Intelligence and Income

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Introduction

- Cognitive and noncognitive skills and family background are important determinants of education
- Policies can change the relative importance of these factors (Ichino, Rustichini, and Zanella 2022)
- Growing evidence on interplay between genes and environment (Rustichini et al. 2023)

Contributions

Determinants of education: Heckman, Stixrud, and Urzua (2006), Almlund et al. (2011), Björklund and Salvanes (2011), Ichino, Rustichini, and Zanella (2022)

Focus on all three characteristics: cognitive, noncognitive and family background

Link empirical specifications to indivdiual optimization

Genes and environment in education: Rustichini et al. (2023)

Nonlinear effort choice

UK Household Longitudinal Study (2009-)

Working sample: 22 881 individuals

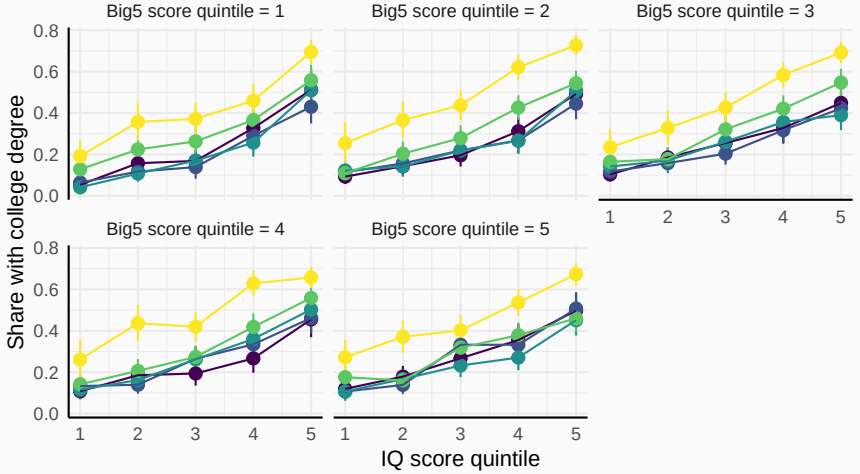
- college: ever had HE degree as highest qualification
- predicted discounted present value of earnings Profiles
- cognitive test scores CFA, Big 5 personality scores PCA
- parental background: education and employment status PCA

METADAC

Genotyped subsample: 3 413 individuals Table

- polygenic score (PGS) of fluid intelligence (Savage et al. 2018) Plot

College and individual characteristics



Probability of college

	Born in 1950-64		Born in 1965-79		Born in 1980-94	
	OLS	Logit ME	OLS	Logit ME	OLS	Logit ME
IQ score	0.137***	0.152***	0.151***	0.151***	0.130***	0.130***
	(0.005)	(0.007)	(0.005)	(0.005)	(0.006)	(0.006)
Fam score	0.050***	0.054***	0.077***	0.077***	0.074***	0.074***
	(0.005)	(0.008)	(0.006)	(0.006)	(0.006)	(0.006)
Big5 score	0.006	0.015**	0.010*	0.010*	0.014*	0.014*
	(0.006)	(0.006)	(0.006)	(0.006)	(0.006)	(0.006)
Obs.	9 539	9 539	10 586	10 586	8 409	8 409

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

SEM of college and wages

	Born in 1950-64		Born in 1965-79		Born in 1980-94	
	Pred. wage	College	Pred. wage	College	Pred. wage	College
College	0.820***		0.804***		0.651***	
	(0.020)		(0.016)		(0.015)	
IQ score	0.082***	1.018***	0.077***	0.917***	0.045***	0.788***
	(0.009)	(0.046)	(0.007)	(0.039)	(0.007)	(0.044)
Fam score		0.382***		0.492***		0.453***
		(0.051)		(0.040)		(0.041)
Big5 score		0.082*		0.081**		0.128***
		(0.037)		(0.033)		(0.037)
Indirect effect	0.126***		0.136***		0.096***	
	(0.006)		(0.005)		(0.005)	
Total effect	0.208***		0.213***		0.140***	
	(0.009)		(0.007)		(0.007)	
Obs.	9 496	9 496	10 488	10 488	8 382	8 382

