Simulation of age-dependent skill formation

Karsten Reuß
Centre of European Economic Research
Mannheim, Germany

International Conference on Economics of Education, Firm Behaviour and Training Policies

June 27th 2008

Overview

- A simulation model of skill formation over the life cycle
- Differences in skill formation of a heterogeneous population
- Analysis of Returns to education in early and later life
- In whom should a society invest ?
- The influence of the labor market on adult skill formation

Cognitive Skills

- Memory power of the brain
- Brain information processing speed
- mathematical, logical and language skills …
- most of these skills are formed until the age of six years
- Early environment (in utero conditions, family) are important

Romanian adoptees: Cognitive Skills at the age of 6 subject to time of adoption

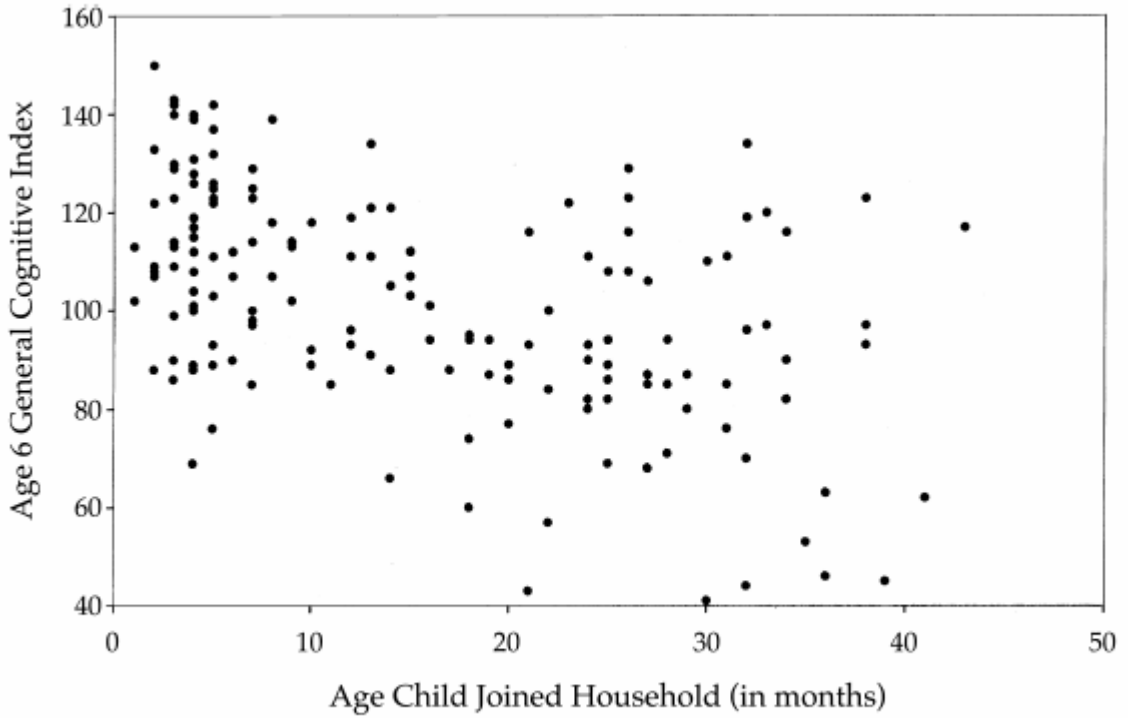


Figure 2 Scattergram of Age at Entry GCI Score at age 6 years for the Romanian adoptees only.

O'Connor, Thomas G.; Rutter, Michael (2000),
The Effects of Global Severe Privation on Cognitive Competence: Extension and Longitudinal Follow-up,
Child Development 71, 376-390.

Motivational Skills

- self-regulation
- motivation
- social integration
- persistance
- Young age is more important than old age, but skills remain more malleable at later ages compared to cognitive skills
- Familiy, school, peer group interactions are important

The Technology of skill formation

Cunha, F. and J. J. Heckman (2007), The Technology of Skill Formation, *The American Economic Review* 97 (2), 31-47.

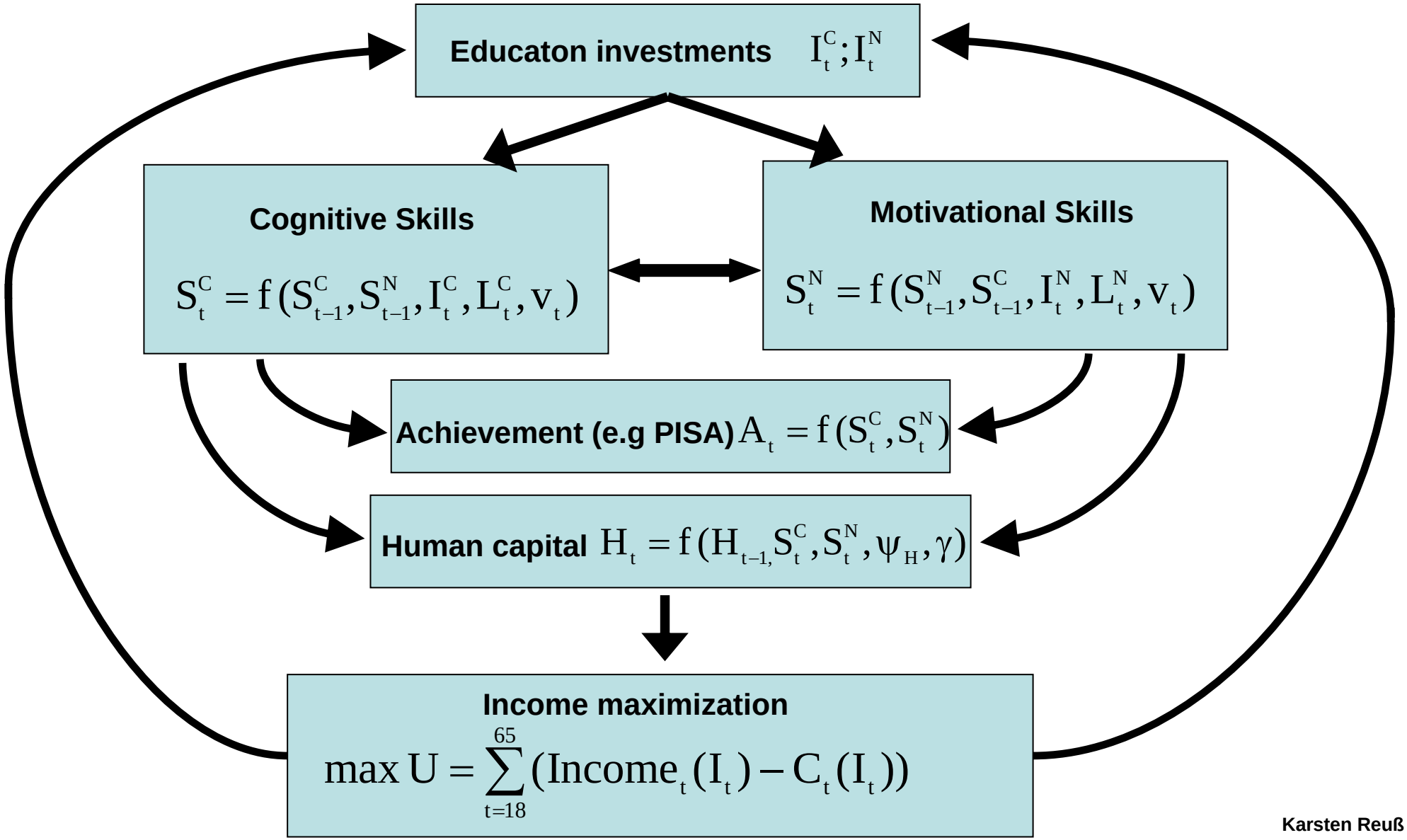
- Skills acquired in one period are available in later periods (**self-productivity, recursive productivity**)
- Skills acquired in the past make subsequent investments more productive (**direct complementarity**)
- Sensitive or critical periods (evidence form other disciplines: neurobiology, developmental psychology)
- Early investments yield the highest returns

$$S_2^C = \left\{ \gamma_1 (S_1^C)^\alpha + \gamma_2 (S_1^N)^\alpha + (1-\gamma_1-\gamma_2)(I_2^C)^\alpha \right\}^{\frac{1}{\alpha}}$$

Adding novel features to the technology of skill formation to cover a life-span perspective

