# Returns to Education

Philipp Eisenhauer

*Housekeeping*

## Lecture Material

- constantly updated and available at

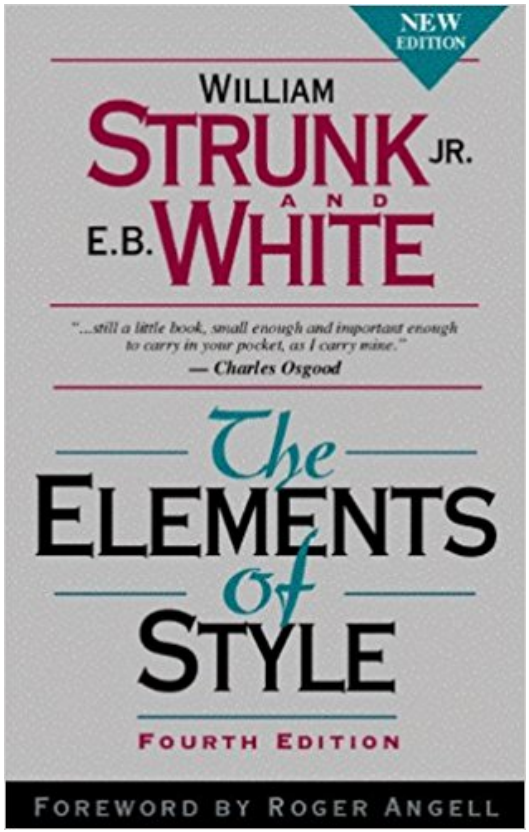
  https://github.com/policyMetrics/talks

- for additional material be sure to check out

  https://github.com/policyMetrics/course/wiki

There will be no lecture on the 16th of November, all lectures will simply be postponed by one week.

Figure: Book Recommendations



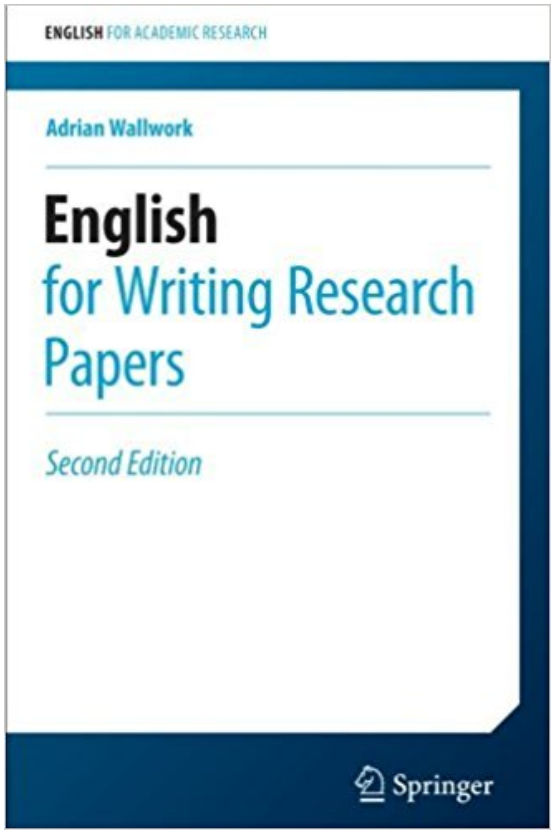
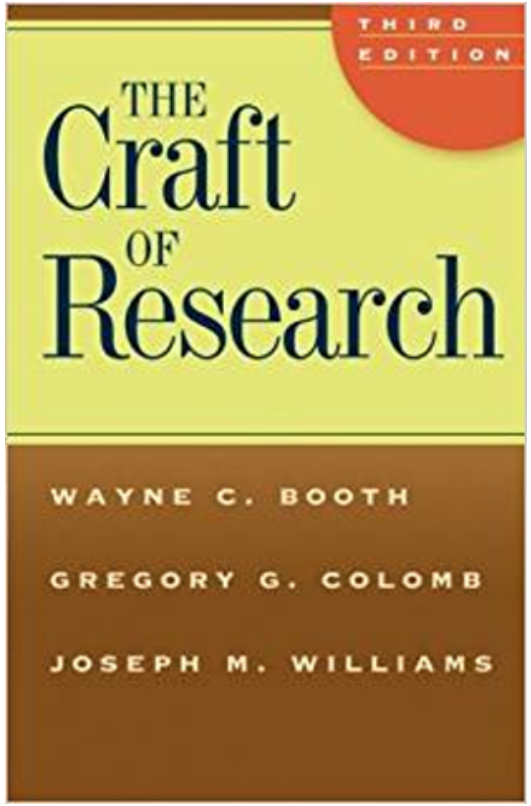



Figure: Book Recommendations

# Returns to Education

Philipp Eisenhauer

I heavily draw on the material presented in:

- Heckman, J. J., Lochner, L. J., and Todd, P. E. (2006a). Earnings functions, rates of return and treatment effects: The mincer equation and beyond. In Hanushek, E. A. and Welch, F., editors, *Handbook of the Economics of Education*, volume 1, pages 307–458. North-Holland Publishing Company

We will look at two papers that explore reduced-form estimations of the returns to education .

- Carneiro, P. and Heckman, J. J. (2002). The evidence on credit constraints in post-secondary schooling. *The Economic Journal*, 112(482):705–734
- Bhuller, M., Mogstad, M., and Salvanes, K. G. (2017). Life cycle earnings, education premiums and internal rates of return. *Journal of Labor Economics*, 35(4):993–1030

We will look at two papers that explore structural estimations of the returns to education .

- Cunha, F., Heckman, J. J., and Navarro, S. (2005). Separating uncertainty from heterogeneity in life cycle earnings. *Oxford Economic Papers*, 57(2):191–261
- Eisenhauer, P., Heckman, J. J., and Mosso, S. (2015). Estimation of dynamic discrete choice models by maximum likelihood and the simulated method of moments. *International Economic Review*, 56(2):331–357

Why are returns to education important?

- help explain wage inequality
- judge relative profitability of investment in education?
- ...

## Mincer Equation

$$\ln Y(s, x) = \alpha + \rho_s s + \beta_0 x + \beta_1 x^2 + \epsilon$$

$\Rightarrow$ How to interpret the *Mincer Coefficient* $\rho_s$?

## Conceptual Frameworks

- compensating differences model
- accounting-identity model

# *Compensating Differences Model*

$$V(s) = Y(s) \int_s^T e^{-rt} dt = \frac{Y(s)}{r}(e^{-rs} - e^{-rT})$$

Equalizing present value of earnings across schooling levels:

$$\ln Y(s) = \ln Y(0) + rs + \ln\left(\frac{1 - e^{-rs}}{1 - e^{-r(T-s)}}\right)$$

$\Rightarrow \rho_s$ equals the market interest rate and the internal rate of return to schooling by construction.

Model Features:

- identical abilities and opportunities
- no credit constraints
- perfect certainty
- no direct cost of schooling
- no nonpecuniary benefits of school and work

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- identical abilities and opportunities
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- perfect certainty
- no direct cost of schooling
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# *Accounting-Identity Model*

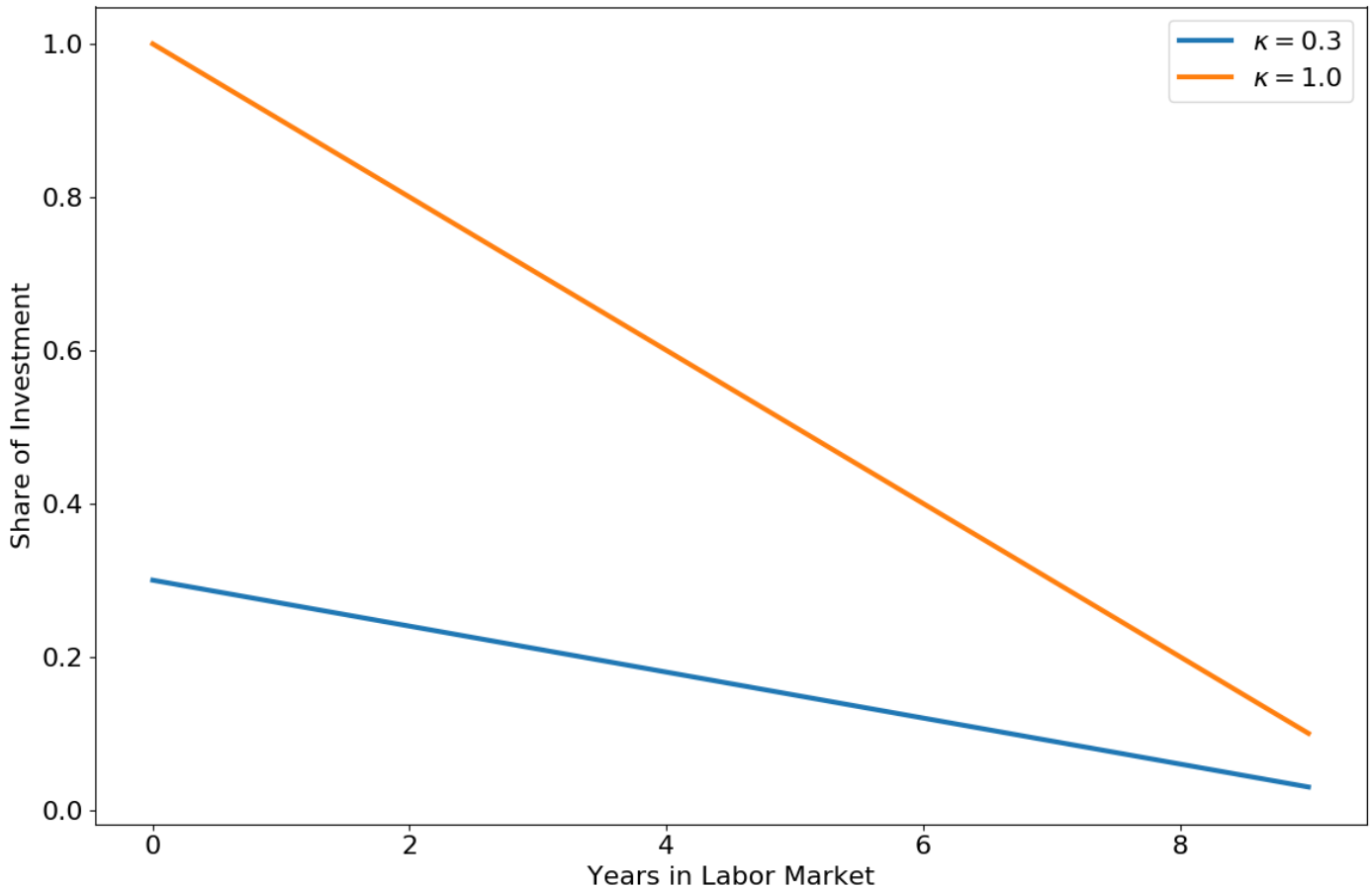
$$P_t \equiv P_{t-1}(1 + k_{t-1}\rho_{t-1}) \equiv \prod_{j=0}^{t-1}(1 + \rho_j k_j)P_0$$

$$\begin{aligned}\ln P_t &\equiv \ln P_0 + s\ln(1 + \rho_s) + \sum_{j=s}^{t-1}\ln(1 + \rho_0 k_j) \\ &\approx \ln P_0 + s\rho_s + \rho_0 \sum_{j=s}^{t-1} k_j\end{aligned}$$

