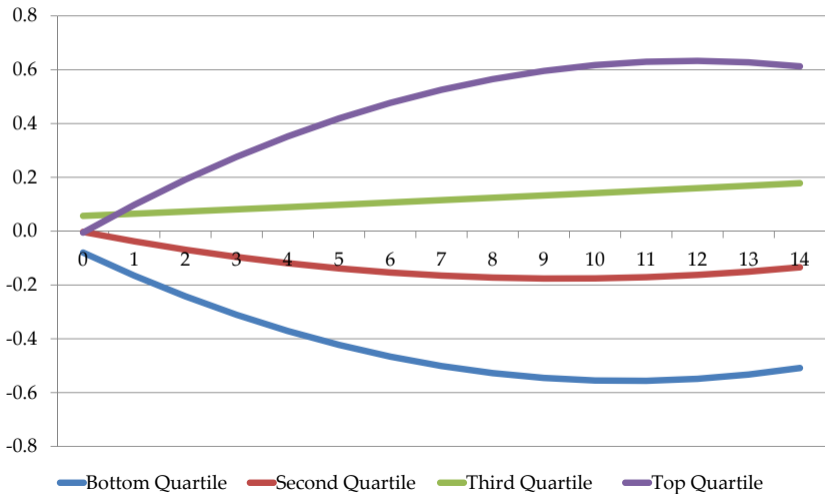# Eliciting Maternal Beliefs about the Technology of Skill Formation

Jennifer Culhane, Flávio Cunha, and Irma Elo

CHOP and University of Pennsylvania

November 2012

**Figure**
**Dynamics of Cognitive Skills**
**For Different Groups of Permanent Income**

**Investments in Human Capital of Children**

by Quartiles of Permanent Income

Legend:
- kdensity Bottom
- kdensity Second
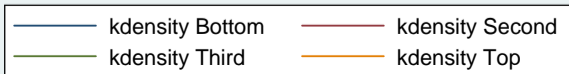- kdensity Third
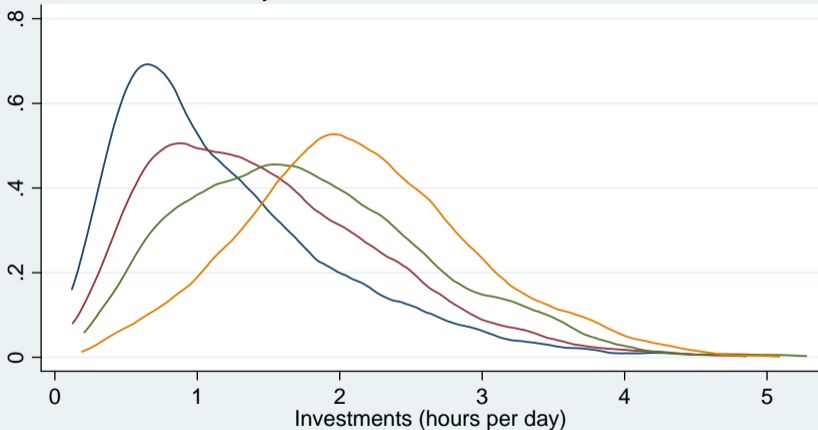- kdensity Top

X-axis: Investments (hours per day)

