (0.17)
Years of work experience	21.86 (14.30)	20.43 (13.80)	19.93 (12.94)
Number of observations	1734	1595	1511

Table 2
The parameters of the standard Mincer equation for 1968, 1981 and 1991

	1968	1981	1991
Constant	1.124 (0.045)[a]	2.865 (0.039)	3.596 (0.038)
Years of schooling	0.087 (0.004)	0.045 (0.003)	0.046 (0.003)
Years of work experience	0.049 (0.002)	0.028 (0.002)	0.026 (0.002)
Years of work experience squared/100	−0.081 (0.005)	−0.040 (0.004)	−0.037 (0.004)
Log-likelihood values	−4782.73	−5956.4	−6793.94
Adjusted *R*-square	0.414	0.301	0.326

[a] White (1980) heteroskedastic-consistent standard errors in parentheses.

Table 2 shows the estimated regression coefficients of the standard Mincer equation for 1968, 1981 and 1991. The most notable message in the table is the decline of the schooling coefficients from 0.087 in 1968 to 0.045 in 1981, and to 0.046 in 1991.[5] The parameters of work experience also changed. The estimated parameters imply that, in all years, wages peaked in the range 30–35 years of work experience. But the parameters for 1968 imply a much faster wage growth during the first years of work experience than the parameters for 1981 and 1991.

[5] We note that using a shorter age interval, 25–55 years old, at most changes any of these coefficients by 0.007. The estimates for the three years are 0.080, 0.042 and 0.047. A shorter age interval could be motivated by endogeneity of schooling and retirement decisions.

4. The functional form

The simple linear Mincer equation can be extended in several directions. One way is to apply a Box–Cox transformation to some of the variables in the equation.[6] In so doing, we obtain a more flexible model without introducing many new parameters to be estimated. The Box–Cox procedure transforms the dependent variable (earnings) and the explanatory variable (schooling) as follows:

$$\frac{y_i^{\lambda_1}-1}{\lambda_1}=\beta_0+\beta_1\frac{s_i^{\lambda_2}-1}{\lambda_2}+\beta_2x_i+\beta_3x_i^2+\varepsilon_i. \quad (3)$$

[6] See Box and Cox (1964), Box and Tidwell (1962), Judge, Griffiths, Hill, Lütkepohl, and Lee (1985), Spitzer (1982) and Zarembka (1968) for alternative presentations.

Table 3
Box–Cox estimations of wage equations for 1968, 1981 and 1991

	1968			1981			1991		
	I	II	III	I	II	III	I	II	III
Constant	1.124 (0.045)[a]	0.889 (0.247)	0.958 (0.075)	2.865 (0.039)	2.013 (0.153)	2.294 (0.121)	3.596 (0.038)	1.781 (0.115)	1.846 (0.121)
Years of schooling	0.087 (0.004)	0.247 (0.098)	0.162 (0.013)	0.045 (0.003)	0.184 (0.098)	0.023 (0.004)	0.046 (0.003)	0.039 (0.025)	0.006 (0.001)
Years of work experience	0.049 (0.002)	0.084 (0.006)	0.084 (0.006)	0.028 (0.002)	0.015 (0.002)	0.015 (0.002)	0.026 (0.002)	0.004 (0.001)	0.004 (0.001)
Years of work experience squared/100	−0.081 (0.005)	−0.135 (0.011)	−0.136 (0.011)	−0.040 (0.004)	−0.021 (0.004)	−0.022 (0.004)	−0.037 (0.004)	−0.005 (0.001)	−0.006 (0.001)
Lamda one	0.0	0.229 (0.027)	0.232 (0.027)	0.0	−0.171 (0.041)	−0.172 (0.041)	0.0	−0.435 (0.048)	−0.434 (0.047)
Lambda two	1.0	0.818 (0.168)	1.0	1.0	0.172 (0.211)	1.0	1.0	0.273 (0.248)	1.0
Log-likelihood value[b]	−4782.7	−4742.3	−4742.8	−5956.4	−5940.4	−5947.9	−6793.9	−6752.0	−6756.0

[a] White (1980) heteroskedastic-consistent standard errors in parentheses.
[b] Accounted for the left-hand side transformation.

