Education Attainment and Structural Transformation

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June 9, 2022

Motivation

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- Structural Transformation due to:
  1. Income Effect: Increased income reduces the demand for food relative to other goods
  2. Productivity Effect: Increased relative productivity of agricultural sector

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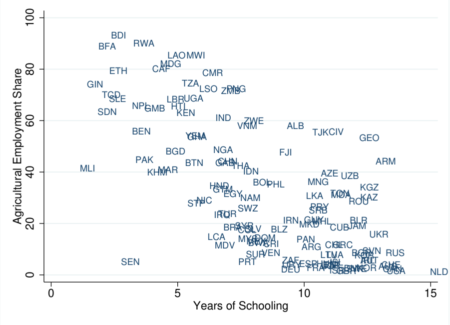
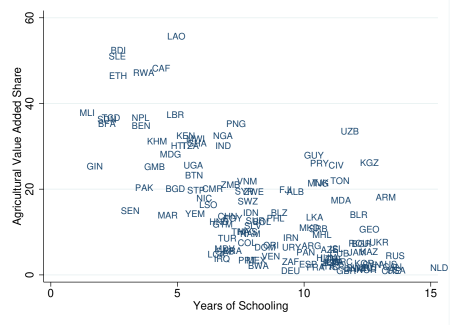
  1. Income Effect: Increased income reduces the demand for food relative to other goods
  2. Productivity Effect: Increased relative productivity of agricultural sector
- We emphasize the importance of education in structural transformation

Motivation

- Correlation between sectoral allocation and education





Proposed Mechanism

- Nonagricultural sector has higher human capital intensity
- Individuals make endogenous education decision
- Places that are wealthier and with better education policies results in larger stock of human capital
- More people self-selected into nonagricultural sector
- Rybczynski Theorem

What we did?

- We develop a lifecycle framework to study the role of human capital accumulation in determining the process of structural transformation and cross-country productivity difference
  - Life-cycle schooling and work decision
  - Quality and stock of human capital differ by talent, personal wealth, government policies, and schooling
  - Intensity of human capital differs by sectors
- Calibrate the model using U.S. data and carry out cross-country analysis

Literature

- There are three main groups of literature
  1. Sectoral choice based on exogenous human capital
     - Lagakos & Waugh (2013), Pozio, Rossi & Santangelo (2021)
     - Human capital exogenous (policy, macroeconomic response)
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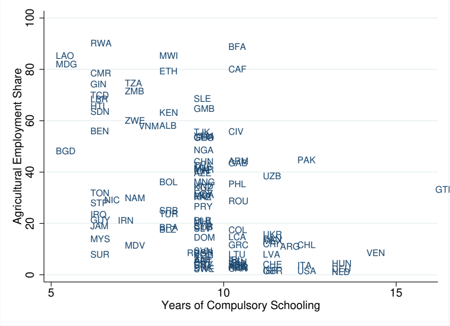
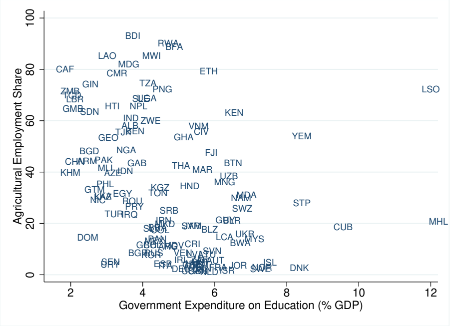
  3. Structural transformation
     - Acemoglu & Guerrieri (2008) on Rybczynski Theorem, Herrendorf, Rogerson & Valentinyi (2014)
     - No emphasis on education
     - Buera, Kaboski, Rogerson & Vizcaino (2021): exogenous sectoral productivity progress