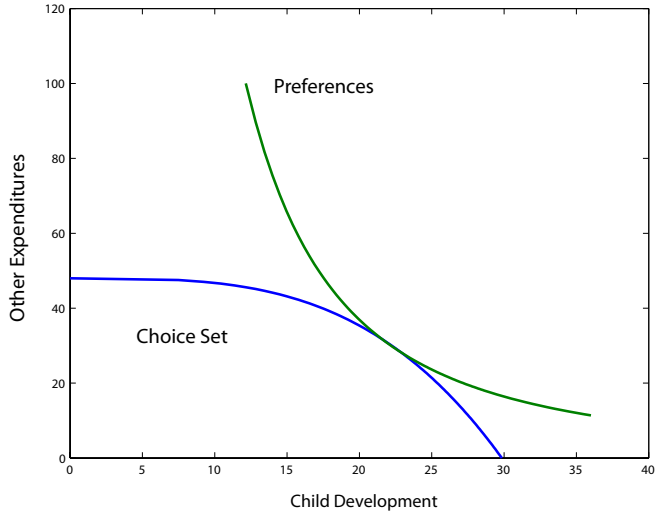Figure
Choice Set and Preferences

# Parental Information about the Technology of Skill Formation

► 1. Iodine Defficiency: Roy (2009); Field, Robles, and Torero (2009).
2. The 1964 Surgeon General Report on Smoking: Aizer and Stroud (2010).
3. Time spent and appropriateness of activities: Kalil, Ryan, and Corey (2012).
4. Health intervention in Brazil: Neri (2006).

Figure
Choice Set and Preferences

Red: Mother underestimates returns
Blue: Mother has unbiased returns

Other Expenditures

Child Development
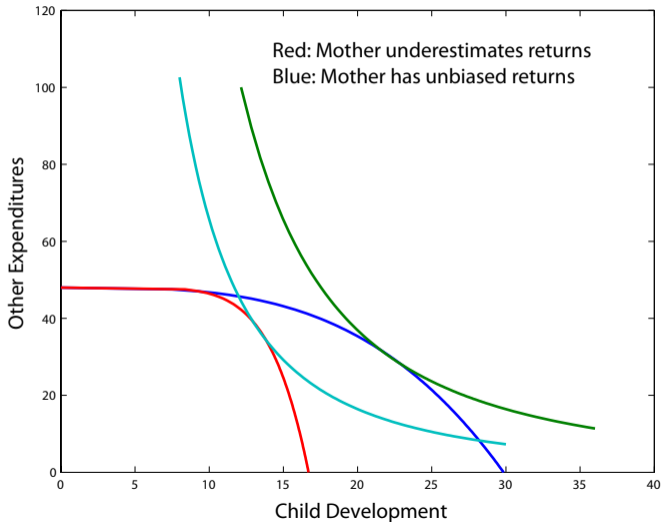
# The Technology of Skill Formation?

- Let $x_i$ denote investment.
- Let $q_{i,0}$ denote the human capital of the child at birth.
- Let $q_{i,1}$ denote the human capital of the child at age 24 months.
- Let $\theta_i$ and $\nu_i$ denote unobservable components.

$$\ln q_{i,1} = \ln A + \rho \ln q_{i,0} + \gamma \ln x_i + \theta_i + \nu_i$$

# Maternal Beliefs about the Technology Parameters

- Mother has beliefs about $\gamma$.

# Maternal Beliefs about the Technology Parameters

- Mother has beliefs about $\gamma$.
- For mother $i$, $\gamma$ is a random variable:

$$\gamma \sim N\left(\mu_{\gamma,i}, \sigma^2_{\gamma,i}\right)$$

and $\mu_{\gamma,i}, \sigma^2_{\gamma,i}$ are heterogeneous across mothers.

# Eliciting Beliefs about Technology of Skill Formation

- ▶ Disadvantaged sample:
    1. Respondents are eligible for medicaid.
    2. 72.5% is African-American and 11.5% is Hispanic.
    3. 50% of respondents are 21 years-old or younger, 80% are 24 years-old or younger.
    4. 20% of respondents are married or cohabiting with partner, 80% single mothers.
    5. 56.5% are primiparous.

- ▶ Two main reasons to choose disadvantaged sample:
    1. Evidence of underinvestment.
    2. Survey is complex.

# Today

- Objective estimation of the technology of skill formation
  - Similar to Cunha, Heckman, and Schennach (2010):
    1. Skills are measured in "mental" age of development (measured in months).
    2. Investments (HOME) are scaled in months per year.
- Elicit subjective beliefs about the technology of skill formation.
  - How to construct a measure of expected development that is consistent with the measure of skills used in the objective estimation?
  - Create hypothetical scenarios to zero in on the heterogeneity in beliefs about $\gamma$.