Table 4
Estimates of models with dummies for years of schooling

	1968			1981			1991		
	I	II	III	I	II	III	I	II	III
Constant	1.978 (0.097)	1.912 (0.067)	1.618 (0.037)	2.411 (0.145)	2.405 (0.138)	3.077 (0.033)	1.874 (0.130)	1.879 (0.128)	3.833 (0.038)
Years of schooling									
7	0.199 (0.052)	0.221 (0.047)	0.120 (0.026)	0.041 (0.019)	0.033 (0.017)	0.064 (0.024)	0.013 (0.009)	0.009 (0.009)	0.072 (0.033)
8	0.374 (0.073)	0.419 (0.063)	0.222 (0.031)	0.062 (0.024)	0.056 (0.021)	0.113 (0.034)	0.012 (0.010)	0.007 (0.009)	0.059 (0.033)
9	0.529 (0.088)	0.592 (0.075)	0.309 (0.037)	0.096 (0.029)	0.096 (0.024)	0.186 (0.030)	0.023 (0.011)	0.018 (0.010)	0.143 (0.037)
10	0.586 (0.094)	0.663 (0.076)	0.354 (0.033)	0.105 (0.030)	0.107 (0.026)	0.206 (0.029)	0.033 (0.013)	0.028 (0.011)	0.208 (0.040)
11	0.548 (0.109)	0.639 (0.088)	0.345 (0.045)	0.138 (0.034)	0.146 (0.029)	0.278 (0.031)	0.042 (0.014)	0.038 (0.012)	0.272 (0.038)
12	0.748 (0.127)	0.854 (0.105)	0.454 (0.050)	0.154 (0.037)	0.146 (0.029)	0.319 (0.034)	0.042 (0.014)	0.037 (0.012)	0.271 (0.039)
13	1.193 (0.151)	1.314 (0.130)	0.690 (0.050)	0.202 (0.044)	0.218 (0.040)	0.419 (0.037)	0.056 (0.016)	0.051 (0.014)	0.371 (0.041)
14	1.439 (0.172)	1.575 (0.153)	0.819 (0.068)	0.193 (0.045)	0.214 (0.040)	0.413 (0.042)	0.058 (0.017)	0.054 (0.015)	0.389 (0.047)
15	1.504 (0.197)	1.657 (0.153)	0.858 (0.082)	0.228 (0.051)	0.253 (0.047)	0.485 (0.047)	0.068 (0.019)	0.064 (0.017)	0.477 (0.052)
16	2.069 (0.228)	2.234 (0.209)	1.116 (0.074)	0.238 (0.053)	0.268 (0.049)	0.511 (0.045)	0.081 (0.022)	0.078 (0.020)	0.579 (0.055)
17	1.927 (0.245)	2.098 (0.225)	1.079 (0.091)	0.270 (0.057)	0.306 (0.054)	0.587 (0.051)	0.081 (0.022)	0.079 (0.020)	0.575 (0.047)
18	2.020 (0.269)	2.206 (0.246)	1.124 (0.111)	0.231 (0.058)	0.273 (0.052)	0.522 (0.055)	0.074 (0.022)	0.072 (0.019)	0.529 (0.074)
19–	1.783 (0.271)	2.058 (0.208)	1.032 (0.076)	0.266 (0.062)	0.316 (0.055)	0.609 (0.053)	0.073 (0.023)	0.071 (0.019)	0.530 (0.062)
Work experience	0.072 (0.014)	0.089 (0.007)	0.050 (0.003)	0.009 (0.004)	0.015 (0.002)	0.029 (0.002)	0.003 (0.001)	0.004 (0.001)	0.027 (0.002)
Work experience squared/100	−0.110 (0.029)	−0.143 (0.012)	−0.081 (0.005)	−0.007 (0.007)	−0.021 (0.004)	0.040 (0.004)	−0.003 (0.002)	−0.006 (0.001)	−0.037 (0.004)
Schooling×work experience/100	0.195 (0.150)	–	–	0.062 (0.033)	–	–	0.007 (0.009)	–	–
Schooling×work experience squared/1000	−0.040 (0.035)	–	–	−0.015 (0.007)	–	–	−0.002 (0.002)	–	–
Lambda one	0.253 (0.027)	0.253 (0.027)	0.0	−0.172 (0.041)	−0.172 (0.041)	0.0	−0.434 (0.049)	−0.434 (0.048)	0.0
Log-likelihood	−4715.3	−4716.3	−4764.2	−5930.0	−5932.6	−5941.1	−6735.5	−6736.5	−6775.3

Table 5
Estimates of models with Box–Cox transformation of earnings, with and without interactions

	1968		1981		1991	
	I	II	I	II	I	II
Constant	0.980 (0.134)	0.958 (0.075)	2.451 (0.148)	2.294 (0.121)	1.846 (0.124)	1.846 (0.121)
Years of schooling	0.160 (0.016)	0.162 (0.013)	0.017 (0.004)	0.023 (0.004)	0.006 (0.002)	0.006 (0.001)
Years of work experience	0.084 (0.013)	0.084 (0.006)	0.007 (0.004)	0.015 (0.002)	0.004 (0.001)	0.004 (0.001)
Years of work experience squared/100	−0.138 (0.028)	−0.136 (0.011)	−0.006 (0.007)	−0.022 (0.004)	−0.005 (0.002)	−0.006 (0.001)
Schooling×work experience/100	−0.003 (0.141)	–	0.088 (0.036)	–	0.002 (0.009)	–
Schooling×work experience squared/1000	0.005 (0.033)	–	−0.016 (0.008)	–	−0.001 (0.002)	–
Lambda one	0.232 (0.027)	0.232 (0.027)	−0.152 (0.042)	−0.172 (0.041)	−0.434 (0.049)	−0.434 (0.047)
Log-likelihood value	−4742.8	−4742.8	−5943.9	−5947.6	−6755.8	−6756.8

This is a non-linear regression model with the semi-log functional form (the standard Mincer equation) as the special case when λ_1 approaches 0 and λ_2 approaches 1. The transformations not only affect the economic interpretation of the equation, but also the statistical properties of the error term. The parameter λ_1 primarily affects the properties of the error term, and λ_2 primarily affects the functional form. Using the wrong transformation of the dependent variable leads to error terms that are not normally distributed, homoskedastic or symmetric. Heckman and Polachek (1974) used the Box–Cox transformation on US data, but restricted the admissible values of λ_1 and λ_2 to be −1, 0 and +1. They found that the semi-log relationship between earnings and schooling is preferable to other simple transformations.