Empirical Facts

Fact 1

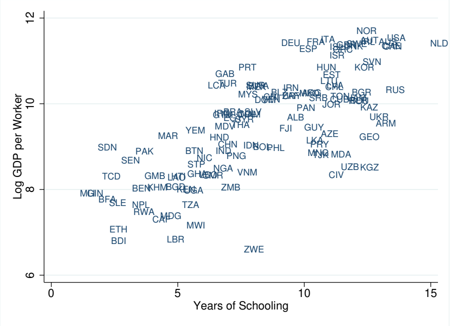
- Education policies are important to understand structural transformation





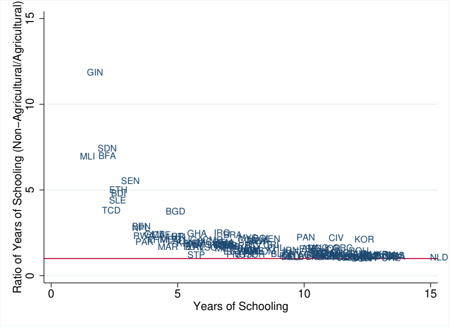
Fact 2

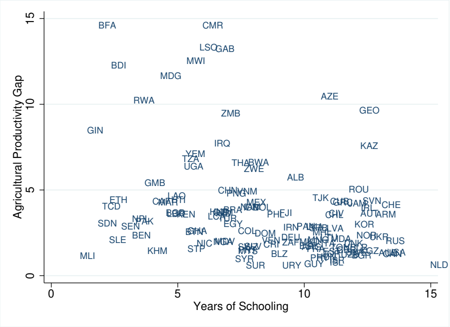
- Sectoral distribution of human capital, effect of human capital on productivity



Fact 3

- Education reduces sectoral schooling gap and agricultural productivity gap





Model

Highlight

- Lifecycle model, similar to Córdoba & Ripoll (2013), with heterogeneity and sectoral allocation
- Individuals differ by their endowment of 1) initial wealth b, 2) ability ψ, and 3) farming skill l. The distribution assume to follow:

$$G(b, \psi, l) = G^b(b) G^{\psi,l}(\psi, l)$$

- Individuals make schooling decision $\{s, e_p(\tau)\}$, knowing $\{b, \psi, l\}$, to determine human capital $h(s)$
- Given $h(s)$, individual make sectoral choice among other decisions

Household Problem

- Individual in sector i solves

$$V_i(b;\psi,l) = \max_{c(\tau),e_p(\tau),s,\kappa(s)} \int_6^T e^{-\rho(\tau-6)} u(c(\tau))d\tau$$

s.t.

$$\int_6^s e^{-r(\tau-6)}[c(\tau)+e_p(\tau)]d\tau + e^{-r(s-6)}\kappa(s) \leq b$$

$$\int_s^T e^{-r(\tau-6)}c(\tau)d\tau \leq \int_s^R e^{-r(\tau-6)} w_i\left(h(s),\tau-s;\psi,l\right)d\tau + e^{-r(s-6)}\kappa(s)$$

$$h(s) \leq z_h\left[\int_6^s \psi(e_p(\tau)+e_g(\tau))^{\alpha} d\tau\right]^{\frac{\gamma}{\alpha}}$$

$$e_p(\tau) \geq 0 \text{ for all } \tau$$

$$\kappa(s) \geq 0$$

Household Problem

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- $w_i\left(h(s),\tau-s;\psi,I\right) = \widetilde{w}_i(h(s);\psi,I)e^{\nu_{1i}(\tau-s)+\nu_{2i}(\tau-s)^2}$
- The sectoral choice S is such that

$$S = \arg\max_{S\in\{0,1\}}\{SV_a(b|\psi,I)+(1-S)V_m(b|\psi,I)\}$$

Preference

- The utility function $u(c(\tau)) = \frac{c(\tau)^{1-\sigma}}{1-\sigma}$, where

$$c(\tau) = \frac{\tilde{c}(\tau) - p_a(\tau)\bar{c}}{\left[\zeta p_a(\tau)^{1-\eta} + (1-\zeta)p_m(\tau)^{1-\eta}\right]^{\frac{1}{1-\eta}}}$$