# Objective Estimation of the Technology of Skill Formation:

- ▶ Consider a Cobb-Douglas specification (CHS, 2010).
- ▶ Our goal is to estimate the parameters (especially $\gamma$) of the following equation:

$$\ln q_{i,1} = \ln A + \rho \ln q_{i,0} + \gamma \ln x_i + \theta_i + \nu_i$$

1. Need to find a metric for $q$ and $x$.
2. Address endogeneity of $x$.
3. Account for measurement error in $q$ and $x$.

## SECTION 3:  MOTOR AND SOCIAL DEVELOPMENT

### PART H:  (22 MONTHS - 3 YEARS, 11 MONTHS)

---

**MOTHER/GUARDIAN:**

If _____ is **at least 22 months** old, but **not yet 4 years** old,
      Child's Name         please answer these 15 questions.

---

1. Has your child ever let someone know, without
   crying, that wearing wet (soiled) pants or            YES.... 1
   diapers bothered him/her?                             NO..... 0              72/

2. Has your child ever spoken a partial sentence of      YES.... 1
   3 words or more?                                      NO..... 0              73/

3. Has your child ever walked upstairs by                YES.... 1
   himself/herself without holding on to a rail?         NO..... 0              74/

4. Has your child ever washed and dried his/her hands
   without any help except for turning the water         YES.... 1
   on and off?                                           NO..... 0              75/

5. Has your child ever counted 3 objects correctly?      YES.... 1
                                                         NO..... 0              76/

6. Has your child ever gone to the toilet alone?         YES.... 1
                                                         NO..... 0              77/

7. Has your child ever walked up stairs by
   himself/herself with no help, stepping on             YES.... 1
   each step with only one foot?                         NO..... 0              78/

8. Does your child know his/her own age AND sex?         YES.... 1
                                                         NO..... 0              79/

9. Has your child ever said the names of at least 4
   colors?                                               YES.... 1
                                                         NO..... 0              80/

Please turn to next page

|  | | Table 2 | | | | | |
|  | | Estimation of the Technology of Skill Formation | | | | | |
|  | | Mother Fixed Effect Models | | | | | |
|  | (1) | (2) | (3) | (4) | (5) | (6) | (7) |
| Age range of children at the date that human capital is measured | 2 - 36 | 2 - 36 | 10 - 30 | 17-31 | 18-30 | 19-29 | 20-28 |
| $\rho$ | 0.773 | 0.931 | 0.812 | 0.274 | 0.254 | 0.453 | 0.324 |
|  | (0.278) | (0.280) | (0.326) | (0.287) | (0.327) | (0.461) | (0.721) |
| $\gamma$ | 0.102 | 0.121 | 0.112 | 0.125 | 0.132 | 0.146 | 0.159 |
|  | (0.021) | (0.018) | (0.023) | (0.028) | (0.033) | (0.042) | (0.054) |
| Dummies for age (in months) | Yes | No | No | No | No | No | No |
| Natural log of age (in months) | No | Yes | Yes | Yes | Yes | Yes | Yes |
| Overall $R^2$ | 0.699 | 0.688 | 0.525 | 0.368 | 0.320 | 0.278 | 0.226 |
| Observations | 4497 | 4497 | 3733 | 2581 | 2305 | 2001 | 1653 |

Standard error in parenthesis

# Eliciting Beliefs about the Technology of Skill Formation

- In order to measure returns to investments, we need to come up with a way to measure maternal expectation of child development.
- Take the Motor-Social Development Instrument, but instead of asking:

*"Has your child ever spoken a partial sentence with three words or more?"*

- Suppose we ask:

*"What do you think is the youngest age and the oldest age a baby learns to speak a partial sentence with three words or more?"*

# Eliciting Beliefs about the Technology of Skill Formation

- Our goal is to measure maternal expectations with respect to the development of the child at age 24 months.
- Transform the information of age range into probability.
- Assumption: The mother believes that development is uniformly distributed within the age range she supplies.

