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?

- explain wage inequality within countries
- explain growth differentials across countries
- assess schooling investment on individual level
- evaluate public policies to foster educational attainment
- ...

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* ρ_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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Accounting-Identity Model

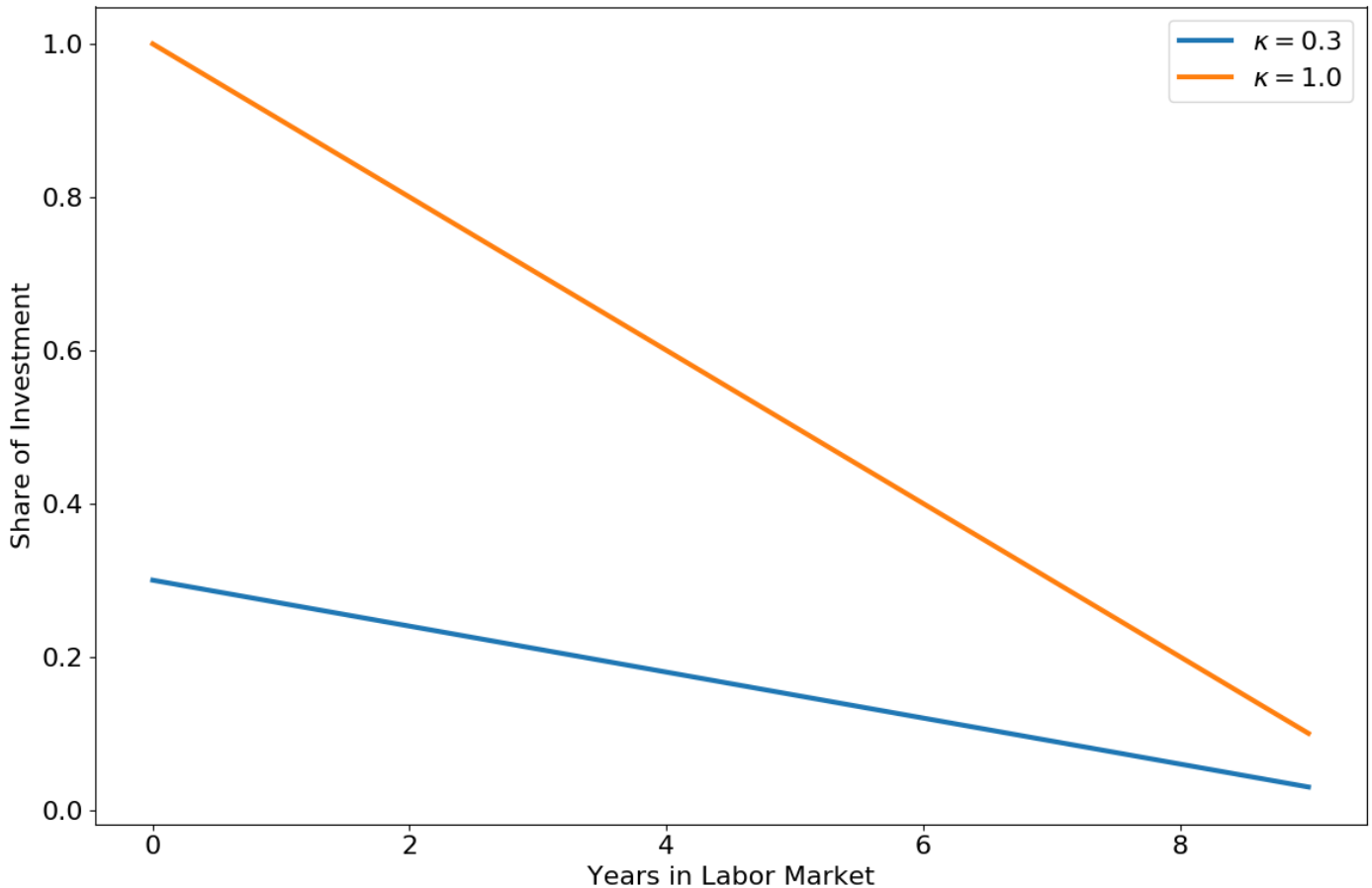
$$P_t \equiv P_{t-1}(1 + k_{t-1}\rho_{t-1}) \equiv \prod_{j=0}^{t-1}(1 + \rho_j k_j)P_0$$

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

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:

