IRVINE NETWORK ON INTERVENTIONS IN DEVELOPMENT

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Work in progress

Early cognitive skill formation: evidence from prenatal investments and randomly-assigned childcare prices

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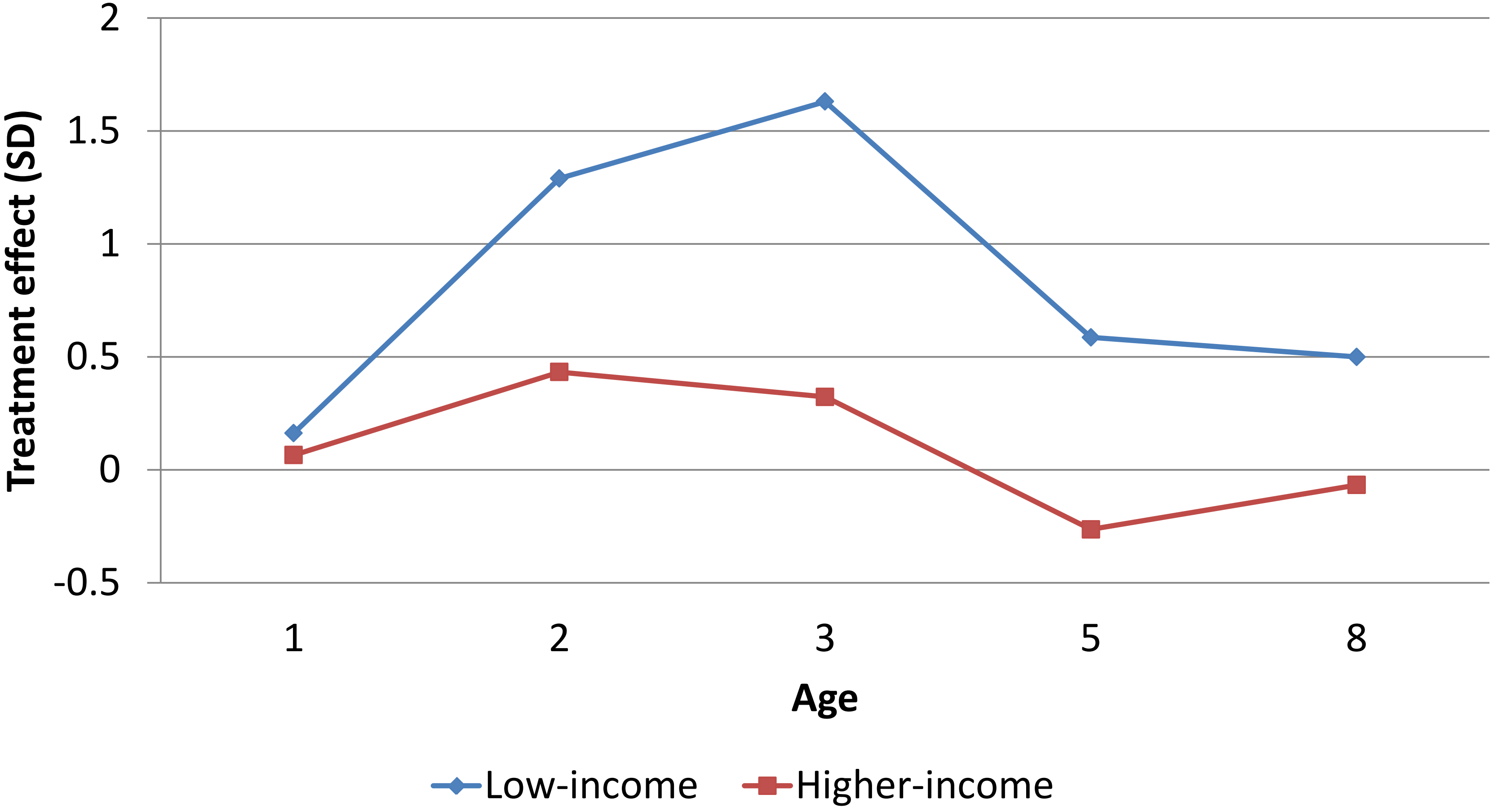
Why do IQ effects differ by family income?



Duncan & Sojourner (2013): using ECLS-B weights

Research Questions

1. Why impacts of ECE experiment differ dramatically between low- and higher-income subsamples

2. Production function for early cognitive skill: effects of pre- & post-natal influences on early IQ, esp. interactions

   – *Inter-temporal:* post-natal investment more productive given better pre-natal endowments?

   – *Intra-temporal*: maternal investments more productive given better non-maternal care?

3. How does parental, post-natal investment respond to an endowment shock (surprisingly good or bad birth status)? Reinforce or compensate?

Research Questions

Inter-temporal: post-natal investment more productive given better human capital at birth (h_0<= prenatal investment & endowment) ?

Cunha & Heckman, 2007; Conti et al 2011; Aizer & Cunha 2012; Del Bono et al 2012; Almond & Mazumder 2013

$$h = \tilde{f}[postnatal; h_0] \Rightarrow \frac{\partial^2 h}{\partial post\ \partial h_0}$$

Intra-temporal: maternal investments more productive given better non-maternal care?

Bernal & Keane 2010; Gelber & Isen 2013; Casico & Schazenbach 2013

$$postnatal = g[nonmaternal; maternal] \Rightarrow \frac{\partial^2 g}{\partial mat\ \partial nonmat}$$

Identifying the production function

$$h = f[postnatal; h_0; \varepsilon]$$

- Concern is correlation between observed and unobserved inputs.
  - Tastes, maternal productivity, and constraints can generate correlation between all three inputs.
  - Reaction to unexpected endowment shocks generate correlation between h_0 and (postnatal, ε).
- Use:
  - structural model of optimal choice
  - random-assignment of post-natal constraint
  - proxy for maternal taste based on pre-natal investment choice made under veil of ignorance (Aizer & Cunha 2012)

The experimental treatment: IHDP

The Infant Health & Development Program (IHDP) recruited a sample at birth and randomly assigned a treatment.
(Brooks-Gunn et al, 1994; McCarton et al, 1997; Gross et al, 1997)