**Figure**
**Converting Age Ranges into Probabilities at Age 24 Months**
**Blue: Age Range is 18 - 28 Months**
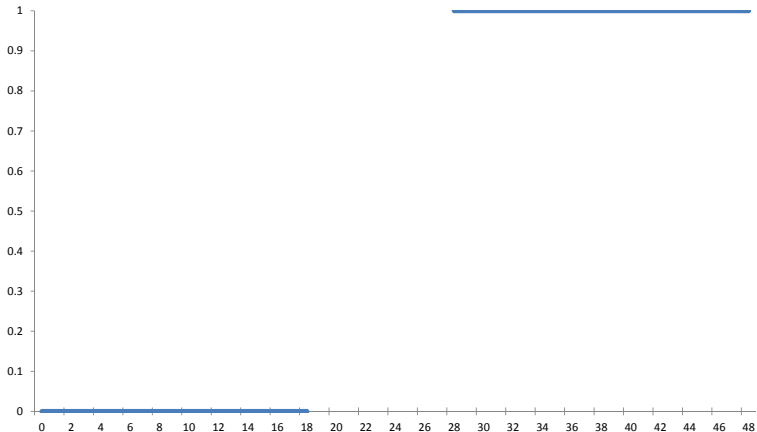
**Figure**
**Converting Age Ranges into Probabilities at Age 24 Months**
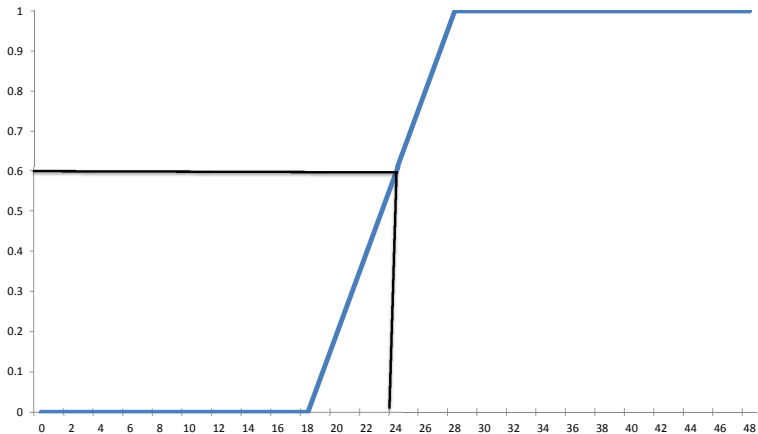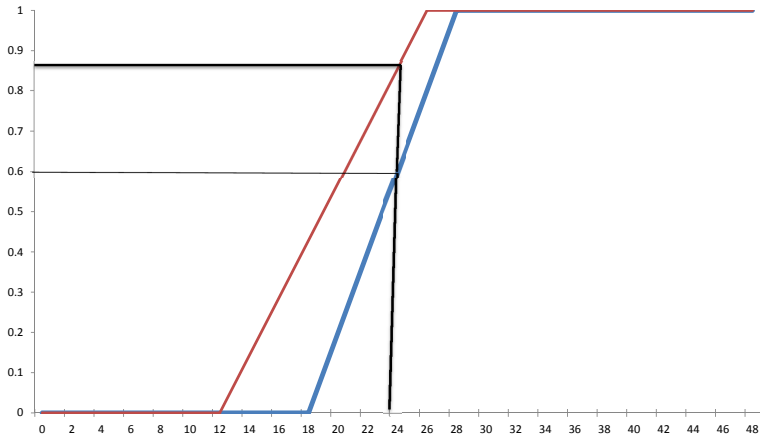**Blue: Age Range is 18 - 28 Months**
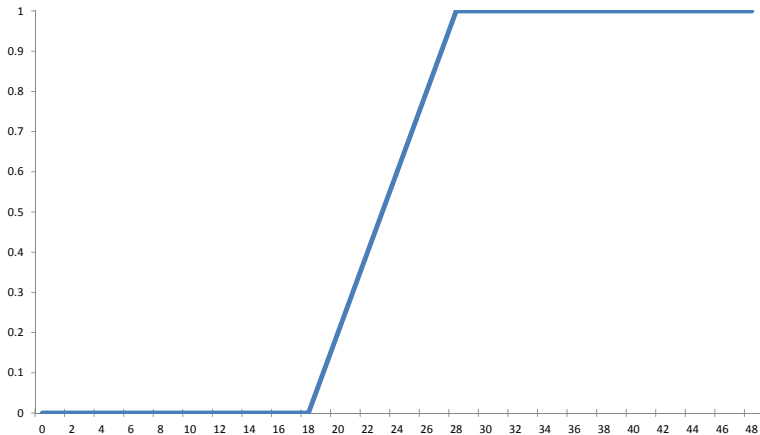
**Figure**
**Converting Age Ranges into Probabilities at Age 24 Months**
**Blue: Age Range is 18 - 28 Months**

