THE TECHNOLOGY OF SKILL FORMATION

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People have diverse abilities: cognitive, noncognitive.

Abilities account for a substantial portion of the variation across people in socioeconomic success.

Persistent and substantial ability gaps across children of various socioeconomic groups emerge before they start school.
Motivation

Children of NLSY

Average percentile rank on PIAT Math score, by income quartile*

*Income quartiles are computed from average family income between the ages of 6 and 10.

Legend:
- Blue line: Lowest income quartile
- Black line: Second income quartile
- Purple line: Third income quartile
- Red line: Highest income quartile
Levels of child’s skills are highly correlated with family background factors.
Motivation

- The **family** plays a powerful role in shaping these abilities:
  - Genetics
  - Parental investments
  - Environment

- Policy designed to reduce inequalities $\Rightarrow$ early vs late remediation investments.
Goal of the paper

Provide a theoretical framework for interpreting the evidence from a vast empirical literature on skill formation and child development.

Present economic models of child development:

- Childhood has more than one stage
- Abilities are both inherited and created
- Skill begets skill through a multiplier process
  - Skill attainment at one stage of the life cycle raises skill attainment at later stages of the life cycle (**self-productivity**)
  - Early investment facilitates the productivity of later investment (**complementarity**)

Provide a framework for designing policies to reduce inequality.
Individual lives for 2T periods:
- Childhood: 1 to T
- Adulthood: T+1 to 2T

Household: child + parent; altruism.

During adulthood the individual works. Supplies labor inelastically.

There are two kinds of skills: Cognitive ($\theta^C_t$) and non-cognitive ($\theta^N_t$)

Each agent is born with initial conditions ($\theta^C_1, \theta^N_1$)

$I^k_t$: parental investments in child skill $k$ at period $t$.

$h'$: level of human capital as the child starts adulthood.

$h' = g(\theta^C_{T+1}, \theta^N_{T+1})$
The technology of production of skill $k$ at period $t$ is

\[ \theta_{t+1}^k = f_t^k(h, \theta_t, l_t^k), \quad \text{for} \quad k = C, N, \ t = 1, T; \theta_t = (\theta_t^C, \theta_t^N). \quad (1) \]

- **Self-productivity**: skills attained at one stage augment skills attained at later stages.

\[ \frac{\partial f_t^k(h, \theta_t, l_t^k)}{\partial \theta_t^j} > 0, \quad j = C, N \quad (2) \]

- **Dynamic complementarity**: Skills produced at one stage raise productivity of investment at subsequent stages.

\[ \frac{\partial^2 f_t^k(h, \theta_t, l_t^k)}{\partial l_t^k \partial \theta_t^j} > 0, \quad k, j = C, N \quad (3) \]
Technology: Example T=2

- First period technology:
  \[ \theta_2^k = f_t^k(\theta_1, l_1^k) = l_1^k. \]

- Second period technology (CES):
  \[ \theta_3^C = f_2^C(\theta_2, l_2^C) = \left\{ \gamma_1(\theta_2^C)^\alpha + \gamma_2(\theta_2^N)^\alpha + (1 - \gamma_1 - \gamma_2)(l_2^C)^\alpha \right\}^{1/\alpha} \]
  \[ \theta_3^N = f_2^C(\theta_2, l_2^C) = \left\{ \eta_1(\theta_2^C)^\nu + \eta_2(\theta_2^N)^\nu + (1 - \eta_1 - \eta_2)(l_2^C)^\nu \right\}^{1/\nu} \]

- Third period. Adult human capital:
  \[ h' = \left\{ \tau(\theta_3^C)^\phi + (1 - \tau)(\theta_3^N)^\phi \right\}^{1/\phi} \]
Technology: Example

Assumptions:

