Micro Evidence on Human Capital as the Engine of Growth*

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Abstract

This study examines a crucial assumption in much of the recent work on endogenous growth, namely, constant returns to scale in the production of human capital. A simple model is constructed to show that the returns to scale in human capital production can be inferred from the relationship between the wage rate and years of schooling. A large international micro dataset is used to estimate this relationship. The empirical evidence is decisive. There are decreasing returns to scale in human capital production; that is, the micro-level evidence is not supportive of endogenous growth driven by human capital accumulation.

JEL Codes: O41, J24, I21

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Introduction

In recent literature endogenous long-run growth is explained by the accumulation of "broadly defined" capital. Typically it is the inclusion of human capital into the analysis which generates endogenous growth.[1] Growth is created in these models by assuming that the capital stocks are produced through constant returns to scale functions of inputs that can be accumulated, i.e., the capital stocks. These constant returns to scale assumptions induce endogenous growth by creating returns to investments which perpetually exceed their costs. Thus net investment in the capital stocks never ceases, which leads to perpetual growth.

An important problem with this class of endogenous growth models, however, is that there is no empirical evidence to support the crucial assumption of constant returns to scale in human capital production.[2] The limited microeconomic evidence on human capital production is not helpful in this regard as it has imposed important restrictions on the estimates of the returns to scale to the inputs that can be accumulated.[3] And the macroeconomic evidence on human capital accumulation as the engine of growth is decidedly

[1]There have been over forty such studies published within the last decade or so. A few examples are Lucas (1988), King and Rebelo (1990), Rebelo (1991), Jones et al. (1993), Mulligan and Sala-i-Martin (1993), and Stokey and Rebelo (1995).

[2]In a related vein, Saint-Paul (1996) and Acemoglu (1996) derive increasing (pecuniary) returns in human capital accumulation based on labor market frictions and the assumption of constant (technological) returns to scale in producing human capital.

[3]Decreasing returns to scale are imposed in the empirical work by Haley (1976) and Heckman (1976). Constant returns are effectively imposed in Ben-Porath (1970) and Rosen (1976).

inconclusive.[4]

Moreover, there is no compelling intuitive reason to believe that there are constant returns in producing human capital. Although constant returns in providing educational services (i.e., teaching) follows from a standard replication argument, this does not imply constant returns to scale in producing human capital. Human capital is obviously embodied in individuals (an important fact that is glossed over in the common two-sector endogenous growth models), and the most important input in its production is the time individuals spend learning - an input which is not obviously replicatable. Hence, the replication argument for constant returns to scale does not apply to human capital production.

This study attempts to redress this important shortcoming in the understanding of the forces of long-run economic growth. A simple model is constructed to show that the returns to scale in human capital production (from education) can be inferred from the rate of return to education. In particular, the shape of the rate-of-return function follows the returns to scale (from the inputs that can be accumulated) in the human capital production function. If there are constant (increasing, decreasing) returns to scale in producing human capital through education, then the marginal rate of

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[4]The evidence in Romer (1990), Barro (1991), and Tallman and Wang (1994) is consistent with the notion that human capital accumulation drives long-run growth; while the evidence in Mankiw et al. (1992), Romer (1994), Benhabib and Spiegel (1994), and Jones (1995) is inconsistent with the hypothesis; and the evidence in Barro and Sala-i-Martin (1992, 1995) is inconclusive. These conflicting results may not be surprising, however, given the great difficultly in distinguishing between theories using macro data, especially in this case because of the lack of good data on human capital [on this issue see Benhabib and Jovanovic (1991), Levine and Renelt (1992), Levine and Zervos (1993), and Pack (1994)].

return to education is constant (rising, declining).

Data from the International Social Survey Programme is used to estimate (private) marginal rates of return to education. This data on over 30,000 working-age men in 26 different countries decisively rejects a constant marginal rate of return to education (i.e., constant returns to scale in producing human capital). More precisely, the marginal rate of return is significantly increasing at low levels education (thus indicating significant increasing returns), and the marginal rate of return is decreasing significantly at high levels education (thus indicating significant decreasing returns).

In other words, the data indicates that the human capital production function has a cubic shape; that is, this production function has the shape that is typically taught in introductory microeconomics courses. The implication of this is that, after about twelve years of education, there are significant decreasing (private) returns to the inputs that can be accumulated. Thus the applicability of endogenous growth models driven by human capital accumulation is doubtful.[5]

A Very Simple Model

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[5]Endogenous growth driven by human capital is still possible with decreasing private returns to human capital if there are sufficiently large external returns. Limited empirical evidence, however, suggests that this is unlikely. Wyckoff's (1984) estimate of the external benefit from educational human capital (for grades K-12, where the marginal external benefits are presumably larger than for higher education) is 9 percent of the private benefit (and is not statistically significant). Moreover, the vast majority of the models of endogenous growth driven by human capital assume constant private returns to scale [some notable exceptions are Lucas (1988), Mulligan and Sala-i-Martin (1993), and Barro and Sala-i-Martin (1995)].

Following standard practice, human capital is defined such that it linearly increases labor productivity and hence the wage rate, w:[6]

(1) $w = rH,$

where r is the rental rate on human capital, H. Human capital accumulation is assumed to be governed by the production function

(2) $dH_t/dt = N x_t^{"} y_t^{(} H_t^{*},$

where t is the time instant, x is time invested in human capital, y is goods (i.e., the services from teachers, physical capital, etc.) invested in human capital, N is a productivity parameter (i.e., learning ability), and ", (, and * are returns elasticities.[7] If an interior solution is imposed (which is not necessary in this analysis), then there must be decreasing returns to x and y together (i.e., " + (< 1). But this does not restrict the returns to the inputs that can be accumulated (i.e., (+ *), which is what matters for endogenous growth.

Following Haley (1976), the first-order conditions for optimal production can be used to substitute y out of the production function. In particular, equation (2) becomes

(3) $dH_t/dt = M x_t^{"+(} H_t^{(+*},$

where M / N((r/"p)$^{(}$, and p is the price of y.

The only decent data on the inputs into individuals' human

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[6]Blinder and Weiss (1976) and Rosen (1976) use an alternative, but essentially equivalent, definition: human capital is produced linearly but is non-linearly related to productivity.

[7]Depreciation of human capital does not affect any of the subsequent analysis, hence it is ignored.

capital production are years of school, thus the focus here is on human capital from education. If each year of full-time schooling is assumed to take an equal input of time, then x is constant during schooling and the production function can be further simplified. In particular, setting this constant to unity, without loss of generality, makes the human capital production function

$$\text{(4)} \qquad dH_t/dt = MH_t^F \quad \text{for } 0 < t \text{ \# } S,$$

where F / (+ * (the returns elasticity to the inputs that can be accumulated), and S is cumulative years of schooling.

