Explaining Educational Attainment across Countries and over Time

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Introduction

Facts: Schooling across Countries, 1950–2005

1. Schooling differences across countries are “large”
2. Schooling increased in all countries
3. Schooling differences smaller in 2005 than in 1950
   - Schooling increased faster for poor
   - True even if poor’s GDP/cap. did not catch up

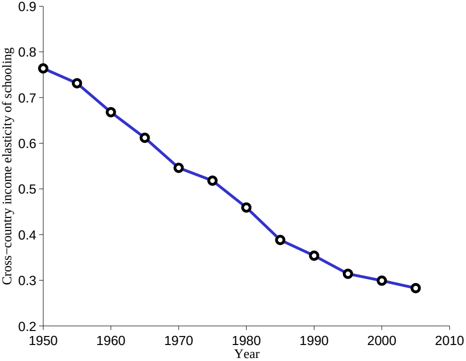
Years of Schooling and GDP per capita (U.S. = 1)

	1950		2005		
Decile	y_{50}	s_{50}	y_{05}	s_{05}	s_{05}/s_{50}
1	0.05	1.28	0.06	5.01	3.91
2	0.07	1.50	0.05	6.85	4.57
3	0.09	3.18	0.21	8.42	2.65
4	0.12	2.04	0.10	7.88	3.87
5	0.17	2.43	0.22	9.41	3.87
6	0.21	3.91	0.31	9.96	2.55
7	0.24	4.06	0.34	9.95	2.45
8	0.38	5.83	0.61	11.25	1.93
9	0.58	6.70	0.71	11.75	1.75
10	0.81	7.96	0.77	11.15	1.40
$R_{10/1}$	17.56	6.22	13.95	2.23	-
$R_{9/1}$	12.51	5.23	12.85	2.35	-

See data

Income Elasticity of Schooling across Countries

- Holding income differences constant, the differences in years of schooling have decreased



Questions

- What accounts for
  - schooling differences across countries?
  - patterns of schooling changes through time?

Strategy

- A model of schooling based on Bils and Klenow (2000)
  - Exogenous productivity and life expectancy
  - Non-homothetic preferences $\rightarrow$ income effect
  - Endogenous time allocation
  - Home production

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- Fit U.S. time series of schooling and time allocation

Strategy

- A model of schooling based on Bils and Klenow (2000)
  - Exogenous productivity and life expectancy
  - Non-homothetic preferences → income effect
  - Endogenous time allocation
  - Home production
- Fit U.S. time series of schooling and time allocation
- Cross-country experiment
  - Economies differ in
    Productivity
    Life expectancy
  - Ask
    What % of schooling diff. with U.S. accounted for in 1950?
    What % of changes in schooling over time accounted for?

Findings

- Cross Section:
  Model accounts for 90% of differences in schooling between U.S. & poor countries in 1950
- Time Series:
  Model accounts for 64% of changes in schooling over time in poor countries
- Schooling increases faster in poor economies relative to rich even if their income does not
- Emphasize role of productivity improvements for schooling in poor countries

Model

Environment

- Preferences: market & nonmarket cons., leisure time, schooling time
- Human capital
  - inputs of time (schooling) and goods
- Finite lives, perfect foresight, perfect credit market
- Exogenous variables
  - Productivity (market and nonmarket)
  - Life expectancy

Preferences

- Lifetime utility, generation τ

$$\int_{\tau}^{\tau+T_\tau} e^{-\rho t}\left[U\left(c_{\tau,t}\right)+\alpha V\left(\ell_{\tau,t}\right)\right]dt+\beta W\left(s_\tau\right)$$

where

$$\begin{aligned} U\left(c_{\tau,t}\right) &= \ln\left(c_{\tau,t}-\bar{c}\right) \\ V\left(\ell_{\tau,t}\right) &= \frac{\ell_{\tau,t}^{1-\mu}-1}{1-\mu} \\ W\left(s_{\tau,t}\right) &= \ln\left(s_{\tau,t}\right) \end{aligned}$$

- $\bar{c}>0$: constant

Technology

- Human capital technology (from Bils and Klenow, 2000)

$$H(s_{\tau,t}, x_{\tau,t}) = x_{\tau,t}^{\gamma} h(s_{\tau,t})$$

where

$$h(s_{\tau,t}) = \exp\left(\frac{\theta}{1-\psi} s_{\tau,t}^{1-\psi}\right)$$

- $x_{\tau,t}$: goods
- $s_{\tau,t}$: time (schooling)