**Figure**
**Converting Age Ranges into Probabilities at Age 24 Months**
**Blue: Age Range is 18 - 28 Months**
**Red: Age Range is 12 - 26 Months**

# Transform the Probability into Expected Human Capital

- Remember that the NHANES contains data on a representative set of children from ages 2 to 47 months.
- The NHANES dataset allows us to estimate the probability that a child age *A has already spoken a partial sentence with three words or more.*

**Probability as a Function of Child's Age**
NHANES

Probability as a Function of Child's Age
NHANES
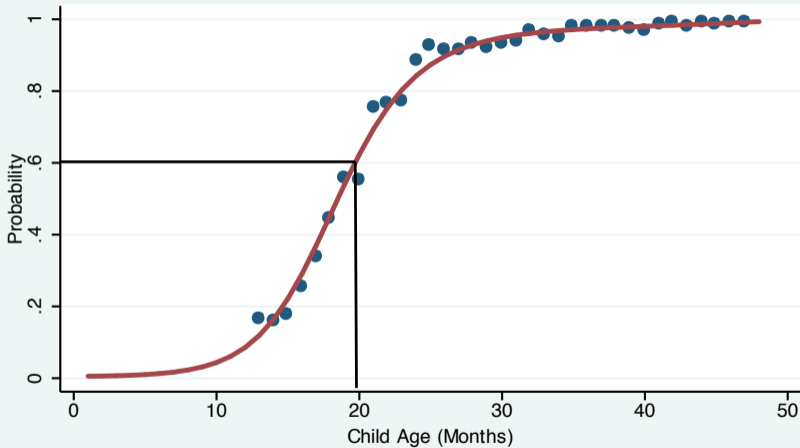
- Speak partial sentence, data
- Speak partial sentence, predicted

Probability as a Function of Child's Age

NHANES

Probability as a Function of Child's Age

NHANES

Legend:
- Speak partial sentence, data
- Know own age and sex, data
- Speak partial sentence, predicted
- Know own age and sex, predicted