Differential equation (4) is a Bernoulli equation with constant coefficients. The solution to this equation at the end of schooling is

$$\text{(5)} \qquad H_S = \begin{cases} H_0 e^{MS} & \text{if } F = 1, \\ (H_0^{1-F} + (1-F)MS)^{1/(1-F)} & \text{if } F \ldots 1, \end{cases}$$

where H_0 is the human capital stock prior to schooling. Substituting equation (5) into equation (1) and taking the logarithm yields

$$\text{(6)} \qquad \ln(w) = \begin{cases} \ln(r) + \ln(H_0) + MS & \text{if } F = 1, \\ \ln(r) + (1-F)^{-1}\ln(H_0^{1-F} + (1-F)MS) & \text{if } F \ldots 1. \end{cases}$$

Ideally the F could be estimated from non-linear equation (6), but this is not feasible. The data are insufficient to identify H_0 and M. And, more importantly, the data indicates that F varies substantially with the level of S. An alternative strategy is to test the restriction implied by F = 1. That is, equation (6) shows that the returns to scale in human capital production can be inferred from the empirical relationship between the log of the wage rate and years of schooling. A linear relationship implies that there are constant returns to the inputs which can be accumulated. A concave (convex) empirical relationship between ln(w) and S indicates that there are decreasing (increasing) returns.[8]

The effect of S on ln(w) is typically interpreted as the rate of return to education and has been estimated literally hundreds of times.[9] Thus, the test for non-constant returns to scale is also a test for a non-constant rate of return to education. In other words, the simple model above suggests that an observed constant (declining, rising) marginal rate of return to education indicates constant (diminishing, increasing) returns in producing human capital through education.

This result is intuitive and fairly obvious once shown. The simple model above, however, clearly shows the assumptions that underlie the conclusion that the returns to scale can be inferred from the observed relationship between years of schooling and its marginal rate of return. Some discussion of some of these assumptions is in order before turning to the evidence.[10]

Schooling is assumed to have a productive role rather than a screening role. Although there is some evidence in favor of screening, the issue has not been settled[11] and the vast majority of

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[8] $M\ln(w)^2/M^2S = (F-1)M^2(H_0^{1-F}+(1-F)MS)^{-2}$. This term is negative (positive) if $F < 1$ (> 1).

[9] See the surveys by Psacharopoulos (1985,1994).

[10] The following assumptions (plus the assumption that $F = 1$) are also made (usually implicitly) in practically all of the literature on the rate of return to education.

[11] See, for example, Hungerford and Solon (1987), Kroch and Sjoblom (1994), Groot and Oosterbeek (1994), Weiss (1995), Heckman et al. (1995), Jaeger and Page (1996), Park (1999), and Chevalier and

research on schooling assumes that it is indeed productive (i.e., it produces human capital). Moreover, the idea of endogenous growth driven by human capital accumulation can be dismissed immediately if schooling is not socially productive. Thus this complication is not addressed here.

The model above solves for the level of human capital at the completion of formal schooling. Clearly, however, wages will also depend on human capital acquired through on-the-job training. Following the empirical work on the rate of return to education, (potential) work experience polynomials are included as control variables in the regressions. Typically a second-order experience polynomial is used, but Murphy and Welsh (1990) argue that a fourth-order polynomial is more appropriate. A fourth-order polynomial is used here, but the results are essentially unchanged when using a second-order polynomial (and also when including an experience-schooling interaction term along with either a second- or fourth-order polynomial).

The first-order conditions for optimal production were used to substitute goods invested in human capital out of the production function. The assumption of an optimal mix of inputs may seem untenable given that most y is publicly provided. But all that is really required to justify the above simplification is the assumption that y is proportionally related to H, which seems reasonable.

The model also assumes that each year of schooling requires an equal input of time (x = 1 Œ S). Casual evidence suggests that higher levels of schooling require more effort. To the extent that

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Walker (1999).

x increases with S there will be a bias in the data toward increasing returns. On the other hand, however, the data on schooling is typically grade completed, as opposed to years in school. This will create a bias toward decreasing returns to the extent slow learners (ie, those whose grade is less than their years in school) obtain lower levels of S and fast learners (grade greater than their years) obtain higher levels of S.

Finally, the model implicitly assumes that education is uncorrelated with unobservables which independently affect human capital and wages. But, as stressed by Card (1995), this is unlikely. Higher-ability individuals are likely to obtain higher levels of both schooling and wages, other things equal. Thus, Card contends that unaccounted for differences in ability could make concave rate-of-return/schooling relationships for individuals appear linear across individuals. Although not emphasized by Card, the same can be said for more motivated individuals, for individuals attending better schools, and for individuals raised in more nurturing homes. In each case, these unobservables are likely to create a bias in the data towards increasing returns.

Recent work on the rate of return typically attempts to deal with this problem by using "natural experiments" to instrument for education. But, again as stressed by Card (1995), this procedure will generally yield an unbiased estimate of the average marginal rate of return only if underlying rate-of-return function is linear. Instruments for education typically only capture variation at one level of education. Thus, in the present context where nonlinearity is explicitly examined, one would obviously need valid instruments that apply to the entire range of educational outcomes.

Unfortunately, such instruments are not available in the subsequent dataset (and perhaps not in any dataset).

Thus, the linear approximation of the returns to scale derived above is potentially biased, but on balance, if there is a bias in the data, it is almost certainly towards finding increasing returns.

The Data

This study uses data from the International Social Survey Programme (ISSP). The ISSP contains cross-sectional data on individuals in 33 countries (28 of these have data on labor-market outcomes) over the period 1985 through 1995 (most of the countries, however, only participated in a few of the years).

There are several desirable features of the ISSP. It is large. Obviously it provides information for many different countries. Moreover, the countries participating in the ISSP vary in their degree of economic development. Thus there is considerable variation in the data. What is particularly useful for this study is that there is generally more variation in cross-country educational attainment than in one country. The returns to scale are inferred from the curvature of the relationship between ln(w) and S. Clearly variation in S is needed for this.

There are also several problems with the ISSP data. For instance, although the ISSP is designed to provide a high degree of cross-country comparability, there are some data inconsistencies across the participating countries. Thus there are only a minimum of control variables. For example, there is no information on work experience. Thus, as in most rate-of-return literature, potential experience (age - S - 5) is used instead. Obviously potential experience will be particularly dubious for women (because of labor-market interruptions due to having children), thus women are excluded from the sample. Observations with negative potential experience are also dropped from the sample.