The added flexibility that follows from the Box–Cox technique may not be sufficient to determine the most appropriate functional form. A second way of extending the standard Mincer model is to use a dummy variable for each year of schooling to capture discrete shifts in the return to schooling; Edin and Holmlund (1995) used such a model on Swedish data. Any deviation from a model with perfectly equalizing differences between jobs requiring education of different lengths would motivate such a pattern. A disadvantage though is that, without many observations, it can be difficult to estimate so many parameters precisely.

Mincer himself gave a third motivation for a more extended model (see Mincer, 1974), as he also derived alternative equations from other assumptions about the evolution of the investment ratio over time. For example, allowing the investment ratio during working life to depend on the level of schooling yields the following equation (see also Kjellström, 1999, essay 1):

$$\ln y_i = \beta_0 + \beta_1 s_i + \beta_2 x_i + \beta_3 x_i^2 + \beta_4 s_i x_i + \beta_5 s_i x_i^2 + \varepsilon_i. \quad (4)$$

Obviously this equation has interaction terms, so *A3* is not fulfilled.

Because our purpose is to examine how deviations from the standard Mincer model affect the interpretation of the schooling coefficient, we decided to follow two regression strategies and illustrate their consequences for estimated internal rates of return. The first regression strategy is to use the advantage of the Box–Cox transformation to save parameters, and abstain from using dummies for years of schooling. We also abstain from interactions between schooling and experience since the Box–Cox transformation already implies such interactions. The second strategy is to start with a general model, which uses dummies for years of schooling, interactions between schooling and experience, and also transforms the earnings variable by means of the Box–Cox transformation.[7] We then test whether simplifying assumptions can be rejected or not.

Table 3 presents maximum likelihood estimates of Eq. (3), i.e., results from the first regression strategy.[8] The estimates of λ_1 and λ_2 are not consistent with the semi-log functional form. Furthermore, the levels of λ_1 and λ_2 have changed over time. For example, λ_1 has decreased from 0.229 in 1968 to −0.435 in 1991. The estimates of λ_2 are 0.818 and 0.273. Especially for the years 1981 and 1991, it also appears that the specification that transforms both earnings and schooling performs better in the log-likelihood sense than the specification restricted to transformed earnings.

Next, we turn to the second regression strategy and the general (including interactions) version of the model

[7] We note that Card (1999, p. 1804) also recommends two such regression strategies.

[8] We use the Limdep program for estimation.