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

$\Rightarrow$ ρ_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

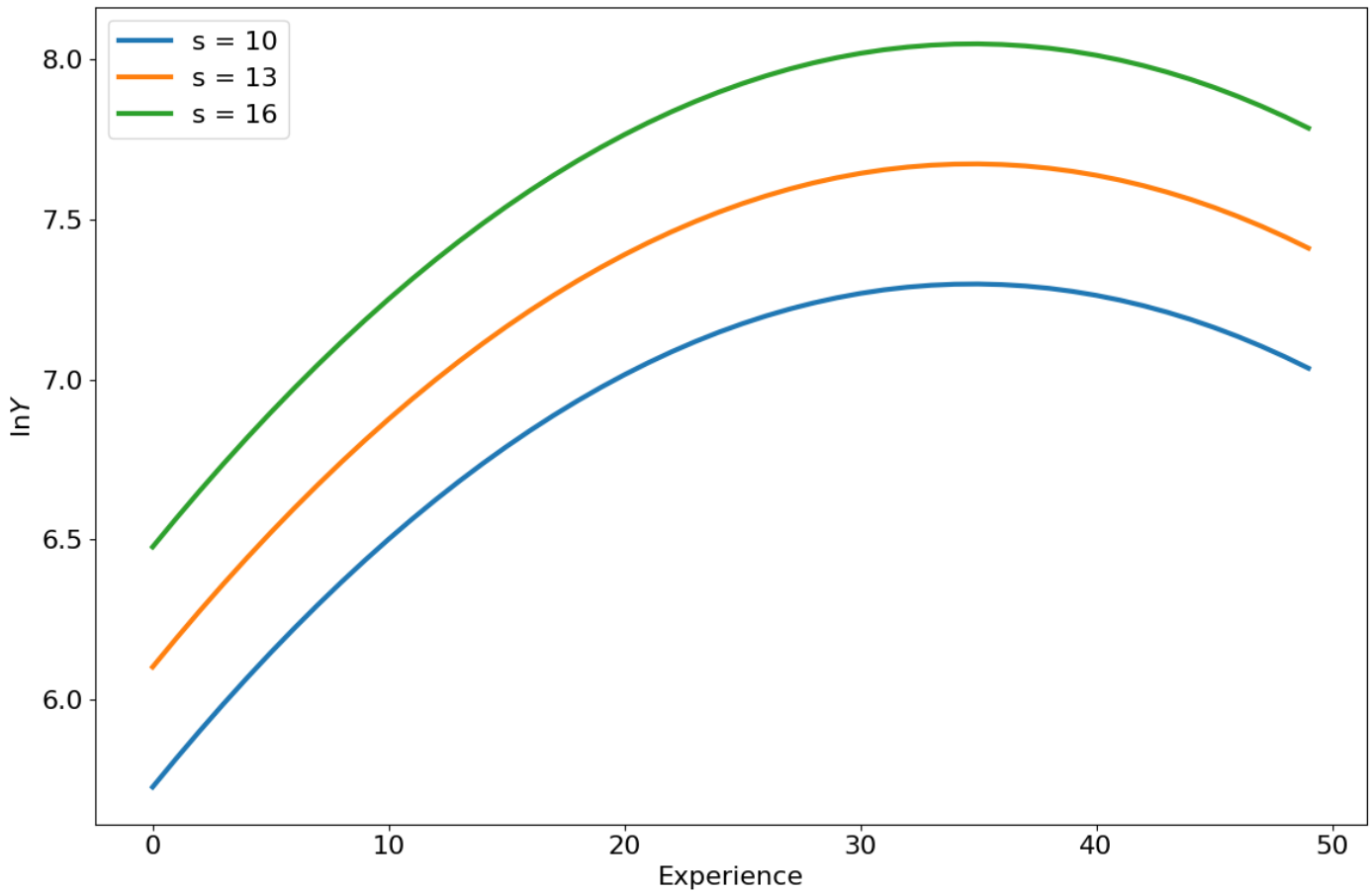


