Models for Social Mobility and Skill Formation

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Econ 350, Spring 2022

- Models of *intergenerational* family influence and the formation of child human capital.
- How markets, parental preferences, and child biological endowments operate to produce differences in adult capabilities (capacities to function).
- OLG Model
    1. One period of childhood
    2. Scalar measure of capability: “ability” or “human capital”
    3. Scalar measure of investment (schooling, etc.)
    4. Role of the parent is through active investment and through dealing with credit markets to secure investment in the child.

θ_g: **Skill** of children in generation g

I_{g-1}: **Investment** in children of generation g by parents of generation $g-1$

G_{g-1}: Investment in children of generation g by schooling (and other public goods)

e_g: Endowment of children at birth

Capabilities (Skills) are created by investment and endowments.

$$\theta_g = \phi(\theta_{g-1}, I_{g-1}, G_{g-1}, e_g)$$

- A deterministic relationship.
- Technology of skill formation.

Endowments: exogenous and subject to shocks u_g:

$$e_g = \lambda_0 + \lambda_1 e_{g-1} + u_g$$

- No direct effect of parents on transmission of endowments.
- Related to genetic transmission.

Markets:

- ⓐ Labor market: rewards human capital θ_g
  W_g: Reward in generation g (payment per unit human capital)
  L_g: "*luck*" in g (out of the control of the agent):

$$Y_g = W_g \theta_g + L_g$$

- ⓑ Credit market in which agents (parents) can lend and borrow
  - ⓘ Becker-Tomes (1979) / Sheshadri and Greenwood (2001)
    Perfect markets (parents can lend and borrow and commit debt to future generation)
  - ⓘⓘ Generalized in Becker-Tomes (1986) to allow for imperfect markets across generations. (Parents cannot commit debt to future generations.)

Preferences:
Parental utility for generation g: U_g
Z_g is parental consumption

$$U_g = \eta(Z_g) + \underbrace{\delta}_{\text{altruism}} U_{g+1}$$

Dynastic form of the utility function:

$$U_g = \sum_{j=0}^{\infty} \delta^j \eta(Z_{g+j})$$

Parents' Problem:
Parents allocate resources between adult consumption Z_g and investment in the child I_{g-1} under different market settings.

Intergenerational Correlations of Earnings and Education

- Y_1 is income in generation "1"; Y_0 is income in generation "0"

$$\underbrace{\ln(Y_1)}_{\substack{\text{child}\\\text{permanent}\\\text{earnings}}} = \omega + \beta \underbrace{\log(Y_0)}_{\substack{\text{parent}\\\text{permanent}\\\text{earnings}}} + \underbrace{L_1}_{\text{``Luck''}} \tag{1}$$

- β: the intergenerational elasticity (IGE)
- (1 - β): measure of intergenerational mobility

- Intergenerational correlation (ρ): an alternative to β

$$\rho = (\sigma_0/\sigma_1)\beta \tag{2}$$

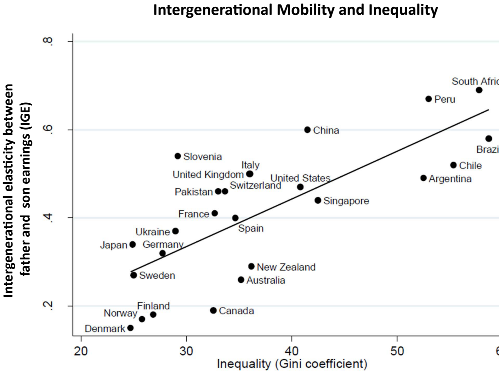
- σ is the standard deviation of log earnings.
- Factors out the cross-sectional dispersion of log earnings in the two generations.
- β can be higher in one society than in another simply because the variance of log earnings in the child's generation is higher in that society.

Issues in estimating the intergenerational elasticity of earnings

- Y should be a measure of permanent earnings.
- Few data sets have information that allows the calculation of lifetime earnings for both fathers and sons.
- Issues
  - a Classical measurement error
  - b Alignment error (ages of father and son)

Intergenerational Mobility and Inequality: The "Great Gatsby Curve"

$$\text{IGE: } \underbrace{\ln Y_1}_{\substack{\text{Income in current}\\ \text{generation}}} = \alpha + \beta \underbrace{\ln Y_0}_{\substack{\text{Income of}\\ \text{parents}}} + \varepsilon$$



Source: Corak 2011, Inequality from generation to generation: the United States in Comparison.
Note:

- Inequality is measured **post-taxes and transfers**.
- Gini index defined on household income.
- IGE measured by **pre-tax and transfer** income of individual fathers and sons.