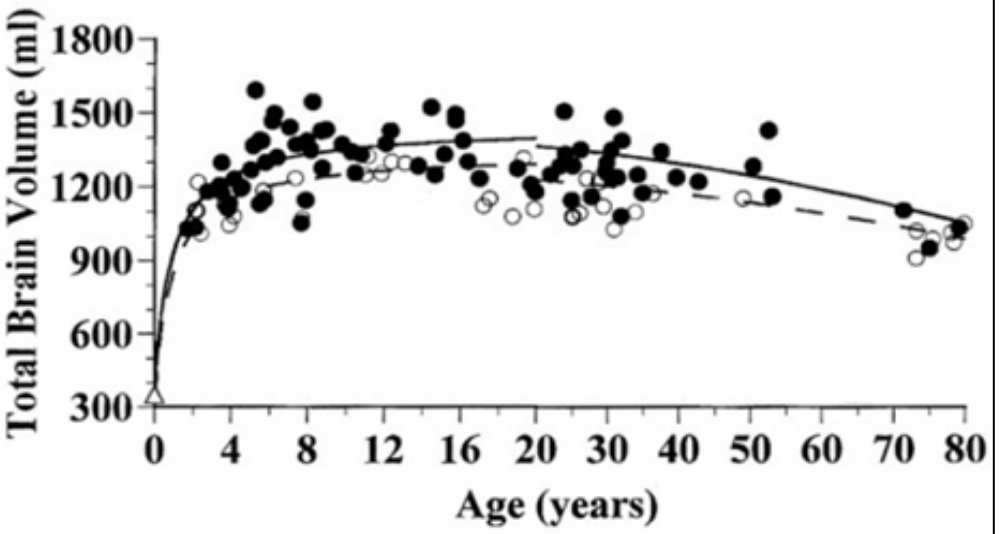
- Integrating biological and social age-dependant aspects of skill formation and depreciation reflected by learning multipliers
- Multiperiod feedback systems (80 periods = 80 years)
- Age-dependant earnings
- Exogeneous investments in childhood (family background)
- Endogeneous investments in adult life
- Heterogeneity in environment and giftedness
- → Computation of the change in lifetime earnings caused by skill investments

Overview of the Simulation Model

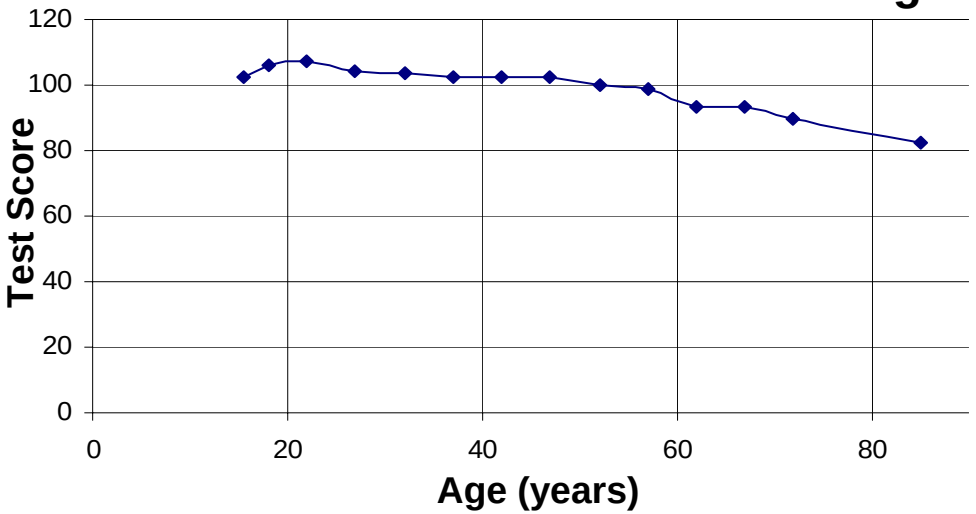


Cognitive Skill Formation over the Life Span

Indicator 1: Brain Volume

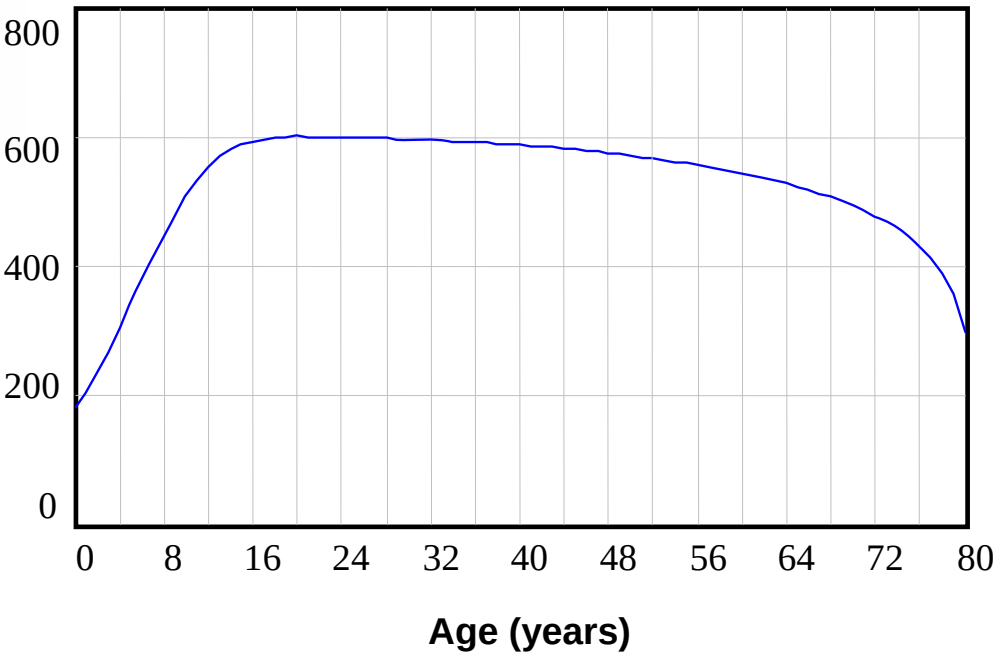


Indicator 2: General Problem Solving



Simulation in model

$$S_t^C = I_t^C \cdot \left(S_{t-1}^{C\,\frac{1}{3}} \cdot S_{t-1}^{N\,\frac{1}{3}} \cdot I_t^{C\,\delta\cdot\frac{1}{3}} \right) + S_{t-1}^C - \frac{S_{t-1}^C}{v_{t-1}}$$



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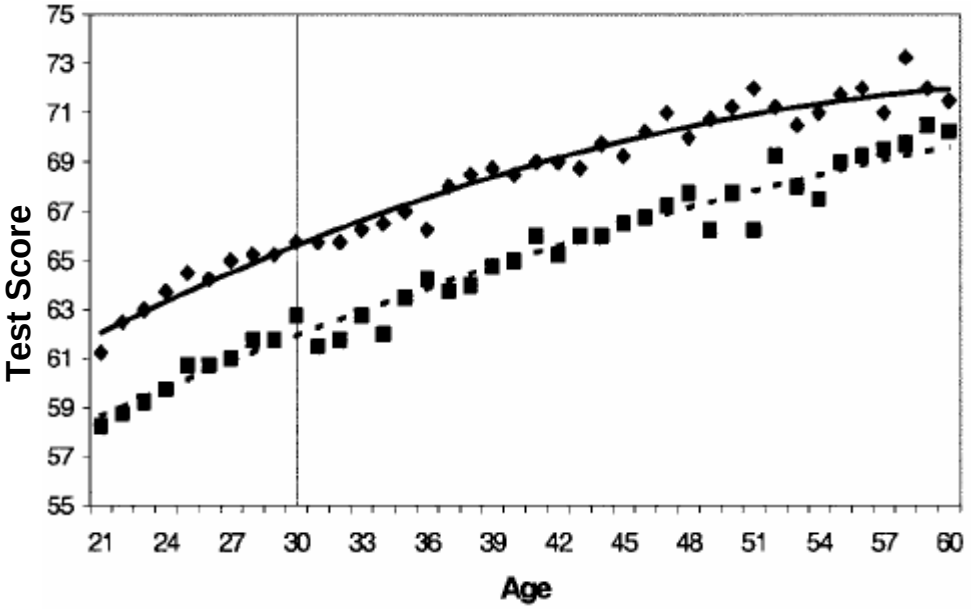
Motivational Skill Formation over the Life Span

One Indicator:

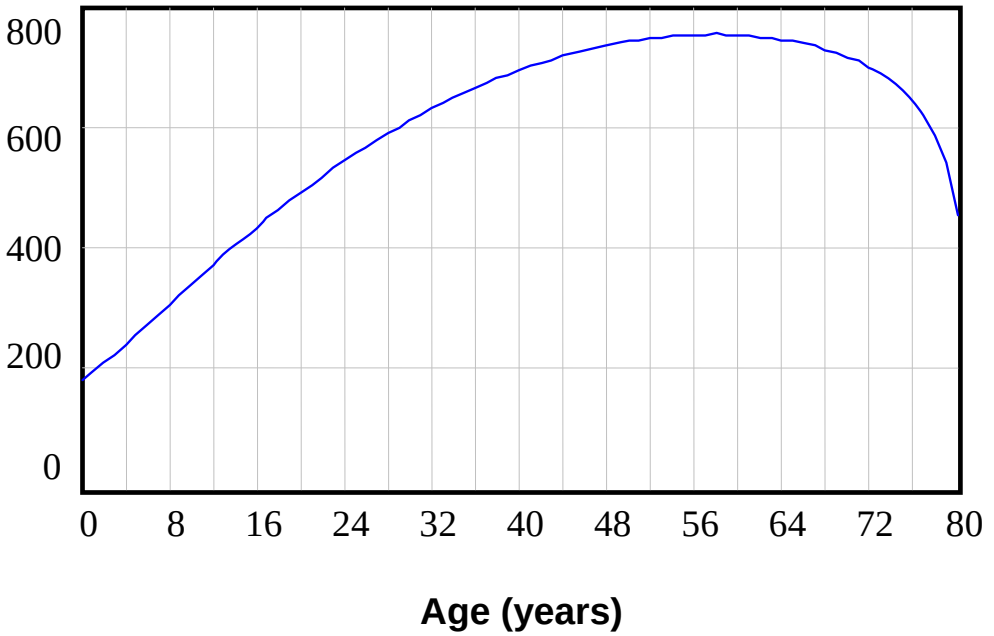
Development of Conscientiousness

- Conscientiousness and school grades are highly correlated
- seems to be closely related with motivational (non-cognitive) skills



Model Simulation

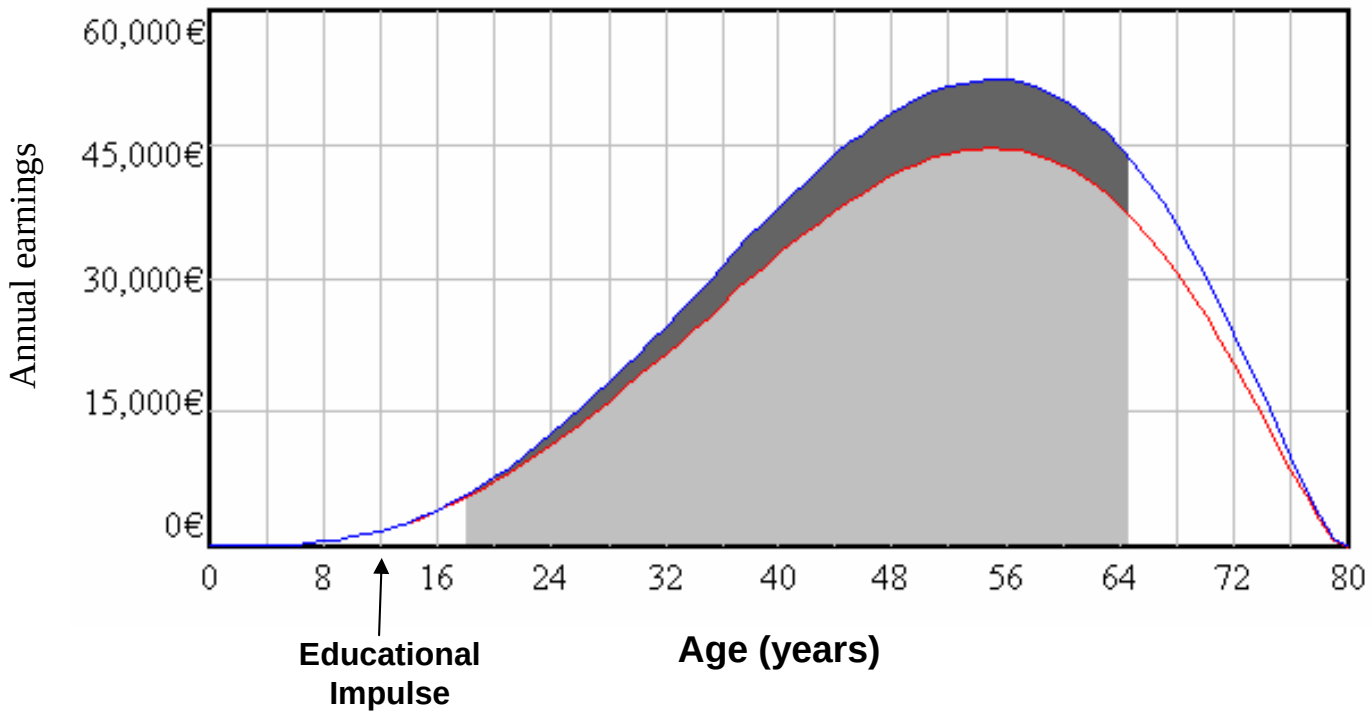
$$S_t^N = l_t^N \cdot \left(S_{t-1}^{N\,\frac{1}{3}} \cdot S_{t-1}^{C\,\frac{1}{3}} \cdot I_t^{N\,\delta \cdot \frac{1}{3}} \right) + S_{t-1}^N - \frac{S_{t-1}^N}{v_{t-1}}$$



Assessing human capital and returns to education

- **new Human capital („ labor markt relevant abilities“) is produced by human capital stock and skills**

$$H_t = \psi_H \cdot \left(S_{t-1}^{C\ \gamma\cdot\frac{1}{3}} \cdot S_{t-1}^{N\ \gamma\cdot\frac{1}{3}} \cdot H_{t-1}^{\ \gamma\cdot\frac{1}{3}} \right) + (1 - \delta_{t-1}^{H}) \cdot H_{t-1}$$