Figure: Mincerian Age Profiles

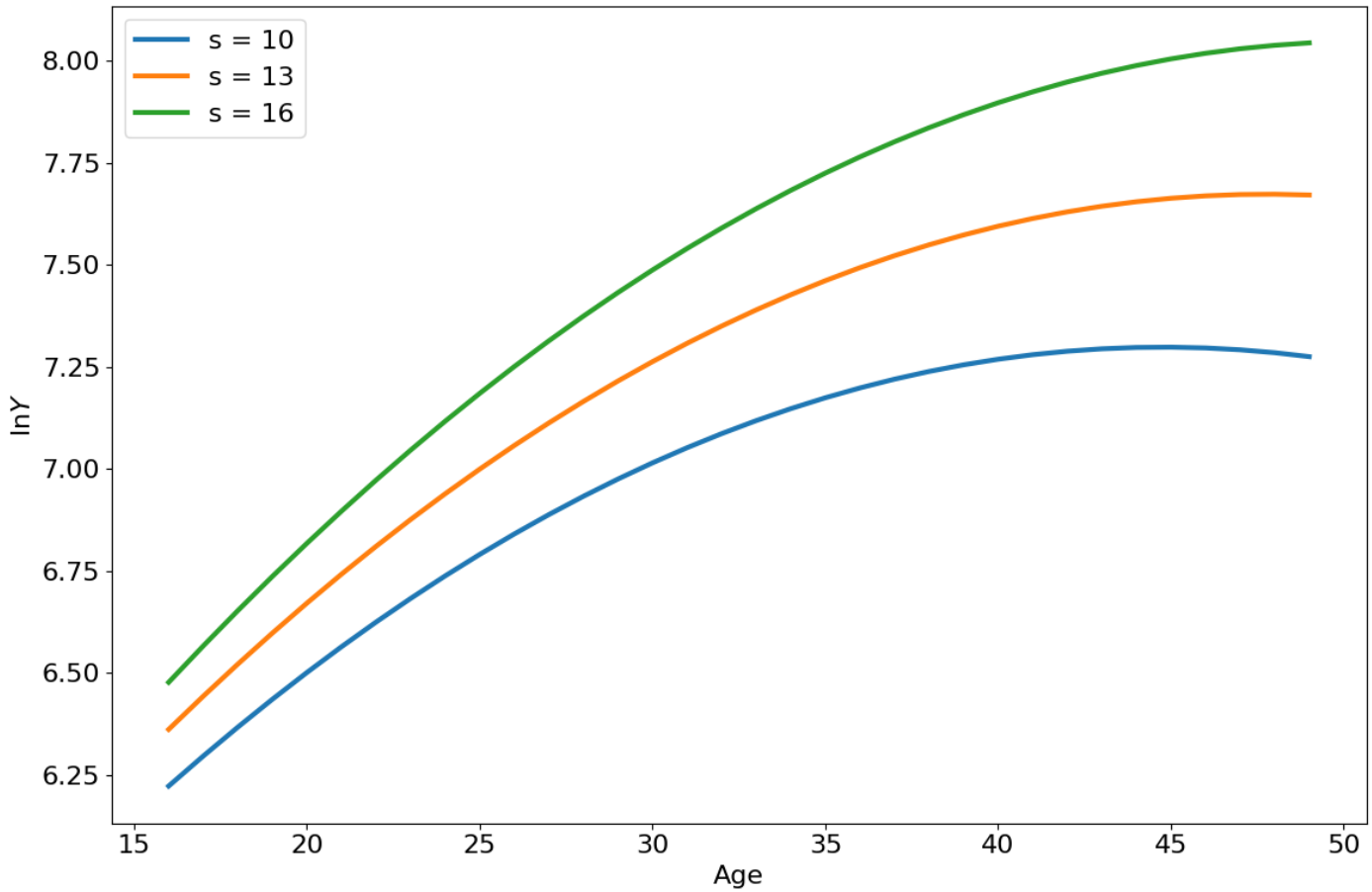
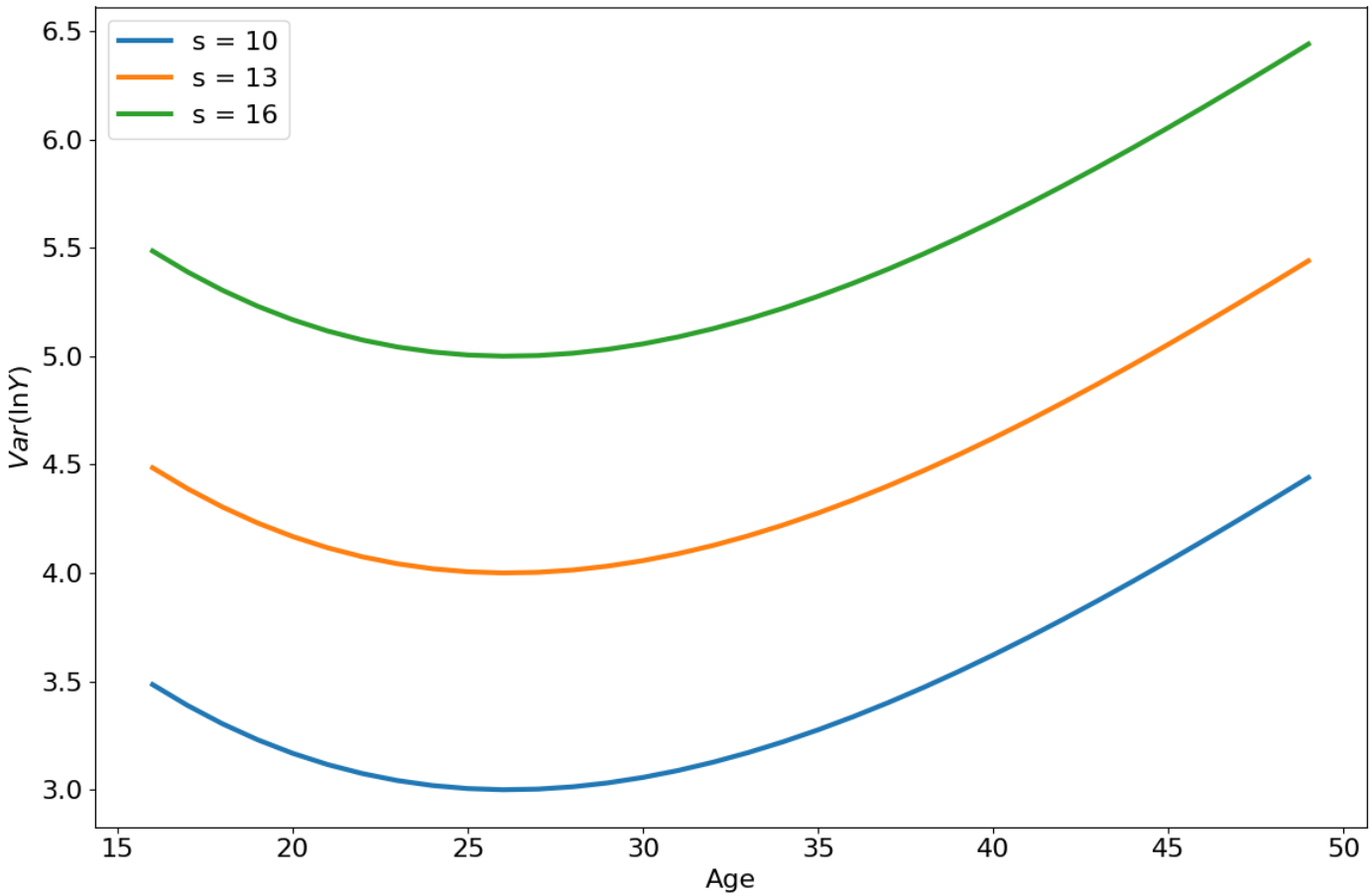
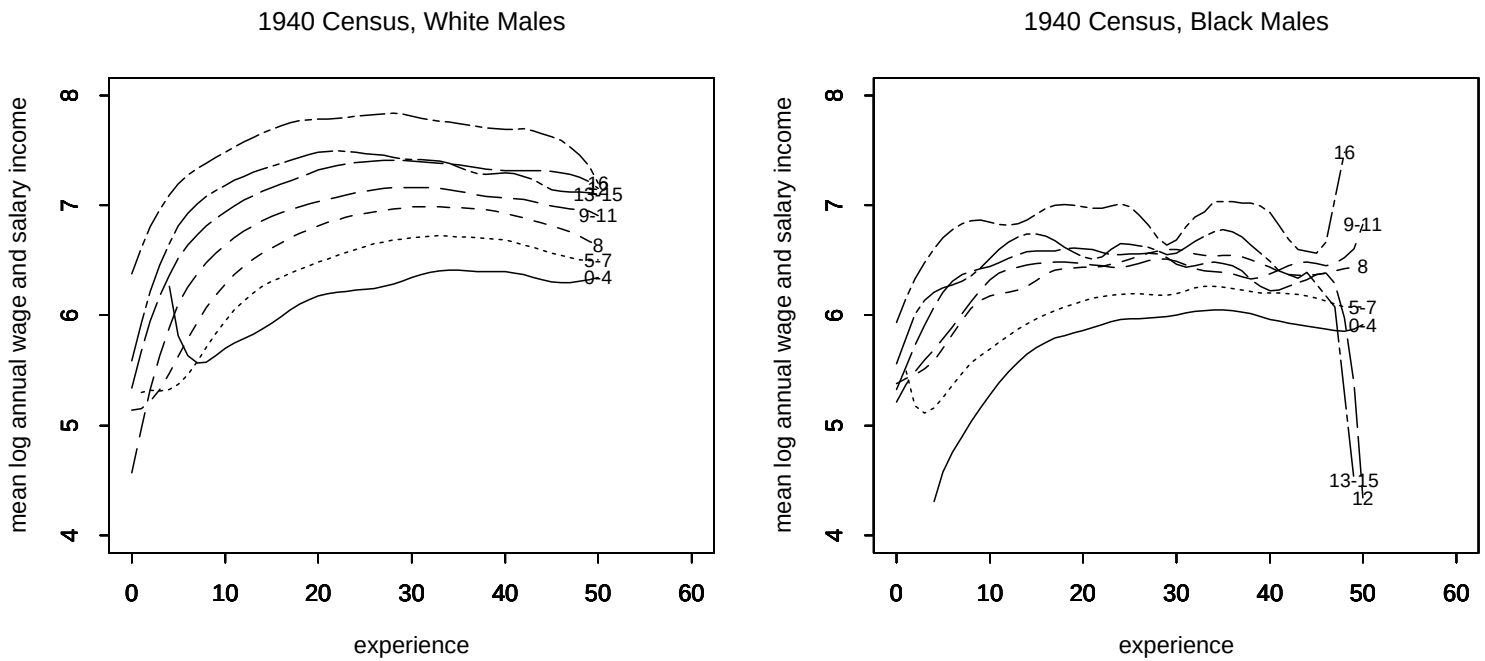