Assuming linearly declining rate of post-school investment:

$$k_{s+x} = \kappa \left(1 - \frac{x}{T}\right), \text{where} \quad x = t - s$$

Figure: Post-School Investment



$$\ln P_{x+s} \approx \ln P_0 + s\rho_s + \left(\rho_0\kappa + \frac{\rho_0\kappa}{2T}\right)x - \frac{\rho_0\kappa}{2T}x^2$$

Accounting for the difference in potential and observed earnings:

$$\begin{aligned}\ln Y(s,x) &= \ln P_{x+s} - \kappa\left(1 - \frac{x}{T}\right) \\ &= [\ln P_0 - \kappa] + \rho_s s + \left(\rho_0\kappa + \frac{\rho_0\kappa}{2T} + \frac{\kappa}{T}\right)x - \frac{\rho_0\kappa}{2T}x^2\end{aligned}$$

$\Rightarrow \rho_s$ is the average earnings increase with schooling

## Standard Mincer Equation

$$\ln Y(s,x) = \alpha + \rho_s s + \beta_0 x + \beta_1 x^2,$$

where

$$\begin{aligned}
\alpha &= \ln P_0 - \kappa \\
\beta_0 &= \left(\rho_0 \kappa + \frac{\rho_0 \kappa}{2T} + \frac{\kappa}{T}\right) \\
\beta_1 &= -\frac{\rho_0 \kappa}{2T}
\end{aligned}$$

## Random Coefficient Version

$$\ln Y(s_i, x_i) = \alpha_i + \rho_{si} s_i + \beta_{0i} x_i + \beta_{1i} x_i^2$$

and let

$$\bar{\alpha} = \mathrm{E}[\alpha_i] \qquad \bar{\rho}_s = \mathrm{E}[\rho_{si}]$$
$$\bar{\beta}_0 = \mathrm{E}[\beta_{0i}] \qquad \bar{\beta}_1 = \mathrm{E}[\beta_{1i}]$$

Dropping individual subscripts ...

$$\ln Y(s,x) = \bar{\alpha} + \bar{\rho}_s s + \bar{\beta}_0 x + \bar{\beta}_1 x^2 + \underbrace{[(\alpha - \bar{\alpha}) + (\rho_s - \bar{\rho}_s)s + (\beta_0 - \bar{\beta}_0)x + (\beta_1 - \bar{\beta}_1)x^2]}_{\epsilon}$$

$\Rightarrow$ If the schooling decision is determined by individual returns, then we are back in the case of a correlated random coefficient model (Heckman et al., 2006b).

Table 2: Estimated Coefficients from Mincer Log Earnings Regression for Men

| | | Whites | | Blacks | |
|---|---|---|---|---|---|
| | | Coefficient | Std. Error | Coefficient | Std. Error |
| 1940 | Intercept | 4.4771 | 0.0096 | 4.6711 | 0.0298 |
| | Education | 0.1250 | 0.0007 | 0.0871 | 0.0022 |
| | Experience | 0.0904 | 0.0005 | 0.0646 | 0.0018 |
| | Experience-Squared | -0.0013 | 0.0000 | -0.0009 | 0.0000 |
| 1950 | Intercept | 5.3120 | 0.0132 | 5.0716 | 0.0409 |
| | Education | 0.1058 | 0.0009 | 0.0998 | 0.0030 |
| | Experience | 0.1074 | 0.0006 | 0.0933 | 0.0023 |
| | Experience-Squared | -0.0017 | 0.0000 | -0.0014 | 0.0000 |
| 1960 | Intercept | 5.6478 | 0.0066 | 5.4107 | 0.0220 |
| | Education | 0.1152 | 0.0005 | 0.1034 | 0.0016 |
| | Experience | 0.1156 | 0.0003 | 0.1035 | 0.0011 |
| | Experience-Squared | -0.0018 | 0.0000 | -0.0016 | 0.0000 |
| 1970 | Intercept | 5.9113 | 0.0045 | 5.8938 | 0.0155 |
| | Education | 0.1179 | 0.0003 | 0.1100 | 0.0012 |
| | Experience | 0.1323 | 0.0002 | 0.1074 | 0.0007 |
| | Experience-Squared | -0.0022 | 0.0000 | -0.0016 | 0.0000 |
| 1980 | Intercept | 6.8913 | 0.0030 | 6.4448 | 0.0120 |
| | Education | 0.1023 | 0.0002 | 0.1176 | 0.0009 |
| | Experience | 0.1255 | 0.0001 | 0.1075 | 0.0005 |
| | Experience-Squared | -0.0022 | 0.0000 | -0.0016 | 0.0000 |
| 1990 | Intercept | 6.8912 | 0.0034 | 6.3474 | 0.0144 |
| | Education | 0.1292 | 0.0002 | 0.1524 | 0.0011 |
| | Experience | 0.1301 | 0.0001 | 0.1109 | 0.0006 |
| | Experience-Squared | -0.0023 | 0.0000 | -0.0017 | 0.0000 |

Notes: Data taken from 1940-90 Decennial Censuses. See Appendix B for data description.

*Implications*

- Log-earnings profiles are parallel across schooling levels.

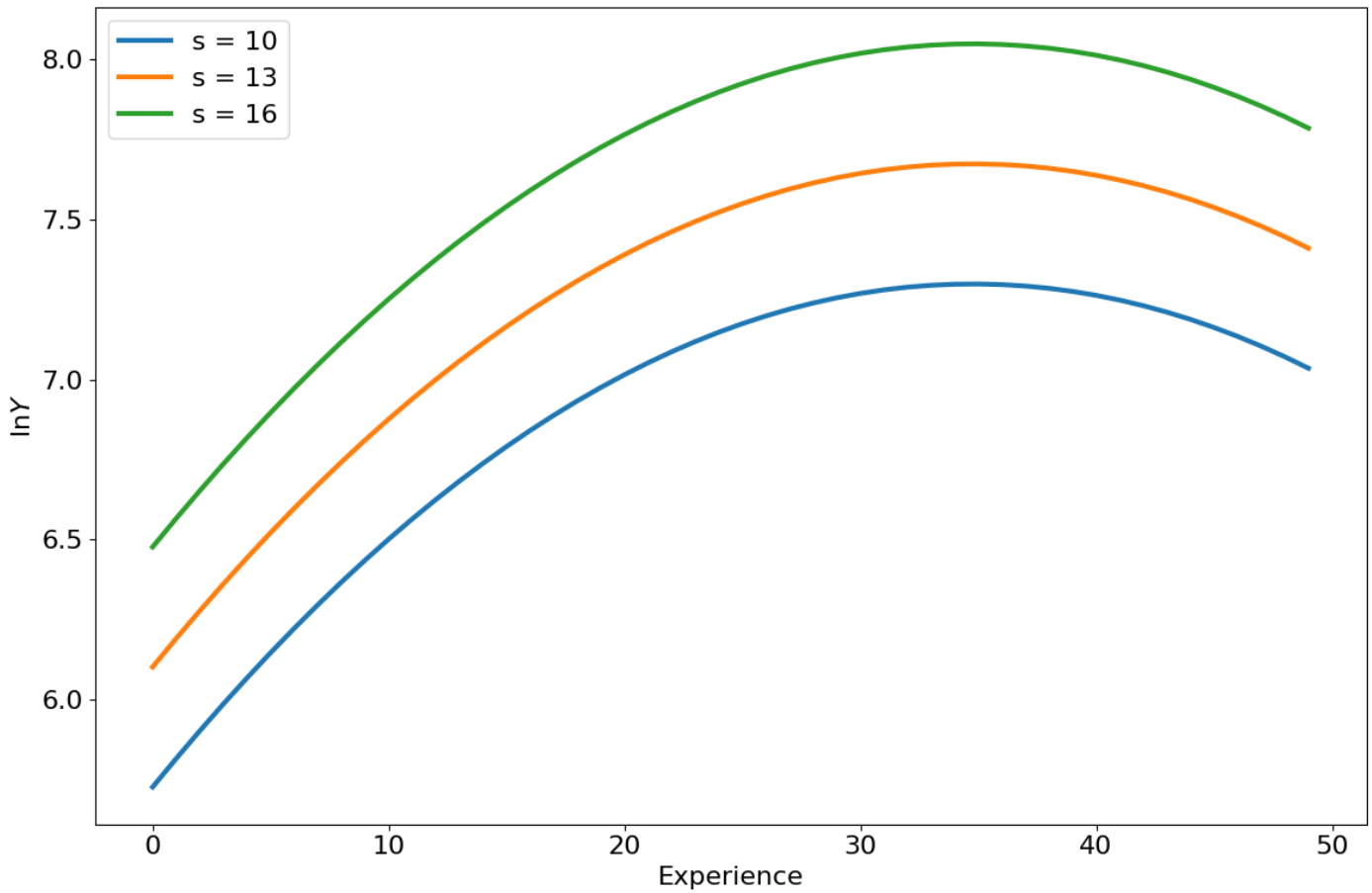
$$\frac{\partial \ln Y(s,x)}{\partial s \partial x} = 0$$

- Log-earnings age profiles diverge with age across schooling levels.

$$\frac{\partial \ln Y(s,x)}{\partial s \partial t} = \frac{\rho_0 \kappa}{T} > 0$$

- The variance of earnings over the life cycle has a U-shaped pattern.