Age 0-1: weekly home visit from staff

Age 1-3: child eligible for child development center (CDC)

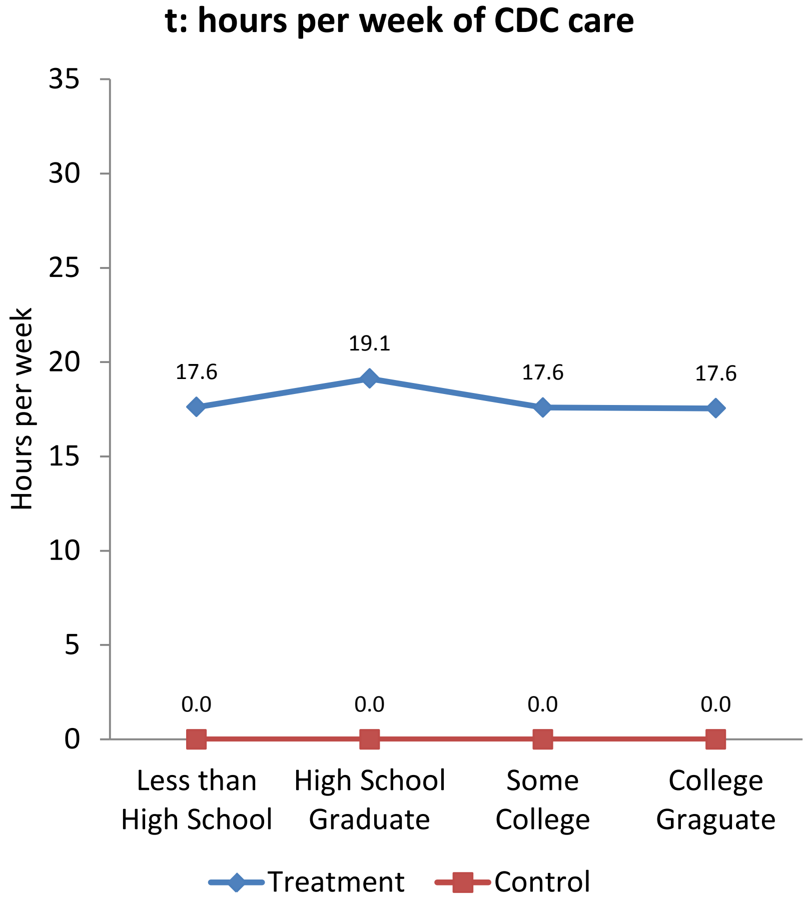
- Free
- Full-day
- High-quality, Abecedarian curriculum
- Free transportation

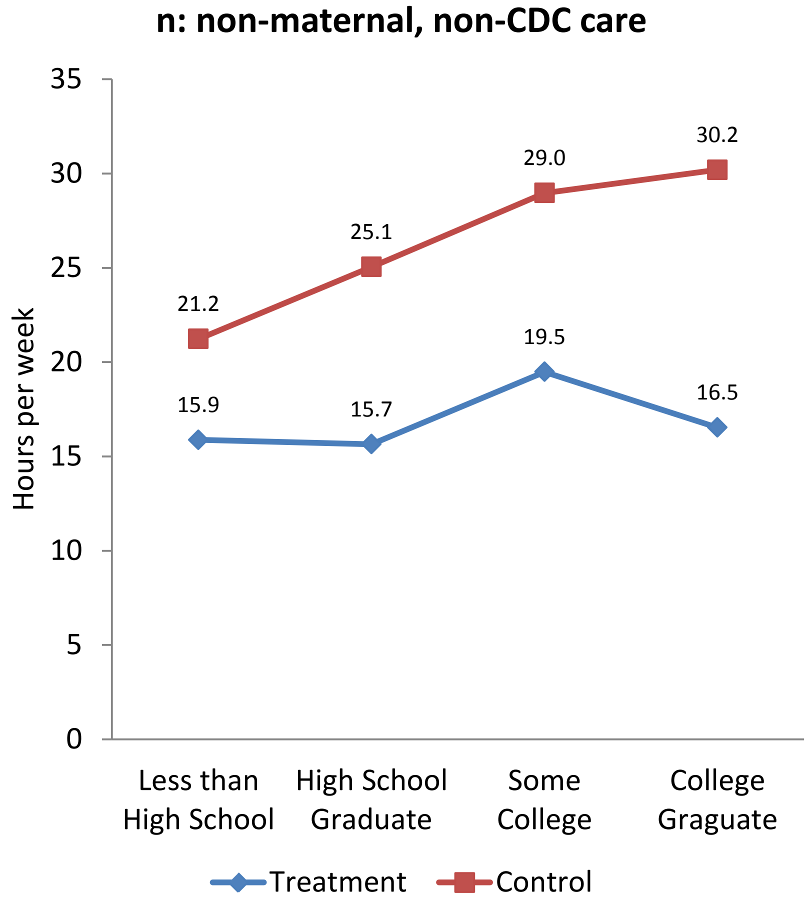
The experimental sample: IHDP

Ethnically and economically diverse but sample only included children born:

- Low-birth weight (≤ 2.5 kg = 5.5 lbs)
- Premature (≤ 37 wks)
- In one of 8 research hospitals around country
- Starting January 7, 1985 until fully enrolled