Figure: Mincerian Variance Profiles



Empirical Evidence

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



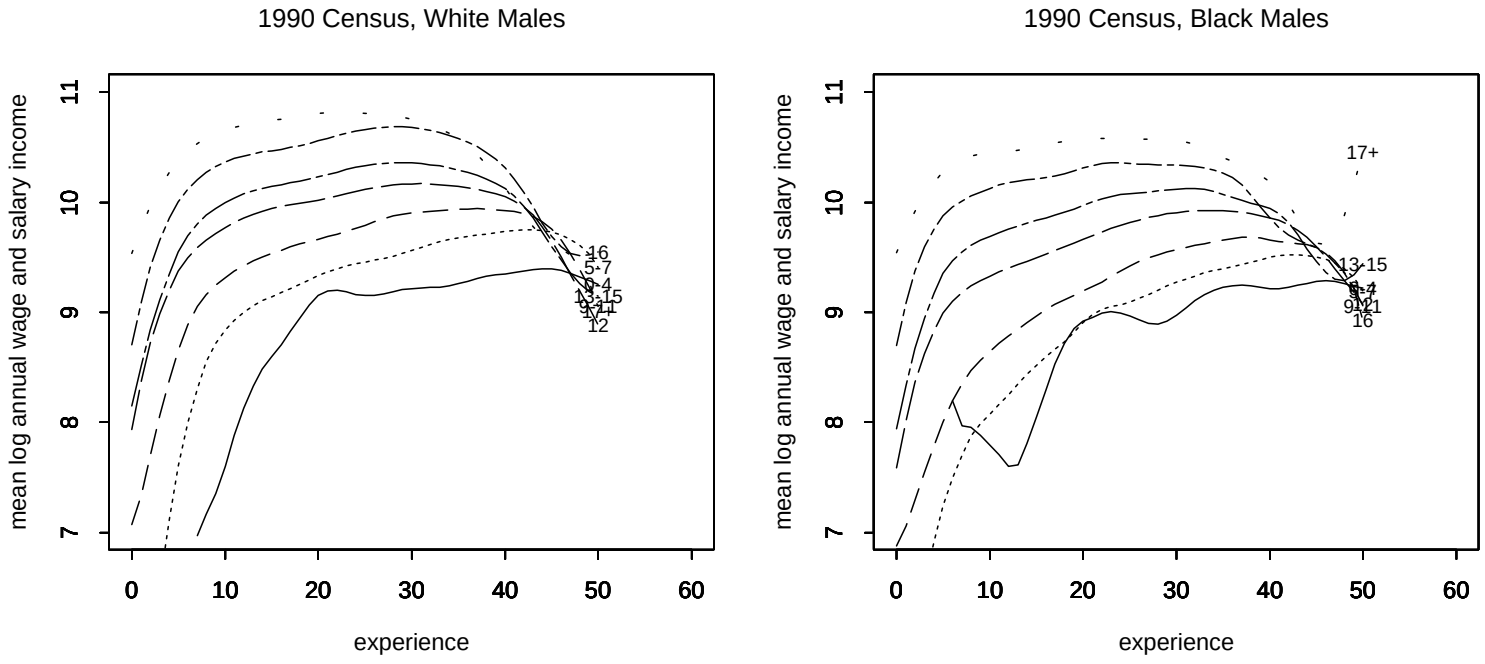
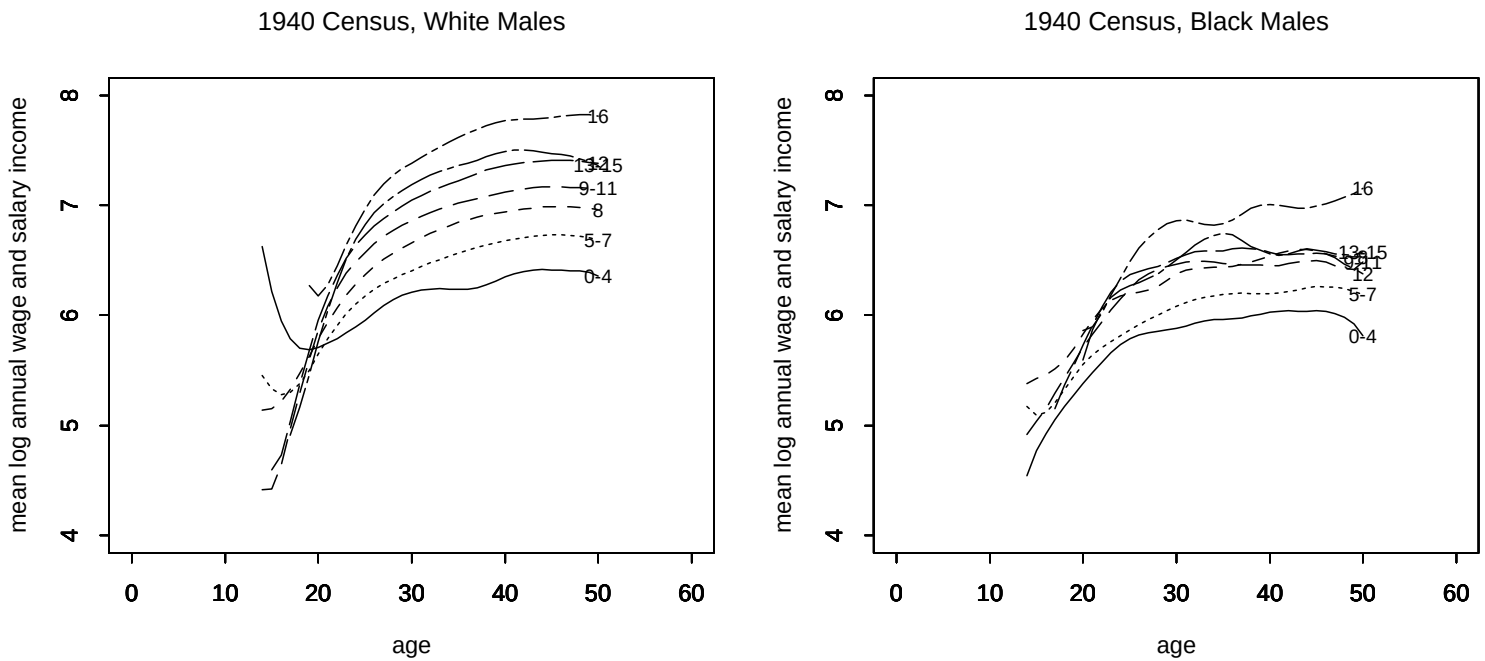