Measured schooling is truncated between 10 and 14 in two countries (Great Britain and Northern Ireland). Thus observations from these countries are excluded from the sample. Observations with more than 20 years of measured education are also excluded.

Some of the data on hours of work appears dubious. Those with very low hours of work have very high wages per hour on average, and those with very high hours of work generally have very low wages per hour. Thus, these outliers are excluded from the sample. In particular, only those with weekly hours between 20 and 80 are included. The results, however, are essentially identical if these small number of outliers are included. Similar results are also obtained using monthly earnings instead of wage rates.

Earnings are measured in categories in many of the countries. In these cases measured earnings are category midpoints rather than actual amounts. Obviously this causes measurement error. This should not bias the results, however, except for the fact that the highest category clearly truncates the upper tail of the earnings distribution. To see if this upper truncation affects the results regressions were run excluding the upper category, but the results were not noticeably different. Similarly, the results were essentially the same when excluding all observations of categorical earnings.

Finally, earnings are measured after tax in many of the countries (and in numerous cases it is unclear if earnings are before or after tax). This will obviously bias the estimate of the returns to scale toward decreasing returns to the extent that earnings taxes are progressive. Thus some regressions are run using only the observations of before-tax earnings.

Table 1 gives some summary statistics for sample used. The sample is employed men aged 18 to 65; not self-employed, retired, or currently in school; and without missing information on earnings, hours of work, or years of education.

The Evidence

The basic regression equation to be estimated is

$$(7) \qquad \ln(w_i) = \beta_0 + \beta_1 S_i + \beta_2 S_i^2 + \beta_3 S_i^3 + \boldsymbol{\beta}'_x \mathbf{X}_i + \varepsilon_i,$$

where **X** is a vector of control variables (a fourth-order polynomial of potential experience, and country-year dummies). In the literature on the rate of return to education there is typically only a linear schooling term. The data, however, strongly suggest that a cubic in schooling better describes the relationship between schooling and wages. The estimated marginal rate of return to education, ρ, is

$$(8) \qquad \hat{\rho}(S) = \hat{\beta}_1 + 2\hat{\beta}_2 S + 3\hat{\beta}_3 S^2.$$

And the null hypothesis to be tested is

$$(9) \qquad \partial^2 \ln(w)/\partial S^2 = \partial\hat{\rho}/\partial S = 2\hat{\beta}_2 + 6\hat{\beta}_3 S = 0,$$

that is, are the returns to scale in human capital production constant? If not, $\partial\hat{\rho}/\partial S > 0$ (< 0) indicates increasing (diminishing) returns.

The results of estimating equation (7) on the full sample are summarized at the top of Table 2. The estimated coefficients (and their t values) on the education polynomial are reported along with the implied estimated marginal rate of return and how it changes with the level of schooling (and their t values). The estimated maximum marginal rate of return and where it is reached (i.e., where returns to scale are constant) are also reported.

The coefficient estimates on all three schooling polynomials are highly significant. $\hat{\beta}_2$ is positive, and $\hat{\beta}_3$ is negative. This indicates that at low (high) levels of schooling there are increasing (decreasing) returns to scale in human capital production. This is also illustrated by the estimates of the marginal rate of return at various levels of S. $\hat{\rho}(S)$ is essentially zero for the first several years of education. It then rises at an increasing rate before peaking at about S = 12. Then $\hat{\rho}(S)$ begins to fall at an increasing rate. Moreover, as demonstrated by the estimates of $\partial^2 \ln(w)/\partial S^2$, the nonlinearity is strong and highly significant (away from the gradient peak near S = 12). The estimated change in the rate of return per year of schooling (away from S = 12) is huge relative to the estimates of the rate of return. Thus, constant returns to scale are decisively rejected at low levels of education in favor of increasing returns, and constant returns to scale are decisively rejected at high levels of education in favor of decreasing returns. Evidently the production function for human capital has the cubic shape of the sort that we typically argue is ubiquitous for firms' production functions in ECON 101.

The second set of results in Table 2 are from a fourth-order polynomial on S. The results are little affected by adding the S^4

term. The results, however, are dramatically different when the S^3 term is dropped. The relationship between ln(w) and S appears essentially linear in the quadratic case. To capture the nonlinearity it is essential to include the cubic term. Apparently the distribution of increasing and decreasing returns is roughly symmetric around the constant-returns level. Thus, in the quadratic regression the initial increasing returns are almost exactly offset by the later decreasing returns, hence constant returns are shown.[12] This is also revealed by the quadratic estimates of D(S) being practically identical to the linear estimate of D. Presumably this is why the vast majority of previous estimates of the rate of return are linear. A first-pass test for nonlinearity will not detect it.

Other than this dramatic sensitivity to adding the cubic term on schooling, the results are very robust. To show this robustness a few additional regressions are reported in Table 3. In particular, a cubic shape also emerges when using monthly earnings rather than wage rates. It also emerges when using only the wage observations which are known to be before tax (and similar results emerge when excluding only the observations known to be after tax). Thus the finding of a cubic shape is not due to the tax structure. The cubic shape also emerges when using only the observations of actual earnings (i.e., the observations with earnings measured in categories are dropped). Hence, this source of measurement error in the wage rate does not appear to bias the coefficient estimates.

The regressions reported in Table 4 illustrate the importance

[12]Similarly, Box-Cox estimates of the relationship between w and S are extremely close to log-linearity (thus strongly suggesting near constant returns).

of both tails of the schooling distribution. Card and Krueger (1992) contend that there is a kink in an otherwise linear relationship between log earnings and education at the education level obtained by the second percentile of the education distribution (in 1980 U.S. data). Thus, following Card and Krueger, the bottom two percent of the sample ($S \leq 6$) is removed in the regression reported at the top of Table 4. But contrary to Card and Krueger's contention, the nonlinearity in the relationship remains. The nonlinearity also remains when removing the top tail of the education distribution ($S \geq 19$ is the top 2.85 percent). These two cases show that there is significant nonlinearity at both ends of the education distribution. In other words, there are significant increasing returns at low S, and significant diminishing returns at high S. In fact, there is remarkable symmetry in the returns to scale. This is further illustrated by the quadratic regressions on the distributions above and below the approximate constant-returns point at S = 12.

The nonlinearity between ln(w) and S is not completely driven by the tails of the education distribution, however. The last set of estimates in Table 4 show that when both tails are ignored, the nonlinearity remains. The nonlinearity is reduced somewhat, but is still statistically significant.

The results of estimating equation (7) on the country subsamples are summarized in Tables 5.1 - 5.4. The same sort of cubic shape emerges in the vast majority of cases. That is, the coefficient estimate on S^2 is positive and the coefficient estimate on S^3 is negative in 23 of the 26 cases (and statistically significant in 10 cases). Moreover, the three opposite cases arise in countries with small samples, and none of the three negative β_2

and the three positive β_3 are close to being statistically significant. The results for countries with the four largest samples all show statistically significant increasing (decreasing) returns at low (high) S.