Introducting hetereogeneity in the model

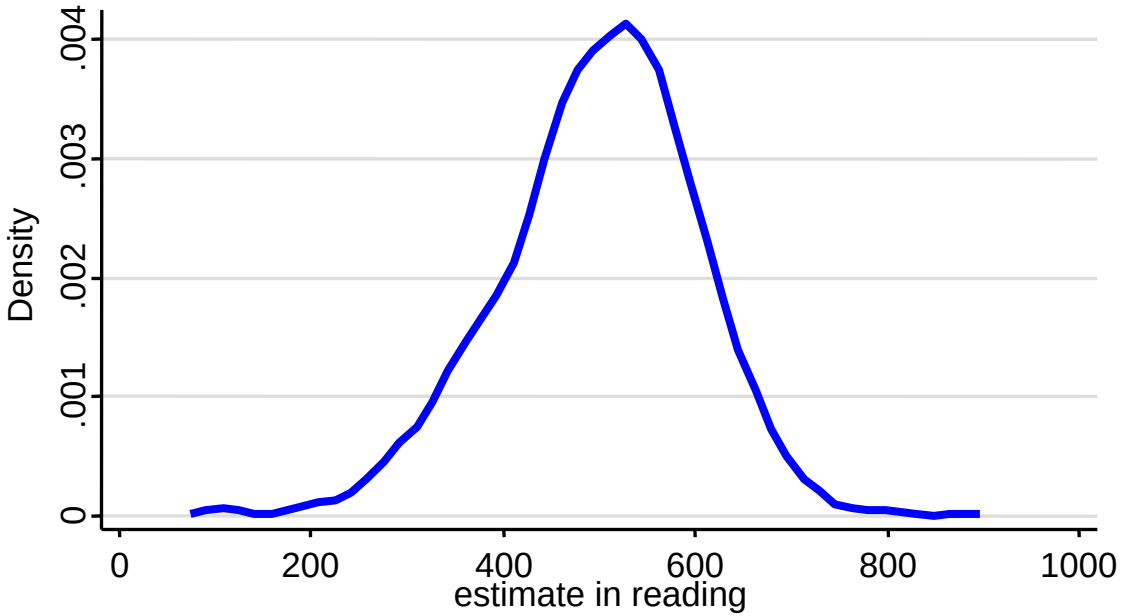
S_0 initial condition

environment

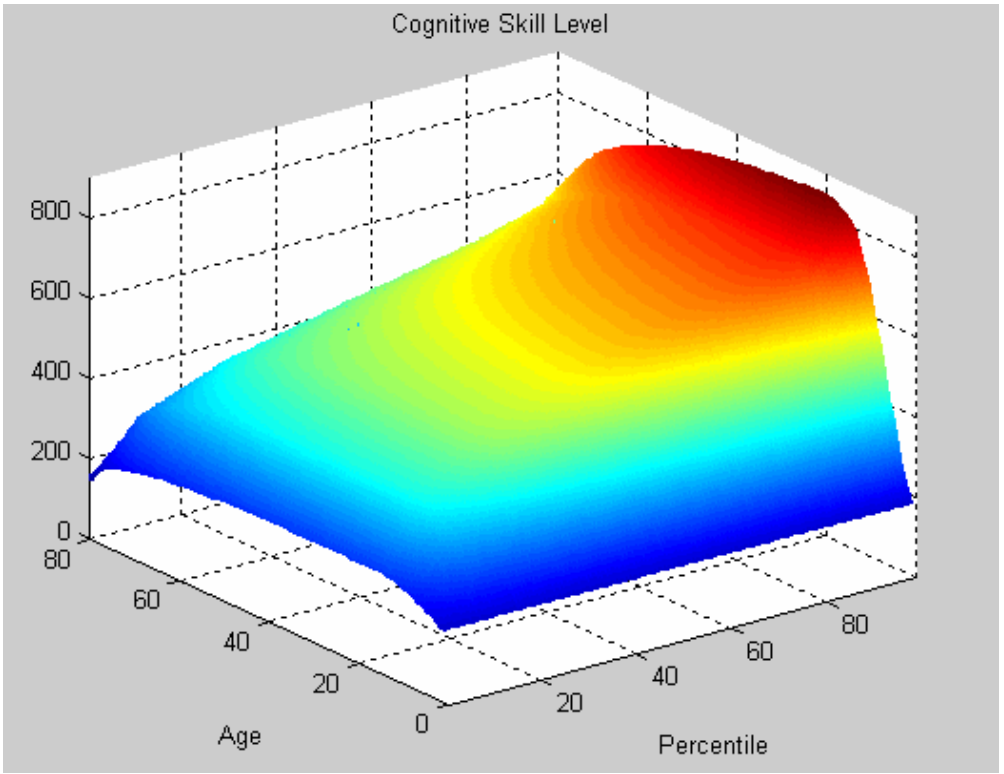
giftedness

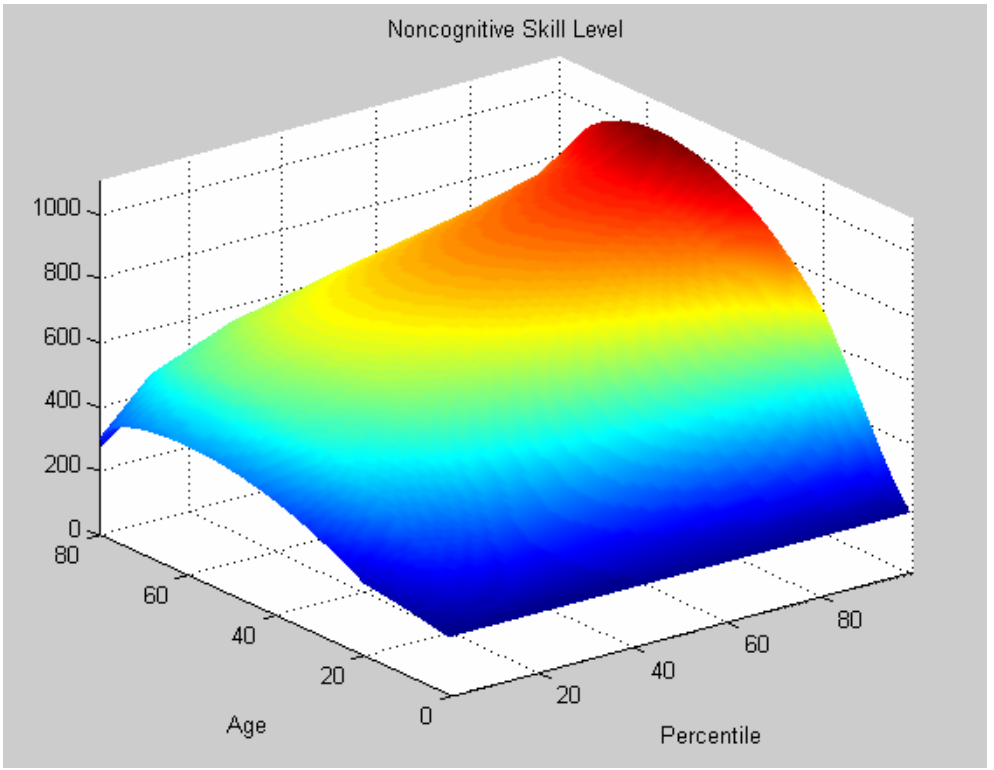
$$\text{skillproduction} = l_t^k \cdot \left(S_{t-1}^{k\,\frac{1}{3}} \cdot S_{t-1}^{j\,\frac{1}{3}} \cdot I_t^{\delta\,\frac{1}{3}} \right)$$

PISA 2000: Reading Literacy, 9th Class



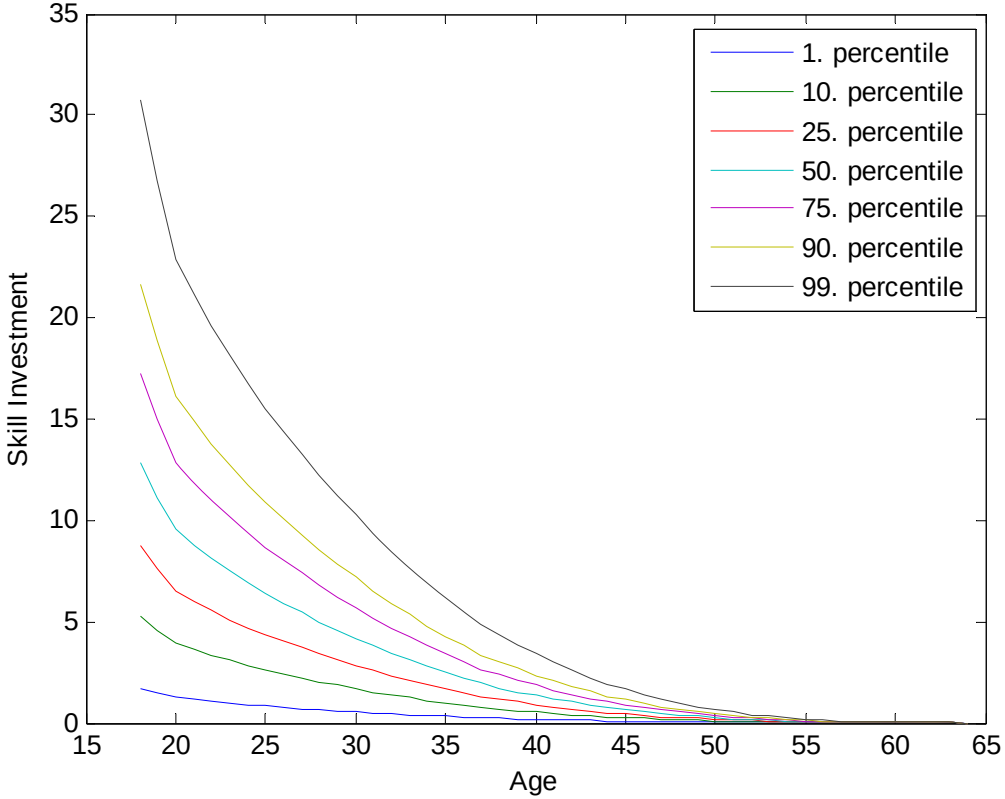
A population of heterogeneous individuals