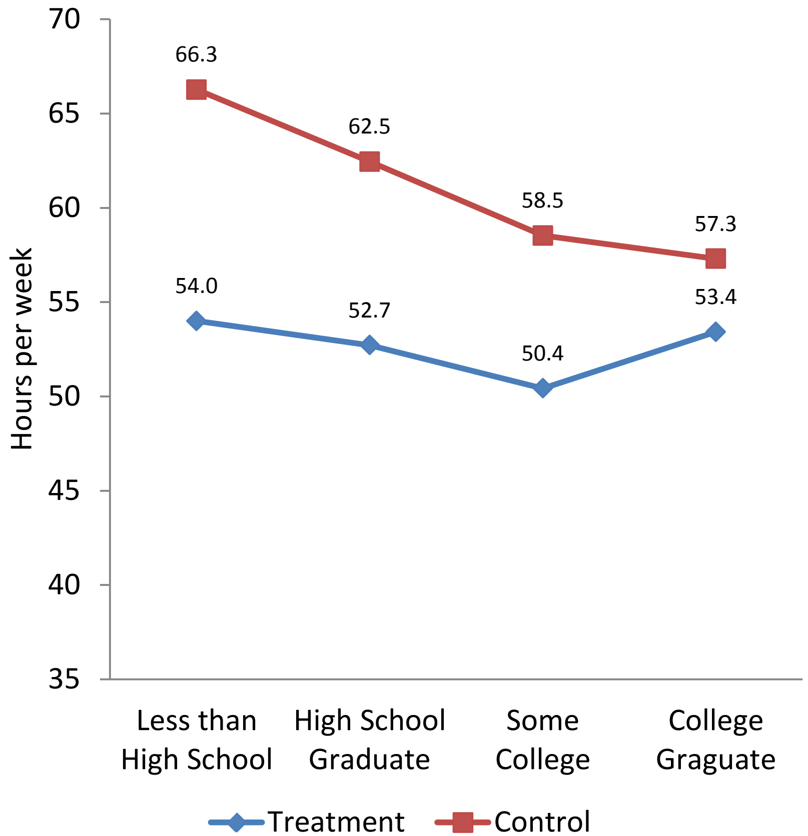
CDC crowds out other care for high-ed, not low-ed



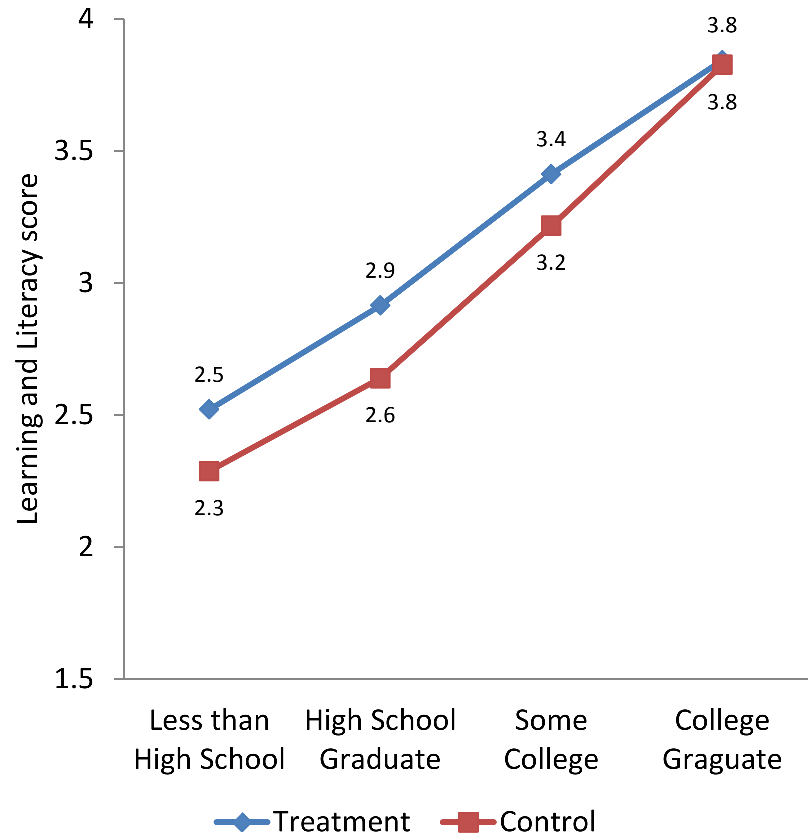


CDC crowds out maternal care **quantity** for low-ed, not high-ed

r: hours per week of maternal care



q^r: quality of maternal care



Model of maternal tastes (post-natal)

$$\text{Max } U(c, l, p, h, t)$$

Utility depends on	
c	Consumption (+)
l	Leisure (+) = 24*7 - parenting hours - labor hours
p	Total parenting effort (-) = (instantaneous parenting effort)*(parenting hours)
h	Human capital of child (+) IQ at age-3 (other outcomes possible!)
t	Hours of care in IHDP-treatment-eligible child dev. center (-)

Post-natal investments ≡ effective units of care

	Caretaker	Quantity of Care	Quality of Care	Effective units of care provided
Maternal Care	Mother	r	q^r	$q^r * r$
Non-maternal Care	Free Daycare (CDC)	t	q^t	$q^t * t$
	Non-maternal, Non-CDC	n	q^n	$q^n * n$

Constraints on the post-natal problem

$$\underset{c,q^n,n,e,r,l,L,t}{\text{Max}} U(c,l,p,h,t)$$

Constraints	
Child's time	$r + n + t = T_c$
Mother's time	$r + L + l = T_p$
Budget	$c + \pi q^n n = wL + Y$
Skill production	$h = f[nonmaternal;\ maternal;\ endowment; \varepsilon]$ $= f[q^n n + q^t t;\ q^r r\ ;\ h_0;\ \varepsilon]$
Maximum CDC time	$t \leq \bar{\tau}$
Parenting effort	$p = e * r$
Wage offer	$w = w(m, \omega)$
Parenting quality	$q^r = q^r(m, \omega, e)$

Optimal choices (interior): marginal benefits = marginal costs

First-order conditions	
L^*	$w = MRS_{l,c}$
t^*	$MRS_{h,c}[f_1 q^t - f_2 q^r] + w - MRS_{p,c}\, e \ \leq -MRS_{t,c}$
n^*	$MRS_{h,c}[f_1 q^n - f_2 q^r] + w - MRS_{p,c}\, e \ \leq \pi q^n$
e^*	$f_2\, q_e^r\, MRS_{h,c} = -MRS_{p,c}$
q^{n*}	$f_1\ MRS_{h,c} = \pi$

Marginal costs:

- Distaste for the CDC.

- Marginal benefit: additional human capital.
- Marginal cost: distaste for effort.