Figure: Mincerian Experience Profiles



## Figure: Mincerian Age Profiles

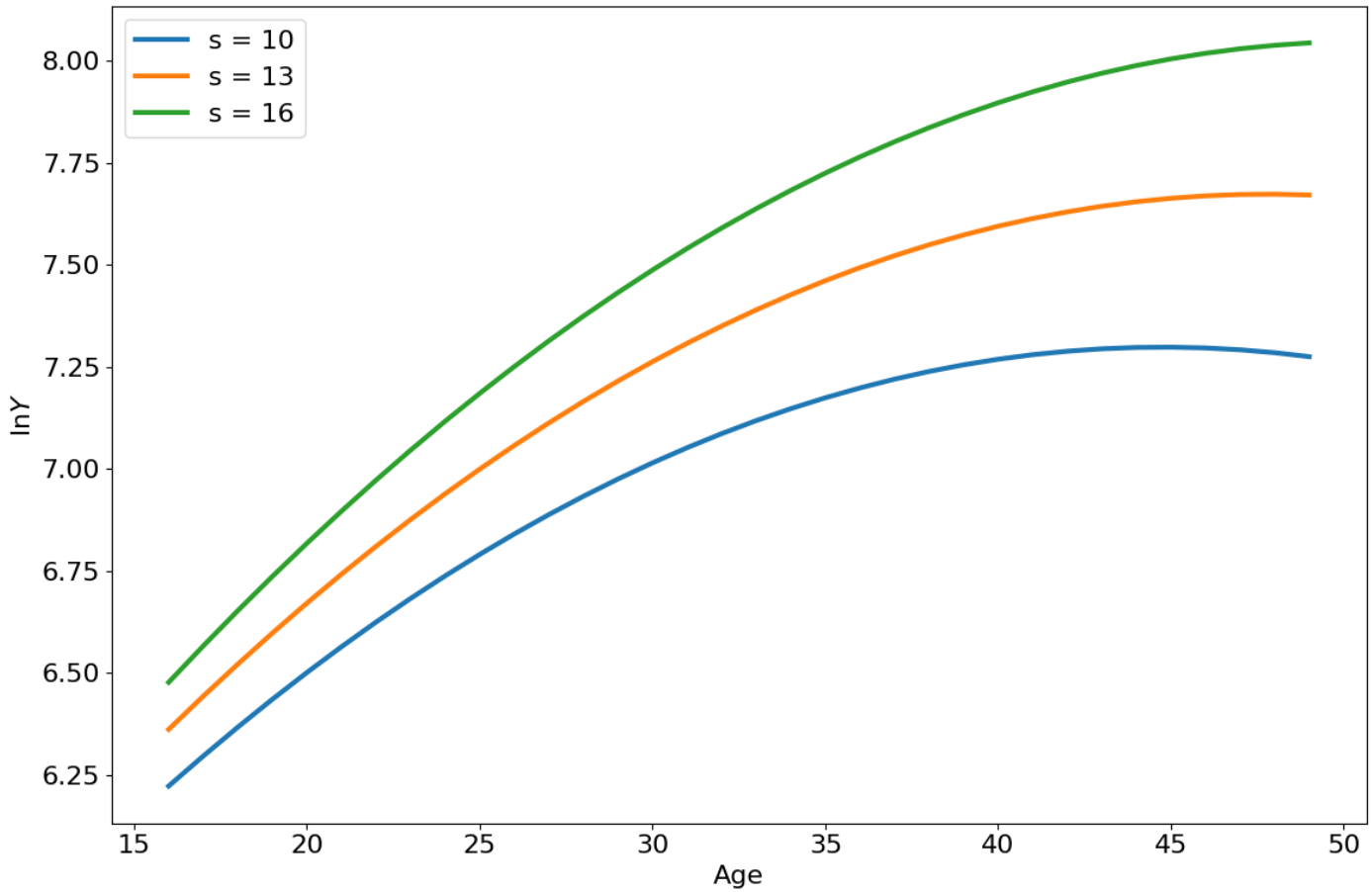
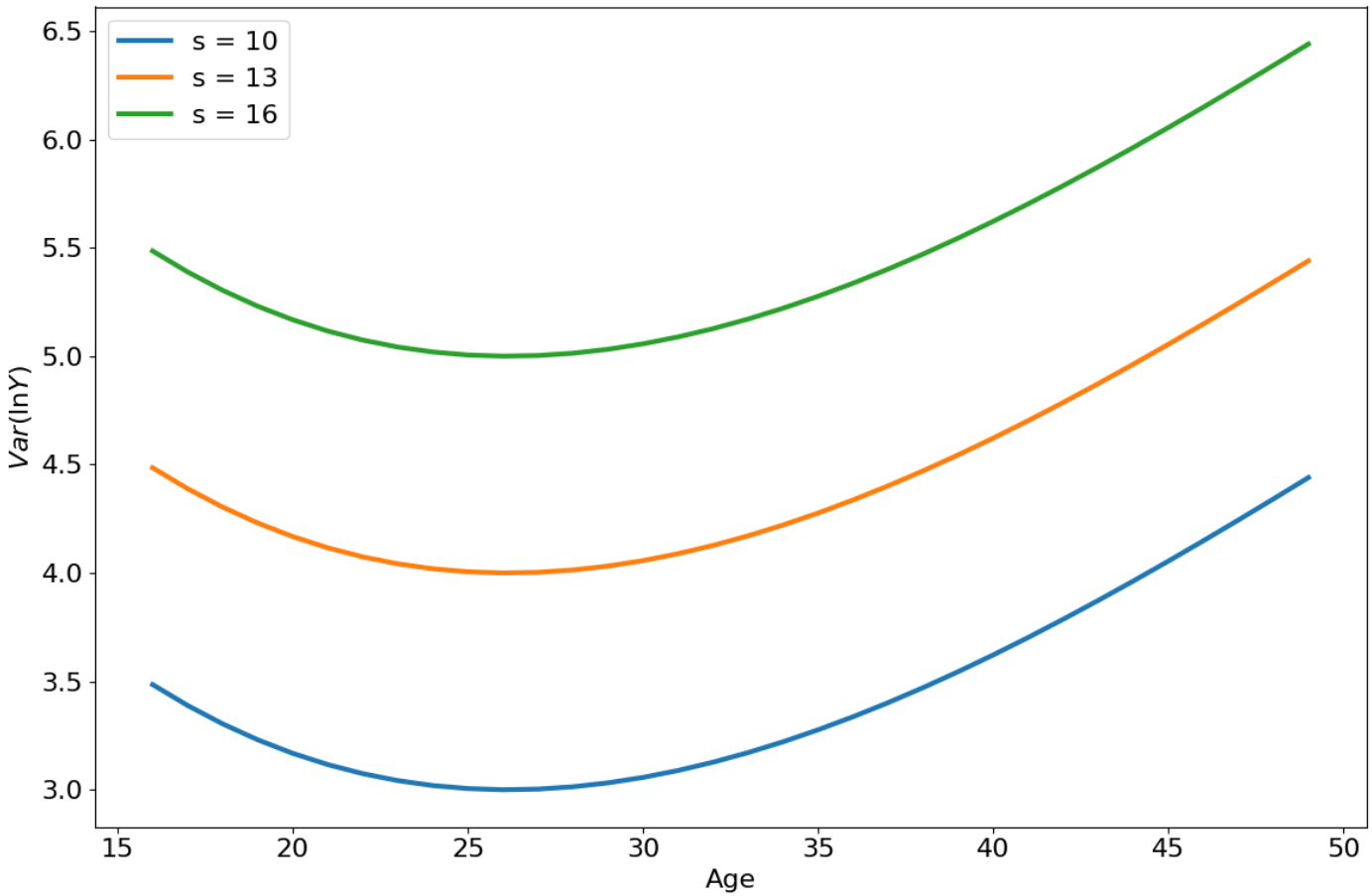
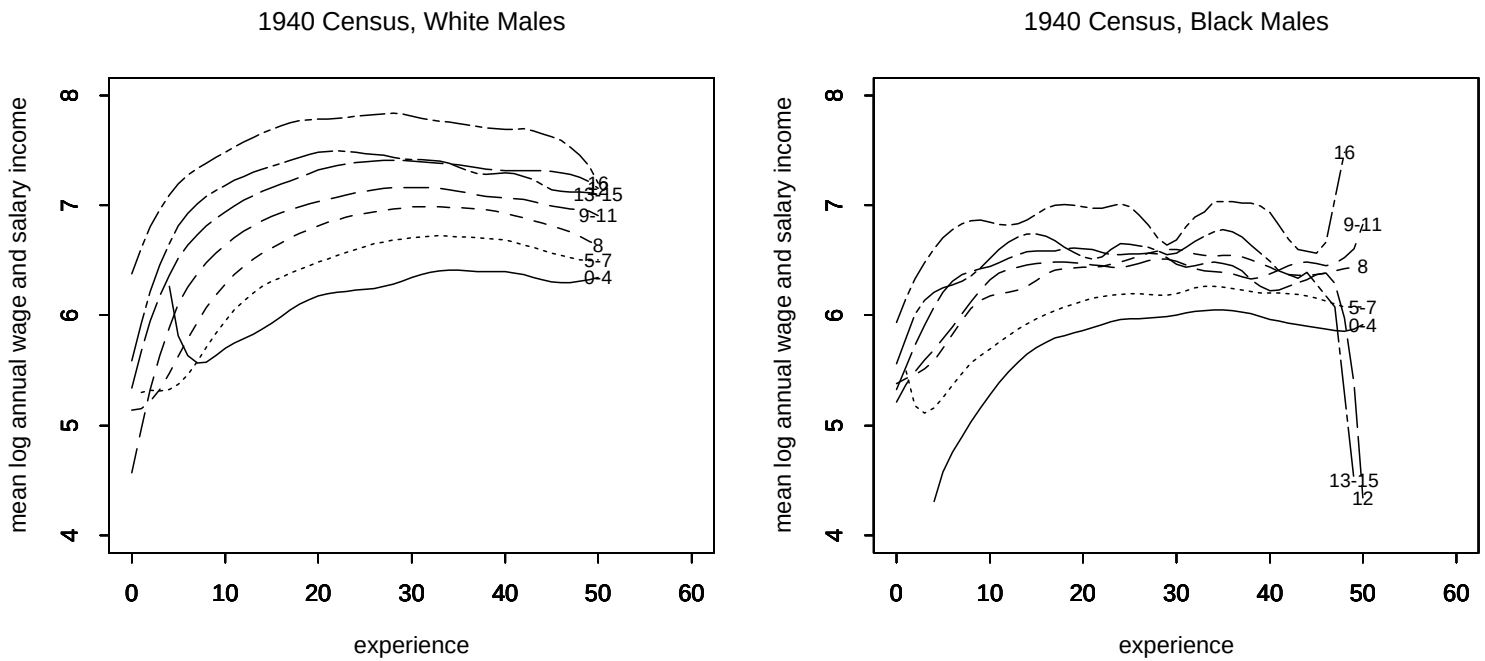