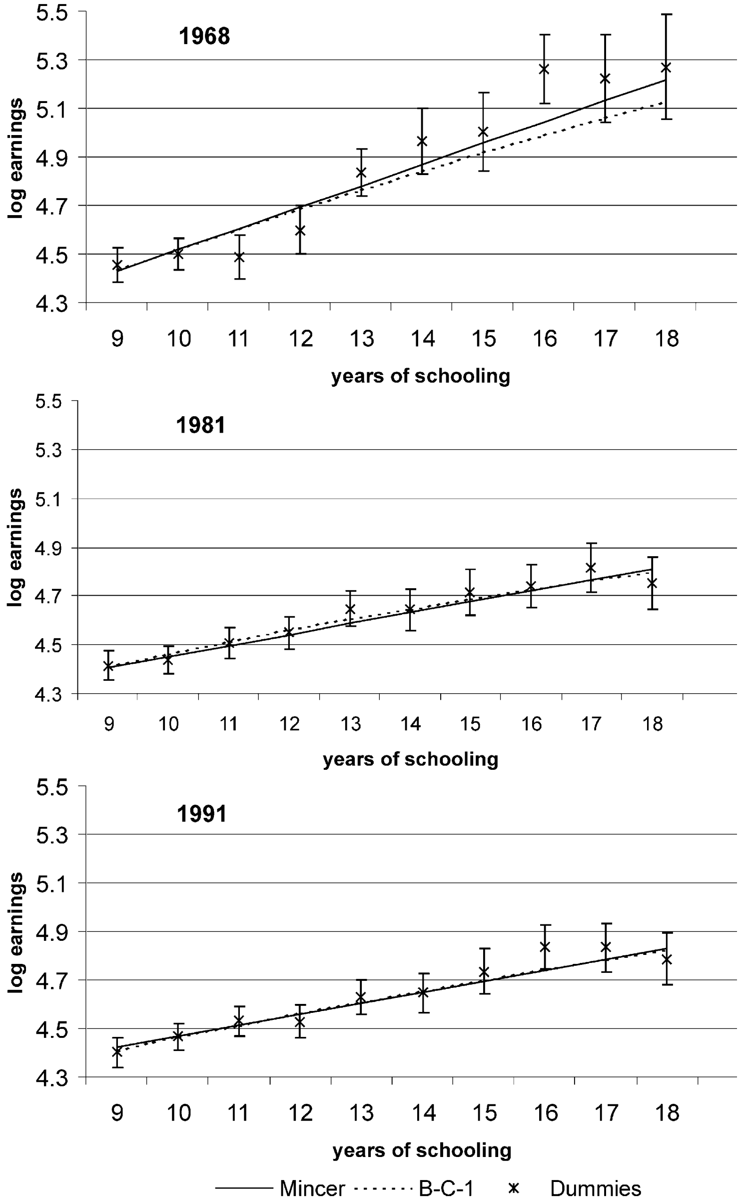

Fig. 1. Log expected earnings using the Mincer equation, the semi-log model with dummies for schooling (with 95% confidence intervals), and the Box–Cox transformation evaluated at 20 years of work experience. Note: we use models I and II in Table 3 and model III in Table 4. We use the CPI to recalculate 1968 and 1981 to 1991 prices.

with dummies for each year of schooling. In Table 4 we present the estimates of this model in columns I, and we add the estimates of the model that imposes zero interactions in columns II of the same table. In column III we present the estimates from use of the semi-log model with dummies for years of schooling. The results reveal (using the likelihood-ratio test) that the model without interactions cannot be rejected, except at the 10% level for 1981. The Box–Cox transformation parameter is, however, significantly different from zero, which is the value implied by the semi-log model.

In Table 5 we present estimates of the model that imposes the impact of schooling to be linear. A comparison between models I and II in Tables 4 and 5 reveals that the log-likelihood values get markedly reduced by this restriction. A likelihood-ratio test based on the reported log-likelihood values in the tables rejects the linear specification at the 1% level for all years. None-

Table 6
Marginal internal rates of return using alternative models

Year	Derived from estimated Mincer equation[a]		Derived from Box–Cox estimates			
	High school[b]	College[c]	High school[b]		College[c]	
			B-C-1[d]	B-C-2[e]	B-C-1[d]	B-C-2[e]
1968	8.7	8.7	9.0	4.5	8.1	13.6
1981	4.5	4.5	5.0	4.4	4.1	5.6
1991	4.6	4.6	4.9	4.3	4.3	6.5

[a] Note that these numbers are identical to those in Table 2.
[b] Derived by finding the interest rate that equalizes the present value of (1) leaving school at age 16 with 9 years of schooling and working until age 62 and (2) leaving school at age 19 with 12 years of schooling and working until age 65.
[c] Derived by finding the interest rate that equalizes the present value of (1) leaving school at age 19 with 12 years of schooling and working until age 62 and (2) leaving school at age 22 with 15 years of schooling and working until age 65 years.
[d] B-C-1: see model II in Table 3.
[e] B-C-2: see model II in Table 4.

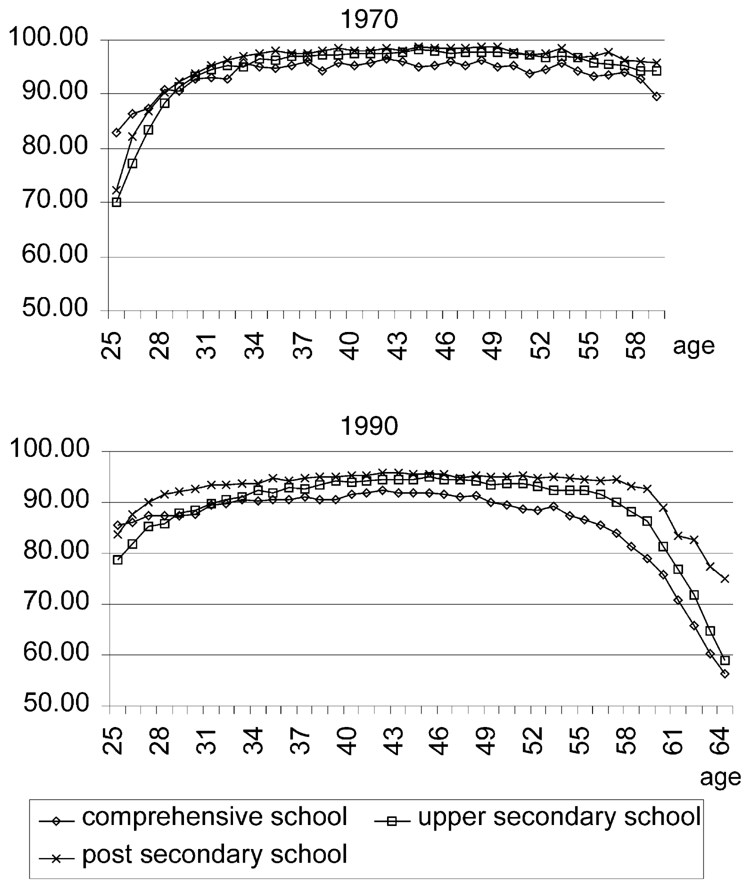

Fig. 2. The number of employed (including self-employed) divided by the population for ages 25 to 59 (in 1970) and 25 to 64 (in 1990), men only. Source: special tabulations from the Swedish censuses in 1970 and 1990. Note: comprehensive school (*grundskola*) 9 years, upper secondary school (*gymnasium*) at least 3 years and post secondary school (*universitetsutbildning*) at least 3 years.