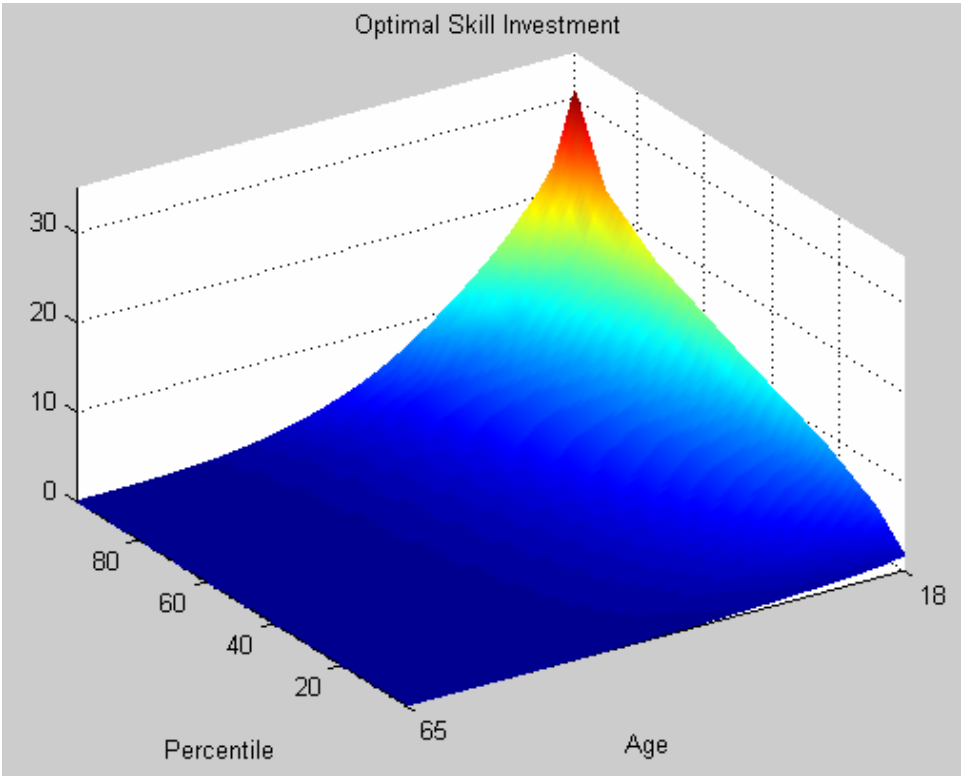




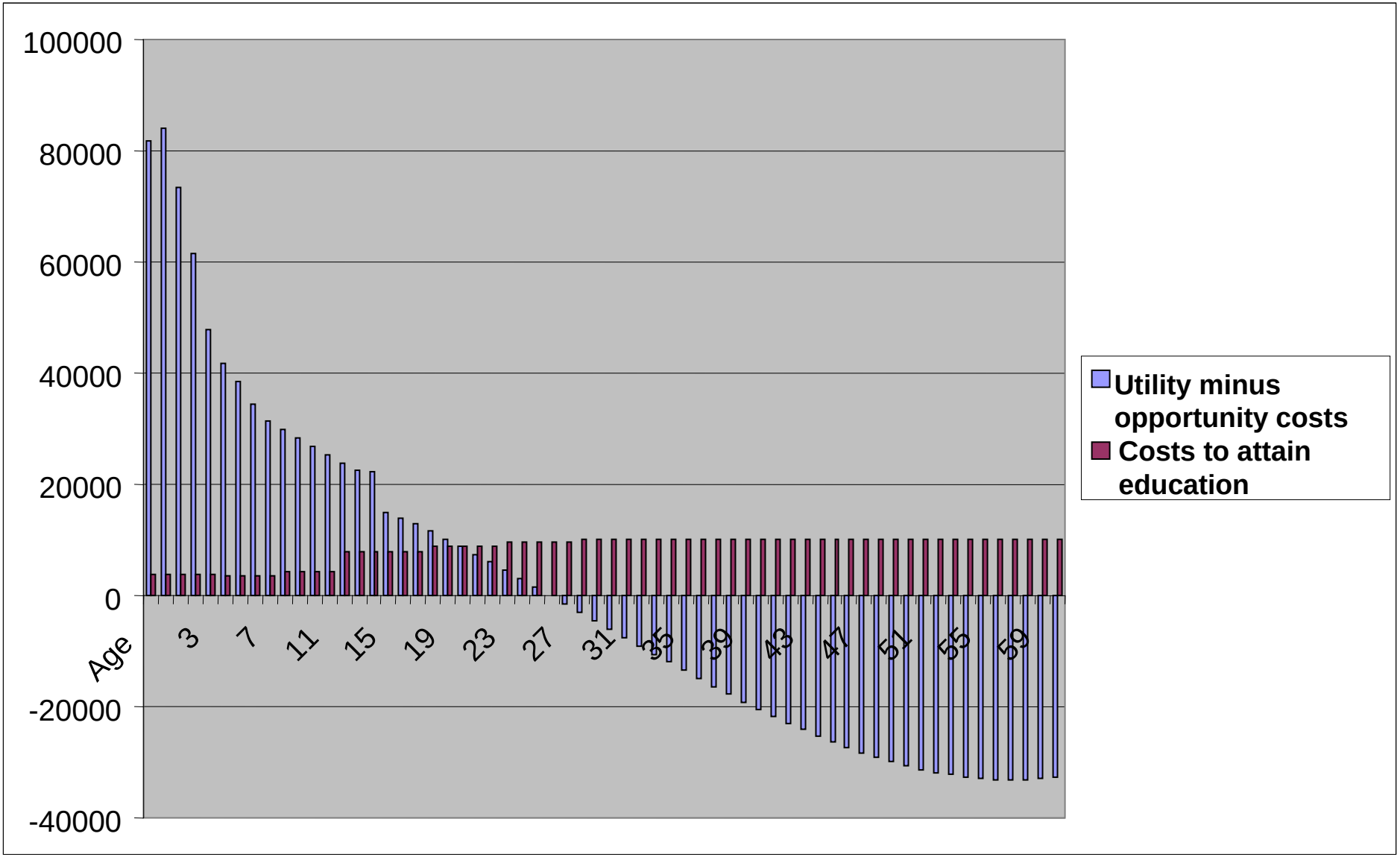
Willingness to pay for adulthood education for a heterogeneous population

$$\max U = \sum_{t=18}^{65} (\text{Income}_t(I_t) - C_t(I_t))$$





Utility and costs of an educational investment



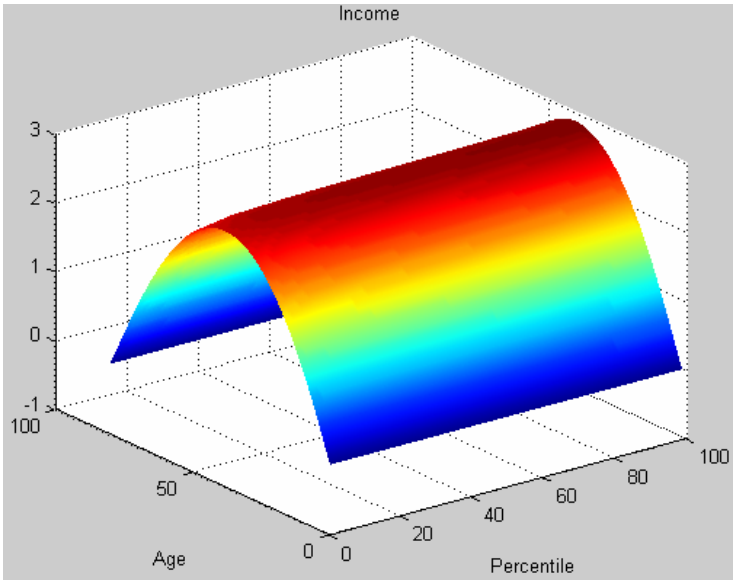
Returns to a primary school investment

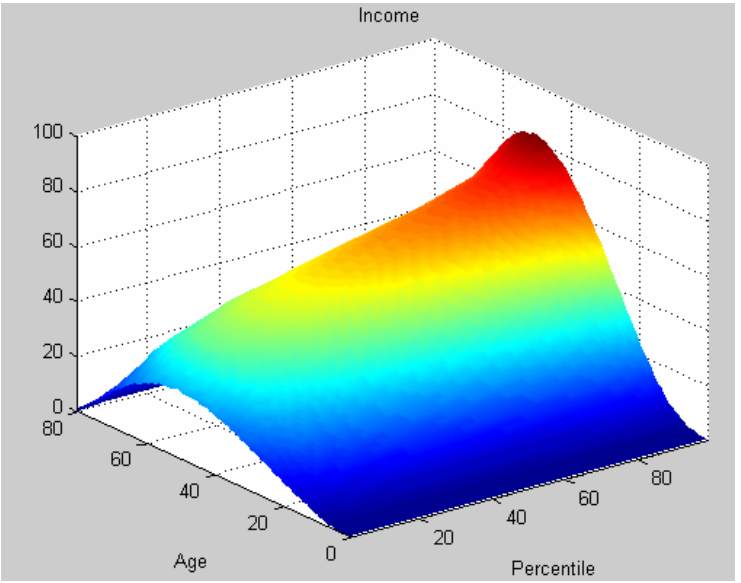
- maximization of social income vs. inequality aversion
- maximization of social income vs. utility maximization