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Model

Individuals described by $z \in Z = \Theta \times X \times Y$

- intelligence $\theta \in \Theta$
- family advantage score $x \in X$
- Big 5 personality score $y \in Y$

Human capital $H \equiv \{nc, c\}$ (no college vs college)

DPV of earnings $W(h, z, \delta) = \sum_{a=18}^{65} \delta^{a-18} W(h, z, a)$

Choose effort $e \in \mathbb{R}_+$ to acquire human capital $h = c$ given cost $\frac{c(e)}{\Gamma(z)}$

$$\max_e \pi(e) \left[W(c, z, \delta) - W(nc, z, \delta) \right] - \frac{c(e)}{\Gamma(z)}$$

Solution

Denote $A = (W(c, z, \delta) - W(nc, z, \delta))\,\Gamma(z)$. Then, optimal effort solution

$$E^{\star}(A; \pi) \equiv \arg\max_{e} \pi(e)A - e$$

Definition
Π is the set of functions $\pi : \mathbb{R}_+ \to [0, 1]$ that are strictly increasing, concave, continuous at 0, $\pi(0) = 0$, $\lim_{x\to\infty} \pi(x) = 1$.

Proposition
For $P(A)$ increasing in A and upper semi-continuous in ΔW, $\exists \pi \in \Pi$ such that

$$P(A) = \pi\left(E^{\star}(A; \pi)\right)$$

Proof

Estimation

We consider four functional forms that can describe $P(A)$:

- Linear probability model $P(A) = A$
- Logit $P(A) = (1 + e^{-A})^{-1}$
- Logit power $P(A) = (1 + e^{-A})^{-\kappa},\ \kappa \in \mathbb{R}_+$ Plot
- Cutoff power $P(A) = \min\{\max\{A, 0\}^{\kappa}, 1\},\ \kappa \in \mathbb{R}_+$ Plot

Two-step estimation:

1. Given δ and κ, fit $P(A)$ to the observed college indicators.
2. Grid search $\hat{\delta}$ and $\hat{\kappa}$ that minimise sum of squared residuals. Plots

Results

	LPM	Logit	Logit power[1]	Cutoff power[1]
IQ score	0.118***	0.089***	0.104***	0.108***
	(0.005)	(0.007)	(0.006)	(0.006)
Fam score	0.061***	0.054***	0.058***	0.058***
	(0.004)	(0.004)	(0.004)	(0.004)
Big5 score	0.025***	0.038***	0.032***	0.031***
	(0.003)	(0.004)	(0.004)	(0.004)
College premium, std	0.026***	0.060***	0.042***	0.040***
	(0.006)	(0.009)	(0.007)	(0.007)
Obs.	31 571	31 571	31 571	31 571
δ	0.925	0.925	0.925	0.925
κ			2.90	1.20
College premium mean	36.95	36.95	36.95	36.95
College premium sd	9.77	9.77	9.77	9.77

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

[1] Bootstrap standard errors

Results with polygenic scores

Simple logit without college premium

	LPM	Logit ME
IQ PGS	0.067***	0.066***
	(0.007)	(0.007)
Fam score	0.094***	0.118***
	(0.008)	(0.010)
Big5 score	0.019**	0.019**
	(0.008)	(0.008)
Obs.	3 602	3 602

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Results with polygenic scores