X-axis: Child Age (Months)
Y-axis: Probability

# Table

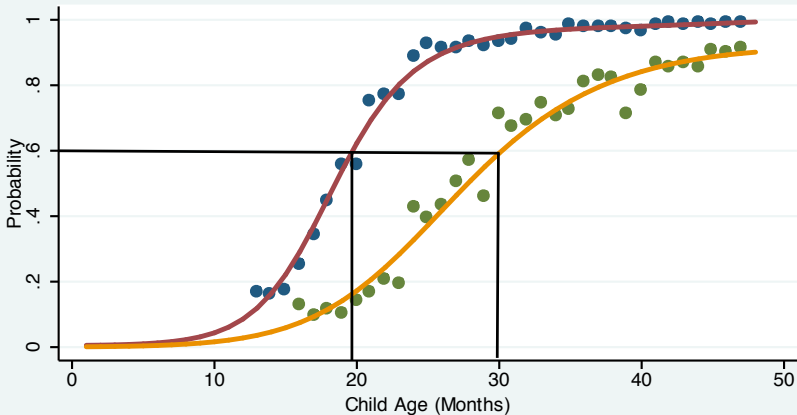| MSD Item | NHANES | Average | Std Error | Median |
|---|---|---|---|---|
| Walk at least 2 steps without holding on to anything or another person? | 100.00% | 69.99% | 30.75% | 60.00% |
| knows object name if somebody names them | 100.00% | 48.97% | 33.54% | 50.00% |
| ever waved goodbye without help | 100.00% | 70.35% | 29.23% | 60.00% |
| Crawl up at least 2 stairs or steps? | 99.91% | 70.91% | 30.68% | 61.29% |
| Say 2 recognizable words besides "mama" and "dada"? | 99.79% | 60.87% | 33.30% | 50.00% |
| Run? | 99.70% | 53.81% | 35.06% | 50.00% |
| Walk up at least 2 stairs with one hand held or holding the railing? | 99.53% | 47.56% | 38.08% | 42.86% |
| Show what he or she wants by pointing, pulling, or making pleasant sounds rather than crying or whining? | 99.14% | 54.52% | 33.94% | 50.00% |
| Say the name of a familiar object such as a ball? | 99.09% | 53.75% | 33.12% | 50.00% |
| Feed himself/herself with a spoon or fork without spilling much? | 96.88% | 38.85% | 35.18% | 37.50% |
| Make a line with a crayon or pencil? | 96.88% | 50.71% | 32.62% | 50.00% |
| Let someone know, without crying, that wearing wet or soiled pants or diapers bothers him or her? | 92.52% | 33.56% | 36.56% | 25.00% |
| Speak a partial sentence of 3 words or more? | 88.54% | 34.11% | 32.06% | 33.34% |

# Transform the Probability into Expected Human Capital

- Each distinct MSD item provides us with one error-ridden estimate of the maternal expectation of child development at 24 months (in a metric of "mental" age).

- Note that we have $K$ such measures, $\ln q_{i,1,k}$ (can tackle measurement error, but wait!)

- To be able to estimate maternal beliefs about the technology parameter $\gamma$, we want to keep constant $q_0$, $x$, and $\theta_i$:

$$E\left(\ln q_1 \,|\, q_0, x, \theta_i\right) = \ln A + \rho \ln q_0 + \mu_{\gamma,i} \ln x + \theta_i$$

# Eliciting Beliefs about the Technology of Skill Formation

- The goal is to obtain information about $\mu_{\gamma,i}$. Remember that:

$$E\left(\ln q_1 \,|\, q_0, x, \theta_i\right) = \ln A + \rho \ln q_0 + \mu_{\gamma,i} \ln x + \theta_i$$

- We create four hypothetical scenarios:
  1. $(q_h, x_h)$ = child is healthy at birth and investment is high.
  2. $(q_u, x_h)$ = child is not healthy at birth and investment is high.
  3. $(q_h, x_l)$ = child is healthy at birth and investment is low.
  4. $(q_u, x_l)$ = child is not healthy at birth and investment is low.

- A video explains to participants what we mean by healthy, not healthy, high, low.

9. What do you think is the youngest age and the oldest age a baby learns to speak a partial sentence of 3 words or more?

| Birth | Half year | 1 Year | 1 + Half Years | 2 Years | 2 + Half Years | 3 Years | 3 + Half Years | 4 Years |
|---|---|---|---|---|---|---|---|---|
| 0 | 3 | 6 | 9 | 12 | 15 | 18 | 21 | 24 | 27 | 30 | 33 | 36 | 39 | 42 | 45 | 48 |

Baby is HEALTHY and mother spends 4 HOURS each day interacting with the baby
12 — 36
0 months — 48 months

Baby is NOT HEALTHY and mother spends 4 HOURS each day interacting with the baby
12 — 36
0 months — 48 months

Baby is HEALTHY and mother spends 3 HOURS each day interacting with the baby
12 — 36
0 months — 48 months

Baby is NOT HEALTHY and mother spends 3 HOURS each day interacting with the baby
12 — 36
0 months — 48 months