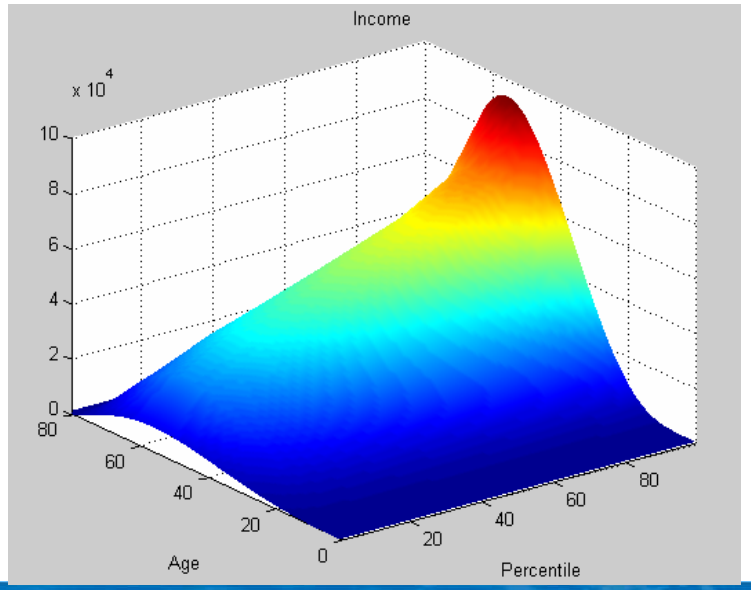
		Giftedness						
Environ-ment	Percentile	1.	10.	25.	50.	75.	90.	99.
	1.	192,761 (1.34%)	528,034 (8.75%)	723,242 (10.56%)	879,665 (11.60%)	1,000,000 (12.24%)	1,090,000 (12.67%)	1,220,000 (13.19%)
	10.	212,571 (1.01%)	628,308 (7.37%)	878,758 (8.84%)	1,080,000 (9.64%)	1,240,000 (10.19%)	1,360,000 (10.54%)	1,540,000 (11.04%)
	25.	224,759 (0.84%)	692,995 (6.68%)	980,378 (7.99%)	1,220,000 (8.80%)	1,400,000 (9.20%)	1,540,000 (9.51%)	1,740,000 (9.84%)
	50.	235,924 (0.70%)	754,169 (6.13%)	1,080,000 (7.37%)	1,340,000 (7.94%)	1,550,000 (8.37%)	1,710,000 (8.73%)	1,950,000 (9.13%)
	75.	245,940 (0.60%)	810,567 (5.70%)	1,170,000 (6.84%)	1,460,000 (7.37%)	1,700,000 (7.75%)	1,870,000 (8.04%)	2,130,000 (8.37%)
	90.	254,462 (0.52%)	859,642 (5.37%)	1,250,000 (6.45%)	1,570,000 (6.98%)	1,820,000 (7.24%)	2,010,000 (7.44%)	2,300,000 (7.80%)
	99.	269,261 (0.40%)	947,191 (4.87%)	1,390,000 (5.81%)	1,760,000 (6.32%)	2,050,000 (6.59%)	2,270,000 (6.83%)	2,600,000 (7.06%)

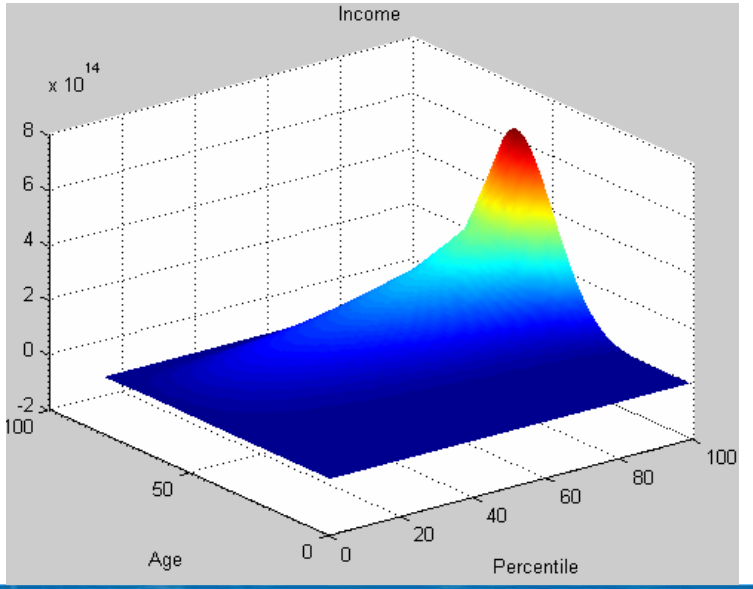
Income heterogeneity for different labour markets

(calibrated to wage inequality data (socio economic panel))





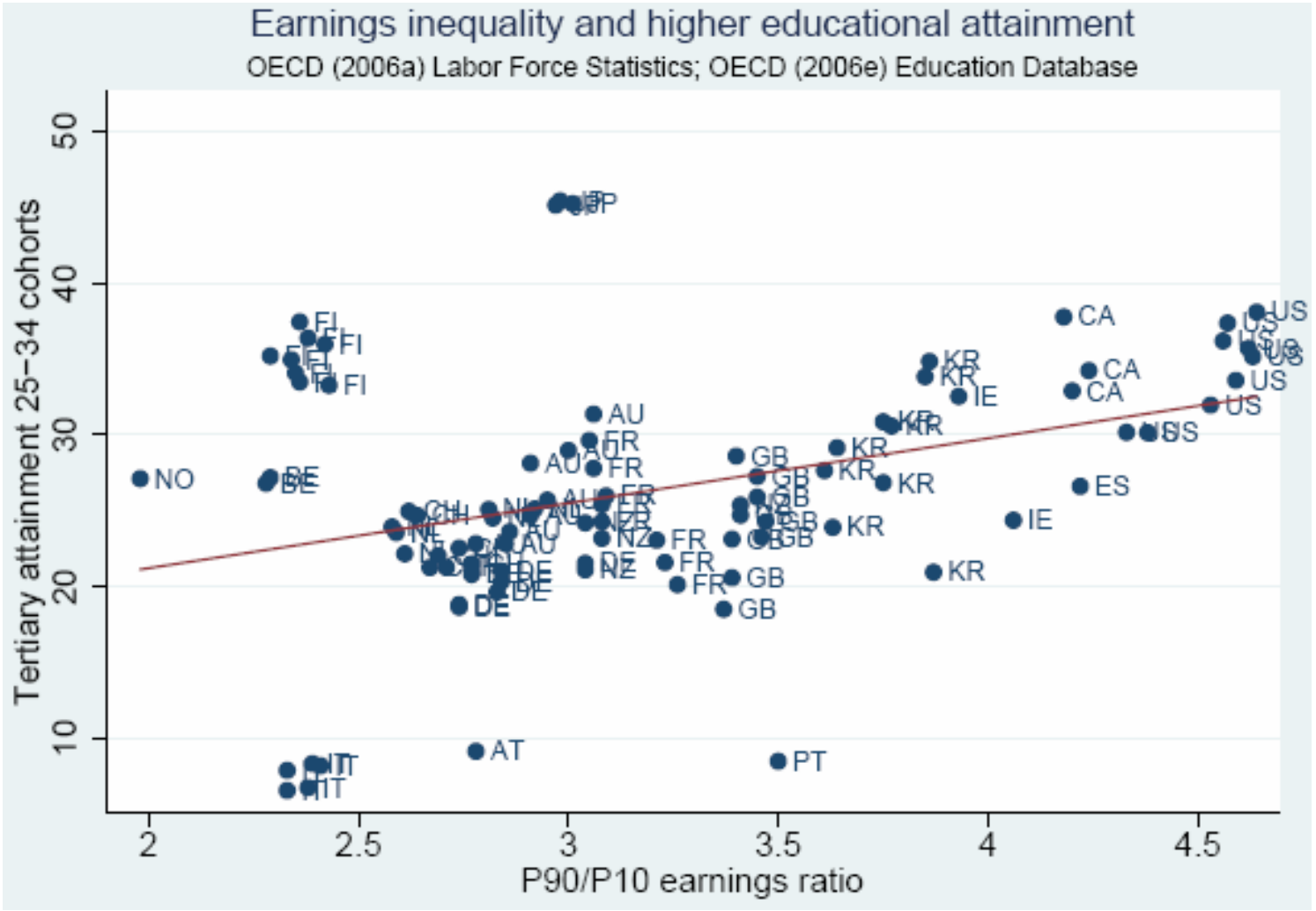




Relative returns to education and wage inequality

Percentile	90:10 ratio of 1.89 (low)	90:10 ratio of 3 (medium)	90:10 ratio of 7 (high)
1.	14.65%	27.59%	54.27%
10.	9.52%	17.78%	33.91%
25.	7.58%	14.13%	26.66%
50.	6.26%	11.70%	21.89%
75.	5.35%	10.02%	18.66%
90.	4.73%	8.87%	16.45%
99.	3.88%	7.32%	13.50%

Attainment of tertiary education and labour market inequality



Future Research questions :

- Evaluating the effect of income shocks with respect to risk aversion, time preference on skill investment and labour market inequality
- Analysing long-term heterogeneity driving factors in a stochastic multigeneration, skill formation model
- Estimation based simulation with new data (Central institute of mental health, Mannheim)
- Modelling early family interactions in a cooperative signalling game and their economic consequences, their consequences for subsequent skill formation

Thank you for your attention

Setting up the skill production functions

- CES production function of Heckman:

$$S_2^C = \left\{ \gamma_1 (S_1^C)^\alpha + \gamma_2 (S_1^N)^\alpha + (1-\gamma_1-\gamma_2)(I_2^C)^\alpha \right\}^{\frac{1}{\alpha}}$$

- transformed to a stock variable:

$$S_t^C = I_t^C \cdot \left(S_{t-1}^{C\,\frac{1}{3}} \cdot S_{t-1}^{N\,\frac{1}{3}} \cdot I_t^{C\,\delta\cdot\frac{1}{3}} \right) + S_{t-1}^C - \frac{S_{t-1}^C}{v_{t-1}}$$

- Calibrations:

a) $\gamma_1 = \gamma_2 = \frac{1}{3}$ and b) $\alpha = 0$

- b) Empircally estimated $\alpha = -0.13$ doesn‘t change results much

Cunha, F., J. J. Heckman and S. Schennach (2008), Estimating the Technology of Cognitive and Noncognitive Skill Formation, *Econometrica* (under revision).