	LPM	Logit	Logit power	Cutoff power
IQ PGS	0.038***	0.034**	0.036**	0.037***
	(0.011)	(0.012)	(0.012)	(0.011)
Fam score	0.085***	0.154***	0.146***	0.134***
	(0.008)	(0.011)	(0.011)	(0.010)
Big5 score	0.109***	0.102**	0.105**	0.115***
	(0.031)	(0.034)	(0.034)	(0.034)
College premium, std	0.007**	0.006**	0.006**	0.007**
	(0.002)	(0.002)	(0.002)	(0.002)
Obs.	3 602	3 602	3 602	3 602
δ	0.925	0.925	0.925	0.925
κ			2.90	1.20
College premium mean	84.86	84.86	84.86	84.86
College premium sd	14.27	14.27	14.27	14.27

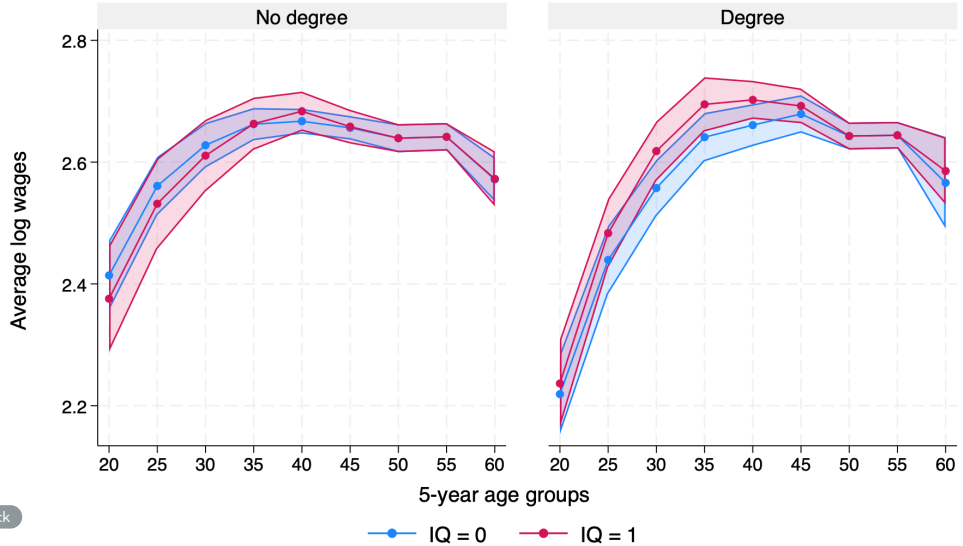
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Summary

- Revisit role of intelligence, personality and family characteristics in education choice
- Conditions linking econometric specification to individual optimization
- Further analysis with polygenic scores

Appendices

Predicted wage profile



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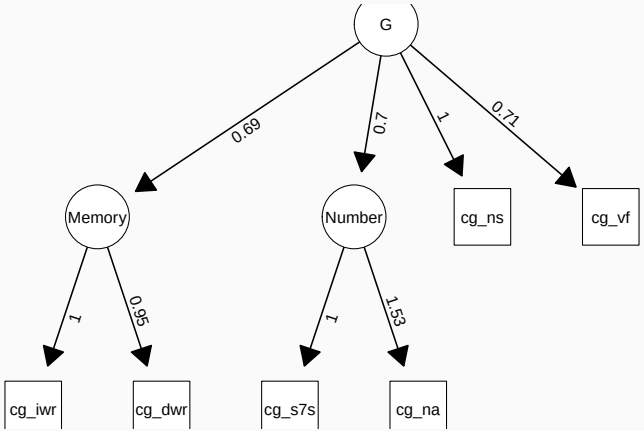
Intelligence score

Combine individual test scores using confirmatory factor analysis



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Big 5 personality score

Combine individual test scores using principal component analysis

Score	Loading
Agreeableness	0.4408
Conscientiousness	0.4970
Extraversion	0.4628
Neuroticism	-0.3751
Openness	0.4514

PC1 explains 36% of variation in the data

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Family advantage score

Combine education of parents and their employment status using principal component analysis

Variable	Loading (mother)	Loading (father)
Years of education	0.4020	0.4286
Work	0.2243	0.5527
Dead	-0.0889	-0.2958
Absent	-0.2042	-0.4023