Why the IGE may differ across countries and over time

- Solon (2004)
- The budget constraint assumes families must allocate all after-tax lifetime income to either parental consumption (Z_0) or investment in the child (I_0):

$$(1-\tau)Y_0 = Z_0 + I_0 \tag{3}$$

(No intertemporal lending or borrowing)

- Human capital of the child (θ_1) is produced by a semi-log production function:

$$\underbrace{\theta_1}_{\substack{\text{human capital}\\ \text{of child}}} = \underbrace{\psi}_{\substack{\text{productivity}\\ \text{of the}\\ \text{transmission}\\ \text{process}}} \log(I_0 + \underbrace{G_0}_{\substack{\text{governmental}\\ \text{investment}}}) + \underbrace{e_1}_{\substack{\text{child initial}\\ \text{endowment}}} \tag{4}$$

- I_0 and G_0 are perfect substitutes.

- Child endowments follow AR(1) process:

$$e_1 = \lambda_0 + \lambda_1 e_0 + \upsilon_1, \tag{5}$$

- $0 \leq \lambda_1 \leq 1$
- e_0: set outside the model.
- υ_1 is white noise (independent over time).
- Earnings equation:

$$\log(Y_1) = \mu + p\theta_1 \tag{6}$$

- p is the return to a unit of human capital.

- The family maximizes
  $U_1 = (1-\delta)\log(Z_0) + \delta\log(Y_1)$.
- δ measures the degree of altruism towards the child.
- $$\begin{aligned} I_0 &= \left[\frac{\delta\psi P}{1-\delta(1-\psi P)}\right](1-\tau)y_0 - \left[\frac{1-\delta}{1-\delta(1-\psi P)}\right]G_0 \\ \ln Y_1 =& \mu + P\left[\psi\ln(I_0+G_0)+e_{it}\right] \end{aligned}$$
- Solon (2004) models provision of governmental goods.
  $G_0/[(1-\tau)Y_0] = \varphi - \gamma\log(Y_0)$.
- $\gamma > 0$ ratio of government investment to after-tax income is decreasing in income.
- γ: a measure of the progressivity of government spending on children.

- By maximizing the utility function with respect to parental investment and collecting terms, one arrives at

$$\log(Y_1) \simeq \mu^* + \underbrace{[(1-\gamma)\psi p]}_{\text{causal parameter}} \log(Y_0) + pe_1 \tag{7}$$

  which is the form of the standard IGE regression.
- Causal model: $Y(0) \uparrow Y(1) \uparrow$.
- e_1 correlated with $\ln(Y_0)$ through common shock e_0 (see Equation 5).

- What doe OLS estimate? (Most of the IGE literature uses OLS).
- Take (7) and lag it one period

$$\log Y(0) = \mu^* + [(1-\gamma)\psi p] \log(Y-1) \\ + pe_0 \tag{8}$$

- This is a causal relationship.
- $\mu^* = f(\delta) \quad \delta \uparrow, \mu^* \uparrow$.
- Use (5):

$$\frac{e_1 - \lambda_0 - \tau_1}{\lambda_1} = e_0, \text{ for } |\lambda_1| > 0$$

$$\log(Y(1)) = \mu^* + [(1-\gamma)\psi p] \log(Y_0) \\ + p[\lambda_0 + \lambda_1 e_0 + \tau_1]$$

- From (5) and (7)

$$\begin{aligned}\log(Y_1) = \mu^* + [(1-\gamma)\psi p] \log Y_0 \\ + p[\lambda_0 + \lambda_1 e_0 + \upsilon_1]\end{aligned}$$

- Substitute for e_0

- From (8)

$$e_0 = \frac{\log Y(0) - \mu^* - [(1-\gamma)\psi p]\log(Y(-1))}{p} \quad \text{replacement function}$$

- **Exercise:** Is this a causal relationship?