1990 Census, White Males
1990 Census, Black Males
mean log annual wage and salary income
experience
7
8
9
10
11
0
10
20
30
40
50
60
17+
16
13-15
12

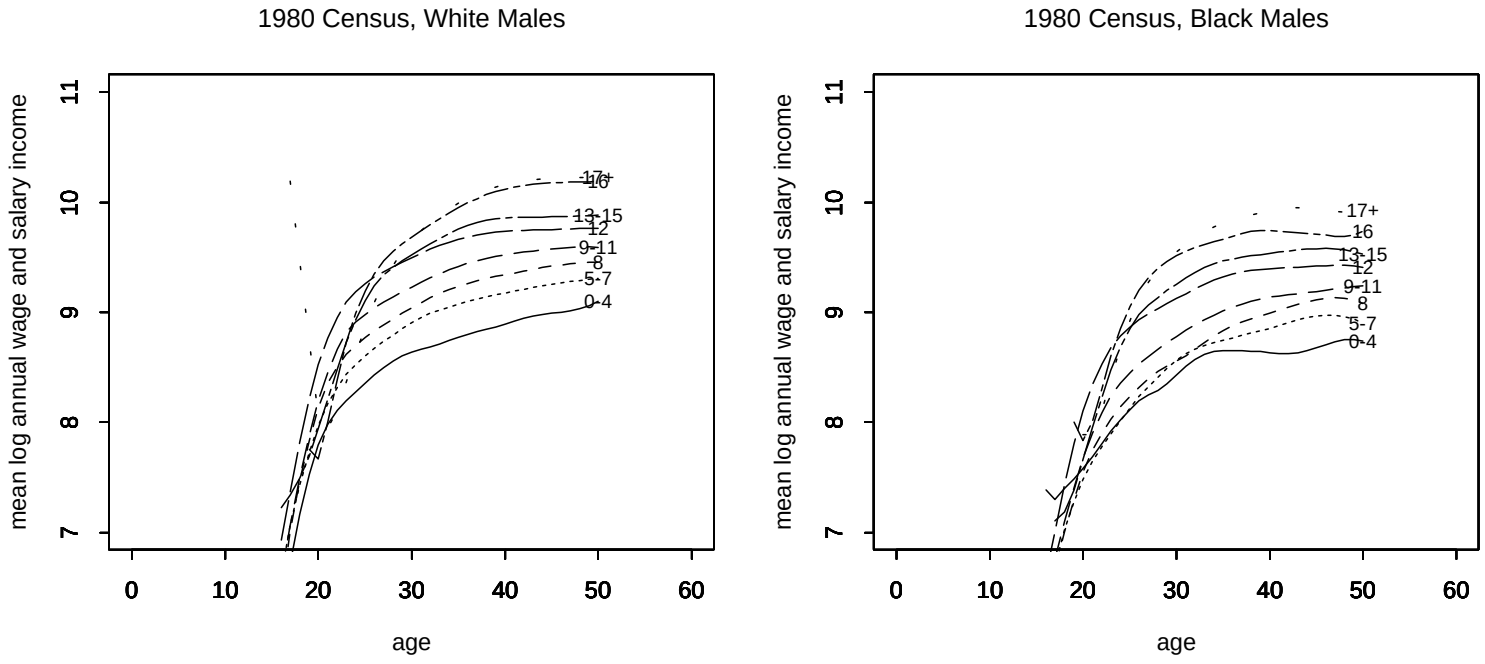
Table 1: Tests of Parallelism in Log Earnings Experience Profiles for Men

		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.

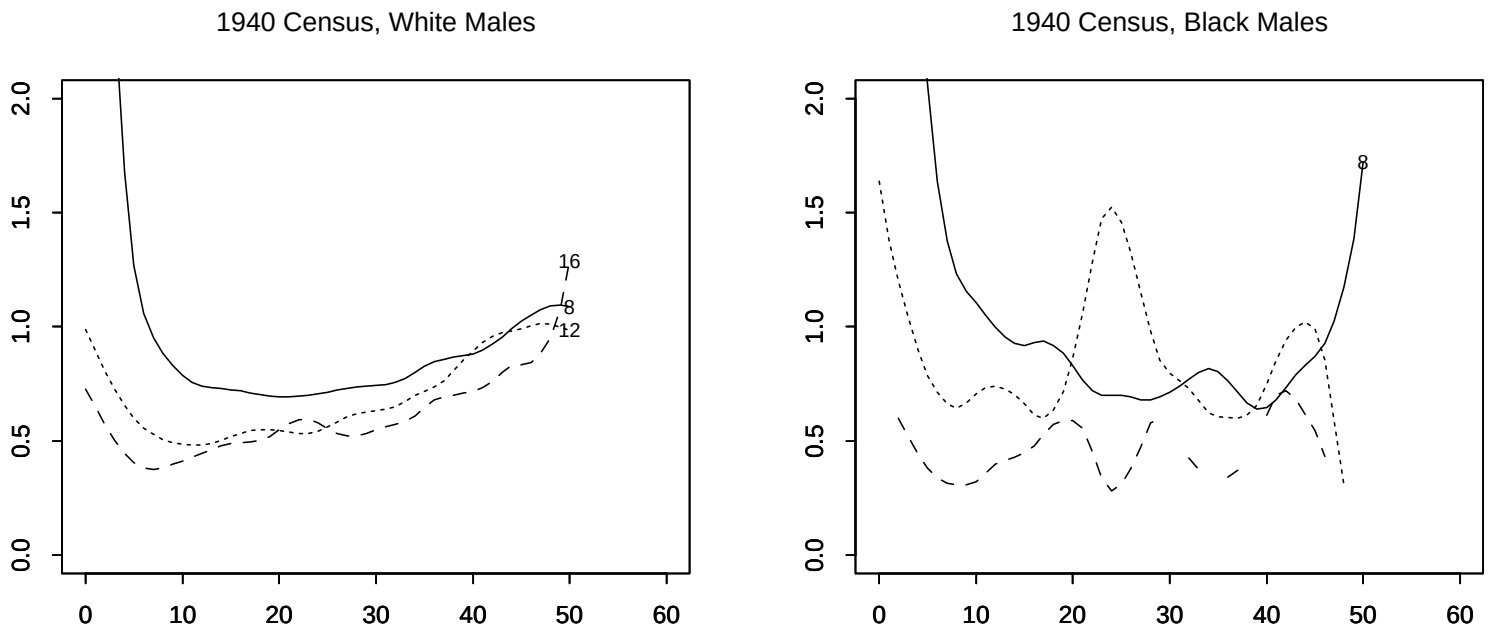
Figure 2: Age-Earnings Profiles, 1940,1960,1980