Moreover, there is considerable similarity in the coefficient estimates across countries, particularly those with larger sample sizes. The similarity across countries in the estimated schooling levels where constant returns are reached is even more remarkable. For example, in the 13 largest samples (which all have the same signs for β_2 and β_3), the estimated constant-returns levels range between 10.75 and 13.56 years of education (roughly the same amount of variation as in mean education across countries). Moreover, there does not appear to be systematic relationship between and the mean S or national income. This suggests that increases in physical capital do not raise the productivity in human capital production enough to offset the diminishing returns.

Perhaps the more interesting source of variation in results across countries is in $\hat{\rho}(S)$. There is considerable variation in the estimated rate of return to education across countries. In other words, there is more cross-country variation in the level of $\hat{\rho}(S)$ than in the shape of $\hat{\rho}(S)$.

Table 6 reports the results of regressing ln(w) against a set of dummy variables for each level of schooling. As found in several previous studies,[13] there is large amount of variation in the estimated marginal rate of return for each year of schooling ($\hat{\beta}_S$ -

[13]See Hungerford and Solon (1987), Card and Krueger (1992), Jaeger and Page (1996), Harmon and Walker (1999), and Chevalier and Walker (1999).

$\$_{S-1}$). Not surprisingly, these dummy-variable results are consistent with the results from the cubic regression. Figure 1 plots the estimated (log) wage differential from the dummy-variable regression along with that from the cubic regression. This figure illustrates the estimated cubic shape of the human capital production function. Figure 2 plots the estimated marginal rate of return from the dummy-variable regression along with that from the cubic regression. There is essentially no return to investment in education for at least the first six years of school.[14] Evidently, the initial increasing returns (i.e., fixed costs) in human capital production are substantial. And other than the upward blip at S = 16, there is generally a downward trend in the marginal rate of return after S = 12.[15]

Conclusion

This study derived and estimated a very simple test for constant returns to scale in human capital production, a crucial assumption in dozens of recent papers on endogenous growth. The empirical evidence is decidedly against this assumption. There is evidence of significant decreasing returns after about the mean level of educational attainment.

The test for constant returns - a linear relationship between the log of the wage rate and years of education - is admittedly simplistic. The test is based a number of simplifying assumptions,

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[14]As found in Card and Krueger's (1992) data, there is a notable kink in the rate-of-return relationship at the second percentile of the education distribution (of male workers).

[15]The blip at S = 16 has been found in previous studies and has often be attributed to a "sheepskin effects".

hence there are a number of potential biases. On the other hand, however, the empirical evidence is arguably overwhelming. The evidence is so strong against constant returns that it is difficult to imagine that it could be due to the potential biases. Moreover, the possible biases generally work against finding diminishing returns.

Thus, it is hard to escape the conclusion that the micro-level evidence is unfavorable for models of endogenous growth driven by human capital accumulation. This, of course, does not imply that human capital is unimportant for growth. Indeed, the finding of significant initial increasing returns suggests that human capital accumulation may have a crucial role in development and transitional growth.

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Table 1
Descriptive Statistics

Country	N	$\bar{S}$	s_S	Tax
All	30607	12.03	3.18	
West Germany	3340	10.45	2.93	after
United States	3231	13.55	2.90	before
Australia	3017	11.65	2.77	before
Norway	2701	12.47	2.90	before
Russia	2453	13.05	3.37	?
Netherlands	2200	12.94	3.49	after
Austria	1892	10.98	2.44	after
Poland	1416	11.02	2.63	after
Italy	1297	11.77	3.81	after
East Germany	1227	10.88	2.87	after
Ireland	1189	11.99	2.95	**
New Zealand	1079	12.63	3.03	before
Japan	851	12.85	2.63	before
Hungary	649	11.45	2.72	after
Sweden	600	11.81	3.39	before
Slovenia	586	11.10	2.75	after
Israel	483	12.69	2.94	?
Czech Republic	462	13.04	2.67	after
Bulgaria	377	11.56	3.03	?
Slovak Republic	368	12.43	2.41	?
Switzerland	305	10.76	3.33	after
Czechoslovakia	301	12.80	2.52	after
Spain	284	10.62	4.28	?
Canada	257	15.01	3.14	?
Philippines	184	9.55	4.06	?
Latvia	154	12.51	3.07	after

N is the number of observations, $\bar{S}$ is mean years of education, s_S is the standard deviation of years of education, and before and after refer to earnings being measured before or after tax. In the cases denoted by ? it is unclear if earnings are before or after tax. In Ireland earnings are before tax in three years and after tax in three years.

Table 2
Full-Sample Regression Results

Cubic:

	$\beta_1 \times 10^2$	$\beta_2 \times 10^3$	$\beta_3 \times 10^4$
	-6.802	11.159	-3.241
	(4.47)	(8.84)	(8.92)

S	$\rho(S)$		$\partial\rho/\partial s$	
6	0.036	(9.06)	0.012	(8.54)
9	0.062	(32.93)	0.006	(7.51)
12	0.070	(45.18)	-0.000	(0.37)
15	0.061	(44.44)	-0.006	(7.50)
18	0.034	(9.00)	-0.012	(8.46)

max $\rho(S)$ = 0.070 @ S = 11.92

Quartic:

	$\beta_1 \times 10^2$	$\beta_2 \times 10^3$	$\beta_3 \times 10^4$	$\beta_4 \times 10^5$
	-0.837	1.631	-3.231	-1.440
	(0.27)	(0.35)	(1.11)	(2.24)

S	$\rho(S)$		$\partial\rho/\partial s$	
6	0.034	(8.17)	0.009	(8.46)
9	0.058	(21.42)	0.007	(3.16)
12	0.071	(44.67)	0.002	(2.22)
15	0.064	(31.43)	-0.007	(1.87)
18	0.029	(6.26)	-0.018	(1.69)

max $\rho(S)$ = 0.071 @ S = 12.71

Quadratic:

	$\beta_1 \times 10^2$	$\beta_2 \times 10^3$
	5.890	0.037
	(10.79)	(0.18)

S	$\rho(S)$	
6	0.059	(19.73)
9	0.060	(31.98)
12	0.060	(57.62)
15	0.060	(43.87)
18	0.060	(24.90)

Linear:

	$\beta_1 \times 10^2$
	5.985
	(60.56)

t statistics are in parentheses. There are unreported controls for a fourth-order polynomial in potential experience, and for each year in each country.

