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Optimal Investment in Human Capital Under Uncertainty

WIM GROOT* and HESSEL OOSTERBEEK†

* Department of Economics, Leiden University, P.O. Box 9521, 2300 RA Leiden, The Netherlands; and
† Department of Economics, University of Amsterdam, Jodenbreestraat 23, 1011 NH Amsterdam, The Netherlands

Abstract — In this paper we extend the standard human capital model with the probability of becoming unemployed and uncertainty about future earnings. Our analysis deviates from earlier human capital cum uncertainty models in assuming risk neutral decision-makers. This allows a straightforward comparison with the standard model and also facilitates calculations of unemployment and uncertainty accounted rates of return to education. The comparative statics of the model reveal that only the effect of changes in the earnings distribution can be signed unambiguously: greater dispersion in earnings by schooling level reduces the returns to schooling. The empirical illustrations suggest that accounting for uncertainty and the probability of becoming unemployed slightly equalizes differences in the rates of return for different levels of schooling.

1. INTRODUCTION[1]

MOST DECISIONS on human capital are taken under uncertainty with respect to the opportunities offered by schooling and the returns on the investment. Schooling decisions are typically taken at an age at which one has only a very limited knowledge about the labor market. The extent to which teenagers without any labor market experience have knowledge about employment and job opportunities, and about the returns on investment is probably not very large. Most human capital models, however, assume that future income streams are known with perfect certainty. In this respect the development of the human capital model seems to have lagged behind other areas of economic theory, where the analysis of economic behavior under uncertainty has become a major field of new and interesting results.

In this paper we formulate a life-time income maximizing model to determine the optimal length of schooling when there is a probability of becoming unemployed after school and under uncertainty with respect to future labor income. The human capital model presented in this paper extends the standard human capital model by taking into account three empirical facts:

(1) individuals consider future (un)employment prospects in their decision on the length of schooling;
(2) post-education earnings are not known with certainty;
(3) job opportunities rise with the length of schooling, as one can accept a job below the educational level but cannot elicit a job offer above the educational level.

It is well-known that there are spill-over effects from the labor market to the educational market. When unemployment rates are high the demand for education rises and when the excess supply on the labor market diminishes the demand for education decreases; see Pissarides (1981, 1982) for time series evidence and Kodde (1985, ch. 8) for cross sectional evidence on this point. From the human capital point of view this can be explained by the opportunity cost of schooling. When unemployment rates increase, the expected foregone earnings of schooling, i.e. the unemployment rate weighted average of unemployment benefits and labor income, decreases

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if unemployment benefits are lower than labor income. On the other hand, unemployment at higher educational levels decreases the returns to education, resulting in a lower demand for education. However, unemployment rates vary dramatically with the level of education; the unemployment rate of the lowest educational levels is often several times higher than the unemployment rate for the higher educational levels. Figures that illustrate this proposition are presented in Section 5 of this paper. Also, unemployment rates for the lower educated generally rise faster in a recession than the unemployment rates for the higher educated.

Finally, with high unemployment rates individuals invest in education to increase the number of potential job opportunities. If job offers are only available at or below the educational level attained, an increase in the educational level increases the number and range of potential job opportunities. This argument fits into the job competition theory; see Teulings and Koopmanschap (1989) for empirical support on this.

There have been a few attempts to model uncertainty in the demand for education. Levhari and Weiss (1974) and Kodde (1985, ch. 7) treat uncertain future earnings in a two period consumption model with human capital formation. Eaton and Rosen (1980) extend the analysis of Levhari and Weiss by incorporating taxes and endogenous labor supply in the model. They also consider the issue of optimal taxation in such a model. Kodde investigates how the optimal demand for education reacts to changes of costs, earnings and the amount of risk. Uncertainty in this model of human capital formation yields positive income effects, causing the total effects of foregone income and direct costs to have a different impact on the demand for education. For the general case of the model the relationship between the expected rate of return and the interest rate is indeterminate. Similarly, the effect of increasing risk on the demand for education cannot be signed unambiguously. Paroush (1976) treats risk effects in a human capital model employing the mean–variance rule. His analysis includes uncertain future earnings as well as interest rate uncertainty, but neglects foregone earnings and the direct cost of education. Williams (1979) uses the optimal control approach and incorporates uncertainty in it.