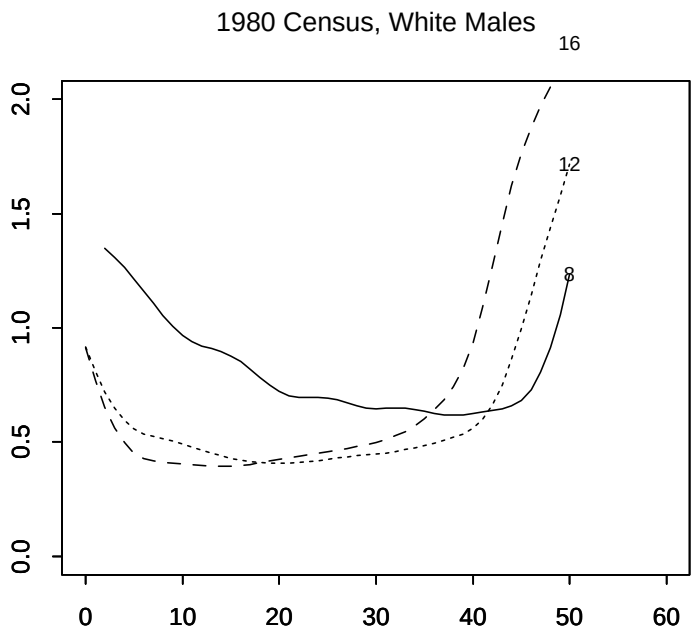


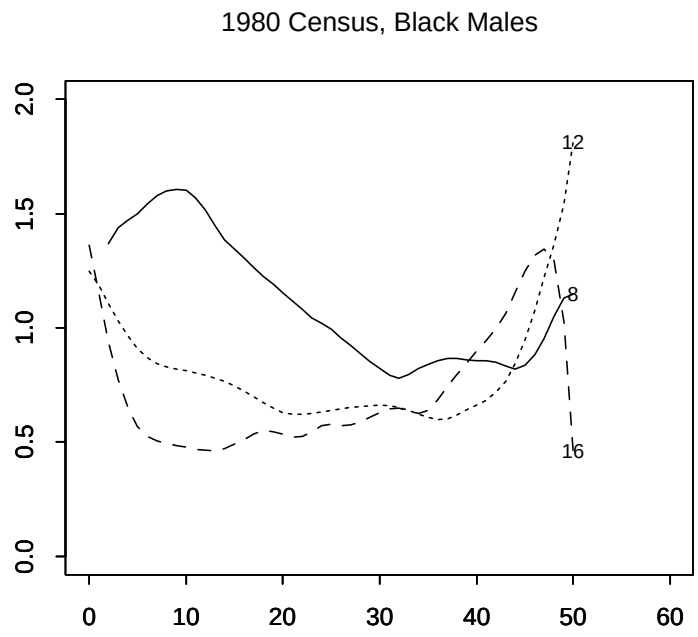

1980 Census, White Males
mean log annual wage and salary income
7
8
9
10
11
0
10
20
30
40
50
60
age
17+
16
13-15
12
9-11
8
5-7
0-4

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
τ	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 and defining $\tilde{r} = (1-\tau)r$ ...

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

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

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

Interpretation

- (1) ... the change in the present value of earnings due to a change in working-life with additional schooling
- (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

All components are expressed as a fraction of the present value of earnings 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

  $\Rightarrow v = 0$ 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

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

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

- parallelism in experience across schooling categories

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

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

- 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)