- The above is a indirect utility function comes from maximizes

$$\left[\zeta^{\frac{1}{\eta}}(c_a - \bar{c})^{\frac{\eta-1}{\eta}} + (1-\zeta)^{\frac{1}{\eta}} c_m^{\frac{\eta-1}{\eta}}\right]^{\frac{\eta}{\eta-1}}$$

subject to

$$p_a(\tau)c_a(\tau) + p_m(\tau)c_m(\tau) \leq \tilde{c}(\tau)$$

Production

- There are two sectors in the economy, both use efficiency unit of labor $\xi_i(h(s);\psi,l)$ as only input, where

$$\xi_a(h(s);l) = \left[\theta_a h(s)^{\frac{1}{\phi_a}} + (1-\theta_a) l^{\frac{1}{\phi_a}}\right]^{\phi_a}$$

$$\xi_m(h(s);\psi) = \left[\theta_m h(s)^{\frac{1}{\phi_m}} + (1-\theta_m) \psi^{\frac{1}{\phi_m}}\right]^{\phi_m}$$

we assume $\theta_m > \theta_a$

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  we assume $\theta_m > \theta_a$
- Denote $x = \{b, \psi, l\}$, the sectoral production function:

$$Y_i = A_i \iint_{\Omega_i} \xi_i(h(s); \psi, l) e^{\nu_{1i}(\tau - s) + \nu_{2i}(\tau - s)^2} N(\tau; x) dG(x) d\Pi(\tau)$$

  or, in steady state, age distribution is stationary and all cohorts are identical

$$Y_i = A_i \int_{\Omega_i} \xi_i(h(s)) e^{\nu_{1i}(\tau - s) + \nu_{2i}(\tau - s)^2} N(x) dG(x)$$

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$$Y_i = A_i \int_{\Omega_i} \xi_i(h(s)) e^{\nu_{1i}(\tau-s)+\nu_{2i}(\tau-s)^2} N(x) dG(x)$$

- The firm maximization problem implies that

$$w_i\left(h(s), \tau-s;\psi,l\right) = \hat{w}_i \xi_i(h(s);\psi,l) e^{\nu_{1i}(\tau-s)+\nu_{2i}(\tau-s)^2}$$

Financial Constraint and Education

- FOC with respect to consumption $c(\tau)$ for $\tau \in [6, s]$ (λ_1) and $\tau \in [s, T]$ (λ_2)

$$J \equiv \frac{\lambda_1}{\lambda_2} = \frac{u_c(c^S(s))}{u_c(c^W(s))} = e^{(\rho - r)(F-6)} \frac{u_c(c(6))}{u_c(c(F))} \geq 1$$

- If $J > 1$, then $c^S(s) < c^W(s)$, constrained and $\kappa(s) = 0$

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- If $J > 1$, then $c^S(s) < c^W(s)$, constrained and $\kappa(s) = 0$
- If $J = 1$, then $c^S(s) = c^W(s)$, not constrained and

$$\kappa(s) = \frac{\frac{b - E^*}{D_6^s} - \frac{I_i(s)}{D_s^T}}{e^{-r(s-6)}\left[\frac{1}{D_6^s} + \frac{1}{D_s^T}\right]} > 0$$

where $E^* = \int_6^s e^{-r(\tau-6)} e_p(\tau) d\tau$, $I_i(s) = \int_s^R e^{-r(\tau-6)} w_i\left(h(s), \tau - s; \psi, I\right) d\tau$ and $D_x^y = \int_x^y e^{-r(\tau-6)} \left(e^{(\rho-r)(\tau-6)}\right)^{-\frac{1}{\sigma}} d\tau$

- The importance of b, which can be affected by family size, family income, among other things.