A common feature of these papers is that they focus mainly on the effects of risk aversion on the demand for education. Comparisons with the basic model are therefore somewhat artificial because the standard model and the uncertainty models do not only differ because of the inclusion of uncertainty, but also because a different shape of the utility function is assumed. In the absence of uncertainty, decision makers in the standard model maximize lifetime earnings instead of a concave utility function.

In this paper a different approach is adopted; we investigate the effects of uncertain future earnings and the probability of becoming unemployed on the optimum amount of schooling under the assumption that lifetime earnings are maximized. This allows us to compare for each extension the outcomes of the basic model and the uncertainty model.

In Section 2 we sketch the standard, perfect certainty model of investment in human capital. Unemployment, unemployment benefits and uncertainty are introduced in Section 3. In Section 4 some comparative static results are derived of changes in unemployment probabilities, unemployment benefits, earnings and uncertainty on the marginal costs and benefits of schooling. In Section 5 we provide some empirical illustrations of the model with data for the Netherlands and the United States for 1979 and 1985. The last section contains the conclusions.

2. THE STANDARD MODEL

We assume that the individual is a life-time income maximizer who chooses his/her optimal length of education. Life-time income, V, consists of the discounted earnings, $w(s)$, after completion of s years of formal schooling minus the discounted cost of schooling.[2] The direct costs of schooling are given by c and the discount rate by r. The lifetime maximization problem can be represented by:

$$\max_S: V = -\int_0^s c\mathrm{e}^{-rt}\mathrm{d}t + \int_s^T w(s)\mathrm{e}^{-rt}\mathrm{d}t \qquad (1)$$
$$= (-c(1 - \mathrm{e}^{-rs}) + w(s)(1 - \mathrm{e}^{-r(T-s)})\mathrm{e}^{-rs})/r;$$

where T is the planning horizon. The optimal length of schooling is determined by s for which $\partial V/\partial s = 0$. Assuming that $T \to \infty$, the optimal length of schooling is determined by:

$$c + w(s) = r^{-1}\partial w(s)/\partial s; \qquad (2)$$

where $c + w(s)$ are the marginal costs of schooling (MC) and $r^{-1}\partial w(s)/\partial s$ are the marginal revenues (MR). This model will henceforth be referred to as the standard model.

If human capital is an investment like other capital investments, we expect that the earnings–schooling relation exhibits decreasing returns to scale: $\partial w(s)/\partial s > 0$ and $\partial^2 w(s)/\partial s < 0$. This implies that the marginal cost curve is upward sloping and the marginal cost curve is downward sloping, and thereby a unique solution for Eqn (2) is guaranteed.

The optimal length of schooling decreases with: (a) a decrease in the derivative of earnings w.r.t. schooling $\partial w(s)/\partial s$; (b) an increase in the direct costs of schooling c; (c) an increase in the discount rate r; and (d) an increase in the educated wage rate $w(s)$.

3. OPTIMAL LENGTH OF SCHOOLING WITH UNEMPLOYMENT AND UNCERTAINTY

We assume that the individual faces a probability π of being unemployed at time t $(t > s)$. As outlined in the Introduction, there is now abundant empirical evidence that unemployment rates differ by education level: the higher educational levels face much smaller chances of becoming unemployed and much shorter unemployment spells if unemployed, than the lower educational levels. So, we assume the unemployment probability to be a function of the length of schooling: $\pi = \pi(s)$, with $\partial\pi(s)/\partial s < 0$. The probability of unemployment is assumed to remain unchanged over time. If unemployed the individual receives unemployment benefits b. Unemployment benefits are assumed to be independent of previous earnings. We further assume that a spell of unemployment does not depreciate wages.