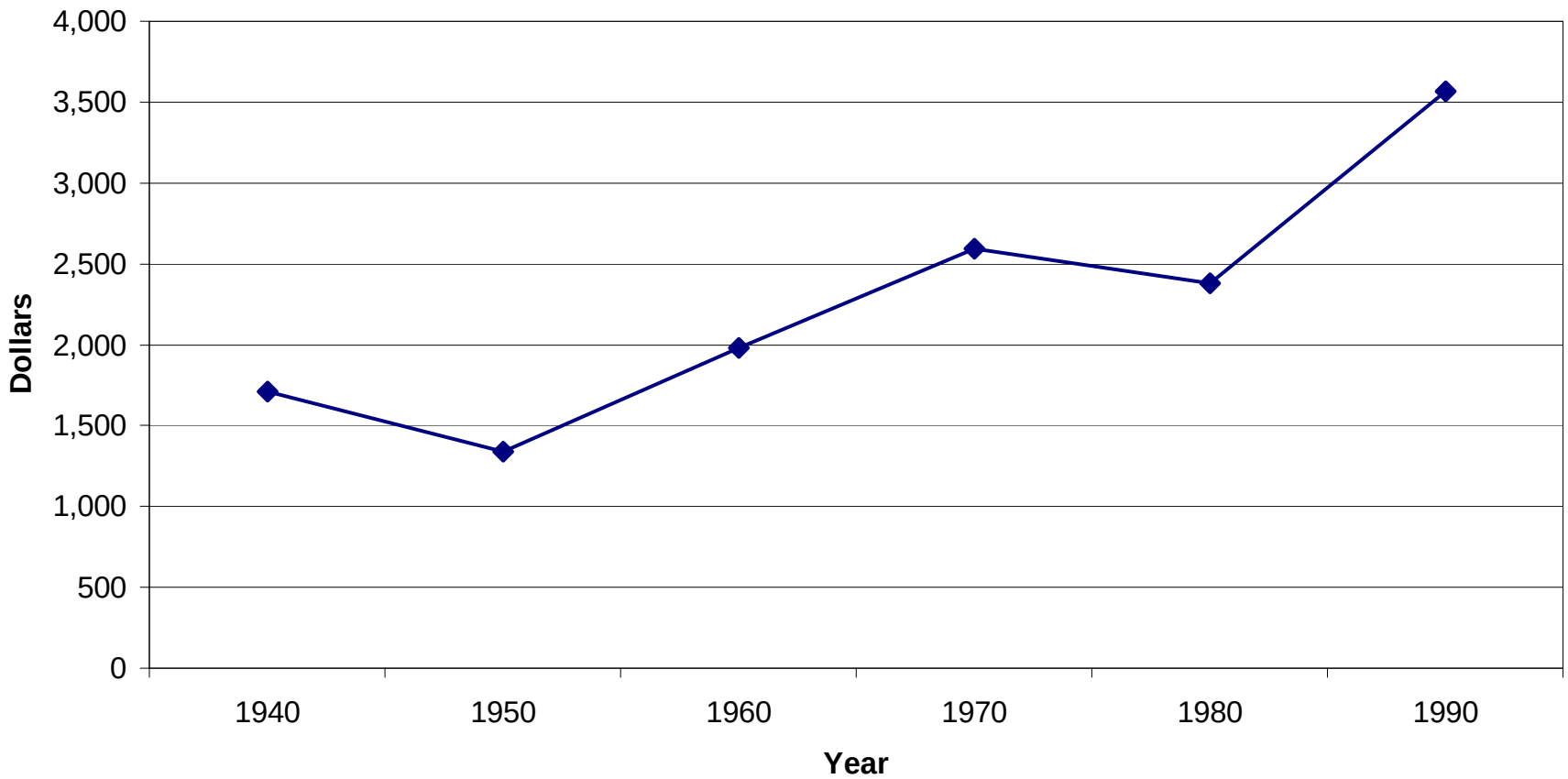


Figure 4b: Marginal Tax Rates
(from Barro & Sahasakul, 1983, Mulligan & Marion, 2000)

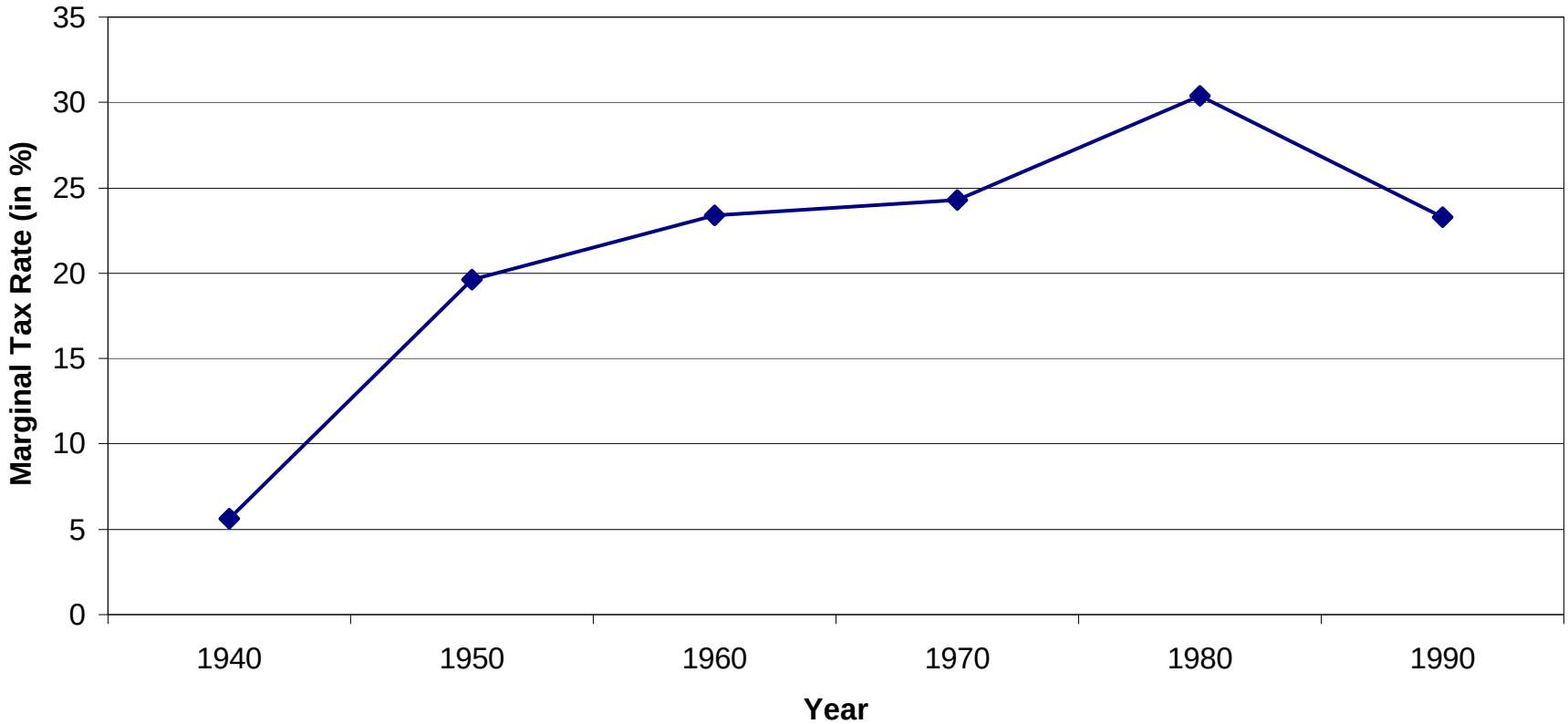


Figure 5: IRR for High School Completion (White and Black Men)