Technology

- Household technology (from McGrattan et al., 1997)

$$c_{\tau,t} = \left[\phi \left(c^m_{\tau,t}\right)^\sigma + (1-\phi) \left(c^n_{\tau,t}\right)^\sigma\right]^{1/\sigma}$$

where

$$c^n_{\tau,t} = z^n_\tau n_{\tau,t}$$

- $c^m_{\tau,t}$: market goods
- $c^n_{\tau,t}$: nonmarket goods
- $n_{\tau,t}$: nonmarket, nonleisure time
- z^n_τ : household productivity

Optimization

- We impose $c^i_{\tau,t} = c^i_\tau$ $(i = m, n)$, $\ell_{\tau,t} = \ell_\tau$, and $n_{\tau,t} = n_\tau$

Optimization

- We impose $c^i_{\tau,t} = c^i_\tau$ $(i = m, n)$, $\ell_{\tau,t} = \ell_\tau$, and $n_{\tau,t} = n_\tau$
- Optimization problem becomes:

$$\max_{c^m_\tau, c^n_\tau, \ell_\tau, x_\tau, s_\tau} \int_0^{T_\tau} e^{-\rho t} \left[U(c_\tau) + \alpha V(\ell_\tau)\right] dt + \beta W\left(s_\tau\right)$$

subject to

$$c^m_\tau \int_0^{T_\tau} e^{-\rho t} dt + x_\tau = z^m_\tau \left(1 - n_\tau - \ell_\tau\right) H(s_\tau, x_\tau) \int_s^{T_\tau} e^{(g^m - \rho)t} dt$$

and technologies

- z^m_τ : market productivity
- g^m : rate of growth of z^m_τ

First Order Condition for s_τ

$$\underbrace{\beta W'(s_\tau)}_{\text{marg. benef.}} = \underbrace{-\frac{\phi}{1-\gamma} a_\tau U'(c_\tau)\, c_\tau \left(\frac{c_\tau^m}{c_\tau}\right)^\sigma \overbrace{\left[\frac{h'(s_\tau)}{h(s_\tau)} + \frac{d_\tau'(s_\tau)}{d_\tau(s_\tau)}\right]}^{A_\tau(s_\tau)}}_{\text{marg. cost}}$$

where $a_\tau = \int_0^{T_\tau} e^{-\rho u} du$ and $d_\tau(s) = \int_s^{T_\tau} e^{(g^m-\rho)u} du$

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- If $\beta = 0$
  - maximize lifetime income: $A_\tau(s_\tau) = 0$
  - s_τ independent of productivity

First Order Condition for s_τ

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- If $\beta = 0$
  - maximize lifetime income: $A_\tau(s_\tau) = 0$
  - s_τ independent of productivity

- If $\beta > 0$, $\bar{c} > 0$
  - Schooling depends upon productivity through c_τ, c^m_τ
  - $U'(c_\tau)\, c_\tau$ decreasing
  - $\uparrow c_\tau$ holding c^m_τ / c_τ constant $\rightarrow \uparrow s_\tau$

First Order Conditions for ℓ_τ and n_τ

- First order conditions for ℓ_τ

$$\alpha V'(\ell_\tau) = \frac{\phi}{1-\gamma}\frac{1}{1-n_\tau-\ell_\tau}U'(c_\tau)\, c_\tau \left(\frac{c_\tau^m}{c_\tau}\right)^\sigma$$

- First order conditions for n_τ

$$(1-\phi)(z_\tau^n)^\sigma (n_\tau)^{\sigma-1}(1-n_\tau-\ell_\tau) = \frac{\phi}{1-\gamma}(c_\tau^m)^\sigma$$

Calibration

Calibration

- Fit model to U.S. time series of
  - Schooling
  - Workweek
- Average 2 percent growth in income per worker
- Nonmarket hours data

Calibration

- Schooling data from Goldin and Katz (2008) ▸ See
  - Years of school completed at age 35 for 1876- to 1975-generation
- Market hours data from Kendrick (1961), McGrattan and Rogerson (2004) and Whaples (1990) ▸ See
  - Hours worked per worker
- Nonmarket hours from Aguiar and Hurst (2007)
  - Transform hours per person into hours per worker
  - 25.6 hours per worker in 1965 and 22.5 in 2005

Calibration

- $\rho = 0.04$
- $\psi = 0.3$, $\gamma = 0.1$ (Bils and Klenow, 2000)
- $\sigma = 0.4$ (McGrattan et al, 1997)