Figure: Mincerian Variance Profiles



# *Empirical Evidence*

Figure 1a: Experience-Earnings Profiles, 1940-1960



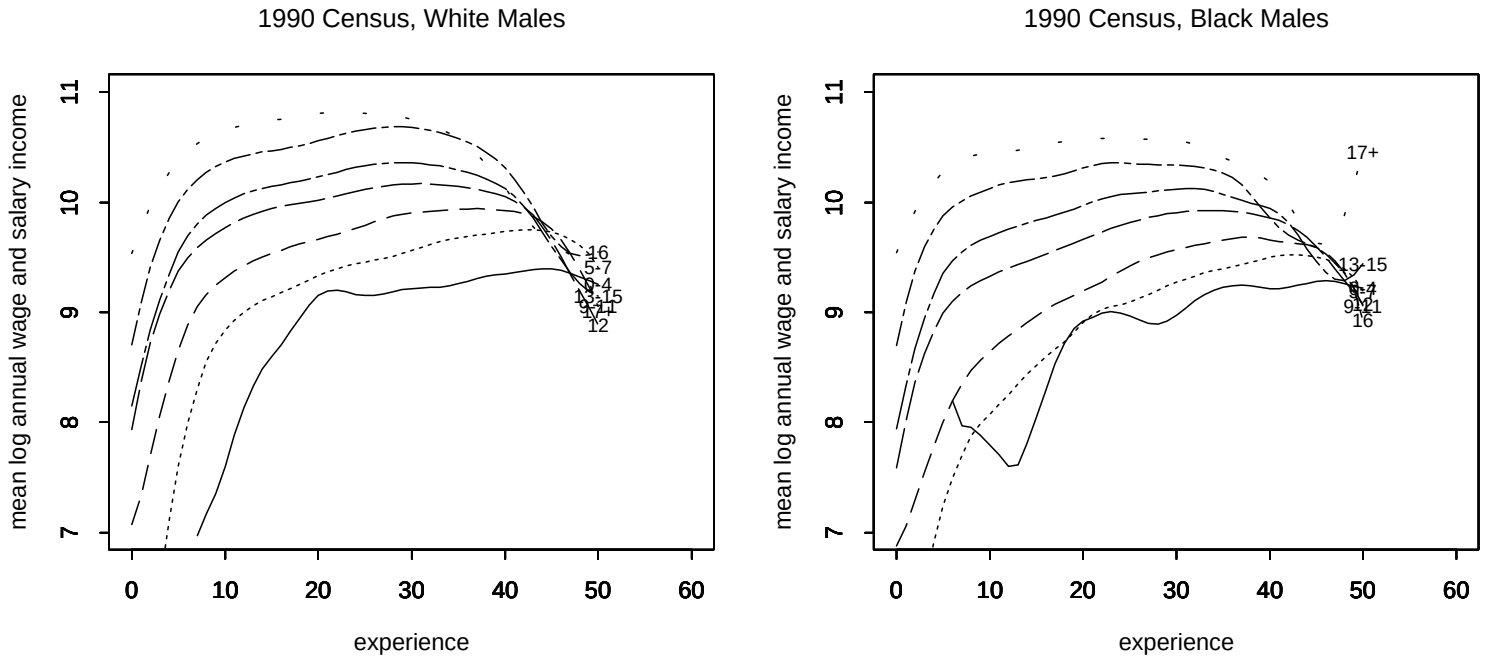
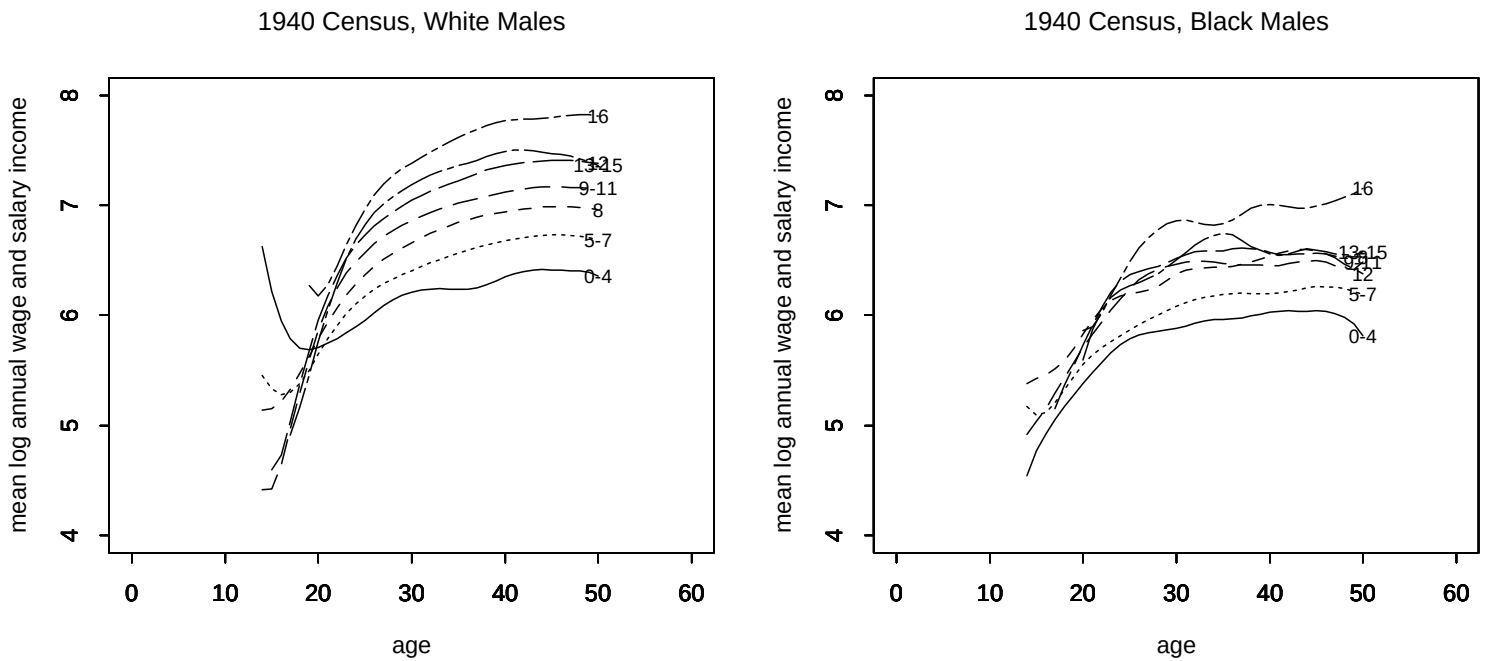

1990 Census, White Males
1990 Census, Black Males
mean log annual wage and salary income
experience
7
8
9
10
11
0
10
20
30
40
50
60
17+
16
13-15
12

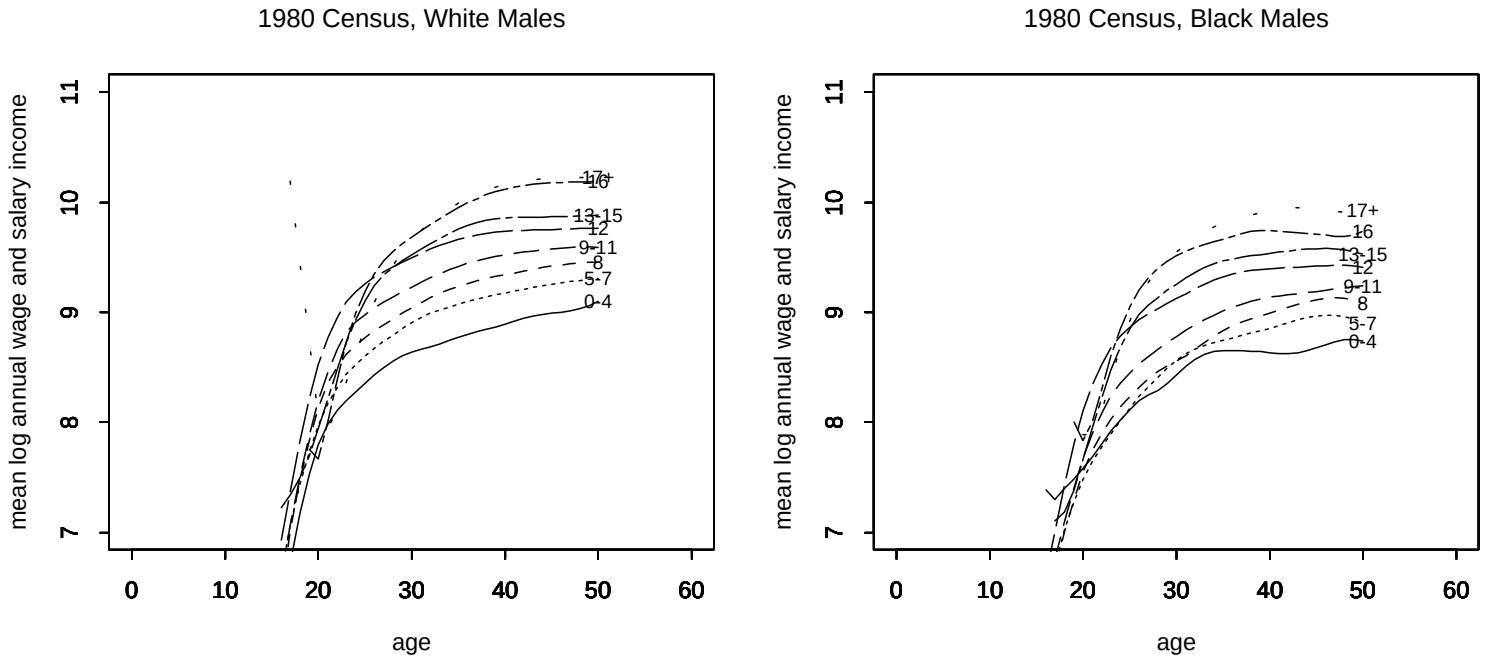
Table 1: Tests of Parallelism in Log Earnings Experience Profiles for Men