Table 3
Sensitivity Analysis

S	D(S) $\$_3 \times 10^4$		MD/Ms			$\$_1 \times 10^2$	$\$\hat{}_2 \times 10^3$
Earnings:					-6.925	11.317	-3.039
					(4.53)	(8.60)	(8.34)
6	0.034	(8.44)	0.012	(8.64)			
9	0.061	(32.17)	0.006	(8.21)			
12	0.071	(45.65)	0.001	(1.79)			
15	0.065	(47.39)	-0.005	(5.88)			
18	0.043	(11.24)	-0.010	(7.26)			
max D(S) = 0.071 @ S = 12.41							
w before tax: (N=12103)					-13.583	17.692	-4.775
					(5.40)	(8.15)	(7.89)
6	0.025	(3.69)	0.018	(8.17)			
9	0.067	(19.30)	0.010	(7.69)			
12	0.083	(29.82)	0.001	(1.37)			
15	0.073	(31.48)	-0.008	(5.52)			
18	0.037	(5.74)	-0.016	(6.83)			
max D(S) = 0.083 @ S = 12.35							
actual w: (N=13632)					-4.896	10.244	-3.002
					(1.98)	(4.69)	(4.83)
6	0.042	(6.73)	0.010	(4.42)			
9	0.063	(21.55)	0.004	(3.61)			
12	0.067	(28.21)	-0.001	(1.56)			
15	0.056	(22.77)	-0.007	(4.46)			
18	0.028	(3.86)	-0.012	(4.77)			
max D(S) = 0.068 @ S = 11.38							

t statistics are in parentheses. There are unreported controls for a fourth-order polynomial in potential experience, and for each year in each country.

Table 4
Results Over Various Ranges of Education

S	$\rho(S)$		$\partial\rho/\partial S$		$\beta_1 \times 10^2$	$\hat{\beta}_2 \times 10^3$	$\beta_3 \times 10^4$
$S \geq 7$: (N=29999)					-12.086	15.616	-4.223
					(3.10)	(5.16)	(5.58)
6	0.021	(1.88)	0.016	(4.79)			
9	0.058	(16.14)	0.008	(4.18)			
12	0.071	(40.01)	0.001	(1.03)			
15	0.063	(36.33)	-0.007	(7.02)			
18	0.031	(6.90)	-0.014	(6.47)			
max $\rho(S)$ = 0.072 @ S = 12.33							
$S \leq 18$: (N=29735)					-4.923	9.456	-2.512
					(2.83)	(5.87)	(5.24)
6	0.037	(9.23)	0.010	(6.40)			
9	0.060	(28.91)	0.005	(6.87)			
12	0.069	(41.67)	0.001	(1.46)			
15	0.065	(32.84)	-0.004	(2.98)			
18	0.047	(7.41)	-0.008	(4.00)			
max $\rho(S)$ = 0.069 @ S = 12.55							
$S \geq 12$: (N=16579)					19.801	-4.531	
					(8.47)	(5.90)	
12	0.089	(17.17)					
15	0.062	(34.38)					
18	0.035	(7.45)					
$S \leq 12$: (N=19142)					-3.375	5.362	
					(2.80)	(8.10)	
6	0.031	(6.75)					
9	0.063	(26.97)					
12	0.095	(20.31)					
$7 \leq S \leq 18$: (N=29127)					-5.099	9.593	-2.544
					(0.94)	(2.15)	(2.15)
6	0.037	(2.61)	0.010	(2.14)			
9	0.060	(16.01)	0.005	(2.09)			
12	0.069	(30.32)	0.001	(1.08)			
15	0.065	(32.53)	-0.004	(1.97)			
18	0.047	(4.99)	-0.008	(2.10)			
max $\rho(S)$ = 0.070 @ S = 12.57							

t statistics are in parentheses. There are unreported controls for a fourth-order polynomial in potential experience, and for each year in each country.

Table 5.1
Individual Country Regression Results

S	D(S)		MD/Ms		$\$_1\times10^2$	$\$\hat{}_2\times10^3$	$\$_3\times10^4$
West Germany (N=3340, w after tax)					-7.100	11.524	-3.257
					(1.52)	(2.99)	(3.20)
6	0.032	(2.58)	0.011	(2.76)			
9	0.057	(12.56)	0.005	(2.30)			
12	0.065	(18.09)	-0.000	(0.37)	(max D = 0.065 @ S = 11.79)		
15	0.055	(16.86)	-0.006	(3.38)			
18	0.027	(3.15)	-0.012	(3.44)			
United States (N=3231, w before tax)					-25.788	31.153	-8.379
					(3.28)	(4.48)	(4.92)
6	0.025	(1.16)	0.032	(4.66)			
9	0.099	(10.27)	0.017	(4.23)			
12	0.128	(17.01)	0.002	(1.03)	(max D = 0.128 @ S = 12.39)		
15	0.111	(20.49)	-0.013	(4.18)			
18	0.049	(3.68)	-0.028	(4.78)			
Australia (N=3017, w before tax)					-15.525	20.733	-5.987
					(3.41)	(4.88)	(4.71)
6	0.029	(2.58)	0.020	(4.90)			
9	0.072	(11.12)	0.009	(4.33)			
12	0.084	(16.13)	-0.002	(0.96)	(max D = 0.084 @ S = 11.54)		
15	0.063	(10.86)	-0.012	(3.61)			
18	0.009	(0.52)	-0.023	(4.15)			
Norway (N=2701, w before tax)					-10.026	12.672	-3.764
					(1.65)	(2.63)	(3.03)
6	0.011	(0.64)	0.012	(2.25)			
9	0.036	(5.61)	0.005	(1.61)			
12	0.041	(10.49)	-0.002	(1.25)	(max D = 0.042 @ S = 11.22)		
15	0.026	(7.30)	-0.009	(4.15)			
18	-0.010	(1.03)	-0.015	(3.78)			
Russia (N=2453)					-7.759	10.322	-2.739
					(0.87)	(1.38)	(1.35)
6	0.017	(0.69)	0.011	(1.38)			
9	0.042	(4.02)	0.006	(1.31)			
12	0.052	(7.16)	0.001	(0.39)	(max D = 0.052 @ S = 12.56)		
15	0.047	(6.85)	-0.004	(0.94)			
18	0.028	(1.34)	-0.009	(1.17)			
Netherlands (N=2108, w after tax)					-0.549	4.028	-0.991
					(0.13)	(1.12)	(1.02)
6	0.032	(2.89)	0.004	(1.19)			
9	0.042	(8.35)	0.003	(1.26)			
12	0.048	(10.60)	0.001	(0.88)	(max D = 0.049 @ S = 13.56)		
15	0.048	(13.87)	-0.001	(0.45)			
18	0.043	(5.14)	-0.003	(0.75)			
Austria (N=1730, w after tax)					-5.956	11.243	-3.219
					(0.54)	(1.28)	(1.42)
6	0.041	(1.37)	0.011	(1.15)			
9	0.065	(7.07)	0.005	(0.91)			
12	0.071	(11.38)	-0.001	(0.30)	(max D = 0.071 @ S = 11.64)		
15	0.060	(9.02)	-0.006	(1.82)			
18	0.032	(1.87)	-0.012	(1.69)			

t statistics are in parentheses. There are unreported controls for a fourth-order polynomial in potential experience, and for each year.