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- $z_\tau^m = e^{g^m(\tau - 1795)}$
- $z_\tau^n = \sum_{i=0}^{3} a_i (z_\tau^m)^i$

Calibration

- $\rho = 0.04$
- $\psi = 0.3$, $\gamma = 0.1$ (Bils and Klenow, 2000)
- $\sigma = 0.4$ (McGrattan et al, 1997)

- $z_\tau^m = e^{g^m(\tau - 1795)}$
- $z_\tau^n = \sum_{i=0}^{3} a_i (z_\tau^m)^i$

- $T_\tau = a_T + b_T \tau$
  Estimate a_T and b_T using U.S. data on years at school + years at work (Hazan, 2009 and Goldin and Katz, 2008)

Calibration

- Remaining parameters

$$\omega = (\bar{c}, \phi, \mu, \theta, \alpha, \beta, g^m, a_0, a_1, a_2, a_3)'$$

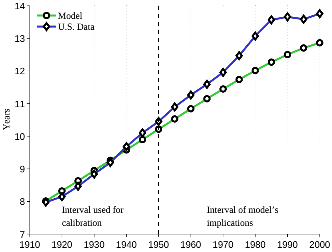
$$\min_{\omega} \sum_{\tau=1880}^{1915} \left(\frac{s_\tau}{s_\tau^{data}} - 1 \right)^2 + \sum_{\tau=1795}^{1965} \left(\frac{1 - \ell_\tau - n_\tau}{1 - \ell_\tau^{data} - n_\tau^{data}} - 1 \right)^2 + M'(\omega) M(\omega),$$

where

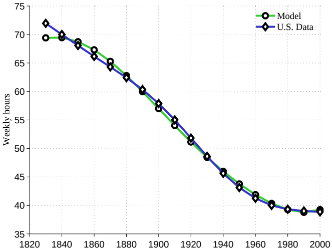
$$M(\omega) = \begin{pmatrix} \frac{y_{1965}/y_{1795}}{e^{0.02 \times 170}} - 1 \\ n_{1968}/22.5 - 1 \\ n_{1938}/25.6 - 1 \end{pmatrix}$$

See details See parameters

Calibration – Results



Years of schooling completed at age 35



Weekly Hours

See time allocation | See value of schooling | See value of $\bar{c}$

Experiments

Baseline Experiment

- Compute 10 economies that differ by
  - Level and growth rate of market productivity z^m_{1795} and g^m
  - Life expectancy in 1950 and 2005
- Discipline
  1. Estimate cross-sectional relation between GDP & Life Expectancy in 1950 and 2005
  2. Using step 1, find z^m_{1795} and g^m to match dist. of GDP/cap. in 1950 and 2005

Baseline Results for 1950

	Dec	Rel Inc	Life Exp	Leis Hrs	Home Hrs	Mkt Hrs	Schl Yrs	$\bar{c}/c$	$\hat{c}/c$	Accounting
										Cross-Section
	1	0.05	20.9	1.3	45.2	65.5	2.2	0.77	1.007	0.90
	2	0.07	24.1	4.8	39.1	68.0	2.6	0.66	1.008	0.87
	3	0.09	26.4	2.3	41.2	68.5	3.7	0.72	1.004	0.92
1	4	0.12	29.2	9.4	33.9	68.7	3.7	0.56	1.006	0.79
9	5	0.17	32.5	10.0	31.9	70.1	5.0	0.54	1.004	0.67
5	6	0.21	34.5	11.4	30.2	70.4	5.8	0.50	1.004	0.71
0	7	0.24	35.7	13.5	28.8	69.7	6.1	0.47	1.004	0.66
	8	0.38	40.1	18.5	25.2	68.3	8.0	0.37	1.003	0.50
	9	0.58	44.1	30.0	22.8	59.2	9.0	0.21	1.003	0.35
	10	0.81	47.3	41.8	23.1	47.1	9.5	0.09	1.003	0.30
	U.S.	1.00	49.3	44.9	23.3	43.8	10.2	0.07	1.003	-

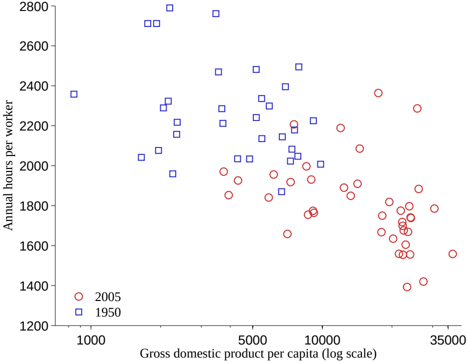
- Model accounts for 90% of difference with U.S. schooling for 1st decile