Let $\Phi[w(s); \sigma(s)]$ represent the distribution of wage offers after s years of schooling and let $F[w(s); \sigma(s)] = 1 - \Phi[w(s); \sigma(s)]$ be the probability that the wage exceeds w. The wage offer distribution is assumed to be known by the individual and assumed to remain unchanged over time. Any offer is viewed as a random drawing from this distribution. For simplicity we assume that the individual receives exactly one wage offer per period from this distribution after leaving school. The variance of the wage offer distribution $\sigma^2(s)$ is assumed to be increasing in s as the range of wage offers increases with the length of schooling: $\partial\sigma(s)/\partial s > 0$.[3] Finally, we assume that all wage offers below the unemployment benefit level b are rejected by the individual.[4] The life-time income maximization problem can now be written as:

$$\max_s: V = -\int_0^s ce^{-rt}dt + \int_s^T [\pi(s)b + (1 - \pi(s)) \int_b^{\cdot} F(w(s),\sigma(s))dw(s)]e^{-rt}dt \tag{3}$$

$$= -(c/r)(1 - e^{-rs}) + r^{-1}[\pi(s)b + (1 - \pi(s)) \int_b^{\infty} F(w(s),\sigma(s)dw(s)]e^{-rs}.$$

The optimal length of schooling is again determined by $\partial V/\partial s = 0$:

$$\partial V/\partial s = -c - [\pi(s)b + (1 - \pi(s)) \int_b^{\infty} F(w(s), \sigma(s))dw(s)] + r^{-1}[\partial\pi(s)/\partial s(b - \int_b^{\infty} F(w(s), \sigma(s))dw(s)) + (1 - \pi(s))(1 - F(b,\sigma(s)))\partial w(s)/\partial s + (1 - \pi(s)) \int_b^{\infty} H_\sigma(w(s),\sigma(s))dw(s)\partial\sigma(s)/\partial s]. \tag{4}$$

Because we do not wish to specify a specific functional form for the wage offer distribution we have made use of the "mean preserving spread" notion of Rothschild and Stiglitz (1970) for determining the partial derivative of $F(.)$ w.r.t. σ. Borrowing the formulation of Mortenson (1986, p. 863), the distribution H is a mean preserving spread of F given that both are defined on positive reals and have the same mean if and only if:

$$\int_0^b H(x)\,dx \geq \int_0^b F(x)\,dx, \text{ for all } b > 0. \tag{5}$$

Hence, if one regards $H(w,\sigma)$ as a family of mean preserving spreads of F where σ is a parameter of relative dispersion so that $\sigma = 0$ defines the member F, then

$$\lim_{\sigma \to 0} \int_0^b \{[H(x,\sigma) - F(x)]/\sigma\}dx = \int_0^b H_\sigma(x,0)dx \geq 0 \text{ for all } b; \tag{6}$$

where $H_\sigma(x,\sigma)$ is the partial derivative of $H(.)$ w.r.t. σ (cf. Mortensen, 1986).

From Eqn (4), which determines the optimal length of schooling, it can be concluded that the marginal costs of schooling are now determined by:

(1) the fixed cost of schooling $c > 0$; and
(2) the foregone earnings, which consist of the unemployment probability weighted average of unemployment benefits and expected employment income:

$$[\pi(s)b + (1 - \pi(s)) \int_b^{\infty} F(w(s), \sigma(s))dw(s)] > 0.$$

If the expected earnings are equal to $w(s)$ in the standard model and $b < w(s)$, higher unemployment rates decrease the marginal costs of schooling compared to the standard model.

Further, it can be concluded from (4) that the marginal revenue of schooling is composed of three effects:

(1) An employment effect, which originates from the fact that more schooling increases the probability of employment:

$$r^{-1}[\partial\pi(s)/\partial s(b - \int_b^\infty F(w(s),\sigma(s))w(s))].$$

If benefits are less than expected earnings the employment effect is positive.

(2) A wage effect, because the expected wage increases with the length of schooling:

$$r^{-1}(1 - \pi(s))(1 - F(b,\sigma(s)))\partial w(s)/\partial s \geq 0.$$

Compared to Eqn (2) taking account for unemployment and uncertain job offers has decreased the pure wage effect $\partial w(s)/\partial s$ by the probability of employment, $1 - \pi(s)$, and the probability that a job offer is acceptable, $1 - F(b,\sigma(s))$.

(3) A dispersion effect, because the range of potential job offers increases with the length of schooling:

$$r^{-1}(1 - \pi(s)) \int_b^\infty H_\sigma(w(s),\sigma(s))\mathrm{d}w(s)\partial\sigma(s)/\partial s \geq 0.$$

So, compared to the standard model, schooling now increases earnings through its effect on the probability of having a job (if benefits are less than wages) and through its effect on the range of potential job offers as well. On the other hand, the pure wage effect is smaller than in the standard model as we now have to weigh the wage effect by the probability of being employed and the probability that a job offer is acceptable.