Table 7
Marginal internal rates of return with alternative assumptions about the retirement age and employment rates

Year	Assumption[a]	Derived from estimated Mincer equation		Derived from Box–Cox estimates			
		High school[b]	College[c]	High school[b]		College[c]	
				B-C-1[d]	B-C-2[e]	B-C-1[d]	B-C-2[e]
1968	*A*	8.7	8.7	9.0	4.5	8.1	13.6
	B	8.5	8.4	8.7	3.4	7.6	13.5
	C	11.2	8.9	8.4	3.9	8.2	13.6
1981	*A*	4.5	4.5	5.0	4.4	4.1	5.6
	B	3.4	3.1	4.0	3.3	2.5	4.6
	C	5.3	4.2	4.3	3.7	3.8	5.5
1991	*A*	4.6	4.6	4.9	4.3	4.3	6.5
	B	3.5	3.2	3.9	3.1	2.8	5.8
	C	5.4	4.3	4.2	3.5	4.0	6.5

[a] *A*, additional schooling maintains the length of working life (retirement ages: 59, 62 and 65, respectively); *B*, retirement age is 62 years independent of schooling; *C*, employment rates from ages 25 to 64 according to the empirical pattern in the 1990 census. From age 65, we assume that the person has retired.

[b] Derived by finding the interest rate that equalizes the present value of (1) leaving school at age 16 with 9 years of schooling and (2) leaving school at age 19 with 12 years of schooling.

[c] Derived by finding the interest rate that equalizes the present value of (1) leaving school at age 19 with 12 years of schooling and (2) leaving school at age 22 with 15 years of schooling.

[d] B-C-1: see model II in Table 3.

[e] B-C-2: see model II in Table 4.

theless, the standard errors of some single-year dummies reported in Table 4 are quite high. The results in Table 5 also show that extension of the models in Table 3 by interactions between schooling and experience does not improve the fit of the models.

All in all, the results show some weaknesses involved in the specification of the Mincer equation. Two alternative models seem to be appropriate to use. From the first regression strategy we have the one with a Box–Cox transformation to earnings and schooling (we call it the B-C-1 model). From the second regression strategy we have the model with a Box–Cox transformation to earnings, but now a dummy variable on each year of schooling rather than years of schooling as a regressor (we call it B-C-2).

We use Fig. 1 to illustrate the deviations from the Mincer model that are caused by two extensions of the model. The figure shows the relationships between years of schooling and the log of expected earnings implied by three models, namely the Mincer equation, the Box–Cox model (B-C-1) and the semi-log model with dummies for years of schooling. All models are evaluated at 20 years of work experience.[9] Both the extended models show a tendency for the impact of schooling to taper off after 16 and 17 years. This decline in marginal wage premiums is the most marked deviation for the dummy-variable model. Further, the Box–Cox model cannot capture the higher return to the 16th year of schooling that is quite visible for 1968 and 1991.

4.1. *The preferred functional forms and the internal rates of return*

These models can now be used to compute the internal rate of return to schooling, and make comparisons with the standard Mincer model. The internal rate of return to schooling is the discount rate that makes the present values of lifetime earnings for two different educational

[9] We first compute mean earnings for all models. For the Box–Cox model we transform to the arithmetic mean earnings by using the estimator proposed by Taylor (1986, p. 115):

$$\hat{y}=\left[1+\hat{\lambda}_1\left(\hat{\beta}_0+\hat{\beta}_1\frac{s^{\hat{\lambda}_2}-1}{\hat{\lambda}_1}+\hat{\beta}_2x+\hat{\beta}_3x^2\right)\right]\left(1+\frac{\hat{\sigma}^2(1-\hat{\lambda}_1)}{2(1+\hat{\lambda}_1\{\hat{\beta}_0+\hat{\beta}_1[(s^{\hat{\lambda}_2}-1)/\hat{\lambda}_2]+\hat{\beta}_2x+\hat{\beta}_3x^2\})^2}\right).$$

For a semi-log model, i.e., λ_1 approaches zero, this estimator simplifies to: $e^{\hat{\beta}_0+\hat{\beta}_1s+\hat{\beta}_2x+\hat{\beta}_3x^2}(1+1/2\hat{\sigma}^2)$. Note that the part in parentheses cancels in Eq. (5) when we compute internal rates of return. Finally, we log the arithmetic mean earnings.

Table 8
Graduation from high school and university by age (%). Cohorts born in 1943, 1948, 1953, 1958 and 1958[a]

High school graduation (%)												
Age	–17	18	19	20	21	22	23	24	25–29	30–34	35–	Unknown[b]
1953 cohort (n=10,635)	1.4	3.9	45.0	17.4	4.9	2.3	1.6	1.2	5.8	6.4	10.2	20.0
1958 cohort (n=9873)	0.8	2.7	38.9	8.9	3.3	2.5	2.0	1.9	9.6	9.6	2.9	20.4
1963 cohort (n=13,346)	1.1	3.3	54.2	9.5	3.6	3.6	3.7	3.8	13.7	3.6[c]	–	16.1