Baseline Results for 2005

	Dec	Rel Inc	Life Exp	Leis Hrs	Home Hrs	Mkt Hrs	Schl Yrs	$\bar{c}/c$	$\hat{c}/c$	Accounting
										Time Series
	1	0.06	35.6	15.2	29.4	67.4	5.2	0.45	1.004	0.64
	2	0.05	38.5	16.6	29.7	65.6	5.0	0.44	1.005	0.42
	3	0.21	42.9	27.5	22.2	62.3	9.6	0.23	1.003	0.97
2	4	0.10	44.1	27.4	25.1	59.5	7.0	0.28	1.004	0.47
0	5	0.22	48.2	33.9	22.3	55.8	10.1	0.16	1.003	0.53
0	6	0.31	50.3	36.4	21.6	54.0	11.7	0.12	1.003	0.76
5	7	0.34	51.0	38.0	21.6	52.4	12.0	0.10	1.003	0.75
	8	0.61	54.0	41.7	21.3	49.0	14.4	0.05	1.002	0.89
	9	0.71	56.0	46.1	22.4	43.5	14.1	0.03	1.002	0.80
	10	0.77	57.4	49.4	23.4	39.2	13.0	0.02	1.002	0.91
	U.S.	1.00	58.7	48.9	23.1	40.0	13.0	0.02	1.002	-

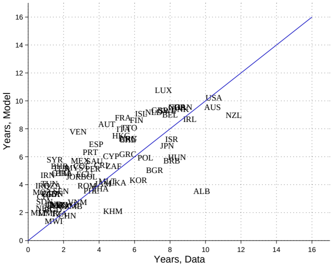
- Model accounts for 64% of observed growth rate of s in 1st decile
- Elasticity of schooling to gdp: 0.52 (v. 0.76 in data) $\rightarrow$ 0.35 (v. 0.28)

Work Hours Across Countries

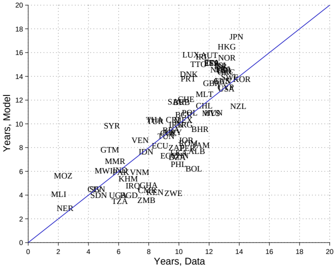


Schooling–Country by Country Implications

Years of Schooling, Model v. Data



1950, $R^2 = 78\%$

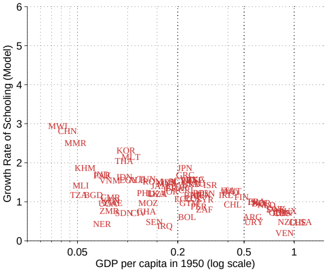


2005, $R^2 = 81\%$

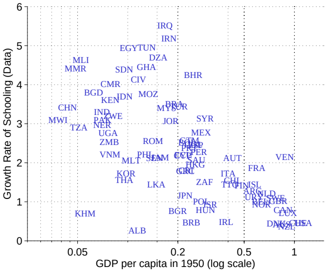
Back

Schooling–Country by Country Implications

Growth Rate of Schooling by 1950 Income



Model



Data

Experiments

- Experiment 1: The effect of equal productivity growth
- Experiment 2: The effect of equal productivity growth AND equal change in life expectancy

Experiments

		Experiment 1				Experiment 2			
	Dec	Rel Inc	Mkt Hrs	Schl Yrs	Accounting	Rel Inc	Mkt Hrs	Schl Yrs	Accounting
					Cross Section				Cross Section
	1	0.05	65.4	2.2	0.90				
	2	0.07	67.9	2.8	0.85				
	3	0.09	69.0	3.3	0.99				
1	4	0.12	69.4	3.9	0.78				
9	5	0.17	68.2	4.6	0.72				
5	6	0.21	66.6	5.2	0.80				
0	7	0.24	65.1	5.5	0.76				
	8	0.38	58.5	6.9	0.76				
	9	0.58	51.4	8.3	0.55				
	10	0.81	46.4	9.5	0.33				
	U.S.	1.00	43.8	10.2	-				
					Time Series				Time Series
	1	0.06	67.4	5.3	0.65				
	2	0.08	65.0	6.1	0.51				
	3	0.10	62.8	7.1	0.80				
2	4	0.12	59.5	7.6	0.51				
0	5	0.16	55.1	8.9	0.48				
0	6	0.19	52.3	9.6	0.66				
5	7	0.21	50.4	9.9	0.65				
	8	0.33	44.4	11.3	0.75				
	9	0.51	40.2	12.3	0.70				
	10	0.75	38.9	12.8	0.89				
	U.S.	1.00	40.0	13.0	-				