If we take the three effects together it depends on whether

$$\partial\pi(s)/\partial s(b - \int_b^\infty F(w(s),\sigma(s))w(s)) + (1 - \pi(s)) \int_b^\infty H_\sigma(w(s),\sigma(s))\mathrm{d}w(s)\partial\sigma(s)/\partial s \geq [1 - (1 - \pi(s))(1 - F(b,\sigma(s)))]\partial w(s)/\partial s \quad (7)$$

for this combined employment, wage and dispersion effect to be less than the wage effect in the standard model.

4. COMPARATIVE STATICS

In this section we derive some comparative static results of changes in unemployment probabilities, benefits, earnings and uncertainty on the marginal costs and revenues of schooling.

4.1. The Effects of a Change in the Unemployment Probability

The effect of a change in the unemployment probability on the cost of schooling is:

$$b - \int_b^\infty F(w(s),\sigma(s))\mathrm{d}w(s). \quad (8)$$

If the benefit level is less than the expected earnings, Eqn (8) is negative. In this case an increase in the unemployment probability leads to a downward shift in the marginal cost curve. The reverse holds if the unemployment benefits are greater than the expected earnings.

The effects on the marginal revenue of schooling are:

$$-r^{-1}[(1 - F(b,\sigma(s)))\partial w(s)/\partial s + \int_b^\infty H_\sigma(w(s),\sigma(s))\mathrm{d}w(s)\partial\sigma(s)/\partial s] < 0 \quad (9)$$

as all the terms between the square brackets are positive. Therefore, an increase (decrease) in the unemployment probability decreases (increases) the expected revenues of schooling.

Combining the effects of a change in the unemployment probability on the marginal cost and revenue of schooling we see that an increase (decrease) in the unemployment probability has an ambiguous effect on the optimal length of schooling as both the marginal cost curve and the marginal revenue curve shift downward (upward): a higher overall probability of becoming unemployed after school reduces both the (opportunity) costs and the revenues of schooling.

4.2. The Effects of a Change in the Unemployment Benefit Level

The effect on the marginal cost of schooling of a change in the benefit level b is:

$$\pi(s) + (1 - \pi(s))(1 - F(b,\sigma(s))) > 0. \quad (10)$$

The effect on the marginal revenue of schooling is:

$$r^{-1}[\partial\pi(s)/\partial sF(b,\sigma(s)) + (1 - \pi(s))((1 - H_\sigma(b,\sigma(s))) \partial\sigma(s)/\partial s - \partial F(b,\sigma(s))/\partial b\partial w(s)/\partial s] \quad (11)$$

The sign of Eqn (11) is indetermined. An increase (decrease) in the benefit level leads to an upward (downward) shift in the marginal cost curve and an undetermined effect on the marginal revenue curve.

4.3. The Effects of a Change in Earnings

The effects of a change in earnings on the cost of schooling are:

$$(1 - \pi(s))(1 - F(b,\sigma(s)) > 0. \quad (12)$$

Higher expected earnings increase the opportunity cost of schooling.

The effect on the marginal revenue of schooling is:

$$r^{-1}[-\partial\pi(s)/\partial s(1 - F(b,\sigma(s))) + (1 - \pi(s)) (1 - H_\sigma(b,\sigma(s)))\partial\sigma(s)/\partial s] > 0. \quad (13)$$

Higher expected earnings raise the revenues of schooling.

As an increase in post-education earnings shifts both the marginal cost curve and the marginal revenue curve upwards, the total effect remains indeterminate.

4.4. The Effects of a Change in the Dispersion

The effect of a change in $\sigma(s)$ on the marginal cost of schooling is:

$$(1 - \pi(s)) \int_b^\infty H_\sigma(w(s),\sigma(s))\mathrm{d}w(s) > 0. \quad (14)$$

If the range of wage offers increases the opportunity cost of schooling increases.