University graduation (%)												
Age	–22	23	24	25	26	27	28	29	30	31–34	35–	Unknown[b]
1943 cohort (n=12,104)	1.7	2.6	5.6	10.0	10.1	10.3	7.6	5.4	4.3	11.4	31.1	26.6
1948 cohort (n=15,789)	2.5	6.0	11.3	13.6	11.1	6.9	5.0	4.1	3.7	12.2	23.5	20.4
1953 cohort (n=13,499)	3.6	5.7	11.4	11.8	8.8	7.3	5.8	5.3	5.3	16.5	18.5	18.7
1958 cohort (n=13,136)	4.1	5.5	11.0	13.0	12.0	10.1	8.9	7.5	5.9	13.3	8.6	12.9
1963 cohort (n=12,482)	4.9	7.1	12.8	15.8	14.8	12.7	8.5	6.2	5.0	12.3[d]	–	12.7

[a] Source: special tabulations from the *utbildningsregistret* (education database), version 01/01/97. The data refer to those with high school and university as highest degrees. Only high school degrees of 3 years and university degrees of 3 years or longer (excluding doctoral degrees) are included.

[b] Missing information on age at graduation.

[c] The age interval is 30 to 33.

[d] The age interval is 31 to 33.

Table 9
Marginal internal rates of return using alternative assumptions about age at start of high school and college studies

Year	Age at school start (highest educational level)	Derived from estimated Mincer equation		Derived from Box–Cox estimates			
		High school[a]	College[b]	High school[a]		College[b]	
				B-C-1[c]	B-C-2[d]	B-C-1[c]	B-C-2[d]
1968	16	8.7	–	9.0	4.5	–	–
	19	8.7	8.7	8.8	4.4	8.1	13.6
	25	8.7	8.7	8.6	4.4	7.8	13.0
	30	8.7	8.7	8.4	4.3	7.7	12.7
	40	8.7	8.7	8.3	4.3	7.5	12.4
1981	16	4.5	–	5.0	4.4	–	–
	19	4.5	4.5	5.0	4.5	4.1	5.6
	25	4.5	4.5	5.1	4.5	4.2	5.7
	30	4.5	4.5	5.1	4.5	4.2	5.8
	40	4.5	4.5	5.1	4.6	4.3	5.8
1991	16	4.6	–	4.9	4.3	–	–
	19	4.6	4.6	4.9	4.4	4.3	6.5
	25	4.6	4.6	5.0	4.5	4.4	6.8
	30	4.6	4.6	5.1	4.5	4.5	7.0
	40	4.6	4.6	5.2	4.6	4.6	7.2

[a] Derived by finding the interest rate that equalizes the present value of (1) leaving school at age 16 with 9 years of schooling and working until age 62 and (2) leaving school at age 19 with 12 years of schooling and working until age 65.
[b] Derived by finding the interest rate that equalizes the present value of (1) leaving school at age 19 with 12 years of schooling and working until age 62 years and (2) leaving school at age 22 with 15 years of schooling and working until age 65 years.
[c] B-C-1: see model II in Table 3.
[d] B-C-2: see model II in Table 4.

levels (s_1 and s_2) equal, i.e., the interest rate that solves the following equation:

$$\int_0^n f(s_1, x)\, e^{-r(s_1+x)}\, dx = \int_0^n f(s_2, x)\, e^{-r(s_2+x)}\, dx. \qquad (5)$$

We use the expression in [9] to compute actual earnings, $f(s, x)$, for the alternative models.

The internal rate of return is computed for those with high school and college as the highest educational level.[10] Table 6 shows the results. It appears that the Box–Cox transformation alone, B-C-1, affects the returns quite little. For all years, the returns to high school are higher than the ones implied by the standard Mincer equation, and the returns to college a little lower. The differences in magnitude never exceed 0.6. But the use of dummies for years of schooling has some notable consequences for the internal rates of return. The most striking one is that the fall in returns to schooling from 1968 to 1981 is mainly attributable to college education. The standard Mincer equation predicts a fall from 8.7 to 4.5% for all types of schooling. But the B-C-2 model predicts a fall from 4.5 to 4.4% for high school and a fall from 13.6 to 5.6% for college. This is a marked difference that is hidden by using the more restrictive model. Further, the standard Mincer equation predicts almost the same returns in 1981 and 1991. But the B-C-2 model predicts a rise from 5.6 to 6.5% for college education.

5. The other assumptions

5.1. The length of working life (A4)

Next we consider the assumption that the length of working life is the same for all lengths of schooling. Fig. 2 shows descriptive data on employment rates (including self-employment) by education for ages 25–64 (25–59 in 1970) from the Swedish censuses of 1970 and 1990. We

[10] More specifically, we estimate the returns for three additional years of schooling after 9 and 12 years of schooling, respectively. For most of the period that is covered by our data, those who continued directly to high school started there in their 10th year of schooling. Similarly, those who continued directly to university started there in their 13th year of schooling.