Modeling maternal productivity

- Wage (unobserved):
  - Expected potential wage ($\widehat{w}$) based on a Heckman selection model (Mulligan & Rubinstein, 2008) with 1986-89 CPS sample of mothers with 1+ child age 0-5.

$$ln[w] = ln[\widehat{w}(m)] + ln(\omega) = ln[\widehat{w}(m)] + \mu_\omega$$

- Quality of maternal care (observed):

$$q^r = Q\left[\widehat{w}(m)^{\chi_m}\omega^{(1-\chi_m)}\right] + e$$

IHDP: less old, educated, white, married

	CPS (March 1986-89)				IHDP		
Maternal education							
		Share (%)	N			Share (%)	N
Less than High School		18.4	5,682			40.0	394
High School graduate		43.7	13,505			27.4	270
Some College		19.9	6,157			20.0	197
College graduate		18.0	5,545			12.6	124
Race and Ethnicity							
		Share (%)	N			Share (%)	N
Non-Hispanic White		70.4	21,752			33.4	329
African American		11.0	3,383			52.5	517
Hispanic		14.6	4,513			10.7	105
Other		4.0	1,241			3.5	34
Marital status							
		Share (%)	N			Share (%)	N
Married		80.8	24,964			46.2	455
Single		8.6	2,661			45.8	451
Sep./Div./Wid.		10.6	3,264			8.0	79

CPS Sample Selection Criteria: 1986 – 1989. March CPS. Women, age 15 to 55, with at least one child under the age of 5. Unpaid family workers and self-employed women not included. Wages below \$3.73 and above \$80 in 2012 dollars are trimmed.

=> lower expected potential wage

		CPS (March 1986-89)			IHDP		
		Mean	Std. Dev.	N	Mean	Std. Dev.	N
***w(m)*: expected potential wage, Log, US$ of 2012**	Working mothers only	2.60 ($13.5)	0.56	18,680	2.09 ($8.1)	0.71	542
	All the sample	-	-	-	1.89 ($6.6)	0.83	985
Worked Indicator		0.60	0.49	30,889	0.52	0.50	913
Potential experience (years)		9.61	5.60	30,889	6.49	5.28	985
Number of own children under age 5		1.30	0.53	30,889	1.50	0.71	985
Age of youngest own child in household		1.75	1.39	30,889	1.70	0.68	985
Number of own children 5 years old or older		0.77	1.03	30,889	0.46	0.84	985

CPS Sample Selection Criteria: 1986 – 1989. March CPS. Women, age 15 to 55, with at least one child under the age of 5. Unpaid family workers and self-employed women not included. Wages below $3.73 and above $80 in 2012 dollars are trimmed.

A veil of ignorance: pre-natal investment choice proxies for maternal tastes

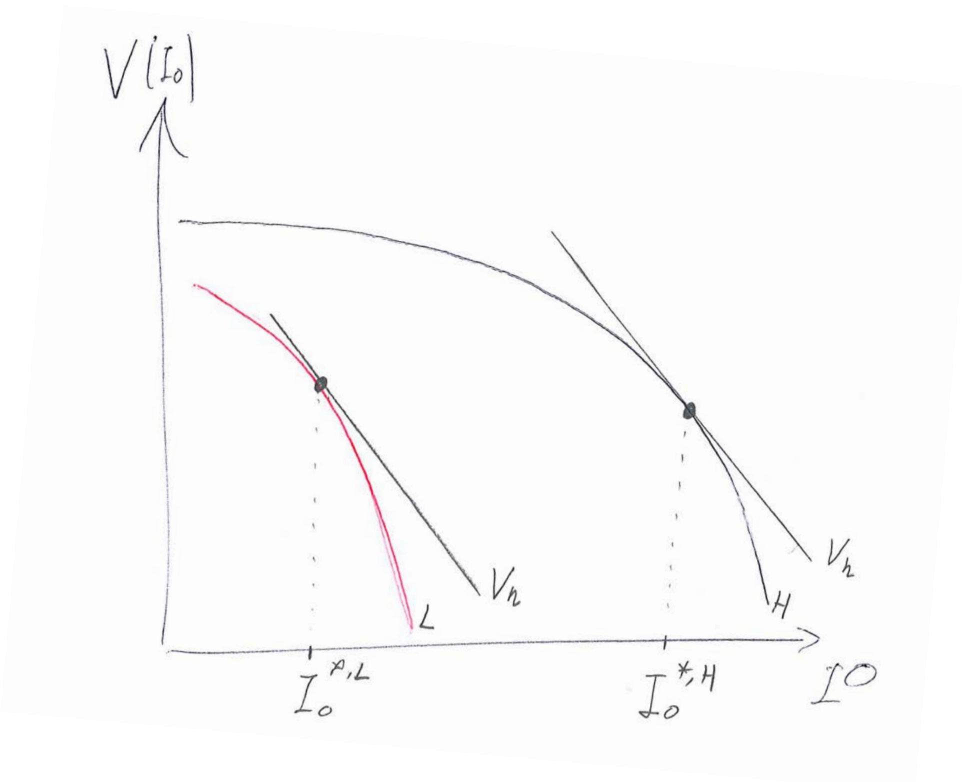
$$\underset{I_0}{\text{Max}}\ E_\phi[V(I_0, h)]$$

s.t.

$$h_0 = b[I_0\,, \phi]$$

$$h = f[q^n n + q^t t,\ q^r r\,, h_0, \varepsilon]$$

$$\phi\ \sim F_\phi$$



I_0	Prenatal investment
ϕ	Child's endowment (with CDF F_ϕ)
$b[I_0\,, \phi]$	Human capital at birth technology