Financial Constraint and Education

- Consider the following optimal schooling:

$$\frac{\partial}{\partial s}\int_s^R e^{-r(\tau-6)} w_i\left(h(s),\tau-s;\psi,I\right)d\tau$$
$$= Je^{-r(s-6)}\left[\frac{u(c^W(s))-u(c^S(s))+u_c(c^S(s))c^S(s)-u_c(c^W(s))c^W(s)}{u_c(c^S(s))}+e_p(s)\right]$$
$$= RHS_{J>1}$$

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$$= RHS_{J>1}$$

- Notice that with $J = 1$, $RHS_{J=1} = e^{-r(s-6)} e_p(s)$
- So, $RHS_{J>1} > RHS_{J=1}$ for our assumed utility function (applies to power and log utilities).
- **Budget constrained individuals face higher marginal cost on schooling.**

Government Policy $\{\underline{s}, \bar{s}, e_g\}$ and Education

- Assume no public education (i.e. $e_g = 0$), call optimal private education expenditure in this hypothetical regime $\hat{e}^*(\tau)$:

$$\hat{e}^*(\tau)$$

$$= \left[\frac{\psi \gamma z_h^{\frac{\alpha}{\gamma}} h(s)^{1-\frac{\alpha}{\gamma}} \int_s^R e^{-r(\tau-6)} \widetilde{w}_i'(h(s), \tau - s; \psi, I) e^{\nu_{1i}(\tau-s)+\nu_{2i}(\tau-s)^2} d\tau}{J} \right]^{\frac{1}{1-\alpha}} e^{\frac{r(\tau-6)}{1-\alpha}}$$

$$= \hat{e}(0) e^{\frac{r(\tau-6)}{1-\alpha}}$$

Government Policy $\{\underline{s}, \bar{s}, e_g\}$ and Education

- Now, introduce public education $e_g(\tau) \equiv e_g$ for $\tau \in [\underline{s}, \bar{s}]$ define total education investment $e(\tau) = e_p(\tau) + e_g(\tau)$

$$e(\tau) = \begin{cases} \hat{e}^*(\tau) & \text{for } \tau \leq \min\{s, \underline{s}\} \\ e_g & \text{for } \min\{s, \underline{s}\} \leq \tau \leq s_g \\ \hat{e}^*(\tau) & \text{for } s_g \leq \tau \leq s \end{cases}$$

where $s_g \equiv \min\{s, \bar{s}, \max[\underline{s}, s_{ug}]\}$ and s_{ug} is defined as $\hat{e}^*(s_{ug}) = e_g$

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- $s_{ug} = \frac{1-\alpha}{r} ln\left(\frac{e_g}{\hat{e}(0)}\right) + \underline{s}$, depends negatively on $\hat{e}(0)$ which is related to one's general endowment

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- As $\hat{e}^*(\tau)$ is increasing in τ, for all $\tau > s_{ug}$, $\hat{e}^*(\tau) > e_g$ (private investment)
- s_g is the (potential, contingent on $\min\{s, \underline{s}\} \leq s_g$) upper bound age that an individual solely depends on public education investment Example
- Finally, one's human capital will be:

$$h(s) = z_h \psi^{\frac{\gamma}{\alpha}} \hat{e}(0)^{\gamma} \left[\int_6^{\min\{s,\underline{s}\}} e^{\frac{r\alpha(\tau-6)}{1-\alpha}} d\tau + \int_{\min\{s,\underline{s}\}}^{s_g} \left(\frac{e_g}{\hat{e}(0)}\right)^{\alpha} d\tau + \int_{s_g}^{s} e^{\frac{r\alpha(\tau-6)}{1-\alpha}} d\tau \right]^{\frac{\gamma}{\alpha}}$$

Numerical Analysis

Calibration

- Distribution of (ψ, l, b)
  - Assume ψ, l, b follows log-normal, i.e. $\ln(y) \sim \mathcal{N}(\mu_y, \sigma_y)$ with cdf $G^y(y)$ and

$$G(\psi, l, b) = G^b(b) G^{\psi,l}(\psi, l)$$

  - $G^{\psi,l}(\psi, l)$ with $\rho_{\psi,l}$ determining the extent of dependence in Frank copula
  - Set $\mu_\psi = \mu_l = 1$ and calibrate $\mu_b, \sigma_x, \rho_{\psi,l}$