Experiments

	Dec	Experiment 1 Rel Inc	Mkt Hrs	Schl Yrs	Accounting	Experiment 2 Rel Inc	Mkt Hrs	Schl Yrs	Accounting
					Cross Section				Cross Section
	1	0.05	65.4	2.2	0.90	0.05	65.4	2.2	0.90
	2	0.07	67.9	2.8	0.85	0.07	67.9	2.8	0.85
	3	0.09	69.0	3.3	0.99	0.09	69.0	3.3	0.99
1	4	0.12	69.4	3.9	0.78	0.12	69.4	3.9	0.78
9	5	0.17	68.2	4.6	0.72	0.17	68.2	4.6	0.72
5	6	0.21	66.6	5.2	0.80	0.21	66.6	5.2	0.80
0	7	0.24	65.1	5.5	0.76	0.24	65.1	5.5	0.76
	8	0.38	58.5	6.9	0.76	0.38	58.5	6.9	0.76
	9	0.58	51.4	8.3	0.55	0.58	51.4	8.3	0.55
	10	0.81	46.4	9.5	0.33	0.81	46.4	9.5	0.33
	U.S.	1.00	43.8	10.2	-	1.00	43.8	10.2	-
					Time Series				Time Series
	1	0.06	67.4	5.3	0.65	0.06	66.9	4.4	0.51
	2	0.08	65.0	6.1	0.51	0.08	64.5	5.1	0.40
	3	0.10	62.8	7.1	0.80	0.09	62.0	5.7	0.58
2	4	0.12	59.5	7.6	0.51	0.11	58.8	6.5	0.39
0	5	0.16	55.1	8.9	0.48	0.15	54.3	7.6	0.36
0	6	0.19	52.3	9.6	0.66	0.18	51.4	8.2	0.50
5	7	0.21	50.4	9.9	0.65	0.20	49.6	8.7	0.50
	8	0.33	44.4	11.3	0.75	0.31	43.7	10.2	0.61
	9	0.51	40.2	12.3	0.70	0.49	39.8	11.7	0.61
	10	0.75	38.9	12.8	0.89	0.74	38.8	12.6	0.85
	U.S.	1.00	40.0	13.0	-	1.00	40.0	12.9	-

Experiments

- Experiment 1: The effect of equal productivity growth
  - Cross Section: accounts for 90% of diff. with U.S. schooling in 1950 (v. 90 in baseline)
  - Time Series: accounts for 65% of growth rate (v. 64% in baseline)

  - Productivity growth differences across countries are small
  - Effect of labor margin on returns to schooling

Experiments

- Experiment 1: The effect of equal productivity growth
  - Cross Section: accounts for 90% of diff. with U.S. schooling in 1950 (v. 90 in baseline)
  - Time Series: accounts for 65% of growth rate (v. 64% in baseline)

  - Productivity growth differences across countries are small
  - Effect of labor margin on returns to schooling

- Experiment 2: The effect of equal productivity growth AND equal change in life expectancy
  - Cross Section: same as Exp. 1 by construction
  - Time series: accounts for 51% of growth rate (v. 64% in baseline)
  - Elasticity: 0.51 in 1950 $\rightarrow$ 0.34 in 2005

Conclusion

Conclusion

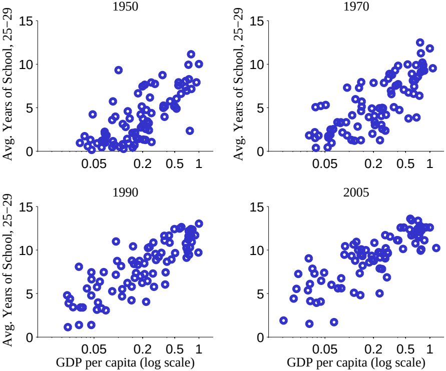
- We developed a model of human capital accumulation to assess the quantitative importance of productivity and life expectancy in explaining differences in educational attainment across countries and over time
- The model accounts for 90 percent of the difference in schooling between rich and poor countries in 1950 and 64 percent of the increase in schooling levels over time in poor countries
- The model generates a faster increase in schooling levels in poor than in rich countries, explaining the convergence in cross-country schooling levels observed in the data