Table 5.2
Individual Country Regression Results

S	$\rho(S)$		$\partial\rho/\partial s$		$\beta_1\times10^2$	$\hat{\beta}_2\times10^3$	$\beta_3\times10^4$
Poland (N=1416, w after tax)					-11.817	18.213	-5.345
					(0.79)	(1.37)	(1.41)
6	0.043	(1.29)	0.017	(1.31)			
9	0.080	(8.38)	0.008	(1.16)			
12	0.088	(10.02)	-0.002	(0.75)	(max ρ = 0.089 @ S = 11.36)		
15	0.067	(6.73)	-0.012	(1.44)			
18	0.018	(0.44)	-0.021	(1.44)			
Italy (N=1297, w after tax)					-5.691	10.692	-3.316
					(0.77)	(1.71)	(2.00)
6	0.036	(1.97)	0.009	(1.43)			
9	0.055	(9.10)	0.003	(0.93)			
12	0.056	(8.37)	-0.002	(1.68)	(max ρ = 0.058 @ S = 10.75)		
15	0.040	(7.01)	-0.008	(2.97)			
18	0.006	(0.46)	-0.014	(2.56)			
East Germany (N=1227, w after tax)					-18.074	17.876	-4.765
					(1.25)	(1.54)	(1.59)
6	-0.018	(0.45)	0.019	(1.49)			
9	0.025	(2.17)	0.010	(1.39)			
12	0.042	(6.65)	0.001	(0.55)	(max ρ = 0.043 @ S = 12.50)		
15	0.034	(5.69)	-0.007	(1.58)			
18	-0.000	(0.00)	-0.016	(1.63)			
Ireland (N=1147)					-1.206	10.414	-2.905
					(0.12)	(1.20)	(1.24)
6	0.082	(2.83)	0.010	(1.14)			
9	0.105	(8.91)	0.005	(0.98)			
12	0.112	(14.19)	-0.000	(0.00)	(max ρ = 0.112 @ S = 11.95)		
15	0.104	(12.64)	-0.005	(1.09)			
18	0.081	(3.32)	-0.011	(1.21)			
New Zealand (N=1079, w before tax)					-13.131	14.662	-3.640
					(3.02)	(3.45)	(2.85)
6	0.005	(0.49)	0.016	(4.01)			
9	0.044	(5.21)	0.010	(4.68)			
12	0.063	(8.44)	0.003	(1.86)	(max ρ = 0.066 @ S = 13.43)		
15	0.063	(11.21)	-0.003	(0.99)			
18	0.043	(2.73)	-0.010	(1.77)			
Japan (N=851, w before tax)					-55.739	55.386	-1.502
					(1.84)	(2.31)	(2.43)
6	-0.055	(0.65)	0.057	(2.20)			
9	0.075	(2.73)	0.030	(1.98)			
12	0.123	(10.45)	0.003	(0.49)	(max ρ = 0.124 @ S = 12.30)		
15	0.091	(9.26)	-0.024	(2.69)			
18	-0.023	(0.51)	-0.051	(2.63)			
Hungary (N=649, w after tax)					21.767	-13.770	4.343
					(1.17)	(0.87)	(1.01)
6	0.099	(2.18)	-0.012	(0.73)			
9	0.075	(5.58)	-0.004	(0.46)			
12	0.075	(6.44)	0.004	(1.10)	(min ρ = 0.072 @ S = 10.57)		
15	0.098	(8.67)	0.012	(1.45)			
18	0.144	(3.65)	0.019	(1.26)			

t statistics are in parentheses. There are unreported controls for a fourth-order polynomial in potential experience, and for each year.

Table 5.3
Individual Country Regression Results

S	Đ(S)		MĐ/Ms		$\$_1\times10^2$	$\hat{\$}_2\times10^3$	$\$_3\times10^4$
Sweden (N=600, w before tax)					-3.994	8.217	-2.496
					(0.92)	(2.01)	(2.05)
6	0.032	(3.01)	0.007	(1.89)			
9	0.047	(6.91)	0.003	(1.45)			
12	0.049	(8.42)	-0.002	(0.98)	(max Đ = 0.005 @ S = 10.97)		
15	0.038	(7.24)	-0.006	(1.88)			
18	0.013	(0.86)	-0.011	(2.00)			
Slovenia (N=586, w after tax)					-34.558	36.657	-9.571
					(2.71)	(2.95)	(2.51)
6	-0.009	(0.39)	0.039	(3.42)			
9	0.081	(6.87)	0.022	(4.19)			
12	0.120	(10.54)	0.004	(1.01)	(max Đ = 0.122 @ S = 12.76)		
15	0.108	(6.01)	-0.012	(1.25)			
18	0.043	(0.79)	-0.030	(1.78)			
Israel (N=483)					-26.324	30.432	-8.351
					(3.30)	(4.21)	(4.01)
6	0.012	(0.56)	0.031	(4.28)			
9	0.082	(6.29)	0.016	(4.04)			
12	0.106	(9.79)	0.001	(0.28)	(max Đ = 0.106 @ S = 12.15)		
15	0.086	(10.45)	-0.014	(2.77)			
18	0.021	(0.88)	-0.029	(3.39)			
Czech Republic (N=462, w after tax)					-6.289	9.250	-2.537
					(0.46)	(0.84)	(0.87)
6	0.021	(0.53)	0.009	(0.80)			
9	0.042	(2.37)	0.005	(0.70)			
12	0.050	(4.15)	0.002	(0.00)	(max Đ = 0.050 @ S = 12.16)		
15	0.043	(5.56)	-0.004	(0.77)			
18	0.024	(0.96)	-0.009	(0.87)			
Bulgaria (N=377)					-4.929	8.281	-2.182
					(0.66)	(1.11)	(0.93)
6	0.027	(1.38)	0.009	(1.27)			
9	0.047	(3.11)	0.005	(1.35)			
12	0.055	(4.48)	0.001	(0.22)	(max Đ = 0.055 @ S = 12.65)		
15	0.052	(3.90)	-0.003	(0.44)			
18	0.037	(1.02)	-0.007	(0.63)			
Slovak Republic (N=368)					4.467	0.986	-0.452
					(0.18)	(0.05)	(0.09)
6	0.052	(0.77)	0.000	(0.00)			
9	0.051	(2.41)	-0.000	(0.00)			
12	0.049	(3.61)	-0.001	(0.28)	(max Đ = 0.052 @ S = 7.26)		
15	0.044	(4.45)	-0.002	(0.28)			
18	0.036	(1.05)	-0.003	(0.05)			
Switzerland (N= 305, w after tax)					20.296	-8.443	1.783
					(2.09)	(0.96)	(0.69)
6	0.121	(4.70)	-0.010	(1.20)			
9	0.094	(6.24)	-0.007	(1.52)			
12	0.077	(6.51)	-0.004	(1.13)	(min Đ = 0.070 @ S = 15.78)		
15	0.070	(6.17)	-0.001	(0.14)			
18	0.072	(2.21)	0.002	(0.22)			