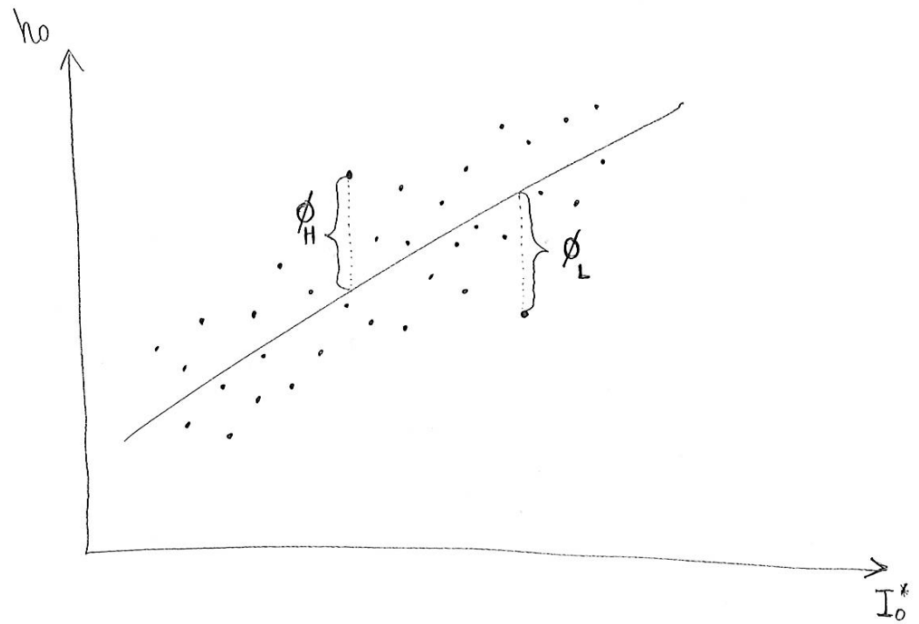
$$E_\phi\left[V_{I_0} + V_h\left(f_1\left[\frac{\partial q^{n*}}{\partial h_0}n^* + q^{n*}\frac{\partial n^*}{\partial h_0}\right] + f_2\left[q_e^r\frac{\partial e^*}{\partial h_0}r^* + q^r(e^*, m)\frac{\partial r^*}{\partial h_0}\right] + f_3\right)b_{I_0}\right] = 0$$

Measuring pre-natal investment choice (I_0^*) using ECLS-B

From theory to measurement:

$$h_0 = \pi_0 + \pi_1 I_0^* + \pi_2 X + \phi$$

$$\begin{pmatrix} W \\ A \end{pmatrix} = \pi_0 + \pi_1 C_0 + \pi_2 X + \begin{pmatrix} \phi_W \\ \phi_A \end{pmatrix}$$



$E[h_0 | I_0^*, X]$ in the IHDP sample misleading. Use same variables in nationally-representative ECLS-B sample.

IHDP vs. national norm (ECLS-B)

	ECLS-B			IHDP	
Variables	Mean	Std. Dev.		Mean	Std. Dev.
Conditions at birth					
Weight (kg)	3.3	0.6		1.8	0.4
Gestational age (wk)	38.7	2.4		33.0	2.7
Prenatal investment choices					
Used drugs	0.04			0.04	
Cigs/day	TBA			4.3	7.9
Drinks/wk.	TBA			0.4	1.8
Weight gain	35.1	23.1		23.5	13.0
Trimester of care	1.2	0.5		1.3	0.6
No prenatal care	0.01			0.05	
Fixed characteristics					
Fetus female	0.49			0.51	
Non-singleton fetus	0.03			0.11	
African-American	0.14			0.52	
Hispanic	0.25			0.10	
Other race/ethnicity	0.07			0.03	
Never married	0.26			0.45	
Widowed, div., or separated	0.07			0.08	
Maternal age	28.3	6.33		24.7	6.0
Education < HS	0.20			0.40	
HS < Education < BA	0.27			0.20	
Education = BA+	0.24			0.12	
Child parity	1.03	1.18		1.90	1.17

ECLS-B gives national distribution of:

- endowment shock
- pre-natal investment

IHDP sample:

Endowment shock

- Mean z-score: -2.5
- Median percentile: 3rd

Pre-natal investment

- Mean z-score: -0.78
- Median percentile: 19th

Joint normality for taste (residual) and unobserved maternal productivity

- Use pre-natal investment choice as a proxy for maternal value on child human capital relative to own consumption:

$$ln\left(MRS_{h,c}\right) = \kappa_0 + \kappa_1 I_0^* + \mu_h$$

$$\left[\mu_h, ln\left(-MRS_{p,c}\right),\ ln\left(-MRS_{t,c}\right), ln\left(MRS_{l,c}\right),\ ln(\omega)\ \right]' \equiv \left[\mu_h, \mu_p, \mu_t, \mu_l, \mu_\omega\right]'$$

$$\sim\mathcal{N}\left[\mathbf{0}, \mathbf{\Sigma} = \begin{bmatrix} \sigma_h^2 & & & & \\ \sigma_{hp} & \sigma_p^2 & & & \\ \sigma_{ht} & \sigma_{pt} & \sigma_t^2 & & \\ \sigma_{hl} & \sigma_{pl} & \sigma_{tl} & \sigma_l^2 & \\ \sigma_{h\omega} & \sigma_{p\omega} & \sigma_{t\omega} & \sigma_{l\omega} & \sigma_\omega^2 \end{bmatrix}\right]$$

Estimation: maximum likelihood

- $\ell(\Theta\,;\ l, t, n, e, q^n)$
  $= \ell(\Theta\,; l \mid t, n, e, q^n) + \ell(\Theta\,; t \mid n, e, q^n) + \ell(\Theta\,; n \mid e, q^n) + \ell(\Theta\,; e \mid q^n) + \ell(\Theta;\ q^n)$

- $\ell(\Theta;\ q^n) = ln\left[\phi\left(\frac{ln(\pi)-ln(f_1)-\kappa_0-\kappa_1 I_0^*}{\sigma_h}\right)\right] - ln[\sigma_h]$

- $\ell(\Theta\,; e \mid q^n) = ln\left[\phi\left(\frac{ln(f_2)+\kappa_0+\kappa_1 I_0^*}{\gamma_{h,p}}\right)\right] - ln\left[\gamma_{h,p}\right]$

- $\ell(\Theta\,; n \mid n > 0, e, q^n) = ln\left[\phi\left(\frac{(1-\chi_m)ln[\widehat{w}(m)]-ln(f_2)-\kappa_0-\kappa_1 I_0^*-ln(Q)}{\gamma_{h,\omega}}\right)\right] - ln\left[\gamma_{h,\omega}\right]$

- $\ell(\Theta\,; n \mid n = 0, e, q^n) = ln\left[1 - \Phi\left(\frac{(1-\chi_m)ln[\widehat{w}(m)]-ln(f_2)-\kappa_0-\kappa_1 I_0^*-ln(Q)}{\gamma_{h,\omega}}\right)\right]$

Allow corner solutions in non-maternal, non-CDC care hours (n*).

where,

$$\gamma_{h,p} = \sqrt{\sigma_p^2 + \sigma_h^2 - 2\sigma_{hp}} \qquad \gamma_{h,\omega} = \sqrt{\sigma_h^2 + (1-\chi_\omega)^2\sigma_\omega^2 - 2(1-\chi_\omega)\sigma_{h\omega}}$$

Estimation: maximum likelihood

Allow corner solutions in CDC care hours (t*).