| | | Estimated Difference Between College and High School Log Earnings at Different Experience Levels | | | | | |
|---|---|---|---|---|---|---|---|
| Sample | Experience Level | 1940 | 1950 | 1960 | 1970 | 1980 | 1990 |
| Whites | 10 | 0.54 | 0.30 | 0.46 | 0.41 | 0.37 | 0.59 |
| | 20 | 0.40 | 0.40 | 0.43 | 0.49 | 0.45 | 0.54 |
| | 30 | 0.54 | 0.27 | 0.46 | 0.48 | 0.43 | 0.52 |
| | 40 | 0.58 | 0.21 | 0.50 | 0.45 | 0.27 | 0.30 |
| | p-value | 0.32 | 0.70 | <0.001 | <0.001 | <0.001 | <0.001 |
| Blacks | 10 | 0.20 | 0.58 | 0.48 | 0.38 | 0.70 | 0.77 |
| | 20 | 0.38 | 0.05 | 0.25 | 0.22 | 0.48 | 0.69 |
| | 30 | -0.11 | 0.24 | 0.08 | 0.33 | 0.36 | 0.53 |
| | 40 | -0.20 | 0.00 | 0.73 | 0.26 | 0.22 | -0.04 |
| | p-value | 0.46 | 0.55 | 0.58 | 0.91 | <0.001 | <0.001 |

Notes: Data taken from 1940-90 Decennial Censuses without adjustment for inflation. Because there are very few blacks in the 1940 and 1950 samples with college degrees, especially at higher experience levels, the test results for blacks in those years refer to a test of the difference between earnings for high school graduates and persons with 8 years of education. See Appendix B for data description. See Appendix C for the formulae used for the test statistics.

Figure 2: Age-Earnings Profiles, 1940,1960,1980

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age
17+
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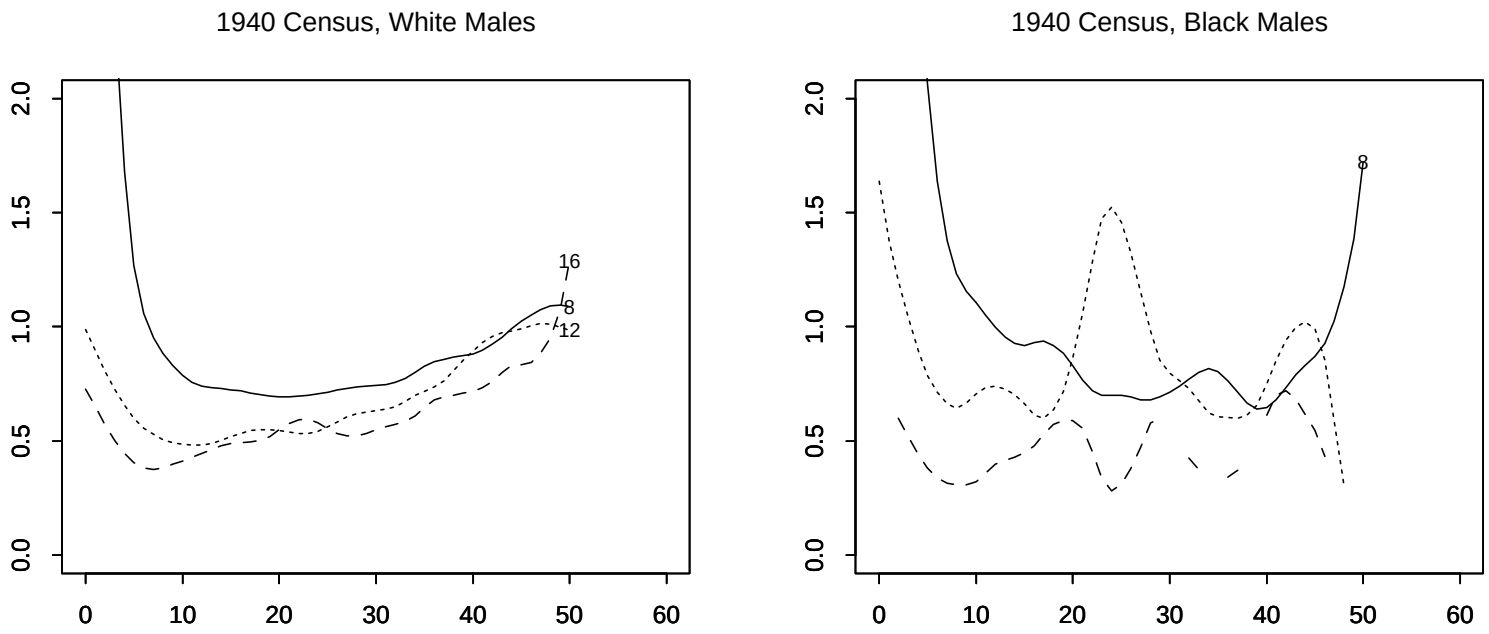
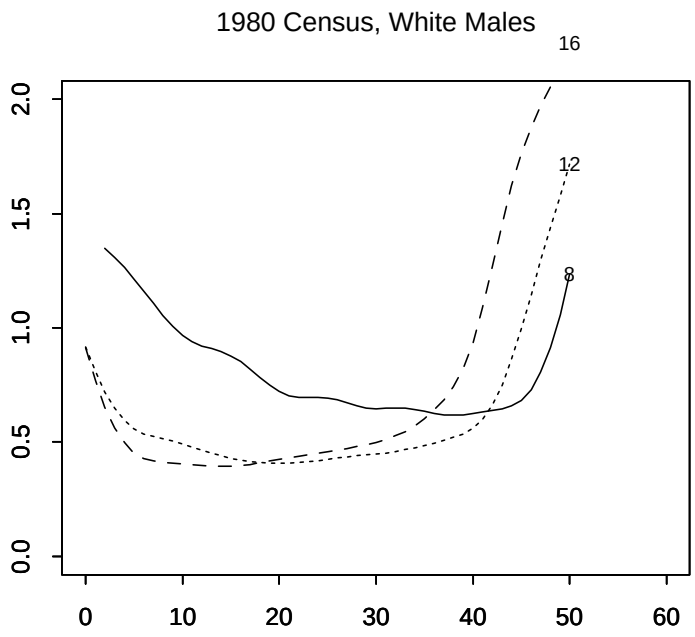
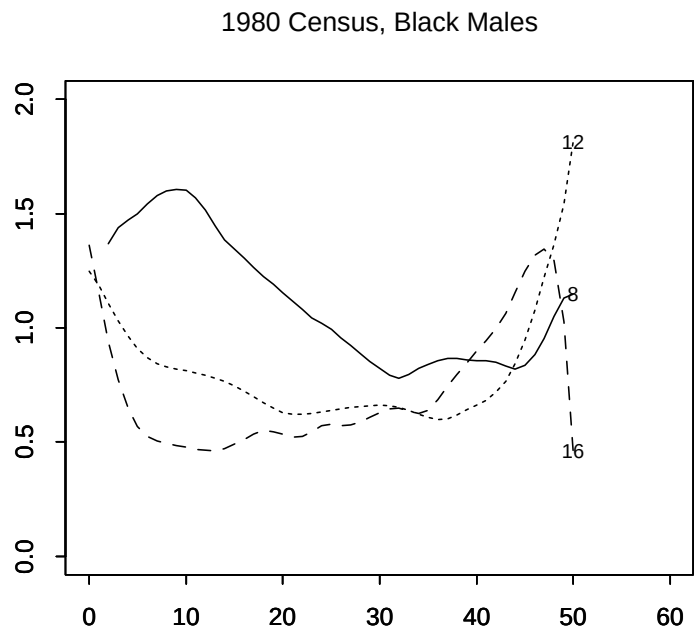
13-15
12
9-11
8
5-7
0-4


1980 Census, Black Males
mean log annual wage and salary income
7
8
9
10
11
0
10
20
30
40
50
60
age
17+
16
13-15
12
9-11
8
5-7
0-4

Figure 3: Experience-Variance Log Earnings




1980 Census, White Males
16
12
8
0.0
0.5
1.0
1.5
2.0
0
10
20
30
40
50
60


1980 Census, Black Males
12
8
16
0.0
0.5
1.0
1.5
2.0
0
10
20
30
40
50
60

In the end, Heckman et al. (2006a) conclude:

> *In common usage, the coefficient on schooling in a regression of log earnings on years of schooling is often called a rate of return. In fact, it is a price of schooling from a hedonic market wage equation. It is a growth rate of market earnings with years of schooling and not an internal rate of return measure, except under stringent conditions which we specify, test and reject in this chapter.*

# *Estimating Internal Rates of Return*

## Income Maximization under Perfect Certainty (??)

| | |
|---|---|
| $s$ | schooling level |
| $x$ | experience level |
| $Y(s,x)$ | wage income |
| $T(s)$ | last age of earnings |
| $v$ | tuition and psychic cost of schooling |
| $\tau$ | proportional tax rate |
| $r$ | before-tax interest rate |