- $\therefore$ (7) can be written as

$$\begin{aligned}\log Y(1) = \mu^* + [(1-\gamma)\psi p] \log(Y_0) \\ + p\left[\lambda_0 + \lambda_1\right]\left[\frac{\log Y(0) - \mu^* - [(1-\gamma)\psi p] \log Y(-1)}{p}\right] \\ + \upsilon_1\end{aligned}$$

$$\begin{aligned} \log Y(1) = {} & \{\mu^*(1-\lambda_1) + p\lambda_0\} \\ & + \{[(1-\gamma)\psi p] + \lambda_1\} \log(Y(0)) \\ & - [(1-\gamma)\psi p] \log Y(-1) \\ & + \upsilon_1 \end{aligned} \tag{9}$$

Exercise: Can you consistently identify the coefficients on $\log(Y(0))$ and $\log Y(-1)$ by OLS? Why?

Exercise: Is the coefficient on $\log Y(0)$ in (9) a causal parameter? Why?

Exercise: How can you identify the ceteris paribus effect of $\log(Y(0))$ on $\ln(Y(1))$ in (7)?

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Exercise: Is the coefficient on $Y(-1)$ in (9) a causal effect of $Y(-1)$ on $Y(1)$? What is being held constant?

OLS Estimates of IGE β

- In steady state, $\sigma_0 = \sigma_1$, where σ_0 and σ_1 are the sd of $Y(0)$ and $Y(1)$

$$\beta = \frac{(1-\gamma)\upsilon p + \lambda_1}{1 + (1-\gamma)\upsilon p \lambda_1} \quad \uparrow \text{ as } \lambda_1 \uparrow, \tau \uparrow, p \uparrow, \gamma \downarrow .$$

- Estimated IGE (and intergenerational correlation) greater if
  1. the heritability coefficient λ is higher so ability is more highly correlated across generations,
  2. ψ is higher so that the human capital accumulation process is more efficient,
  3. earnings returns to human capital are higher so p is larger, or
  4. governmental investment in human capital is less progressive so γ is smaller.

- Cross section variance of log Y_1 (steady state)

$$\text{Var}(\ln Y) = \frac{[1 + (1-\gamma)\tau p \lambda_1] p^2 \, \text{Var}(\upsilon)}{[1 + (1-\gamma)\psi p \lambda_1](1-\lambda_1^2)[1-(1-\gamma)\psi p]^2}$$

$$\uparrow \text{ in } \lambda_1, \psi, p, 1-\gamma$$

New term not in β is $\text{Var}(\upsilon)$

Can show that out of steady state as income inequality ↑, $\beta \uparrow$

  - **Exercise:** Show this
  - **Exercise:** Why does δ only appear in the intercept of the Gatsby equation?

- Expand the original framework to recognize:
  1. Multiple stages of childhood and adulthood
  2. Moves beyond "schooling" as investment to allow economists to address the benefits and costs of different types of investments
     a. Schooling
     b. Training
     c. Preschool and early childhood investments
  3. Recognizes the modern literature on the biology and psychology of skill formation and the literature on critical and sensitive periods in development
  4. Multiple capabilities (cognitive, noncognitive, and biological capabilities)
  5. Child preference formation and emergence of decision making (transition from child to adult)
  6. Interactions between child and parents in shaping investment (principle-agent problems)

- Children possess a vector of capabilities at each age t.
- $\theta_t = (\theta_t^C, \theta_t^N, \theta_t^H)$
- Each component may be a vector.

Cunha and Heckman (2007)

- Individual lives $2T$ years. ($T \geq 2$)
- The first T years, the individual is a child of an adult parent.
- From age $T+1$ to $2T$ the individual lives as an adult and is the parent of a child.
- The individual dies at the end of the period in which he is $2T$ years-old, just before his child's child is born.

- A household consists of an adult parent and their child.
- Parents invest in their children because of altruism.
- I_t: parental investments in child skill when the child is t years-old, where $t = 1, 2, \ldots, T$.
- The output of the investment process is a skill vector.