The effect on the marginal revenue of schooling is:

$$r^{-1}[-\partial\pi(s)/\partial s \int_b^\infty H_\sigma(w(s),\sigma(s))\mathrm{d}w(s) - (1 - \pi(s))H_\sigma(b,\sigma(s))\partial w(s)/\partial s + \int_b^\infty H_{\sigma\sigma}(w(s),\sigma(s))\mathrm{d}w(s)\partial\sigma(s)/\partial s], \quad (15)$$

which is negative if $H_{\sigma\sigma} < 0$.

As the effect of greater dispersion on the marginal cost of schooling is positive and on the marginal revenue of schooling is negative, the total effect is negative: greater dispersion in earnings by schooling level reduces the returns to schooling.

5. EMPIRICAL ILLUSTRATIONS

In this section we illustrate the effects of unemployment and uncertainty on the returns to schooling empirically. We use data on unemployment and earnings for 1979 and 1985 for both The Netherlands and the United States. For The Netherlands the data sources are: the Wage Structure Survey (1979) and Annual Wage Survey (1985) for earnings and the Labor Force Survey (1979 and 1985) for unemployment statistics. All data were collected by the Dutch Central Bureau of Statistics. For the United States the unemployment rates were calculated from the Statistical Abstracts of the U.S.A., and the earnings data come from the Current Population Reports "Money Income of Households, Families and Persons in the United States". All data for the U.S. were collected by the Bureau of the Census.

To control for the effects of gender, participation behavior and work experience we used earnings of males working full-time, aged between 35 and 44. The first three columns in Tables 1 to 4 give the statistics on unemployment rates and the mean and standard deviations of gross monthly earnings of full-time workers by level of education.

If we assume that a job offer is acceptable if and only if the wage exceeds the benefits level, the mean wage earnings of the workers with s years of education, $\mu(s)$, can be written as:

$$\mu(s) = E(w(s)|w(s) > b) = \int_b^\infty F(w(s),\sigma(s)\mathrm{d}w(s)). \quad (16)$$

The unemployment rates are total population averages. Tables 1 and 2 relate to The Netherlands, and Tables 3 and 4 to the United States. In The Netherlands the unemployment rate decreases with level of education, in the United States the unemployment rate peaks for high school drop-outs. In both countries unemployment is more severe in 1985 than in 1979. Earnings in both countries increase with the level of education. In The Netherlands the standard deviation of earnings increases with the level of earnings, and thus with the level of education, in the United States this relation is less uniform.

Table 1. Marginal rates of return to schooling; males 35–44, The Netherlands 1979

Education (years)	u(%)	Earnings Mean	Earnings S.D.	Rates of return (1)	(2)	(3)	(4)
Primary (6)	8	2495	536				
Lower vocational (10)	3	2716	512	2.12	2.46	2.44	2.55
Extended primary (10)	4	2893	827	3.70	3.91	3.76	2.77
Secondary general (12)	2	3660	952	11.76	12.03	10.90	10.49
Secondary vocational (14)	2	3309	728	4.94	4.97	4.55	4.10
Higher vocational (16)	2	4542	1103	15.84	15.96	13.47	12.85
University (18)	2	6208	1674	8.81	8.74	6.80	6.58

Unemployment benefits: 1751.

Table 2. Marginal rates of return to schooling; males 35–44, The Netherlands 1985

Education (years)	u(%)	Earnings Mean	Earnings S.D.	Rates of return (1)	(2)	(3)	(4)
Primary (6)	23	2948	622				
Lower vocational (10)	12	3191	653	1.98	2.77	2.84	2.73
Extended primary (10)	15	3668	906	5.48	5.63	5.46	4.80
Secondary general (12)	13	4187	1138	6.62	6.64	6.35	5.64
Secondary vocational (14)	6	3699	909	3.69	4.15	4.03	3.48
Higher vocational (16)	5	4685	1129	11.85	11.76	10.59	10.17
University (18)	5	6248	1619	6.67	7.27	6.35	6.18

Unemployment benefits: 1988.

Table 3. Marginal rates of return to schooling; males 35–44, United States 1979

Education (years)	u(%)	Earnings Mean	Earnings S.D.	Rates of return (1)	(2)	(3)	(4)
Elementary (0–7)	3.47	956	40				
(8)	3.71	1190	50	5.46	5.35	4.81	4.74
High school (9–11)	7.92	1299	29	4.38	2.80	2.53	3.08
(12)	4.75	1645	19	11.82	12.83	11.65	12.03
College (13–15)	3.46	1849	35	5.85	6.31	6.00	5.67
(16)	1.90	2453	65	14.14	14.71	12.94	12.60
(≥17)	1.36	2808	66	6.75	6.97	6.54	6.53

Unemployment benefits: 390.