## Present Discounted Value fo Lifetime Earnings

$$V(s) = \int_0^{T(s)-s} (1-\tau) e^{-(1-\tau) r(x+s)} Y(s,x) dx - \int_0^{s} v e^{-(1-\tau) r z} dz$$

First-Order Condition

$$
\begin{aligned}
&[T'(s) - 1]e^{-(1-\tau)r(T(s)-s)}Y(s, T(s) - s) \\
&- (1 - \tau)r \int_0^{T(s)-s} e^{-(1-\tau)rx} Y(s, x)dx \\
&+ \int_0^{T(s)-s} e^{-(1-\tau)rx} \frac{\partial Y(s, x)}{\partial s} dx \\
&- \frac{v}{1 - \tau} = 0
\end{aligned}
$$

Rearranging ...

$$\tilde{r} = \frac{[T'(s) - 1]e^{-\tilde{r}(T(s)-s)}Y(s, T(s) - s)}{\int_0^{T(s)-s} e^{-\tilde{r}x}Y(s, x)dx} \tag{1}$$

$$+ \frac{\int_0^{T(s)-s} e^{-\tilde{r}x}\left[\frac{\partial Y(s,x)}{\partial s}\right]dx}{\int_0^{T(s)-s} e^{-\tilde{r}x}Y(s, x)dx} \tag{2}$$

$$- \frac{\frac{v}{1-\tau}}{\int_0^{T(s)-s} e^{-\tilde{r}x}Y(s, x)dx} \tag{3}$$

Interpretation

- (1) – lifetime-earnings effect - the change in the present value of earnings due to a change in working-life with additional schooling (expressed) as a fraction of the present value of earnings measured at age $s$
- (2) – weighted average effect of schooling on log earnings by experience
- (3) – tuition and psychic costs expressed as a fraction of lifetime income measured at age $s$

Getting back to Mincer ...

- no tuition and psychic costs of schooling

  $\Rightarrow v = 0$

- no loss of working life from schooling

  $\Rightarrow T'(s) = 1$

- multiplicative separability between schooling and experience component of earnings

  $\Rightarrow Y(s, x) = \mu(s)\psi(x)$

$$\tilde{r} = \frac{\mu'(s)}{\mu(s)} \quad \forall \quad s$$

Thus, wage growth must be log linear in schooling and $\mu(s) = \mu(0)e^{\tilde{r}s}$

Heckman et al. (2006a) thus establish ...

> *After allowing for taxes, tuition, variable length of working life, and a flexible relationship between earnings, schooling and experience, the coefficient on years of schooling in a log earnings regression need no longer equal the internal rate of return.*

## Structural Approach for the IRR

The internal rate of return for schooling level $s_1$ versus $s_2$, $r(s_1, s_2)$ solves ...

$$\int_0^{T(s_1)-s_1} (1-\tau)e^{-r(x+s_1)}Y(s_1,x)dx - \int_0^{s_1} ve^{-rz}dz$$
$$= \int_0^{T(s_2)-s_2} (1-\tau)e^{-r(x+s_2)}Y(s_2,x)dx - \int_0^{s_2} ve^{-rz}dz$$

Back to Mincer ....

- no taxes and no direct or psychic costs of schooling

$$\Rightarrow \quad v = 0 \text{ and } \tau = 0$$

$$\int_0^{T(s_1)-s_1} e^{-r(x+s_1)} Y(s_1, x) dx = \int_0^{T(s_2)-s_2} e^{-r(x+s_2)} Y(s_2, x) dx$$

- equal work-lives irrespective of years of schooling

$$\Rightarrow \quad T = T(s_1) - s_1 = T(s_2) - s_2$$

$$\int_0^T e^{-r(x+s_1)} Y(s_1, x) dx = \int_0^T e^{-r(x+s_2)} Y(s_2, x) dx$$

- parallelism in experience across schooling categories

$$\Rightarrow \quad Y(s,x) = \mu(s)\psi(x)$$

$$\int_0^T e^{-r(x+s_1)}\mu(s)\psi(x)dx = \int_0^T e^{-r(x+s_2)}\mu(s)\psi(x)dx$$

- linearity of log earnings in schooling

$$\Rightarrow \quad \mu(s) = \mu(0)e^{\rho_s s}$$

$$\int_0^T e^{-r(x+s_1)}\mu(0)e^{\rho_s s_1}\psi(x)dx = \int_0^T e^{-r(x+s_2)}\mu(0)e^{\rho_s s_2}\psi(x)dx$$

After some further rearranging ...

$$e^{(\rho_s - r)s_1} = e^{(\rho_s - r)s_2}$$

$$\Rightarrow \rho_s = r$$

# *Empirical Evidence*

Table 3a: Internal Rates of Return for White Men: Earnings Function Assumptions
(Specifications Assume Work Lives of 47 Years)

| | Schooling Comparisons | | | | | |
|---|---|---|---|---|---|---|
| | 6-8 | 8-10 | 10-12 | 12-14 | 12-16 | 14-16 |
| 1940 | | | | | | |
| Mincer Specification | 13 | 13 | 13 | 13 | 13 | 13 |
| Relax Linearity in S | 16 | 14 | 15 | 10 | 15 | 21 |
| Relax Linearity in S & Quad. in Exp. | 16 | 14 | 17 | 10 | 15 | 20 |
| Relax Lin. in S & Parallelism | 12 | 14 | 24 | 11 | 18 | 26 |
| 1950 | | | | | | |
| Mincer Specification | 11 | 11 | 11 | 11 | 11 | 11 |
| Relax Linearity in S | 13 | 13 | 18 | 0 | 8 | 16 |
| Relax Linearity in S & Quad. in Exp. | 14 | 12 | 16 | 3 | 8 | 14 |
| Relax Linearity in S & Parallelism | 26 | 28 | 28 | 3 | 8 | 19 |
| 1960 | | | | | | |
| Mincer Specification | 12 | 12 | 12 | 12 | 12 | 12 |
| Relax Linearity in S | 9 | 7 | 22 | 6 | 13 | 21 |
| Relax Linearity in S & Quad. in Exp. | 10 | 9 | 17 | 8 | 12 | 17 |
| Relax Linearity in S & Parallelism | 23 | 29 | 33 | 7 | 13 | 25 |
| 1970 | | | | | | |
| Mincer Specification | 13 | 13 | 13 | 13 | 13 | 13 |
| Relax Linearity in S | 2 | 3 | 30 | 6 | 13 | 20 |
| Relax Linearity in S & Quad. in Exp. | 5 | 7 | 20 | 10 | 13 | 17 |
| Relax Linearity in S & Parallelism | 17 | 29 | 33 | 7 | 13 | 24 |
| 1980 | | | | | | |
| Mincer Specification | 11 | 11 | 11 | 11 | 11 | 11 |
| Relax Linearity in S | 3 | -11 | 36 | 5 | 11 | 18 |
| Relax Linearity in S & Quad. in Exp. | 4 | -4 | 28 | 6 | 11 | 16 |
| Relax Linearity in S & Parallelism | 16 | 66 | 45 | 5 | 11 | 21 |
| 1990 | | | | | | |
| Mincer Specification | 14 | 14 | 14 | 14 | 14 | 14 |
| Relax Linearity in S | -7 | -7 | 39 | 7 | 15 | 24 |
| Relax Linearity in S & Quad. in Exp. | -3 | -3 | 30 | 10 | 15 | 20 |

Table 3b: Internal Rates of Return for Black Men: Earnings Function Assumptions
(Specifications Assume Work Lives of 47 Years)

| | Schooling Comparisons | | | | | |
|---|---|---|---|---|---|---|
| | 6-8 | 8-10 | 10-12 | 12-14 | 12-16 | 14-16 |
| 1940 | | | | | | |
| Mincer Specification | 9 | 9 | 9 | 9 | 9 | 9 |
| Relax Linearity in S | 18 | 7 | 5 | 3 | 11 | 18 |
| Relax Linearity in S & Quad. in Exp. | 18 | 8 | 6 | 2 | 10 | 19 |
| Relax Linearity in S & Parallelism | 11 | 0 | 10 | 5 | 12 | 20 |
| 1950 | | | | | | |
| Mincer Specification | 10 | 10 | 10 | 10 | 10 | 10 |
| Relax Linearity in S | 16 | 14 | 18 | -2 | 4 | 9 |
| Relax Linearity in S & Quad. in Exp. | 16 | 14 | 18 | 0 | 3 | 6 |
| Relax Linearity in S & Parallelism | 35 | 15 | 48 | -3 | 6 | 34 |
| 1960 | | | | | | |
| Mincer Specification | 11 | 11 | 11 | 11 | 11 | 11 |
| Relax Linearity in S | 13 | 12 | 18 | 5 | 8 | 11 |
| Relax Linearity in S & Quad. in Exp. | 13 | 11 | 18 | 5 | 7 | 10 |
| Relax Linearity in S & Parallelism | 22 | 15 | 38 | 5 | 11 | 25 |
| 1970 | | | | | | |
| Mincer Specification | 12 | 12 | 12 | 12 | 12 | 12 |
| Relax Linearity in S | 5 | 11 | 30 | 7 | 10 | 14 |
| Relax Linearity in S & Quad. in Exp. | 6 | 11 | 24 | 10 | 11 | 12 |
| Relax Linearity in S & Parallelism | 15 | 27 | 44 | 9 | 14 | 23 |
| 1980 | | | | | | |
| Mincer Specification | 12 | 12 | 12 | 12 | 12 | 12 |
| Relax Linearity in S | -4 | 1 | 35 | 10 | 15 | 19 |
| Relax Linearity in S & Quad. in Exp. | -4 | 6 | 29 | 11 | 14 | 17 |
| Relax Linearity in S & Parallelism | 10 | 44 | 48 | 8 | 16 | 31 |
| 1990 | | | | | | |
| Mincer Specification | 16 | 16 | 16 | 16 | 16 | 16 |
| Relax Linearity in S | -5 | -5 | 41 | 15 | 20 | 25 |
| Relax Linearity in S & Quad. in Exp. | -3 | -3 | 35 | 17 | 19 | 22 |