PC1 explains 23% of variation in the data

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METADAC vs full sample

	Male	Age	White British	College	Mother worked	Father worked	Father's years of edu	Mother's years of edu
UKHLS								
Working sample	0.440	41.811	0.818	0.304	0.600	0.823	11.775	11.480
	(0.496)	(13.907)	(0.386)	(0.460)	(0.490)	(0.382)	(3.464)	(2.830)
	31 571	31 571	31 571	31 571	31 571	31 571	31 571	31 571
METADAC								
Full sample	0.428	46.345	0.973	0.264	0.666	0.887	11.298	11.259
	(0.495)	(12.901)	(0.161)	(0.441)	(0.472)	(0.316)	(3.524)	(2.369)
	7 281	7 236	7 281	7 251	5 248	5 256	7 281	7 281
Working sample	0.441	45.865	1.000	0.304	0.695	0.898	12.070	11.759
	(0.497)	(10.890)	(0.000)	(0.460)	(0.460)	(0.303)	(3.423)	(2.420)
	3 413	3 413	3 413	3 413	3 413	3 413	3 413	3 413

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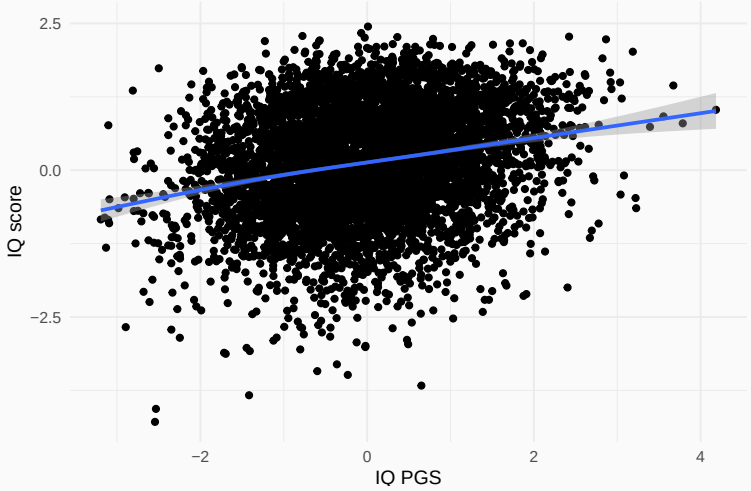
Polygenic score



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Proposition (continuously differentiable)

Redefine the effort choice problem as $e^\star(\alpha;\pi) \equiv \arg\max_e \pi(e) - \alpha e$ where $\alpha = A^{-1}$.

Definition
The set of endogenous probabilities is the set $\mathcal{Q}$ of multivalued functions $Q : \mathbb{R}_+ \to [0,1]$ that are decreasing, closed valued, with $\lim_{\alpha\to 0} Q(\alpha) = 1$, $Q(\overline{\alpha}) = 0$ for some $\overline{\alpha} > 0$.

Proposition
For any function $Q \in \mathcal{Q}$ which is continuously differentiable strictly decreasing in the interval $[\underline{\alpha}, \overline{\alpha}]$, with $Q(\underline{\alpha}) = 0$, $Q(\overline{\alpha}) = 1$, there exists a continuously differentiable function $\pi \in \Pi$ such that for all $\alpha \in \mathbb{R}_+$, $Q(\alpha) = \pi(h(\alpha;\pi))$.

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Proposition proof (continuously differentiable)

Note that $Q(\alpha) = 0$ for $\alpha > \overline{\alpha}$, so we may take the boundary condition

$$h(\overline{\alpha}) = 0$$

Consider the ordinary differential equation

$$\frac{dh}{d\alpha} = \frac{Q'}{\alpha}, \quad \alpha > 0$$

We now define the function π as the solution of $\pi(h(\alpha)) = Q(\alpha)$. The function h satisfies the differential equation, which is the first order necessary and sufficient conditions for optimal effort choice problem, namely $\pi'(h(\alpha)) = \alpha$. Thus, our claim follows.