Calibration

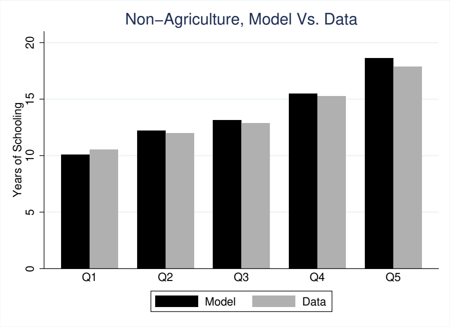
Parameters	Value	Target
Panel A: Predetermined		
Talent	$\mu_\psi = \mu_l = 1$	Normalize
Preference	$\rho = 0.03$, $\zeta = 0.005$, $\sigma = 1.5$, $\eta = 0.85$	Preset or Literature
Human capital	$z_h = 1$, $\underline{s} = 6$, $\bar{s} = 18$	Normalize or Data
Experience	$\nu_{1,a} = 0.0254$, $\nu_{2,a} = -0.0004$, $\nu_{1,m} = 0.0382$, $\nu_{2,m} = -0.0006$	IPUMS USA
Production	$A_a = 1$	Normalize
Life exp. & retirement	$T = 76.6$, $R = 65$	Data
Panel B: Calibrated		
Production	$A_m = 0.33$, $\theta_m = 0.82$, $\phi_m = 4.00$, $\theta_a = 0.74$, $\phi_a = -3.16$	1. Agri. Wage Gap, 2. Var. Agr. Wage, 3. Var Non-agr. Wage, 4. Agr. Emp. Share, 5. Agr. V.A. Share, 6. Agr. School Years, 7. Non-Agr. School Year, 8. Private Exp. on School, 9. Public Exp. on School, 10. Agr. Return to School, 11. Non-agr. Return to School, 12. Wealth-Wage Ratio, 13. S.D. log Wealth, 14. Non-agr. Price Gap
Talent/ Wealth	$\sigma_\psi = 0.45$, $\sigma_l = 0.47$, $\rho_{\psi l} = 10.03$, $\mu_b = 5.65$, $\sigma_b = 0.63$	
Human Capital	$\alpha = 0.25$, $\gamma = 0.26$, $e_g = 6.76$	
Preference	$\bar{c} = 0.15$	

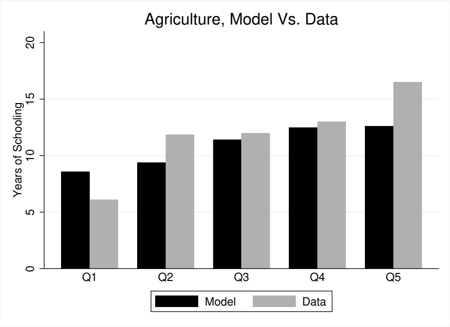
Model Fit

Target	Numerically	Data	Model
Agri. Wage Gap	$\frac{w_m}{w_a}$	1.427	1.469
Var. Agr. Wage	$Var(w_a)$	0.144	0.153
Var. Non-agr. Wage	$Var(w_m)$	0.224	0.220
Agr. Emp. Share (%)	$\frac{L_a}{L}$	1.50	1.51
Agr. V.A. Share (%)	$\frac{Y_a}{Y}$	1.10	1.03
Agr. School Years	s_a	11.55	11.01
Non-Agr. School Years	s_m	13.18	13.92
Private Exp. on School (%)	$\frac{E_p}{Y}$	2.10	2.74
Public Exp. on School (%)	$\frac{E_g}{Y}$	4.95	5.56
Agr. Return to School	$\frac{\partial w_a}{\partial s}$	0.050	0.056
Non-Agr. Return to School	$\frac{\partial w_m}{\partial s}$	0.075	0.074
Wealth-Income Ratio	$\frac{W_i}{w_i}$	2.45	1.92
S.D. log Wealth	$SD(ln(W_i))$	11.41	10.52
Non-agr. Price Gap	$\frac{p_m}{p_a}$	1.60	1.60