Validation of parameter calibration a)

$$\gamma_1 = \gamma_2 = \frac{1}{3}$$

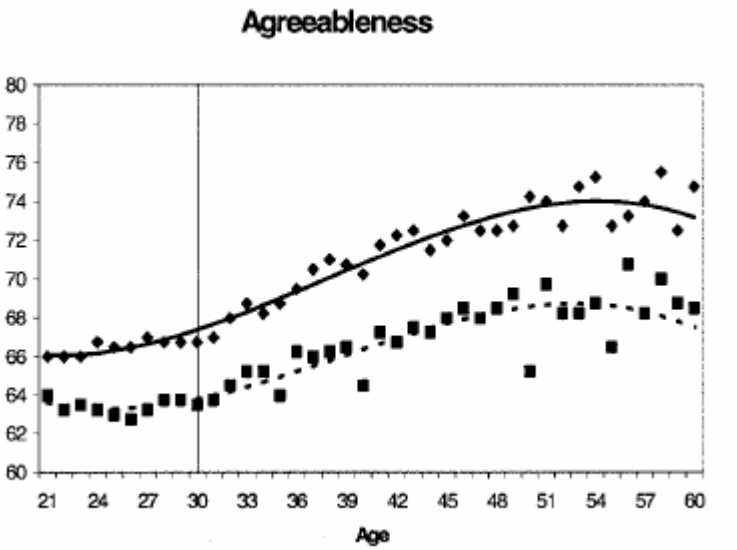
Table 1: Elasticities from Cunha, F. and J. J. Heckman (2008), Formulating, Identifying and Estimating the Technology of Cognitive and Noncognitive Skill Formation, *Journal of Human Resources*, forthcoming.

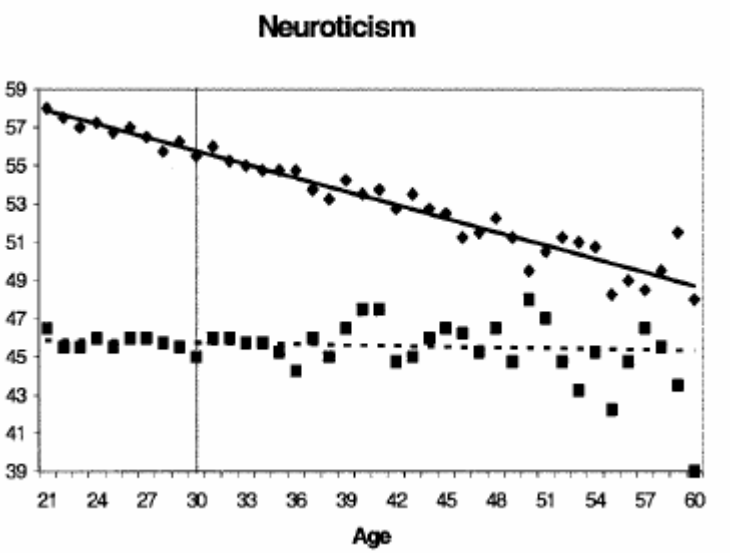
	Next Period Noncognitive	95% Confidence Bounds	Next Period Cognitive	95% Confidence Bounds
Current Noncognitive	0.8835	0.8413; 0.9256	0.0282	0.0025; 0.0539
Current Cognitive	0.0181	-0.0073; 0.0435	0.9814	0.9054; 1.0574
Current Period Investment	0.0601	0.0197; 0.1004	0.0566	0.0297; 0.0835
Mother's Education	0.0067	-0.0105; 0.0239	0.0047	-0.0075; 0.0169
Mother's Ability	-0.0063	-0.0198; 0.0072	0.0290	0.0086; 0.0494

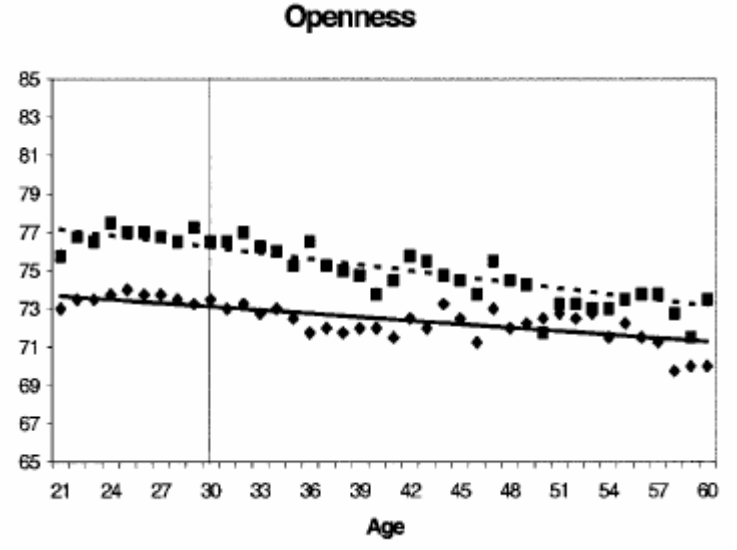
Table 2: Elasticities resulting from our model (2-period mean effects of periods 8 to 13):

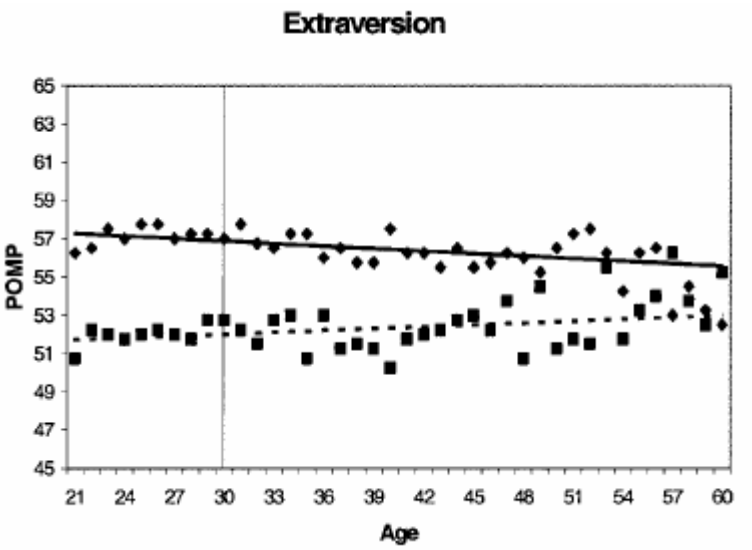
	Next Period Noncognitive	Next Period Cognitive
Current Noncognitive	0.92433	0.04092
Current Cognitive	0.03204	0.91775
Current Investment	0.05095	0.12317