- Agent born with initial conditions: θ_0.
- This can be influenced by family investment (also has genetic component).
- h is parental characteristics (e.g., their IQ, education, etc.).
- θ_t is the vector of capabilities.
- The **technology of production of skill** when the child is t years-old:

$$\theta_{t+1} = f_t(\underset{\uparrow}{h}, \theta_t, I_t), \qquad t = 1, \ldots, T. \tag{10}$$

New idea: parental environmental variables affect productivity of investment

- f_t is neoclassical: strictly increasing, strictly concave, and twice continuously differentiable in I_t.
- Solve recursively to obtain:

$$\theta_{t+1} = m_t\left(h, \theta_1, I_1, \ldots, I_t\right). \tag{11}$$

- *Dynamic complementarity* arises when

$$\frac{\partial^2 f_t\left(h, \theta_t, I_t\right)}{\partial \theta_t \partial I_t'} > 0.$$

- Two distinct ideas:
  1. Higher stocks of skills at age t promote the productivity of investment at that age;
  2. Investment today raises the stock of skills in future periods and raises the productivity of future investment.

- *Self-productivity*:
$$\frac{\partial f_t\left(h, \theta_t, I_t\right)}{\partial \theta_t} > 0.$$
- This includes own and cross effects.
(*Cross complementarity of capabilities*)

- This technology describes learning in rodents and macaques as documented, respectively, by Meaney (2001), Cameron (2004), and Knudsen (2006).
- Early parental emotional environments encourage the animals to explore (and learn) more.
- This technology also captures the critical and sensitive periods in humans and animals.

1. Critical and sensitive periods for investment:
    1. If

$$\frac{\partial f_t(h, \theta_t, I_t,)}{\partial I_t} = 0 \qquad \text{for } t \neq t^*$$

       t^* is the critical period for that investment.
    2. If

$$\frac{\partial f_t}{\partial I_t}(\cdot) > \frac{\partial f_{t'}}{\partial I_{t'}}(\cdot) \qquad t \neq t'$$

       then t is a sensitive period, where “$\cdot$” is a common point of evaluation.

- Special cases of the technology:
  - Ontogenic models:

    $$\theta_{t+1} = f_t(h, \theta_t, I_t) = f_t(h_0, \theta_0), \quad \forall t \geq 0$$

    (initial conditions fully determinative, no investment, no feedback).
  - Initially-determined trajectories fully determine life cycle evolution ("Types" as in Keane and Wolpin, 1997).
  - Dynamic complementarity explains why investment in more able adults is more productive than for the less able.

1. Parental preferences for child outcomes
    - $V^P(V^C)$: the valuation by parents of child value function.
    - $V^P =$ Parental Preference.
    - $V^C =$ Child Preference.
    - Models of Preference Formation.
    - Models of Parent-Child Interactions (Akabayashi; Weinberg; Cosconati; Conti et al.)
    - Parental altruism.
    - Alternative: merit goods: Parents value specific outcomes, not necessarily child utility.

Preferences and the Optimal Life-Cycle Profile of Investments

- Assume $T = 2$; stationary environment. (Two periods of childhood)
- w: wage rate
- r: interest rate
- At the beginning of adulthood, the parents draw the initial level of skill of the child, θ_1, from $J(\theta_1)$, which they can influence through investment.

- On reaching adulthood, parents receive bequest b.
- State variables for the parent: parental skills, h, the parental financial resources, b, and the initial skill level of the child, θ_1.
- c_1 and c_2 denote the consumption of the household in the first and second period of the life cycle of the child.
- The budget constraint is:

$$c_1 + I_1 + \frac{c_2 + I_2}{(1+r)} + \frac{b'}{(1+r)^2} = wh + \frac{wh}{(1+r)} + b. \tag{12}$$

- b': bequest for next generation.
- h': adult human capital of the child.

- β: discount factor
- δ: measure of parental altruism toward the child.
- $\eta(\cdot)$ is the one period utility function.
- Problem of the parent:

$$V\left(h, b, \theta_1\right) = \max\left\{\eta\left(c_1\right) + \beta\eta\left(c_2\right) + \beta^2\delta E\left[V\left(h', b', \theta_1'\right)\right]\right\}. \tag{13}$$

A Special Case

- Assume θ_1, I_1, I_2 are scalars.
- The child's adult stock of skills, h' (adult human capital).

$$h' = m_2 \left(h, \theta_1, I_1, I_2 \right). \tag{14}$$

- Conventional specification of technology (14) implicit in one-period models:

$$h' = m_2 \left(h, \theta_1, \gamma I_1 + \left(1 - \gamma \right) I_2 \right) \tag{15}$$

$$\gamma = 1/2.$$

- Adult stocks of skills do not depend on how investments are distributed over different periods of childhood.