Table 4: Internal Rates of Return for White & Black Men: Accounting for Taxes and Tuition
(General Non-Parametric Specification Assuming Work Lives of 47 Years)

| | | Schooling Comparisons | | | | | |
|---|---|---|---|---|---|---|---|
| | | Whites | | | Blacks | | |
| | | 12-14 | 12-16 | 14-16 | 12-14 | 12-16 | 14-16 |
| 1940 | No Taxes or Tuition | 11 | 18 | 26 | 5 | 12 | 20 |
| | Including Tuition Costs | 9 | 15 | 21 | 4 | 10 | 16 |
| | Including Tuition & Flat Taxes | 8 | 15 | 21 | 4 | 9 | 16 |
| | Including Tuition & Prog. Taxes | 8 | 15 | 21 | 4 | 10 | 16 |
| 1950 | No Taxes or Tuition | 3 | 8 | 19 | -3 | 6 | 34 |
| | Including Tuition Costs | 3 | 8 | 16 | -3 | 5 | 25 |
| | Including Tuition & Flat Taxes | 3 | 8 | 16 | -3 | 5 | 24 |
| | Including Tuition & Prog. Taxes | 3 | 7 | 15 | -3 | 5 | 21 |
| 1960 | No Taxes or Tuition | 7 | 13 | 25 | 5 | 11 | 25 |
| | Including Tuition Costs | 6 | 11 | 21 | 5 | 9 | 18 |
| | Including Tuition & Flat Taxes | 6 | 11 | 20 | 4 | 8 | 17 |
| | Including Tuition & Prog. Taxes | 6 | 10 | 19 | 4 | 8 | 15 |
| 1970 | No Taxes or Tuition | 7 | 13 | 24 | 9 | 14 | 23 |
| | Including Tuition Costs | 6 | 12 | 20 | 7 | 12 | 18 |
| | Including Tuition & Flat Taxes | 6 | 11 | 20 | 7 | 11 | 17 |
| | Including Tuition & Prog. Taxes | 5 | 10 | 18 | 7 | 10 | 16 |
| 1980 | No Taxes or Tuition | 5 | 11 | 21 | 8 | 16 | 31 |
| | Including Tuition Costs | 4 | 10 | 18 | 7 | 13 | 24 |
| | Including Tuition & Flat Taxes | 4 | 9 | 17 | 6 | 12 | 21 |
| | Including Tuition & Prog. Taxes | 4 | 8 | 15 | 6 | 11 | 20 |
| 1990 | No Taxes or Tuition | 10 | 16 | 26 | 18 | 25 | 35 |
| | Including Tuition Costs | 9 | 14 | 20 | 14 | 18 | 25 |
| | Including Tuition & Flat Taxes | 8 | 13 | 19 | 13 | 17 | 22 |
| | Including Tuition & Prog. Taxes | 8 | 12 | 18 | 13 | 17 | 22 |

Notes: Data taken from 1940-90 Decennial Censuses. See discussion in text and Appendix B for a description of tuition and tax amounts.

**Figure 4a: Average College Tuition Paid (in 2000 dollars)**

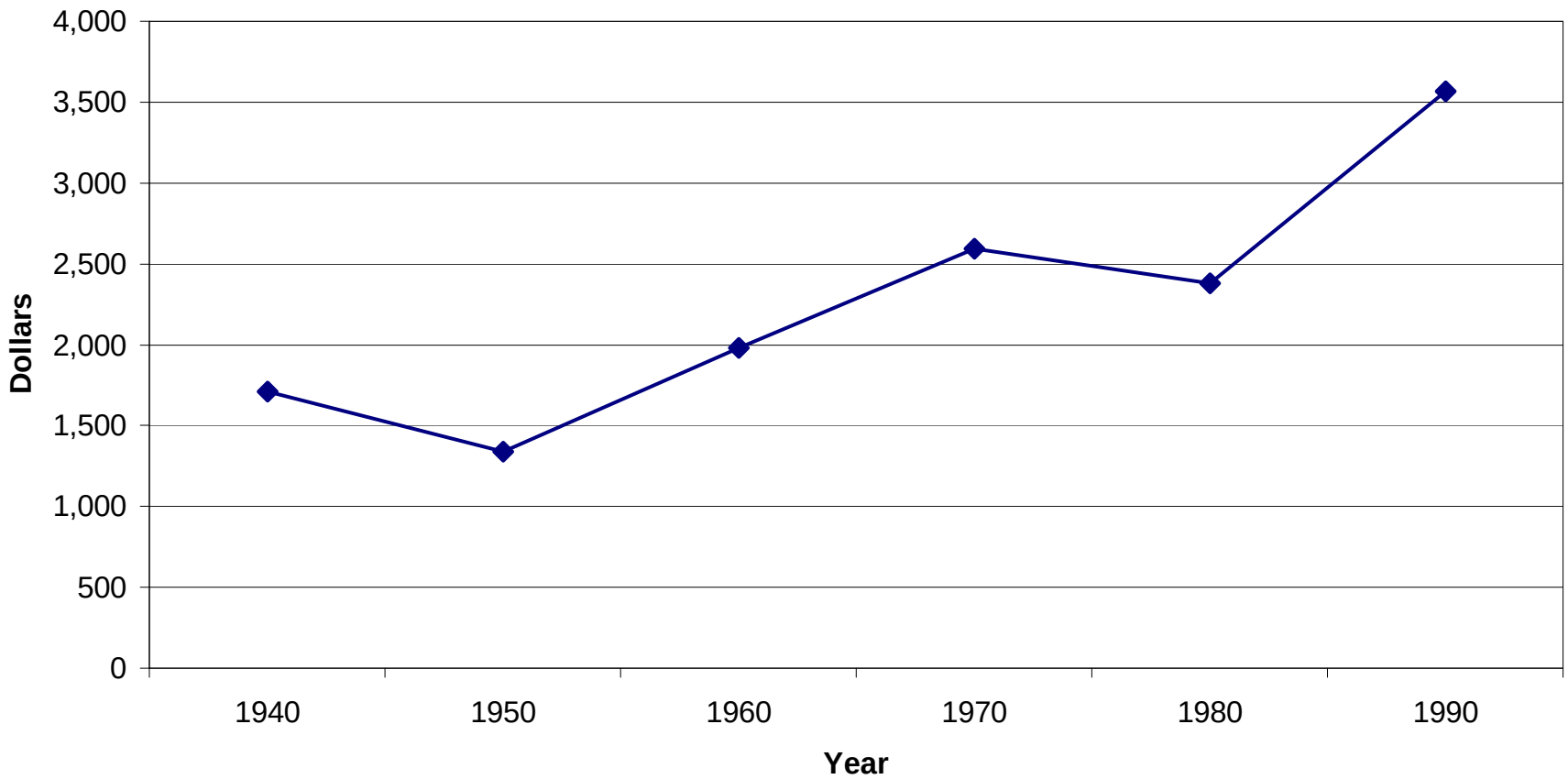
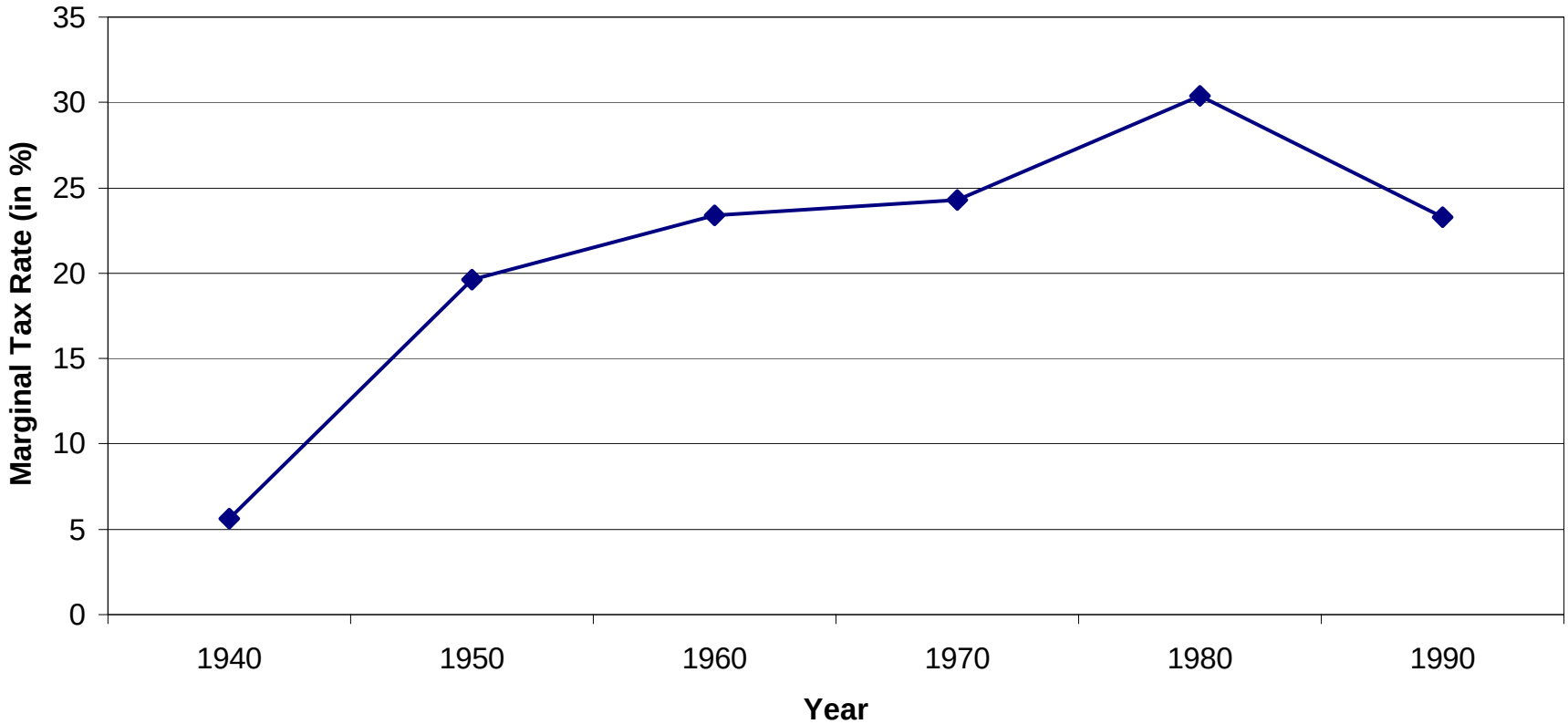
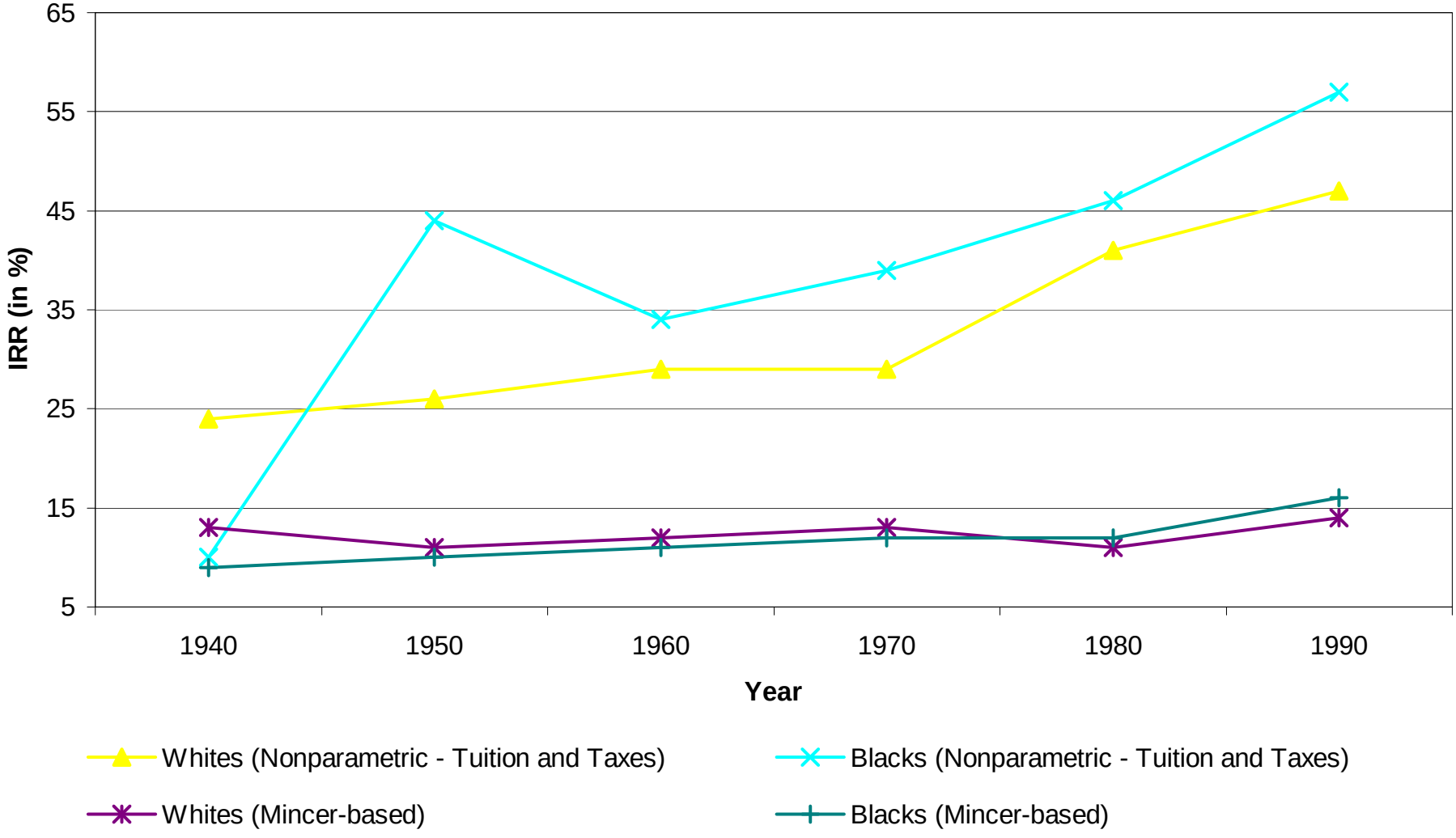