External Validity

- Distribution of Sectoral Years of Schooling





Counterfactual Experiment

	Baseline	$\{A_a, A_m\}$ +10%	$\bar{s}$ +10%	e_g +10%
Agr. YOS	11.01	10.63	11.34	10.96
Non-Agr. YOS	13.92	13.51	14.23	13.92
Agr. HC	1.00	0.98	1.65	1.16
Non-Agr. HC	1.00	0.97	1.16	1.12
Agr. Prod. Gap	1.47	1.45	1.41	1.46
Agr. Emp. Share	1.51%	1.38%	1.46%	1.50%
Agr. V.A. Share	1.03%	0.95%	1.04%	1.03%

Developing Countries

- Choose Bangladesh (BGD) (10th percentile in world income distribution in 2005)
- 10 parameters difference:
  - Preset:
    - Parameters: $\underline{s}, \bar{s}, T, \mu_b, \sigma_b$
  - Calibrated:
    - Parameters: $A_a, A_m, \theta_a, \theta_m, e_g$
    - Targets: GDP ratio, agricultural employment share, sectoral years of schooling, public schooling expenditure

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    - Targets: GDP ratio, agricultural employment share, sectoral years of schooling, public schooling expenditure
- How to set μ_b, σ_b?
  - Assume that wealth concentration, GDP per capita and fertility rate will affect mean of inter vivo transfer in Bangladesh $E(b_{BGD})$

$$E(b_{BGD}) = e^{\mu_{b,USA}+\sigma_{b,USA}/2} \times \frac{wealth/income_{BGD}}{wealth/income_{USA}} \times \frac{gdppc_{BGD}}{gdppc_{USA}} \times \frac{tfr_{USA}}{tfr_{BGD}}$$

  - Back out $\sigma_{b,BGD}$ using the top 10% wealth concentration relative to USA and $\sigma_{b,USA}$

Developing Countries

	Model	Data
Agricultural Output per Worker (Relative to U.S.)	114	79.2
Non-Agricultural Output per Worker (Relative to U.S.)	31.9	3.39
Agricultural Productivity Gap ($\frac{p_m Y_m / N_m}{p_a Y_a / N_a}$)	3.28	3.68

Conclusion

Conclusion and Future Work

- We develop a lifecycle framework to study the role of human capital quality in determining the process of structural transformation and cross-country productivity difference
- Education decision and quality are important for structural transformation and sectoral productivity differences
- Future Work:
  - Schooling decreasing with TFP, endogenize b and e_g to incorporate government spending
  - Calibrate the model to fit international data
  - See how education affects structural transformation and productivity (c.f. Bils and Klenow (2000))

Thank You

Examples of Government Education Policies

- Economy with education policy $[\underline{s}, \bar{s}] = [6, 18]$
- s depends positively on one's general endowment
- $s_{ug} = \frac{1-\alpha}{r} ln\left(\frac{e_g}{\hat{e}(0)}\right) + \underline{s}$, depends negatively on $\hat{e}(0)$ which is related to one's general endowment
- $s_g \equiv \min\{s, \bar{s}, \max[\underline{s}, s_{ug}]\}$, the (potential, contingent on $\min\{s, \underline{s}\} \leq s_g$) upper bound age that an individual solely depends on public education investment

Individual	Schooling until age	s_{ug}	s_g	Limited by
A (PhD)	30	5	6 (no s_g)	$\underline{s}$
B (College Grad)	22	14	14	s_{ug}
C (College Drop Out)	19	20	18	$\bar{s}$
D (No Schooling)	4	24	4 (no s_g)	s

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