- Polar opposite:

$$h' = m_2\left(h, \theta_1, \min\left\{I_1, I_2\right\}\right). \tag{16}$$

- Adult stocks of skills critically depend on how investments are distributed over time.
- If investments in period one are zero, $I_1 = 0$, then it does not pay to invest in period two.
- If late investments are zero, $I_2 = 0$, it does not pay to invest early.

Dual Face of Complementarity

- Complementarity has a dual face.
- It is essential to invest early to get satisfactory adult outcomes.
- But it is also essential to invest late to harvest the fruits of the early investment.

- More general technology:

$$h' = m_2\left(h, \theta_1, \left[\gamma\left(I_1\right)^{\phi} + \left(1-\gamma\right)\left(I_2\right)^{\phi}\right]^{\frac{1}{\phi}}\right), \tag{17}$$

  for $\phi \leq 1$ and $0 \leq \gamma \leq 1$.
- The CES share parameter γ is *a skill multiplier*.
- It arises from the productivity of early investment not only in directly boosting h' (through self-productivity) but also in raising the productivity of I_2 by increasing θ_2 through first period investments.
- Thus I_1 directly increases θ_2 which in turn affects the productivity of I_2 in forming h'.
- γ captures the net effect of I_1 on h' through both self-productivity and direct complementarity.

- Elasticity of substitution $1/(1-\phi)$ is a measure of how easy it is to substitute between I_1 and I_2.
- ϕ represents the degree of complementarity (or substitutability) between early and late investments in producing skills.
- When ϕ is small, low levels of early investment I_1 are not easily remediated by later investment I_2 in producing human capital.
- The other face of CES complementarity is that when ϕ is small, high early investments should be followed with high late investments if the early investments are to be harvested.
- In the extreme case when $\phi \to -\infty$, (17) converges to (16).

- This technology explains — why returns to education are low in the adolescent years for disadvantaged (low h, low I_1, low θ_2) adolescents but are high in the early years.
- In the one-period model of childhood, inputs at any stage of childhood are perfect substitutes.
- Application of the one period model supports the widely held but empirically unsupported intuition that diminishing returns make investment in less advantaged adolescents *more* productive.

Optimal Investment Strategies for $\phi = 1$ (perfect substitutes)

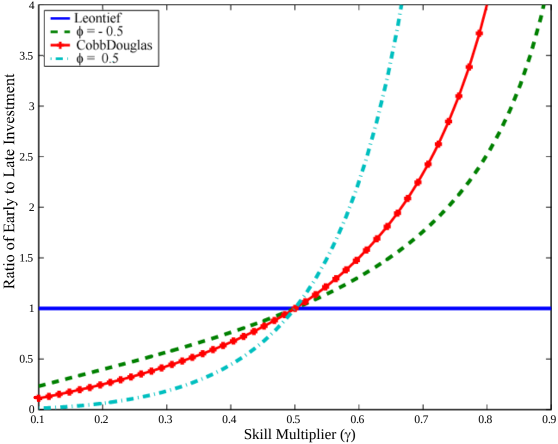
- When $\phi = 1$, early and late investments are perfect CES substitutes, the optimal investment strategy is straightforward.
- The price of early investment is \$1.
- The price of late investment is $\$1/(1 + r)$.
- Productivity of early investment: γ; late investment $(1 - \gamma)$.
- Invest early if $\gamma > \frac{(1-\gamma)}{1+r}$

General Case

- For $-\infty < \phi < 1$, the first-order conditions are necessary and sufficient given concavity of the technology in terms of I_1 and I_2.
- $-\infty < \phi < 1$:

$$\frac{I_1}{I_2} = \left[\frac{\gamma}{(1-\gamma)(1+r)} \right]^{\frac{1}{1-\phi}}. \tag{18}$$

The Ratio of Early to Late Investment in Human Capital As a Function of the Skill Multiplier for Different Values of Complementarity



(Assumes $r = 0$)

Source: Cunha et al. (2007, 2009).