Conclusion

- Model implies faster increase in schooling associated with stronger decline in hours of work, hence, even though human capital increases, per capita income may or may not increase
- This suggest empirical relationship between schooling and per capita income growth across countries, as pioneered for example by Benhabib and Spiegel (1994), does not provide an accurate assessment of the importance of human capital for development
- Our results imply that improving education and welfare in poor countries hinges more on solving their productivity gap with rich countries than pursuing often emphasized educational policies aimed at solving institutional and other frictions

Extra Material

Schooling Across Countries and Over Time

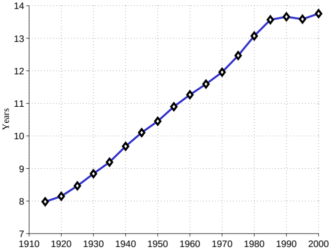


Deciles

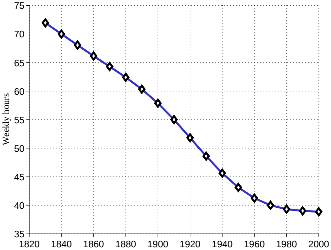
1. MWI,CHN,MMR,TZA,MLI,KHM,BGD,NER
2. PAK,IND,UGA,VNM,ZMB,CMR,KEN,ZWE
3. THA,SDN,KOR,IDN,EGY,MLT,ALB,CIV
4. GHA,PHL,TUN,MOZ,ROM,SEN,LKA,DZA,JAM
5. MYS,IRQ,IRN,JOR,BRA,BGR,TUR,CYP,ECU
6. GRC,JPN,BOL,CRI,GTM,PRT,BRB,BHR,COL
7. HKG,SAU,ESP,PER,MEX,POL,HUN,ZAF,SYR
8. ISR,IRL,ITA,TTO,AUT,CHL,FIN,ARG
9. URY,ISL,FRA,BEL,NOR,NLD,SWE,DNK
10. GBR,AUS,CAN,VEN,NZL,LUX,CHE,USA

Calibration

- HP-filtered schooling and hours



Years of schooling completed at age 35



Weekly hours

Calibration

- Income

$$y_\tau = z_\tau^m e^{35 \times g^m} \left(1 - n_\tau - \ell_\tau\right) H(s_\tau, x_\tau)$$

- Model's output is decision by generation

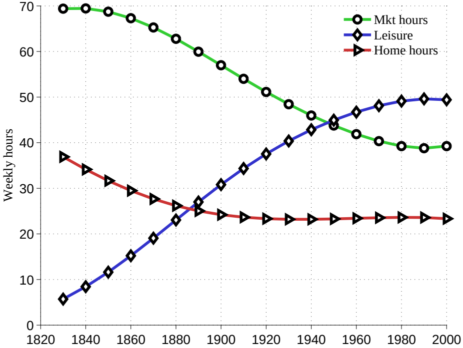
- Associate s_τ with actual schooling of generation τ
- Associate n_τ with actual hours at date $\tau + 35$

- Compute 171 generations from 1795 to 1965
- Match to hours from 1830 to 2000
- Match to schooling of generation 1880 to 1915

Calibration

Preferences	$\rho = 0.04$, $\bar{c} = 0.03$, $\phi = 0.10$
	$\sigma = 0.40$, $\alpha = 0.68$, $\beta = 0.71$, $\mu = 0.23$
Technology	$z^m_{1795} = 1.0$, $g^m = 0.019$
	$a_0 = 0.03410$, $a_1 = 0.00097$, $a_2 = 0.00463$, $a_3 = -0.00010$
	$\gamma = 0.1$, $\psi = 0.30$, $\theta = 0.06$

Time Allocation in Baseline Model



Consumption Value of Schooling

- We compute $\hat{c}_\tau$ such that

$$\int_0^{T_\tau} e^{-\rho t} \left[U(c_\tau) + \alpha V(\ell_\tau)\right] dt + \beta W\left(s_\tau\right) = \int_0^{T_\tau} e^{-\rho t} \left[U\left(\hat{c}_\tau\right) + \alpha V(\ell_\tau)\right] dt + \beta W\left(s_\tau - 1\right)$$

- Find $\hat{c}_\tau / c_\tau < 1.01$

  To compensate for one less year of school, less than a 1% increase in consumption is required

Value of Subsistence

- How large is $\bar{c}$?
- Subsistence can be obtained from income (market) or home production
- We compute $\bar{c}/c_\tau$
- Decline from 63% (1800) to 2% (2000)
- Consistent with expenditure share of food: 5.2% in 1996