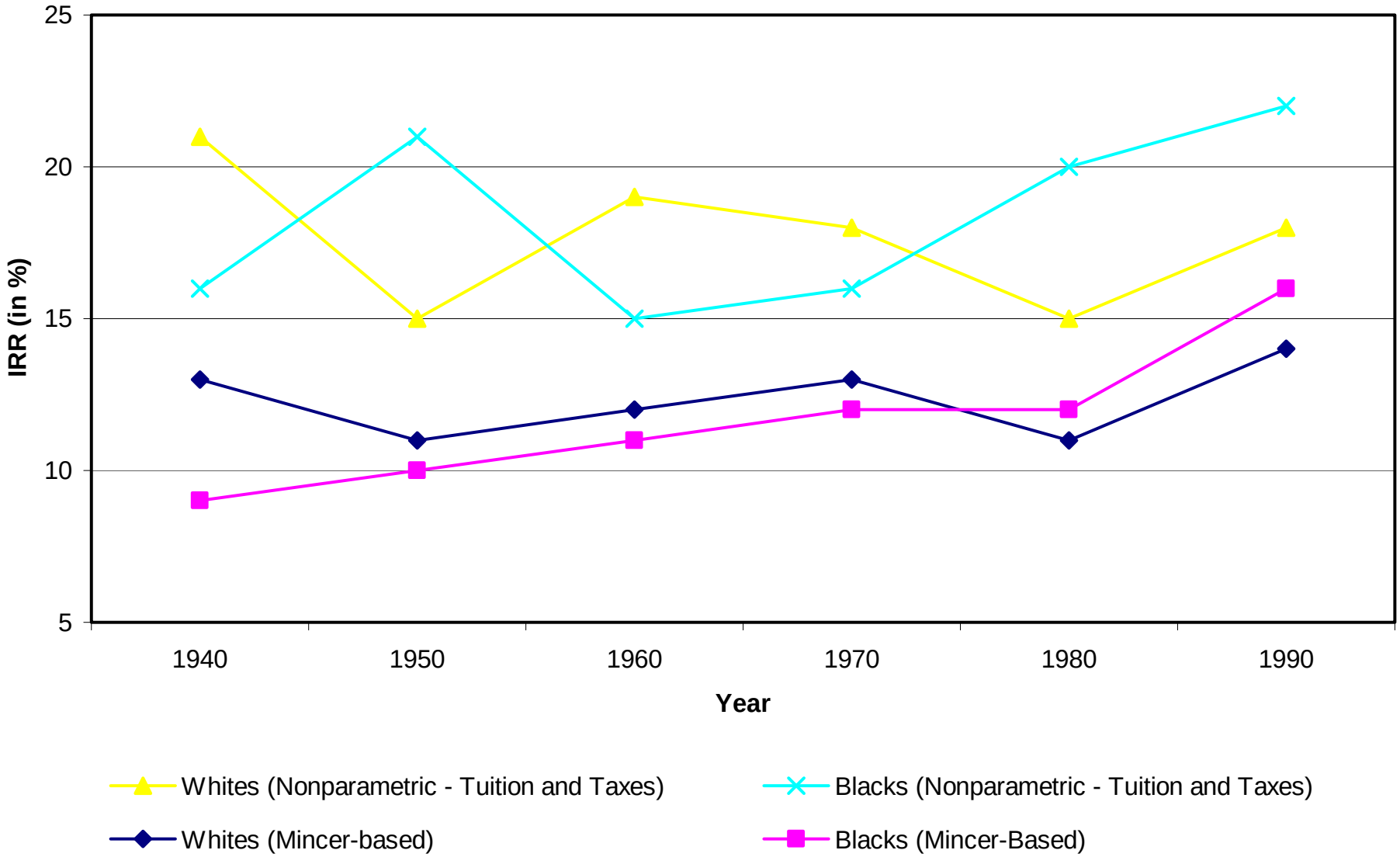
**Figure 4b: Marginal Tax Rates**
**(from Barro & Sahasakul, 1983, Mulligan & Marion, 2000)**



## Figure 5: IRR for High School Completion (White and Black Men)



## Figure 6: IRR for College Completion (White and Black Men)



# Appendix

# *References*

Bhuller, M., Mogstad, M., and Salvanes, K. G. (2017). Life cycle earnings, education premiums and internal rates of return. *Journal of Labor Economics*, 35(4):993–1030.

Carneiro, P. and Heckman, J. J. (2002). The evidence on credit constraints in post-secondary schooling. *The Economic Journal*, 112(482):705–734.

Carneiro, P., Heckman, J. J., and Vytlacil, E. J. (2011). Estimating marginal returns to education. *American Economic Review*, 101(6):2754–2781.

Cunha, F., Heckman, J. J., and Navarro, S. (2005). Separating uncertainty from heterogeneity in life cycle earnings. *Oxford Economic Papers*, 57(2):191–261.

Eisenhauer, P., Heckman, J. J., and Mosso, S. (2015). Estimation of dynamic discrete choice models by maximum likelihood and the simulated method of moments. *International Economic Review*, 56(2):331–357.

Heckman, J. J., Lochner, L. J., and Todd, P. E. (2006a). Earnings functions, rates of return and treatment effects: The mincer equation and beyond. In Hanushek, E. A. and Welch, F., editors, *Handbook of the Economics of Education*, volume 1, pages 307–458. North-Holland Publishing Company.

Heckman, J. J., Urzua, S., and Vytlacil, E. J. (2006b). Understanding instrumental variables in models with essential heterogeneity. *The Review of Economics and Statistics*, 88(3):389–432.

Mincer, J. (1974). *Schooling, Experience and Earnings*. National Bureau of Economic Research, New York, NY.

Mincer, J. A. (1958). Investment in human capital and personal income distribution. *Journal of Political Economy*, 66(4):281–302.