Alternative Market Environments

- In a complete-market model, optimal investment levels do not depend on the parental permanent shocks to wages or endowments or the parameters that characterize the utility function $\eta(\cdot)$.
- Even in this “perfect” credit market setting, parental investments depend on parental skills, h, because these characteristics affect the returns to investment.
- (But not other features of the model.)
- This generalizes Becker-Tomes.
- From the point of view of the child, this is a market failure due to the accident of birth.

Constraints on Borrowing Across Generations

- Suppose parents cannot borrow against child's future earnings. (Becker-Tomes, 1986)
- A second credit constraint: the parental bequests must be non-negative and parents only have access to a risk-free bond, and not to contingent claims.
- The problem of the parent is to maximize (13) subject to (12), the technology (17), and the liquidity constraint:

$$b' \geq 0. \tag{19}$$

- If binding, realized investment $\hat{I}_j$ less than optimal I_j^*
  $\hat{I}_1 \leq I_1^*$ (unconstrained), $\hat{I}_2 \leq I_2^*$ (unconstrained)
- Under liquidity constraints actual investment $\hat{I}_1 < I_2^*$ is lower than the early investment under the perfect credit market model, I_1^*, and $\hat{I}_2 < I_2^*$.
- Under this formulation of market incompleteness, underinvestment in skills starts at early ages and continues throughout the life cycle of the child.
- **Lower investment in both periods** $does\ not$ **affect** $ratio$ **of investments** (I_1/I_2)**.**

- Both early and late investments depend on parental initial wealth b for the families for whom the constraint (19) binds.
- Children who come from constrained families with lower b will have lower early *and* late investments.
- Interventions that occur at early stages would exhibit high returns, especially if they are followed up with resources to supplement late investments.

Parents Themselves Face Lifetime Liquidity Constraints

- Cunha and Heckman (2007).
- Parents are subject to lifetime liquidity constraints and constraints that prevent the parents from borrowing against their own future labor income, which may affect their ability to finance investments in the child's early years.
- Assume that parents' productivity grows exogenously at rate α.

- s: parental savings.
- Parents face a sequence of constraints at each stage of the life cycle of the child:

$$c_1 + I_1 + \frac{s}{(1+r)} = wh + b \tag{20}$$

$$c_2 + I_2 + \frac{b'}{(1+r)} = w\,(1+\alpha)\,h + s, \tag{21}$$

  $s \geq 0$ and $b' \geq 0$.
- $(1+\alpha)$ is growth factor on wages.

- The restriction $s \geq 0$ says that parents cannot borrow income from their old age to finance consumption and investment when the child is in the first stage of the life cycle.
- Some parents may be willing to do this, especially when α is high.
- In the case when $s \geq 0$ and $b' \geq 0$ bind, and investments are not perfect substitutes, early income matters.

- Suppose $\eta(c) = (c^{\lambda} - 1)/\lambda$:

$$\frac{I_1}{I_2} = \left[\frac{\gamma}{(1-\gamma)(1+r)}\right]^{\frac{1}{1-\phi}} \underbrace{\left[\frac{(wh+b-I_1)}{\beta\left((1+\alpha)wh - I_2\right)}\right]}_{\leq 1}^{\frac{1-\lambda}{1-\phi}}.$$

- Now, *ratios* of investment depend on parental preferences and endowments.
- If early income is low with respect to late income, the ratio I_1/I_2 will be lower than the optimal ratio.
- Tug of war between λ and ϕ.
- With sufficiently high λ (e.g. $\lambda = 1$), parental deferred consumption can compensate for early credit constraints (up to feasibility).
- Estimates of Cunha, Heckman, and Schennach (2010) suggests $1/(1-\phi) = .\bar{3}$ ($\phi \doteq -2$), and Attanasio and Browning (1995) estimate $\lambda \in [-3, -1.5]$
- $(1-\lambda)/(1-\phi) \in [0.8\bar{3}, 1.\bar{3}]$. Family resource influence on

- This analysis of credit constrained families joined with a low value of ϕ interprets the fact that the timing of family income in the early stages of childhood apparently affects the level of ability and achievement of the children, although there is still some controversy about the empirical importance of this effect.

Estimating and Interpreting the Estimates of the Technology of Skill Formation

- Cunha and Heckman (2008) and Cunha, Heckman, and Schennach (2010) estimate versions of the technology of skill formation. (Dynamic state space models)
- Can identify the technology under many different credit market structures.