- $\ell(\Theta\,; t \mid n > 0, t > 0, e, q^n) = ln\left[\phi\left(\frac{\kappa_0+\kappa_1 I_0^*+ln(f_1)+ln(q^t)}{\gamma_{t,h}}\right)\right] - ln[\gamma_{t,h}]$

- $\ell(\Theta\,; t \mid n > 0, t = 0, e, q^n) = ln\left[1 - \Phi\left(\frac{\kappa_0+\kappa_1 I_0^*+ln(f_1)+ln(q^t)}{\gamma_{t,h}}\right)\right]$

- $\ell(\Theta\,; t \mid n = 0, t > 0, e, q^n) \approx ln\left[\phi\left(\frac{(1-\chi_m)ln[\widehat{w}(m)]-ln(f_2)-ln(Q)-\kappa_0-\kappa_1 I_0^*}{\gamma_{h,\omega}}\right)\right] - ln[\gamma_{h,\omega}]$

- $\ell(\Theta\,; t \mid n = 0, t = 0, e, q^n) = ln\left[1 - \Phi\left(\frac{(1-\chi_m)ln[\widehat{w}(m)]-ln(f_2)-ln(Q)-\kappa_0-\kappa_1 I_0^*}{\gamma_{h,\omega}}\right)\right]$

- $\ell(\Theta\,; l \mid t, n, e, q^n) = ln\left[\phi\left(\frac{ln[\widehat{w}(m)]}{\gamma_{l,\omega}}\right)\right] - ln[\gamma_{l,\omega}]$

where,

$$\gamma_{t,h} = \sqrt{\sigma_t^2 + \sigma_h^2 - 2\sigma_{ht}} \qquad \gamma_{l,\omega} = \sqrt{\sigma_l^2 + \sigma_\omega^2 - 2\sigma_{l\omega}}$$

Summary of key variables in IHDP

	Variable	Mean	Std. Dev.	Min	Max	N
Stanford Binet IQ at 36M	h	88.49	20.08	43	147	823
Birth Weight (kgs)	h_0	1.80	0.46	0.54	2.5	823
Hours per week with other caretakers	n	22.24	14.41	0	61	823
Hours per week at CDC	t	6.99	10.45	0	40.52	823
Hours per week of maternal care	r	58.27	14.66	12.5	87.5	823
Learning and Literacy score, Avg. 12m 36m	q^r	2.86	1.00	0	4.53	823
Stimulation of Development ORCE, predicted	q^n	3.91	1.00	0	6.27	823
Expected Wage Offer, US$ of 2012 per hour	w	8.78	5.77	0.59	23.69	823
Hours per week of working time	L	16.85	16.62	0	57	823
Prenatal Investment	I_0	1.76	0.01	1.66	1.79	823
Endowment shock	ϕ	3.43	1.20	0.54	6.63	823

- **Quality of maternal care (q^r)**: Factor analysis on most relevant items, Infant / Toddler HOME and Early Childhood HOME (Linver, Martin and Brooks-Gunn, 2004 and Fuligni, Han and Brooks-Gunn, 2004).
- **Quality of non-maternal care (q^n)**: Predict Stimulation of Development ORCE score. Regression model from the NICHD – SECCYD Phase 1 data (Vandell, 2004; Auger & Burchinal, 2013).

Future directions

- Incorporate:
  - Structural form for utility and obtain estimates
  - Add child behavior problems as 2nd skill dimension
  - Policy "experiments"
- Assess sensitivity
- Estimate in other data: ECLS-B…?

Preliminary Conclusions (I)

- Why do IQ effects differ by family income?

	Hours of non-maternal care	Hours of maternal care	Instantaneous parenting effort	Total parenting effort	Qual. maternal care	Quality gap	Child's human capital
	$n+t$	r	e	$p=er$	q^r	$[f_1 q^t - f_2 q^r]$	h
Low Income	+	-	+	+ / -	+	+	+
High Income	0	0	0	0	0	-	0

Preliminary Conclusions (II)

- It makes a difference to account for:
  - Parental tastes and constraints.
  - Quality of non-maternal and maternal care.
  - Feedback between quality and quantity.

- Evidence of:
  - Prenatal-postnatal dynamic complementarity.
  - No intra-temporal complementarity.

Thank you!