t statistics are in parentheses. There are unreported controls for a fourth-order polynomial in potential experience, and for each year.

Table 5.4
Individual Country Regression Results

S	D(S)		MD/Ms		$1×10^2	$^2×10^3	$3×10^4
<u>Czechoslovakia</u> (N=301, w after tax)					-15.125	8.889	-0.965
					(0.50)	(0.38)	(0.16)
6	-0.055	(0.63)	0.014	(0.55)			
9	-0.015	(0.48)	0.013	(0.81)			
12	0.020	(1.22)	0.011	(1.72)	(max D = 0.122 @ S = 30.70)		
15	0.050	(4.05)	0.009	(1.09)			
18	0.075	(2.02)	0.007	(0.40)			
<u>Spain</u> (N=284)					3.204	2.194	-0.469
					(0.65)	(0.67)	(0.29)
6	0.053	(4.33)	0.003	(0.57)			
9	0.060	(5.50)	0.002	(0.79)			
12	0.064	(6.75)	0.001	(0.40)	(max D = 0.066 @ S = 15.58)		
15	0.066	(7.04)	0.000	(0.00)			
18	0.065	(2.68)	-0.001	(0.10)			
<u>Canada</u> (N=257)					-6.962	6.456	-0.868
					(0.33)	(0.38)	(0.20)
6	-0.002	(0.00)	0.010	(0.53)			
9	0.026	(1.12)	0.008	(0.75)			
12	0.048	(2.49)	0.007	(1.46)	(max D = 0.090 @ S = 24.80)		
15	0.065	(4.71)	0.005	(0.77)			
18	0.078	(3.17)	0.004	(0.26)			
<u>Philippines</u> (N=184)					-4.263	12.637	-2.235
					(0.24)	(0.61)	(0.30)
6	0.085	(3.02)	0.017	(1.10)			
9	0.131	(4.42)	0.013	(1.91)			
12	0.164	(6.63)	0.009	(0.63)	(max D = 0.196 @ S = 18.85)		
15	0.186	(2.78)	0.005	(0.20)			
18	0.195	(1.19)	0.001	(0.00)			
<u>Latvia</u> (N=154, w after tax)					61.064	-40.655	9.880
					(0.96)	(0.85)	(0.84)
6	0.229	(1.20)	-0.046	(0.85)			
9	0.119	(1.73)	-0.028	(0.84)			
12	0.062	(1.95)	-0.010	(0.69)	(min D = 0.053 @ S = 13.72)		
15	0.058	(1.93)	0.008	(0.52)			
18	0.107	(1.63)	0.025	(0.76)			

t statistics are in parentheses. There are unreported controls for a fourth-order polynomial in potential experience, and for each year.

Table 6

Dummy-Variable Regression Results

S	β_S		$\beta_S-\beta_{S-1}$	
1	-.0267	(1.73)	-0.267	(1.73)
2	0.147	(1.02)	0.415	(2.72)
3	-0.074	(0.60)	-0.221	(1.83)
4	0.004	(0.03)	0.078	(0.93)
5	0.028	(0.25)	0.024	(0.39)
6	-0.031	(0.29)	-0.059	(1.23)
7	0.055	(0.52)	0.086	(2.28)
8	0.010	(0.96)	0.045	(1.89)
9	0.015	(1.48)	0.054	(4.03)
10	0.233	(2.24)	0.079	(6.28)
11	0.285	(2.74)	0.052	(4.50)
12	0.357	(3.43)	0.071	(6.45)
13	0.438	(4.19)	0.081	(6.95)
14	0.469	(4.48)	0.031	(2.09)
15	0.530	(5.07)	0.061	(3.76)
16	0.667	(6.39)	0.138	(9.03)
17	0.675	(6.43)	0.007	(0.44)
18	0.716	(6.81)	0.041	(1.98)
19	0.691	(6.48)	-0.025	(0.88)
20	0.736	(6.93)	0.045	(1.39)

t statistics are in parentheses. There are unreported controls for a fourth-order polynomial in potential experience, and for each year in each country.