Multidimensionality of noncognitive skills

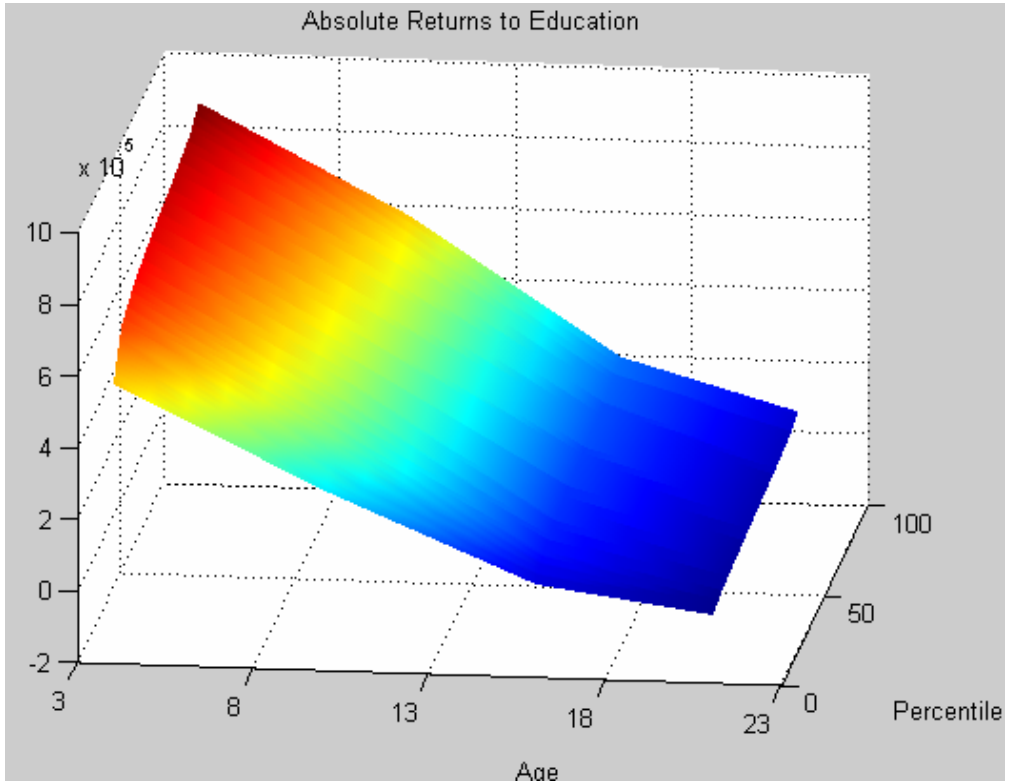




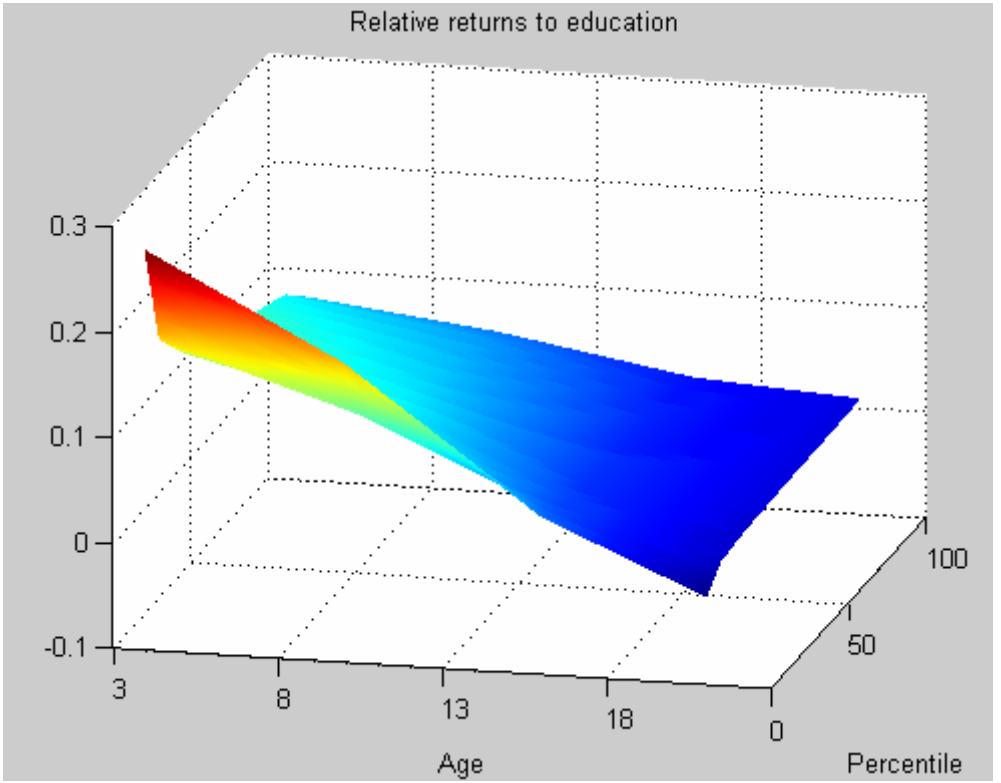




Absolute and relative Returns to Education

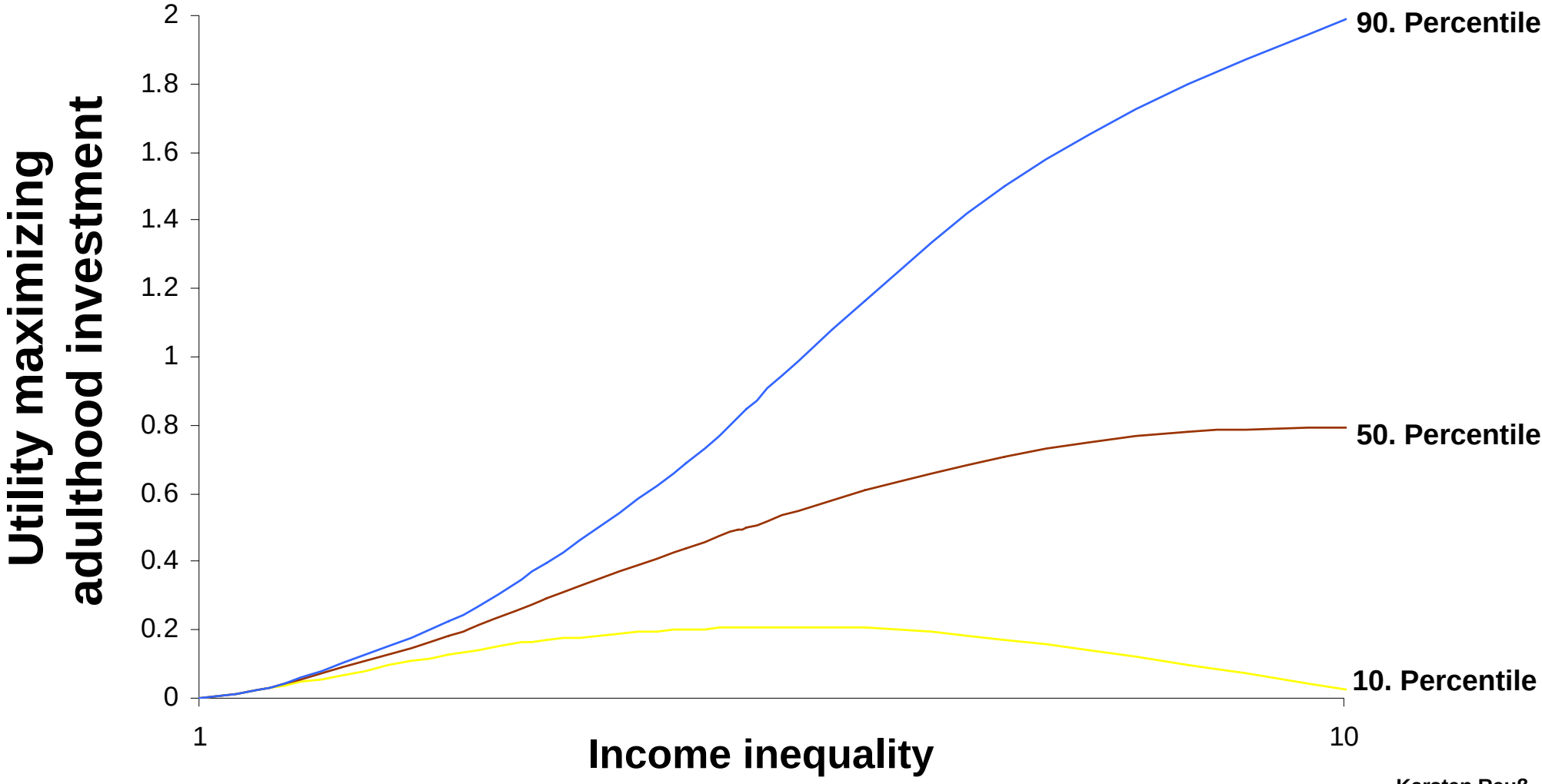


in discounted lifetime earnings



in percentage points

The influence of income inequality on investment incentives



Income Maximization

- **adult education costs money**

- **The price of one unit of tertiary education in both skills is set at 10,613 € annually (this value equals the OECD 2007 calculation for per capita expenditures of tertiary education in Germany)**

- **individuals maximize the cumulated, discounted sum of income**

$$\max U = \sum_{t=18}^{65} (\text{Income}_t(I_t) - C_t(I_t))$$