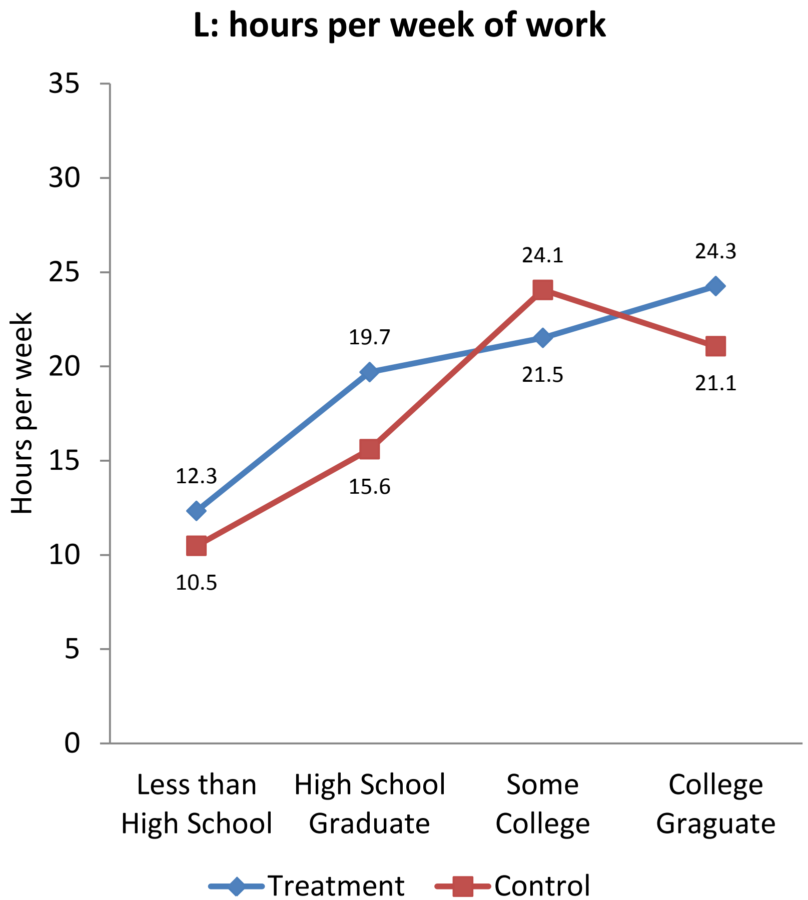
Appendix

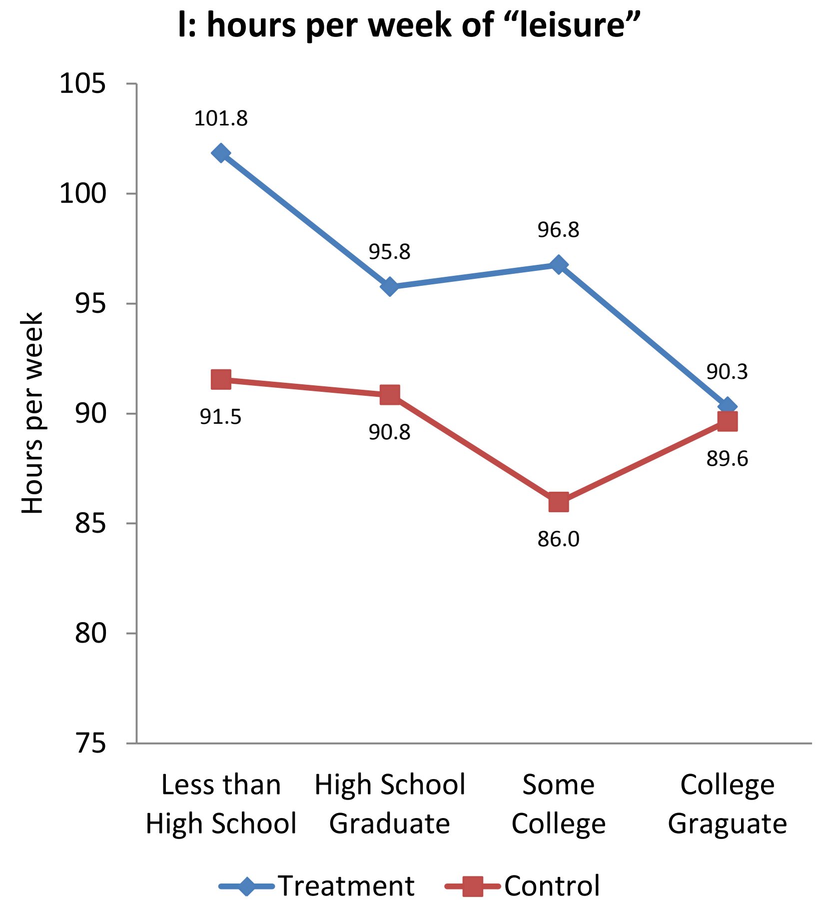
Challenges

- Data on all pieces
  - Birth status <= (prenatal influences, endowment)
  - Maternal care: quantity and quality
  - Non-maternal care: quantity and quality
  - Maternal/family types
  - Outcome: child skills

- Setting that allows credible identification

CDC gave back “leisure” time to low-ed mothers





Model of maternal tastes

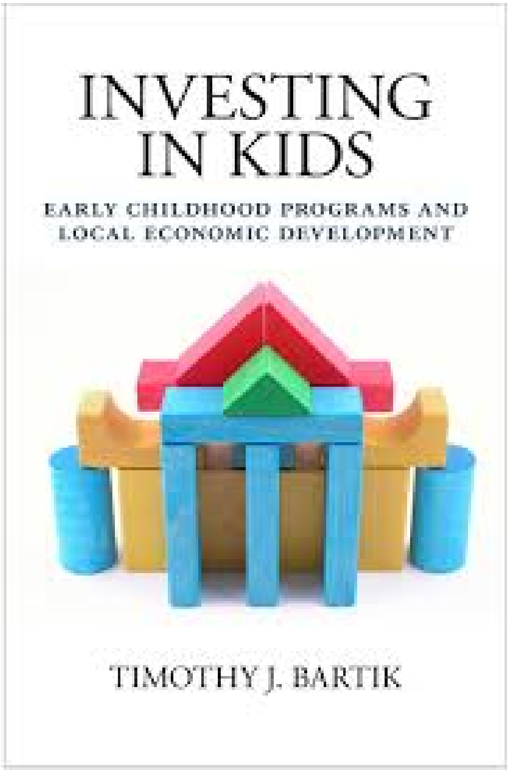
$$\mu_a = \ln(MRS_{ac}) = \ln\left(\frac{U_a}{U_c}\right) = ln\left(\frac{\partial U}{\partial a} \Big/ \frac{\partial U}{\partial c}\right) \text{ for } \forall a \in \{l, p, h, t\}$$

Characterize tastes by marginal rates of substitution w.r.t. consumption	
l	Leisure (μ_l)
p	Total parenting effort = (instantaneous parenting effort)*(hours) (μ_p)
h	Human capital of child, IQ at age-3 (μ_h)
t	Hours of care in child development centers (μ_t)