Table

What do you think is the youngest age and the oldest age a baby learns to

| Cognitive Skills | Child is Healthy and Investment is High | Child is Not Healthy and Investment is High | Child is Healthy and Investment is Low | Child is Not Healthy and Investment is Low |
|---|---|---|---|---|
| Speak a partial sentence of 3 words or more? | 0.3487 | 0.2165 | 0.2718 | 0.1960 |
| His or her own age and sex? | 0.2787 | 0.2088 | 0.2415 | 0.1912 |
| Say his/her first and last name together without anyone's help? | 0.2086 | 0.1594 | 0.1839 | 0.1530 |
| the names of at least 4 colors? | 0.2553 | 0.1740 | 0.2186 | 0.1611 |
| Count 3 objects correctly? | 0.2983 | 0.2099 | 0.2449 | 0.1935 |
| Count out loud up to 10? | 0.2673 | 0.1815 | 0.2206 | 0.1651 |
| Draw a picture of a man or woman with at least two parts of the body besides a head? | 0.1671 | 0.1446 | 0.1747 | 0.1318 |

# Eliciting Beliefs about the Technology of Skill Formation

- So, for each MSD item $k$ and scenario $j$, we have one error-ridden estimate of conditional development at age 24 months, $\ln q_{i,1,k,j}$.

- Let $E\left(\ln q_1 \mid q_{0,j}, x_j, \theta_i\right)$ denote latent maternal expectation:

$$\ln q_{i,1,k,j} = \alpha_{0,k,j} + \alpha_{1,k} E\left(\ln q_1 \mid q_{0,j}, x_j, \theta_i\right) + \tau_{i,k} + \eta_{i,j} + \varepsilon_{i,k,j}$$

- Non-classical measurement error.

- Can identify $E\left(\ln q_1 \mid q_{0,j}, x_j, \theta_i\right)$.

Analysis of Measurement Error

MSD Item 35: Speak partial sentence with at least 3 words

| | Fraction Explained by Maternal Expected Human Capital | Fraction Explained by Item Specific Measurement Error | Fraction Explained by Scenario Specific Measurement Error | Item and Scenario Uniqueness |
|---|---|---|---|---|
| **Scenario 1: Healthy, High Investment** | | | | |
| Healthy vs Not Healthy, 4 Hours vs 3 Hours | 36.91% | 31.89% | 0.64% | 30.56% |
| Normal vs. Small, 4 Hours vs 3 Hours | 20.53% | 50.50% | 0.12% | 28.85% |
| Healthy vs Not Healthy, 6 Hours vs 2 Hours | 31.43% | 32.11% | 1.04% | 35.42% |
| **Scenario 2: Not healthy, Low Investment** | | | | |
| Healthy vs Not Healthy, 4 Hours vs 3 Hours | 54.11% | 29.12% | 0.00% | 16.77% |
| Normal vs. Small, 4 Hours vs 3 Hours | 25.26% | 63.22% | 0.00% | 11.52% |
| Healthy vs Not Healthy, 6 Hours vs 2 Hours | 44.65% | 37.68% | 0.00% | 17.67% |
| **Scenario 3: Healthy, High Investment** | | | | |
| Healthy vs Not Healthy, 4 Hours vs 3 Hours | 40.16% | 44.05% | 0.00% | 15.79% |
| Normal vs. Small, 4 Hours vs 3 Hours | 32.43% | 55.15% | 0.00% | 12.42% |
| Healthy vs Not Healthy, 6 Hours vs 2 Hours | 36.85% | 50.76% | 0.00% | 12.39% |
| **Scenario 4: Not healthy, Low Investment** | | | | |
| Healthy vs Not Healthy, 4 Hours vs 3 Hours | 59.70% | 31.14% | 0.00% | 9.16% |
| Normal vs. Small, 4 Hours vs 3 Hours | 36.73% | 53.25% | 0.00% | 10.02% |
| Healthy vs Not Healthy, 6 Hours vs 2 Hours | 43.24% | 42.71% | 0.00% | 14.05% |

# Eliciting Beliefs about the Technology of Skill Formation

- Taking differences between scenarios $(q_h, x_h)$ and $(q_h, x_l)$ yields:

$$\mu_{\gamma,i} = \frac{E\left[\ln q_1 \,|\, q_h, x_h, \theta_i\right] - E\left[\ln q_1 \,|\, q_h, x_l, \theta_i\right]}{\ln x_h - \ln x_l}.$$