Table 10
Percentage additions to lifetime present value from education using alternative models, assumptions on time of school start and interest rates, 1968, 1981 and 1991

Interest rate	Delay in years[a]	Derived from estimated Mincer equation		Derived from Box–Cox estimates			
		High school[b]	College[c]	High school[a]		College[b]	
				B-C-1[d]	B-C-2[e]	B-C-1[d]	B-C-2[e]
1968							
0.00	0	30.0	30.0	29.4	14.2	26.2	46.5
	5	27.9	27.7	27.1	13.1	24.0	42.4
	15	22.3	21.7	21.4	10.3	18.4	32.6
0.02	0	22.4	22.4	22.1	7.6	19.1	38.4
	5	20.0	19.9	19.5	6.7	16.7	33.5
	15	14.7	14.3	13.9	4.7	11.6	23.3
0.04	0	15.3	15.3	15.2	1.5	12.4	30.8
	5	13.0	12.9	12.6	1.1	10.1	25.3
	15	8.5	8.3	7.9	0.6	6.2	15.6
1981							
0.00	0	14.4	14.4	16.4	14.4	13.4	18.7
	5	13.2	13.1	15.2	13.3	12.3	17.2
	15	10.4	10.1	12.1	10.6	9.6	13.4
0.02	0	7.7	7.7	9.6	7.7	6.8	11.7
	5	6.8	6.7	8.5	6.8	6.0	10.4
	15	4.9	4.7	6.2	5.0	4.3	7.4
0.04	0	1.5	1.5	3.1	1.3	0.5	5.1
	5	1.2	1.2	2.7	1.2	0.5	4.4
	15	0.8	0.7	1.8	0.9	0.4	2.9
1991							
0.00	0	14.7	14.7	16.6	14.3	14.6	23.1
	5	13.5	13.4	15.4	13.2	13.5	21.4
	15	10.6	10.3	12.4	10.6	10.6	16.9
0.02	0	8.0	8.0	9.6	7.4	7.7	15.6
	5	7.0	7.0	8.6	6.7	6.9	14.0
	15	5.0	4.9	6.4	5.0	5.1	10.2
0.04	0	1.7	1.7	3.0	1.0	1.3	8.6
	5	1.4	1.4	2.7	1.0	1.3	7.5
	15	0.9	0.9	2.0	0.9	1.0	5.1

[a] Postponing highest education.
[b] Derived by finding the interest rate that equalizes the present value of (1) leaving school at age 16 with 9 years of schooling and working until age 62 and (2) leaving school at age 19 with 12 years of schooling and working until age 65.
[c] Derived by finding the interest rate that equalizes the present value of (1) leaving school at age 19 with 12 years of schooling and working until age 62 and (2) leaving school at age 22 with 15 years of schooling and working until age 65.
[d] B-C-1: see model II in Table 3.
[e] B-C-2: see model II in Table 4.

see that employment falls by age, but more so for those with low education. The fact that the difference in employment rates between the lowest and the highest educational groups increases with age indicates that schooling really postpones retirement. But the information in the figure also shows that employment rates are higher for those with higher education throughout the entire working life. This pattern motivated us to compute internal rates of the return to additional schooling using alternative assumptions about the retirement age and employment rates.

First, we use the standard assumption that the length of working life is the same independent of the length of schooling (assumption *A* in Table 7). Second, we assume that the retirement age is 62 for all schooling levels (assumption *B*). Third, we use the actual employment rates in the 1990 census for the three major educational levels (assumption *C*). Table 7 shows the internal rates of return to schooling using these alternative assumptions. It is trivial that assumption *A* will give higher rates of return than assumption *B*, but a priori it is hard to tell whether or not the differences would be negligible. In our view, the magnitudes of the differences are not trivial; they are in the range 0.0 to 1.7, and in more than half of all cases, the difference exceeds 1.0. The comparison between assumption *C* (the *actual* case in 1990) and assumption *A* reveals mainly identical estimates for college education and the preferred B-C-2 model. For high school education, the preferred model gives estimates between those for assumptions *A* and *B*. For the standard Mincer equation and high school, assumption *C* tends to give higher estimates than for the alternative assumptions.[11]

We conclude that the retirement age and employment rates could be of great consequence for the magnitude of the return to schooling. So more research that could shed further light on this issue would be of value. The issue that should be addressed is whether schooling has a causal impact on employment rates in general and on the retirement age in particular.

5.2. The timing of schooling and work experience (A5)

Next, we relax the assumption that schooling always precedes work experience, or that all persons do all their schooling from age 7 (the age at school start in Sweden) and then work until retirement. The timing of schooling and work experience does not affect the interpretation of the schooling coefficient in the Mincer equation as an internal rate of return, but it does affect the estimated internal rate of the return to schooling derived from the two more general models. Regardless of the employed model, the present value of additional education differs for alternative assumptions on the timing of schooling and work experience.

In practice, quite a lot of adult education occurs in modern labor markets. It is also quite common to have breaks between, for example, a high school degree and studies at university. In Sweden, the discrepancy between reality and assumption *A5* is probably significant, especially during the 1970s and 1980s when adult education was stimulated in several ways and persons with extensive work experience had easier access to university studies. To get a descriptive view of the age at graduation, we asked Statistics Sweden to provide tabulations from its special educational data set (*utbildningsregistret*). This data set is primarily based on reports from schools and universities about graduations. For five cohorts of Swedes born in 1943, 1948, 1953, 1958 and 1963, we have information about the age at graduation from a university; we confine ourselves to degrees requiring a normal length of study for at least 3 years. For the last three of these cohorts, we also have information about the age at graduation for those with a high school diploma as the highest degree.