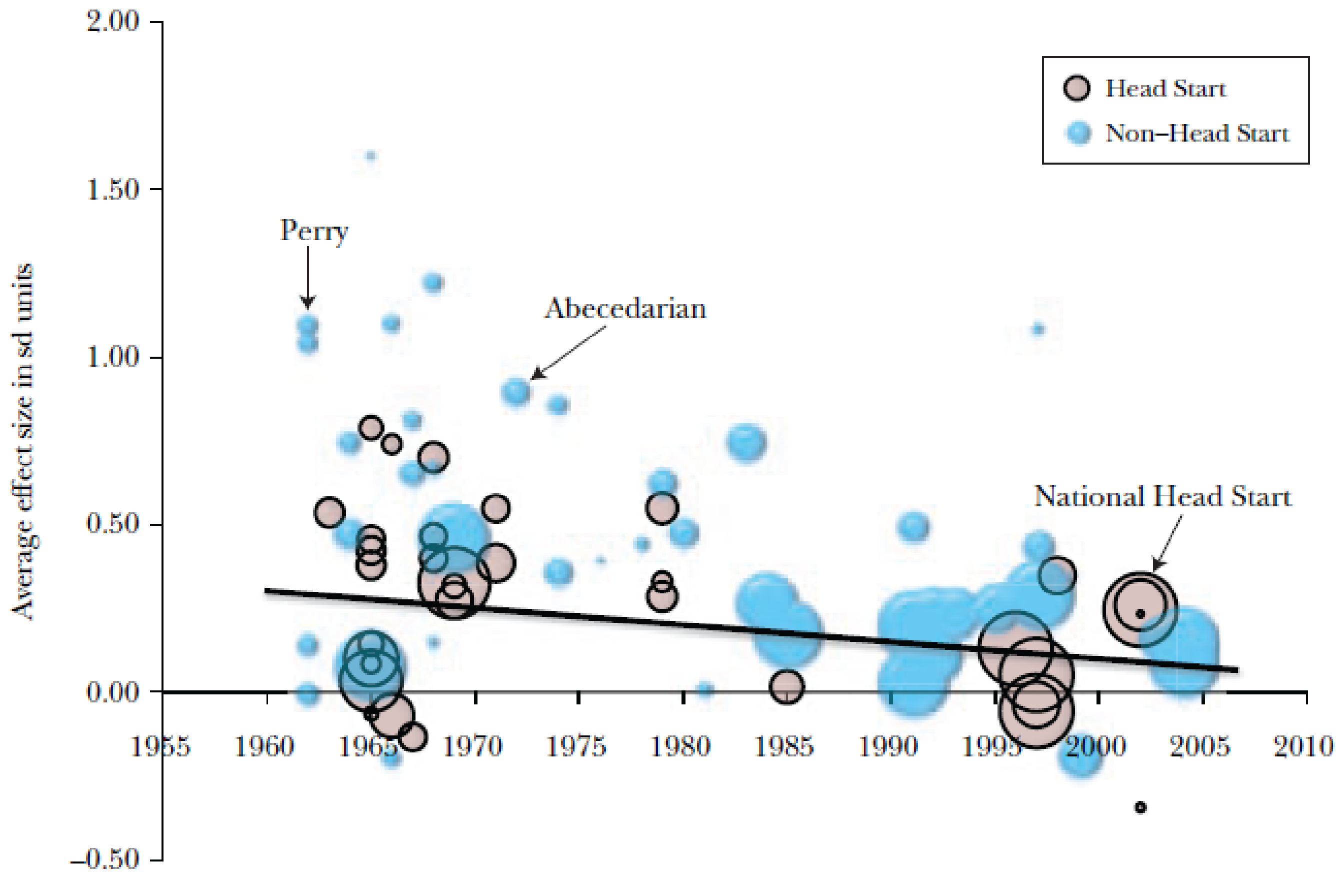
Returns & benefit-cost of targeted program

According to economist Tim Bartik's analysis of our study:

- Cost about $35,000 over 3 years.
- Lifetime earnings increases of 13%.
- "This is a large effect that would have significant effects on the income distribution."
- "…likely to pass a benefit-cost test."



Short-term effects smaller in recent studies



Source: Authors.
Notes: Figure 2 shows the distribution of 84 program-average treatment effect sizes for cognitive and achievement outcomes, measured at the end of each program's treatment period, by the calendar year in which the program began. Reflecting their approximate contributions to weighted results, "bubble" sizes are proportional to the inverse of the squared standard error of the estimated program impact. There is a weighted regression line of effect size by calendar year.

Duncan & Magnuson (2013) Investing in Preschool Programs. *Journal of Economic Perspectives*

Literature

There are large, growing gaps in academic achievement and IQ between kids of different income/SES.
(Duncan & Magnuson, 2011; Reardon , 2011)

Strong experimental evidence that high-quality early childhood environment can raise achievement, but only from samples selected to be low-income.
(Karoly, 2001; Heckman, Grunewald & Reynolds, 2006; Bartik, 2011)

Evidence that impacts among higher-income samples are small or even negative, but nonexperimental.
(Gormley et al, 2008; Bartik et al, 2011; Bernal & Keane, 2010)

Quality of maternal care

12-month Home Assessment	36-month Home Assessment
At least 10 books are present and visible	Child has toys which teach color, size, shape
Muscle activity toys or equipment	Child has three or more puzzles
Push or pull toys	Child has toys permitting free expression
Parent provides toys for child during visit	Child has toys or games requiring refined movements
Learning equipment appropriate to age: cuddly toys or role playing toys	Child has at least 10 children's books
Learning facilitators: mobile, table and chairs, high chair, play pen	At least 10 books are visible in the apartment
Complex eye-hand coordination toys	Child is encouraged to learn the alphabet
Toys for literature and music	Interior of apartment not dark or perceptually monotonous
Parent reads stories to child at least 3 times weekly	Parent converses with child at least twice during visit
Child has 3 or more books of her own	Child is encourage to learn spatial relationships
	Child is encouraged to lean to read a few words
	Child has real or toy musical instrument

Following Linver, Martin and Brooks-Gunn (2004) and Fuligni, Han and Brooks-Gunn (2004).

Distribution of birth weight in IHDP