Figure 1

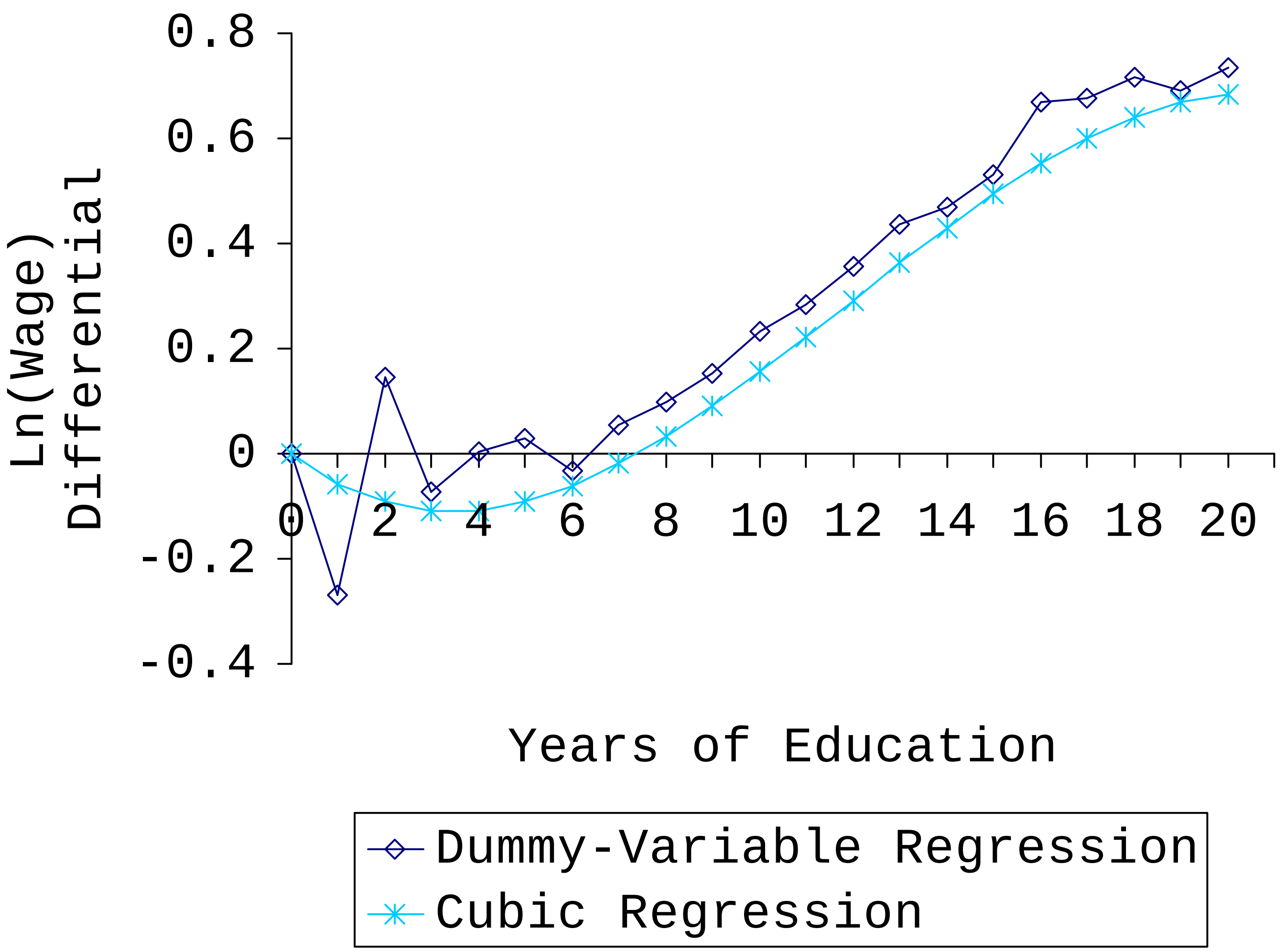
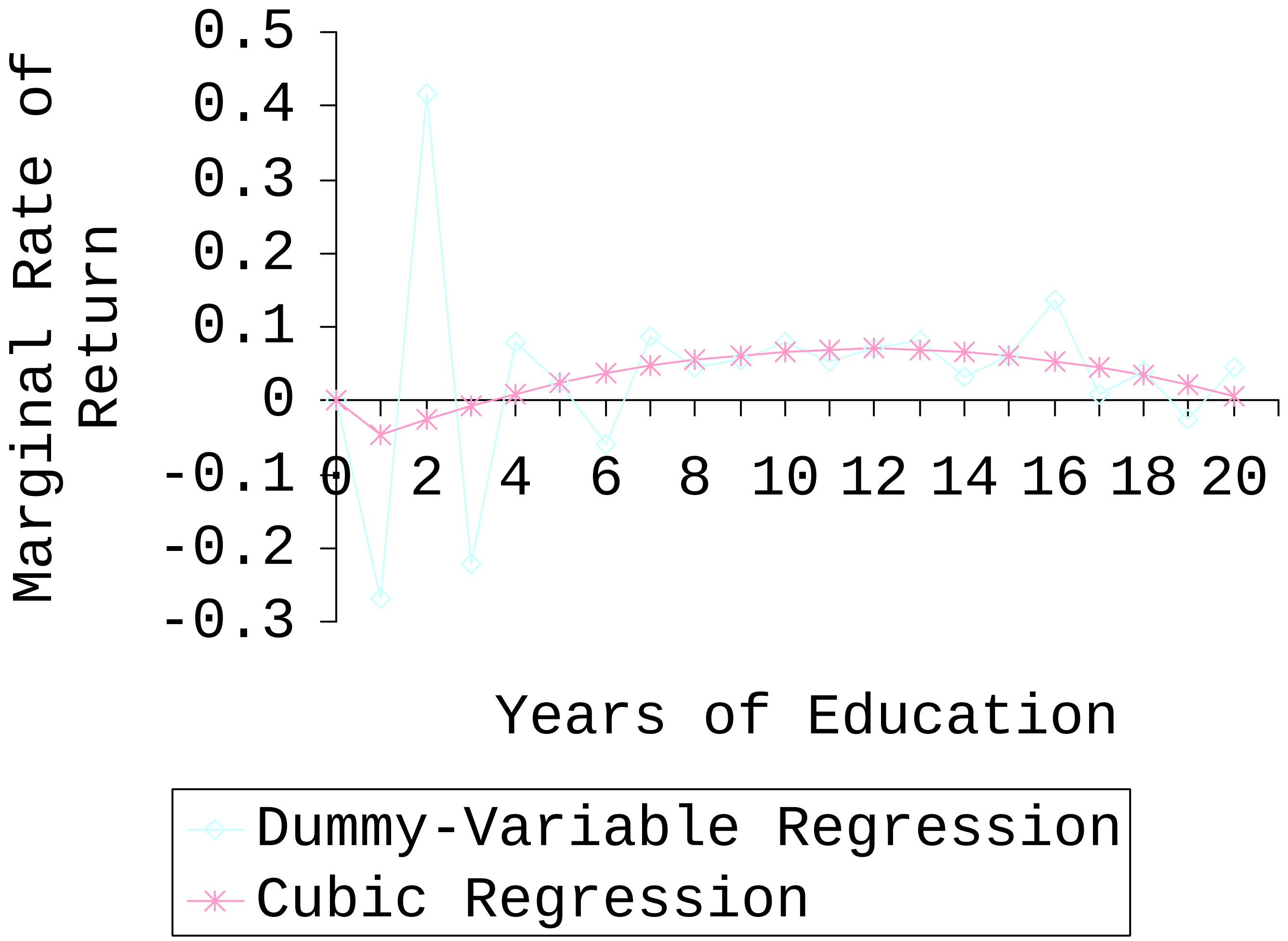

0.8
0.6
0.4
0.2
0
-0.2
-0.4
Ln(Wage) Differential
0
2
4
6
8
10
12
14
16
18
20
Years of Education
Dummy-Variable Regression
Cubic Regression

Figure 2



Marginal Rate of Return
0.5
0.4
0.3
0.2
0.1
0
-0.1
-0.2
-0.3
0
2
4
6
8
10
12
14
16
18
20
Years of Education
Dummy-Variable Regression
Cubic Regression