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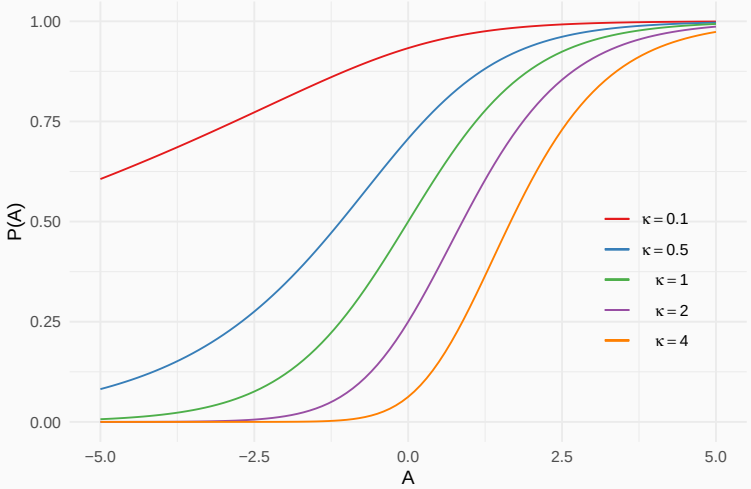
Logit power



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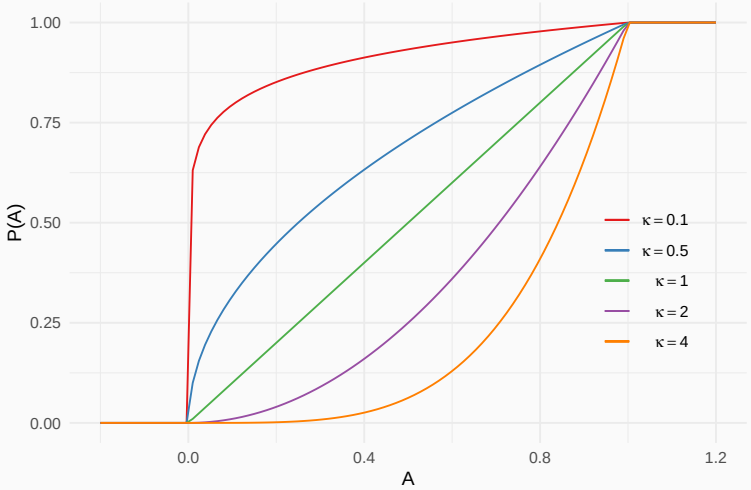
Cutoff power



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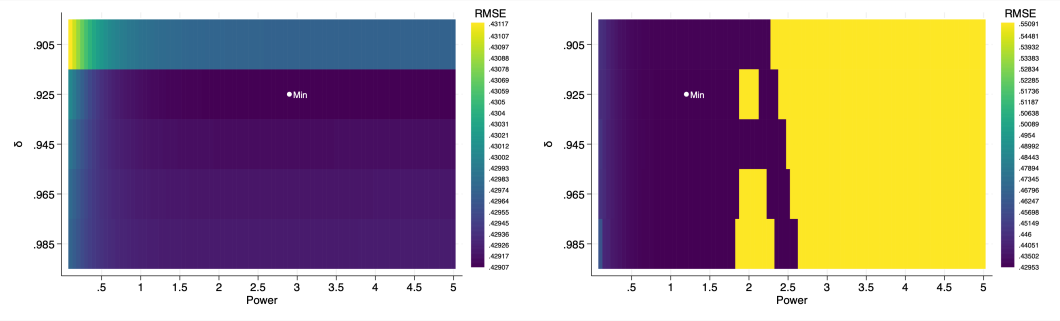
Grid search



(a) Logit power

(a) Cutoff power

Figure 2: RMSE heatmap of grid search over δ and κ

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