- Econometric Challenges
  - ⓐ Multiplicity of measured inputs and measured outputs
  - ⓑ Measurement error in inputs and outputs (we only have proxies)
  - ⓒ Endogeneity of Investment and hence stocks of skills
  - ⓓ Omitted inputs
  - ⓔ Need to go beyond the linear technology to capture the notion of substitution between early and late.
  - ⓕ Output as measured by test scores is meaningless.

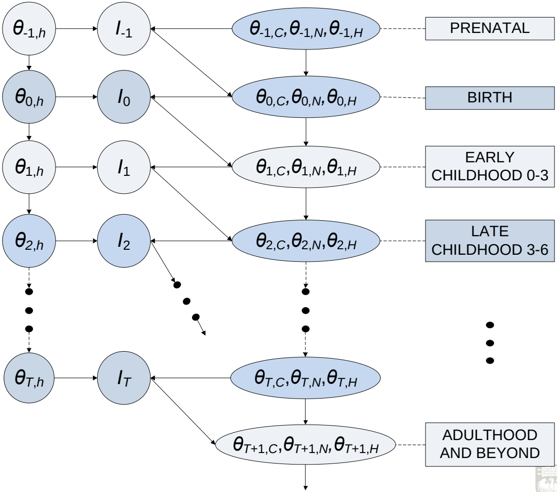
A Life Cycle Framework for Organizing Studies and Integrating Evidence

$\theta_t = (\theta_C, \theta_N, \theta_H)$ capacities at t

$\theta_{t,h}$: parental traits at t

I_t: investment at t

$\theta_{t+1} = f_t(\theta_t, I_t, \theta_{t,h})$: **Technology of Skill Formation**



Findings from Nonlinear Model (Cunha et al., 2010)

- The major findings from these analyses of models with two skills that control for measurement error and endogeneity of inputs are:
  - ⓐ Self-productivity becomes stronger as children become older, for both cognitive and noncognitive skill formation (i.e., $\frac{\partial\theta_{t+1}}{\partial\theta_t} \uparrow t$).
  - ⓑ Complementarity between cognitive skills and investment becomes stronger as children become older. The elasticity of substitution for cognition is *smaller* in second stage production.

c. ($\sigma_C \doteq 0.3$) It is more difficult to compensate for the effects of adverse environments on cognitive endowments at later ages than it is at earlier ages. This pattern of the estimates helps to explain the evidence on ineffective cognitive remediation strategies for disadvantaged adolescents reported in Cunha et al. (2006).
d. Complementarity between noncognitive skills and investments becomes slightly *weaker* as children become older.

- It is slightly easier at *later* stages of childhood to remediate early disadvantage using investments in noncognitive skills.
- Noncognitive traits promote the accumulation of cognitive traits (but not vice versa).
- This econometric evidence is consistent with a broad array of evidence from interventions studies on life cycle profile of rates of return.

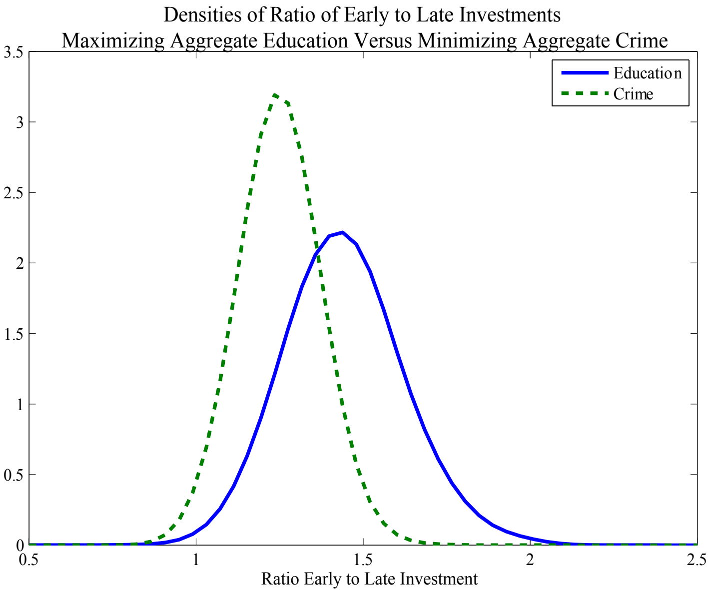
- 34% of the variation in educational attainment in the sample is explained by the measures of cognitive and noncognitive capabilities.
- 16% is due to adolescent cognitive capabilities.
- 12% is due to adolescent noncognitive capabilities.
- Measured parental investments account for 15% of the variation in educational attainment.
- These estimates suggest that the measures of cognitive and noncognitive capabilities are powerful, but not exclusive, determinants of educational attainment and that other factors, besides the measures of family investment that we use, are at work in explaining variation in educational attainment.