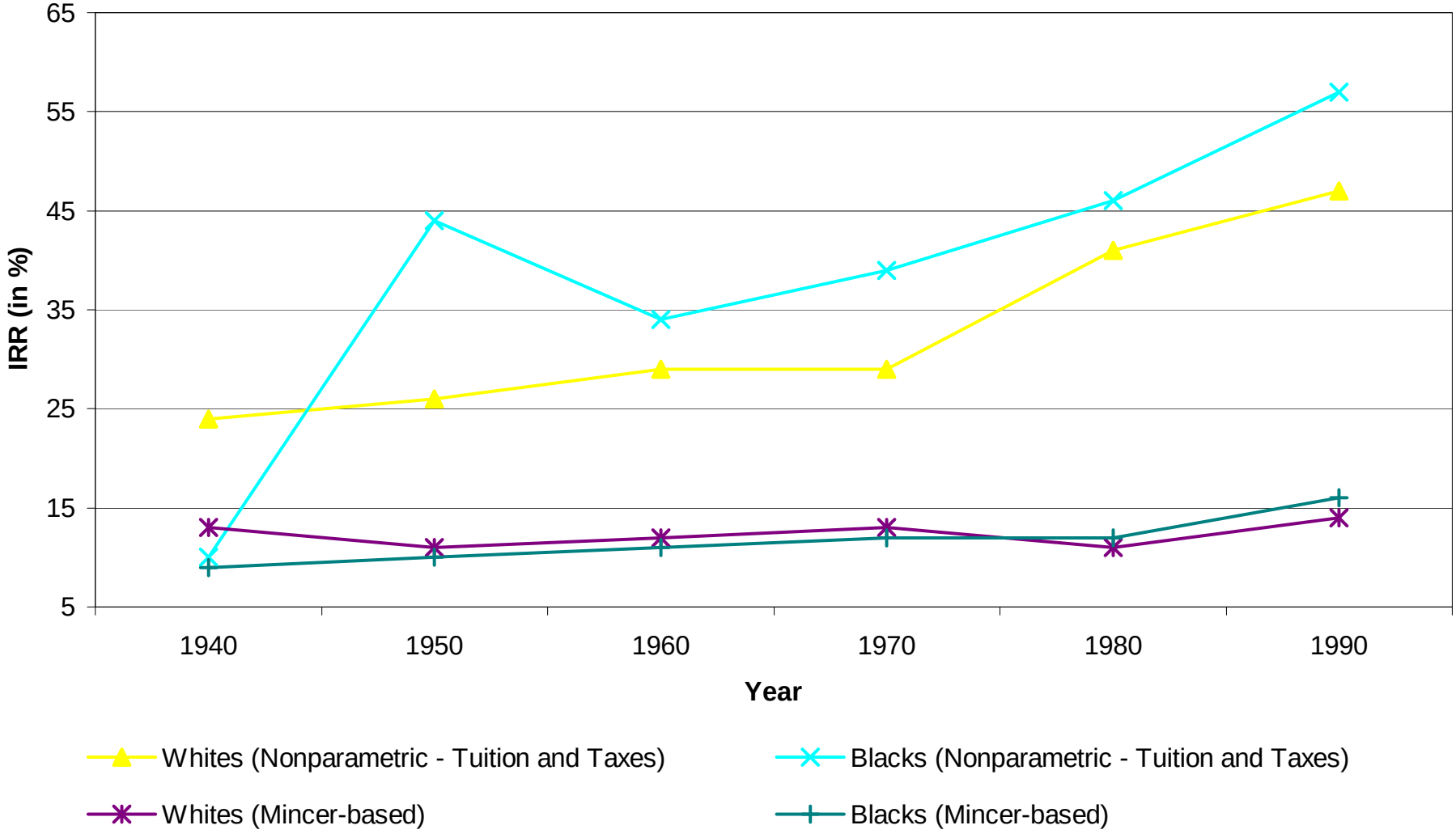
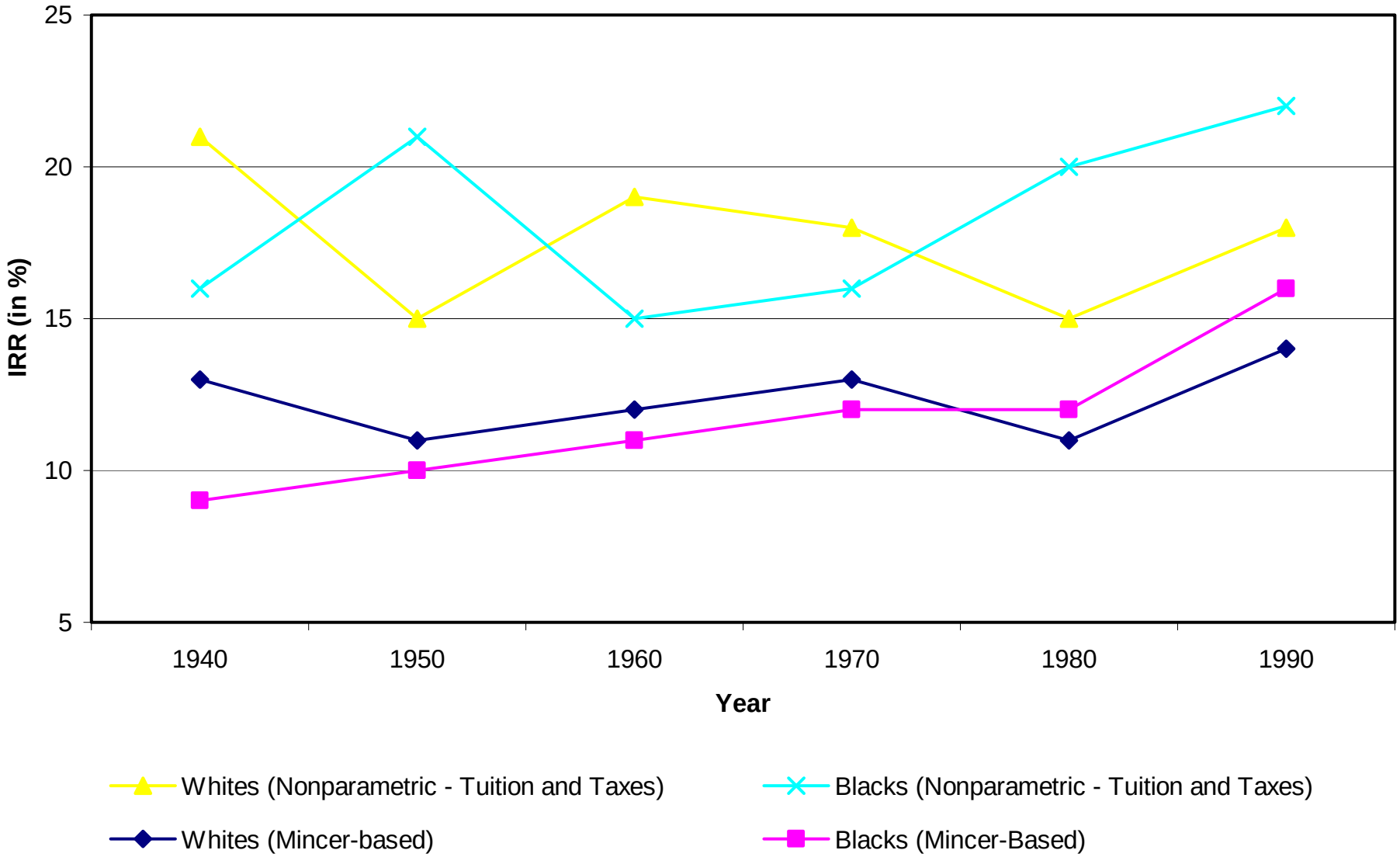


Figure 6: IRR for College Completion (White and Black Men)



Appendix

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