Table 4. Marginal rates of return to schooling; males 35–44, United States 1985

Education (years)	u(%)	Earnings Mean	Earnings S.D.	Rates of return (1)	(2)	(3)	(4)
Elementary (0–7)	5.58	1302	63				
(8)	6.49	1661	85	6.09	5.80	5.12	5.02
High school (9–11)	9.36	1662	45	0.03	−0.99	−1.00	−0.31
(12)	7.00	2160	27	13.10	13.65	12.24	12.73
College (13–15)	4.32	2475	36	6.81	7.78	7.38	7.20
(16)	2.61	3169	67	12.36	12.98	11.62	11.28
(≥17)	1.67	3917	89	10.59	10.96	9.94	9.76

Unemployment benefits: 550.

For most unemployed in The Netherlands unemployment benefits amount to 70% of last earned income for the first 2.5 years of unemployment. School-leavers, the unemployed who have worked less than 26 weeks in their last job and those who are unemployed for more than 2.5 years receive a means tested minimum benefit level (Unemployment Assistance). This is roughly equal to the legal minimum wage. In the U.S. individuals usually receive unemployment benefits dependent on normal earnings during the first 26 weeks of unemployment. After the benefits are exhausted individuals may become dependent on welfare.

Because of the exhaustion of benefits it is difficult to determine the average income during unemployment. To avoid too much arbitrary calculations of income during unemployment, unemployment benefits are assumed to be independent of previous earnings.

The statistics in the first three columns are used to calculate the rates of return to schooling. For simplicity we assume that the direct costs of schooling (c) are neglectable and that the planning horizon (T) tends to infinity.[5] The columns under (1) show the marginal rates of return of the standard model, without unemployment and earnings dispersion. The calculations for schooling length s are based on the formulae:

$$r^1(s) = [\ln(\mu(s)) - \ln(\mu(s - \Delta s))]/\Delta s. \quad (17)$$

In The Netherlands, in both 1979 and 1985 the rate of return is highest at the higher vocational level, in 1979 followed by secondary general, in 1985 by university. In the United States in 1979, completed college gives the highest return (14.1%) followed by completed high school (11.8%). In 1985 these two levels remain the most rewarding, but their ranking is reversed.

With the exception of extended primary, the basic model suggests a decline of the rate of return to the amount of 12–20% between 1979 and 1985 in The Netherlands, thereby confirming the hypothesis of the declining rate of return to education (cf. Freeman, 1975, 1980; Psacharopoulos, 1989; Hartog and Tsang, 1989). On the other hand, for the United States, the basic model reveals with the exceptions of high school drop-outs and completed college, an increasing rate of return between 1979 and 1985. This confirms earlier findings by Willis (1986, p. 537/8) and Kosters (1990).

In columns (2) unemployment and unemployment benefits are included in the model. The rates of return are now based on the formulae:

$$r^2(s) = \{\ln[\pi(s)b + (1 - \pi(s))\mu(s)] - \ln[\pi(s - \Delta s)b + (1 - \pi(s - \Delta s))\mu(s - \Delta s)]\}/\Delta s. \quad (18)$$

The results perfectly mirror the pattern of the unemployment rates. Only for the schooling levels for which the unemployment rate is higher than the unemployment rate at the previous level, the rate of return declines between columns (1) and (2).

Next we introduce uncertainty in the model (columns 3). It is assumed that earnings by educational level follow a log normal distribution with known mean and variance. The upper-bound limit of the distribution function $F(.)$ is calculated by "the mean plus three times the standard deviation". In the calculation in columns (3) we ignore for the moment the dispersion effect caused by the fact that the variance of earnings differs between levels of schooling [the final term between the second pair of square brackets in Eqn (4)]. The rate of return is calculated by:

$$r^3(s) = \Delta\pi(s)[b - \mu(s) + (1 - \pi(s))(1 - F(b,\sigma(s)))\Delta\mu(s)]/[\pi(s)b + (1 - \pi(s))\mu(s)]; \quad (19)$$

where $\Delta\pi(s) = (\pi(s) - \pi(s - \Delta s))/\Delta s$ and $\Delta\mu(s) = (\mu(s) - \mu(s - \Delta s))/\Delta s$.