Role of Luck

- Big role for "*luck*."
- But big role for investment and family influence.
- 50-60% of the variance in lifetime income determined by factors present at the time college-going decisions are being made (Cunha et al., 2005; Hoffman, 2010; Yaron et al., 2010)

Some Implications for Policy

- Targeted strategies
- Arises because compensation for adversity in noncognitive skills is somewhat less costly in the second period, and because of discounting of costs and concavity of the technology, it is efficient to invest relatively more in noncognitive traits in the second period.
- The opposite is true for cognitive skills.


Densities of Ratio of Early to Late Investments
Maximizing Aggregate Education Versus Minimizing Aggregate Crime
Education
Crime
3.5
3
2.5
2
1.5
1
0.5
0
0.5
1
1.5
2
2.5
Ratio Early to Late Investment

Integrating Family Intervention Studies With Family Influence Studies

- Beyond treatment effects
- Understanding mechanisms
- Many experiments that target early childhood—some long running (e.g., Perry Preschool)
- Evidence that they are effective (rate of return is 7–10%), and a primary channel of influence is through noncognitive skills — personality (Heckman, Pinto, and Savelyev, 2013, AER)
- Recent work: Garcia and Heckman (2020) includes health benefits – 13.7% rate of return

- Technology of skill formation allows economists to integrate these diverse studies through their effects on θ_t
  1. Can model interaction of parental investment with governmental investments: components may be perfect substitutes or not.
  2. Identify different technologies (public and private) that both produce the same θ_t
     (may use both)

- I_t^G: government investment
- I_t^P: private (family) investment
- Government technology: $f^G(\theta_t^P, I_t^G, I_t^P, h)$
- Private technology: $f^P(\theta_t^P, I_t^P, I_t^G, h)$
- Can establish the channels through which government (external) investment promotes capabilities.

Appendix

Interpreting the Estimates of Cunha, Heckman, and Schennach

- The promise and limitations of the literature
- To examine the implications of these estimates, analyze a standard social planning problem that can be solved solely from knowledge of the technology of skill formation and without knowledge of parental preferences and parental access to lending markets.
- Determine optimal allocations of investments from a fixed budget to maximize aggregate schooling for a cohort of children.

- Assume that the state has full control over family investment decisions.
- Do not model parental investment responses to the policy or parent-child interactions: This is a huge open issue, currently being investigated. (Principle — agent problems within the family)
- May understate or overstate the parental response.
- These simulations produce a measure of the investment that is needed from whatever source to achieve the specified target.

- Agent heterogeneity in endowments and parental environments.
- Optimal ratio of I_1/I_2 depends on initial conditions.

- Even though there is static complementarity in each period

  $$\frac{\partial^2 f_1(\theta_1, I_1, h)}{\partial I_1 \partial \theta_1} > 0,$$

  the optimal policy is to invest in the less advantaged in early years.
- Not a theorem, but an implication of the empirical estimates.
- Consistent with a large body of empirical research.
- The optimal ratio of early-to-late investment depends on the desired outcome, the endowments of children and the budget.
- Crime is more intensive in noncognitive skill than educational attainment, which depends much more strongly on cognitive skills.

How Does All of This Cause Us to Rethink Education and Human Capital Policies?

- What should be the role of education?
- Can we look to the schools to address inequality?
- Coleman report and importance of families
- Schools have a role.
- But human capital is a vector, and it entails much more than schooling.
- Its efficient production begins before formal schooling begins.
- Education plays an important role, but early life factors create education and play independent roles beyond their effects on education.
- Human capital policy, broadly defined, has important implications for social policy about health, crime, wage inequality, teenage pregnancy.