- Analogously, take differences between scenarios $(q_u, x_h)$ and $(q_u, x_l)$:

$$\mu_{\gamma,i} = \frac{E\left[\ln q_1 \,|\, q_u, x_h, \theta_i\right] - E\left[\ln q_1 \,|\, q_u, x_l, \theta_i\right]}{\ln x_h - \ln x_l}.$$

Table 3
Subjective Beliefs about the Technology of Skill Formation
Objective Estimate: $\gamma_1 = 0.121$ (s.e. 0.0108).

| | Healthy vs. Not Healthy 4 Hours vs 3 Hours | | | Normal vs Small 4 Hours vs 3 Hours | | | Healthy vs. Not Healthy 6 Hours vs 2 Hours | | |
|---|---|---|---|---|---|---|---|---|---|
| | 25th Percentile | Median | 75th Percentile | 25th Percentile | Median | 75th Percentile | 25th Percentile | Median | 75th Percentile |
| **Accounting for Measurement Error in Maternal Responses** | | | | | | | | | |
| Overall | -0.043 | 0.050 | 0.297 | -0.031 | 0.183 | 0.668 | 0.003 | 0.105 | 0.263 |
| Healthy Scenarios | 0.011 | 0.125 | 0.443 | -0.008 | 0.291 | 0.815 | 0.019 | 0.121 | 0.280 |
| Not healthy Scenarios | -0.107 | -0.002 | 0.203 | -0.068 | 0.163 | 0.549 | 0.004 | 0.117 | 0.247 |
| Motor Development Items | 0.000 | 0.059 | 0.321 | 0.014 | 0.213 | 0.731 | 0.000 | 0.126 | 0.289 |
| Cognitive Development Items | -0.022 | 0.034 | 0.187 | -0.041 | 0.142 | 0.586 | 0.000 | 0.098 | 0.254 |
| **Not Accounting for Measurement Error in Maternal Responses** | | | | | | | | | |
| Overall | -0.001 | 0.072 | 0.343 | 0.000 | 0.136 | 0.641 | 0.003 | 0.147 | 0.267 |
| Healthy Scenarios | -0.001 | 0.112 | 0.450 | 0.000 | 0.186 | 0.602 | 0.000 | 0.150 | 0.332 |
| Not healthy Scenarios | -0.001 | 0.003 | 0.237 | 0.000 | 0.064 | 0.451 | 0.000 | 0.095 | 0.237 |
| Motor Development Items | 0.000 | 0.063 | 0.307 | 0.000 | 0.049 | 0.444 | 0.000 | 0.134 | 0.351 |
| Cognitive Development Items | 0.000 | 0.000 | 0.331 | 0.000 | 0.063 | 0.677 | 0.000 | 0.138 | 0.278 |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Healthy | Gestation lasts 9 months Weight at birth is 7 pounds Baby stays at most 3 days at hospital | | | Normal | Gestation lasts 9 months Weight at birth is 8 pounds Baby is 20 inches long at birth | | | Healthy | Gestation lasts 9 months Weight at birth is 7 pounds Baby is 20 inches long at birth |
| | Not Healthy | Gestation lasts 7 months Weight at birth is 5 pounds Baby stays at most 8 days at hospital | | | Small | Gestation lasts 8 and 1/2 months Weight at birth is 6 pounds Baby is 19 inches long at birth | | | Not Healthy | Gestation lasts 8 months Weight at birth is 5 pounds Baby is 18 inches long at birth |

# Conclusion

▶ In general, economic models of human development assume that mothers have rational expectations about the technology of skill formation.

▶ This assumption implies that all women – regardless of their race, education, or socio-economic status – know the objective distribution function of the marginal returns to investments on the development of their children.

▶ When such models are structurally estimated, the variation in observed investments across families is attributed to shocks, heterogeneity in the characteristics of the children or families, but not to the heterogeneity in the knowledge base of the mother.

▶ Important for policy and methodological reasons.