The rates of return show that uncertainty has a depressing effect on the rates of return. With the (minor) exception of lower vocational education in The Netherlands, all rates of return decline from columns (2) to (3). However, the magnitude of the uncertainty effect is relatively small. The decline is largest for the schooling levels with the highest rates of return.

Finally the effect of the range of potential job offers, the dispersion effect, on the rate of return is included in the calculations (columns 4). The formulae now reads:

$$r^4(s) = \Delta\pi(s)[b - \mu(s) + (1 - \pi(s))(1 - F(b,\sigma(s)))\Delta\mu(s) + (1 - \pi(s)) \int H_\sigma(w(s), \sigma(s))dw(s)\Delta\sigma(s)]/[\pi(s)b + (1 - \pi(s))\mu(s - \Delta s)]; \quad (20)$$

where $\Delta\sigma(s) = (\sigma(s) - \sigma(s - \Delta s))/\Delta s$. For a numerical approximation of the integral terms we used the Simpson rule.

The differences between columns (3) and (4) now reflect the patterns of the standard deviation of earnings; an increase of the standard deviation causes a decrease of the rate of return. Comparison of the results in columns (1) (the basic model) and columns (4) (the unemployment–uncertainty model) gives rise to the following comments. First, in The Netherlands the rates of return for different schooling levels in columns (4) are more equal than in columns (1) (in 1979 the standard deviation of the rates of returns falls from 5.26 to 4.29; in 1985 from 3.36 to 2.63). In the United States such a converging effect is absent (1979: from 3.95 to 3.95; 1985: from 4.9 to 4.7). Second, the decline of the rate of return between 1979 and 1985 in The Netherlands, as suggested in columns (1) no longer occurs if we look at the rates in columns (4). This indicates that the decline of the simple rate of return is partly offset by a decreasing dispersion of wage offers, and relatively better employment opportunities. For the United States the results in columns (1) and (4) give the same picture with respect to the changing rates of return for the different levels. This suggests that part of the changes in rates of return are due to changes in employment opportunities and uncertainty. A final interesting result from the comparison in columns (1) and (4) for The Netherlands, is that the difference between the rates of return between general and vocational education is smaller in columns (4) than in columns (1). This suggests that part of the higher returns to general education consists of a risk premium.

6. CONCLUSIONS

In this paper we extended the basic human capital model with the effects of the probability of becoming unemployed and uncertainty with respect to earnings. Theoretically the effects of changes of unemployment probability, unemployment benefits and wages on the optimal schooling length are ambiguous. The latter finding contradicts the results from the standard model in which an increase in the educated wage rate decreases the optimal length of schooling. This is due to the fact that in the extended model a change in post-education wages also affects the marginal revenue curve of schooling. Only the effect of changes in the earnings distribution can be signed unambiguously: greater dispersion in earnings by schooling level reduce the returns to schooling.

We also investigated empirically the effects of our extensions on the rates of return to education in the Netherlands and the United States. The overall conclusion is that the differences in unemployment rates and uncertainty in earnings tend to depress the rates of return slightly and to equalize the rates of return to different schooling levels. The impression of a decline in the simple rate of return may reflect changes in employment opportunities and uncertainty, to the extent that the unemployment rate-uncertainty-corrected rate of return remains virtually unchanged.

NOTES

1. We received helpful comments from an anonymous referee.
2. Investments in specific human capital after school (on-the-job training) and their returns are ignored.
3. See Levhari and Weiss (1974, p. 954/5) for empirical evidence corroborating this assumption. See also Section 5 of this paper.
4. The benefit level can be seen as the reservation wage within the job search context. Note that rejection of wage offers below b may also explain why unemployment disproportionally hits the lower educated.
5. Mincer (1974) argues that the costs of education are roughly offset by an individual's earnings while in school, and that earnings profiles for men with different amounts of schooling are roughly parallel once men enter the labor force; see also Murphy and Welch (1990).

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