- $I_t^C = I_t^N = I_t$
- $\alpha = \nu = \phi$

Adult human capital stock:

$$h' = \left\{ \gamma I_1^\phi + (1 - \gamma) I_2^\phi \right\}^{1/\phi}$$

- $\gamma = \tau(\gamma_1 + \gamma_2) + (1 - \tau)(\eta_1 + \eta_2) \Rightarrow$ Skill multiplier
  - Self productivity
  - Direct complementarity

- $\phi$: Degree of complementarity (susstitutability) between early and late investments
  $\Rightarrow$ how easy is to compensate for low levels of stage 1 skills in producing late skills.
Technology: CES complementarity/susstitutability

1) Perfect CES Substitutes: \( \phi = 1 \)

\[
h' = \{\gamma l_1 + (1 - \gamma) l_2\}
\]

- it is possible in a **physical productivity sense**, to compensate for early investment deficits by later investments.
- Special case \( \gamma = 1/2 \) \(\Rightarrow\) only matters the total amount of human capital investments, regardless of how it is distributed across childhood periods.

2) Perfect CES Complements (leontief case): \( \phi \to -\infty \)

\[
h' = \min \{l_1, l_2\}
\]

- Early investments are a **bottleneck** for later investments.
- Later investments are needed to harvest early investments.
- Compensation for adverse early environments through late environments is impossible.
Parent chooses $l_1$, $l_2$ and level of risk free assets $b$ that maximizes the present value of net wealth of their children.

$$\max_{l_1, l_2, b} \left\{ \frac{1}{(1 + r)^2} \left[ qh'(l_1, l_2) + b \right] \right\}$$

subject to

$$l_1 + \frac{l_2}{1 + r} + \frac{b}{(1 + r)^2} = M$$

$$b \geq 0$$

where $q = \sum_{t=3}^{4} \left( \frac{1}{(1+r)} \right)^{t-3} w_t$
Optimal timing of investments

1) Perfect CES substitutes (\( \phi = 1 \)):

\[
\text{Invest early if } \gamma > (1 - \gamma)(1 + r) \Rightarrow \gamma > \frac{1 + r}{2 + r}
\]

2) Perfect CES complements (\( \phi \to -\infty \)):

\[I_1 = I_2\]
Optimal timing of investments

3) \(-\infty < \phi < 1\)

\[
\frac{l_1}{l_2} = \left(\frac{\gamma}{(1-\gamma)(1+r)}\right)^{1-\phi}
\]

Figure 2. Ratio of early to late investment in human capital as a function of the skill multiplier for different values of complementarity.

Notes: Assumes \(r = 0\).
Consequences of credit constraints

- Assume: $M^A > M^B \Rightarrow$ family A unconstrained; family B is constrained
- $I^A_1 > I^B_1 ; I^A_2 > I^B_2$

Facts: Ability gaps between individuals and across socioeconomic groups open up at early ages (Blau & Currie, 2006).
Late remediations for disadvantaged children

Optimal policy → critically depend on the technology of skill production:
- Lower returns if early and late investments are not perfect substitutes.
- Late investment is more productive the higher the level of early investments.

⇒ **Equity-efficiency trade-off** in late remediation policies.

Facts:
- Returns to secondary schooling and post-secondary schooling are higher for high-ability people than for low-ability people
- Higher returns to the most able in job training programs.
- College enrollment response to unanticipated increases in returns to college were initially strong for adolescents from advantaged families.
Early remediations for disadvantaged children

⇒ There is no trade-off between equity and efficiency in early childhood investments.

- The marginal return to one dollar invested in the poor child from family B is above the marginal return to the same dollar invested in the rich child from family A

Facts:

- High economic returns to interventions targeted toward young disadvantaged children (Barbnet 2004).
- If early investments in disadvantaged is not followed up by later investments, its effects at later ages is lessened (Currie & Thomas 1995)
Conclusions

- Considering different stages during childhood + special features of technology of skill formation is important:
  - To understand empirical evidence on child development.
  - To guide further research on optimal policy interventions to reduce inequalities.