Table 8 shows that many graduates received their degrees much later than would have followed from an educational career without any interruptions. For example, more than 20% of the high school graduates were 25 years or older when they received their degree. And for the three oldest cohorts, about 40% of those with a university degree were at least 30 years old when they received their diplomas. These high numbers of old graduates from the Swedish school system suggest that quite large errors can be made if estimates of the return to education are based on the assumption that no interruptions are made in the educational career.

Table 9 shows the impact of postponing education until an older age on the marginal internal rates of return. In calculating the hypothetical internal rates of return for those with 12 years of schooling, we assume that all work experience that precedes schooling started at age 16. For those with 15 years of schooling, we assume that the first period of work experience start at age 19. As expected, the internal rates of the return to schooling derived from the Mincer equation are unaffected by the alternative assumptions about age at the start of high school and college studies. But note that postponing education to an older age has some effect on the marginal internal rate of return derived from Box–Cox estimates. For example, postponing education results in lower internal rates for the 1968 sample, whereas the internal rates of return increases for the other two samples.

We prefer the use of lifetime present values from education to illustrate the consequences of postponing education. The results in Table 10 show, as expected, that postponement of education leads to lower lifetime earnings. Of course, the differences in present values become smaller, the higher the interest rate is. We find the magnitudes of the differences quite large, so we conclude that it is important to put more emphasis on this issue in future studies of the return to schooling. A more ambitious study should also address the issue of whether the same earnings functions are applicable to youth and adult education.

5.3. Allowing for wage growth (A6)

Finally, we discuss the assumption of an economy in steady state without any wage growth. Suppose that we

[11] We were somewhat surprised by the high number for high school education in 1968, using the estimated Mincer equation and assumption *C* (11.2) compared with the preferred model B-C-2 (4.1). To understand the reasons, we generated the wage–experience profiles for 16 and 19 years of schooling for the two alternative earnings equations. It turned out that the Mincer equation predicts markedly higher wage premiums during the entire career.

stick to the aim of estimating the expected (ex ante) return to schooling. In that case, it seems quite reasonable to assume that some expected wage growth should be accounted for. Technically, this is trivial for all the internal rates of returns. As is evident from Eq. (5), it is only a matter of adding the expected exponential growth rate of wages to the computed internal rates of return. During the period of our study, the real wage growth rates were 0.8% for the entire period, 0.9% from 1968 to 1981 and 0.7% from 1981 to 1991. Adding these growth rates (assuming "static-growth expectations") obviously raises the internal rates of return only a little. But in countries with higher growth, it can be important to account for expected growth.

Even if the impact of growth on the internal rates of return is simply additive to the numbers presented in our tables, the additions to lifetime present value of taking education at an early age (the results in Table 10) are affected by expected growth in a more complicated manner. Some calculations that we made (not presented) suggest that a higher growth rate tends to make the relative loss in present value of postponing education smaller when the interest rate is zero, otherwise generally larger.

6. Conclusions

Our examination of the usefulness of the schooling coefficient in the standard Mincer equation yields three results that we believe are important for an understanding of the Swedish labor market and for future research in this field. First, the semi-log functional form turns out to be misleading in one respect. The dramatic decline in the return to schooling from 1968 to 1981 is mainly attributable to a fall in the return to college education, whereas the return to high school education is quite stable. Without a more flexible functional form for years of schooling than the semi-log one, this result would not have been detected. Recent research on US data yielded stronger support for the semi-log functional form (see Card, 1999), so there might be a difference between countries.

Second, we find that the internal rates of return to schooling are quite sensitive to the assumption made about the length of the working life, or the retirement age for persons with different length of schooling. Rather crude descriptive data for Sweden show that more highly educated persons tend to retire later, so the implicit assumption behind using the Mincer schooling coefficient as an estimate of the internal rate of return to schooling is not markedly at variance with the data. Nonetheless, the sensitivity of our estimates suggests that the impact of education on the length of working life is an important topic for future research. It is reasonable to believe that education has such a causal effect, for example, via better health investments or via physically less-demanding jobs. But empirical studies are called for to investigate if it is reasonable to assume a causal effect.

Third, we show that the advantages of taking education at a young age, rather than at an older age, is generally not revealed by the schooling coefficient or an estimate of the internal rate of return based on a schooling coefficient. We could demonstrate that, for the present value of lifetime earnings, there is an advantage in taking education early in life. We find this important to stress in light of the great political interest in adult education, especially in Sweden. In doing these computations, we apply the same earnings functions on all education. Whether or not this is appropriate requires further empirical analysis.

Our study perhaps raises as many questions as it answers. Indeed, a closer examination of all assumptions that are involved in estimating the rate of return to education highlights many important questions about schooling and the labor market. We stress again that we did not dig into the issues involved in assumptions *A1* (that hourly earnings is a complete measure of the output of schooling) and *A2* (that there are direct costs of education). Any such attempt would have raised many difficult but probably most important questions.

Finally, although we stress that it can be misleading to interpret the schooling coefficient in a standard Mincer equation as returns to investments in education, we conclude by expressing our deep respect for this contribution to labor economics. If simplicity is called for in an analysis of the impact of schooling and work experience on wages, it is definitely hard to beat the Mincer equation.

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