

Accounting for Cross-Country Income Differences Revisited

David Lagakos

Boston University

Todd Schoellman

Minneapolis Fed

The views expressed herein are those of the authors and not necessarily those of the Federal Reserve Bank of Minneapolis or the Federal Reserve System.

Motivation

The big question: why does output per worker vary so much across countries?

Development accounting helps answer this question

- ▷ Given F and measured $Y_i, K_i, L_i \Rightarrow$ solve for A_i
- ▷ Use F to evaluate each factor's contribution
- ▷ *Account*, not *explain*: proximate sources, not root causes

Analogy: decomposing mortality gaps

Decompose mortality gaps by cause of death

- ▷ Malaria, diarrheal disease account for much of higher mortality in developing countries
- ▷ Does not pinpoint the root cause or most effective policies
- ▷ Useful information for researchers and policy makers

Benchmark: Caselli (2005)

Inputs account for little; most of development attributed to TFP

- ▷ “As of now, the answer to the development accounting question – do observed differences in the factors employed in production explain most of the cross-country variation in income – is: no, way no”
- ▷ Needed: A Theory of TFP (Prescott, 1998)

Similar findings pervasive in early literature, some updates

- ▷ Klenow and Rodríguez-Clare (1997), Hall and Jones (1999), Hsieh and Klenow (2010), Caselli (2016)

This article: two decades of improved measurement

Synthesize the literature since Caselli (2005), with updated calculations

- ▷ Hours: workers in poorer countries work *more* – deepens the puzzle (–5%)
- ▷ Physical capital: still a small role (7%)
- ▷ Human capital: much larger role (58 to 66%)

Bottom line: inputs account for 55 to 70% of GDP per worker differences

- ▷ Classic specification with the same data: 30%
- ▷ Suggests a shift back toward research on variation in inputs

Outline

① Overview of Basic Structure and Facts

② Measures of the Labor Input

③ Measurement of Physical Capital

④ The Constructive Approach to Human Capital

⑤ The Deductive Approach to Human Capital

⑥ Imperfect Substitution Between Skill Types

⑦ Other Advances and Open Areas

⑧ Conclusion

Development accounting structure

Common aggregate production function:

$$Y_i = F(A_i, K_i, L_i) \quad \Rightarrow \quad Y_i = K_i^\alpha (A_i L_i)^{1-\alpha}$$

Cobb-Douglas consistent with stable factor shares

- ▷ Original evidence: $\alpha \approx 1/3$ (Gollin, 2002)
- ▷ More recent evidence: $\alpha \approx 1/2$ (Feenstra, Inklaar and Timmer, 2015)
- ▷ We use 1/3, but results are not sensitive under capital-output specification

Standard measures and data sources

GDP per worker

- $\text{rgdpo} / \text{emp}$ (Feenstra, Inklaar and Timmer, 2025)

Physical capital

- Cumulated, depreciated investment expenditures (Pritchett, 2000)
- Now constructed and provided as cn (Feenstra, Inklaar and Timmer, 2025)

Human capital

- Macro-Mincer: $h_i = \exp(0.1 \times S_i)$ (Bils and Klenow, 2000)
- S_i , years of schooling (Barro and Lee, 2013; World Bank, 2026)

Two specifications

Capital-per-worker specification:

$$y_i = k_i^\alpha (A_i h_i)^{1-\alpha}$$

- Holds k fixed when varying A , h – direct, but implies large changes in MPK

Capital-output specification:

$$y_i = \left(\frac{K_i}{Y_i} \right)^{\frac{\alpha}{1-\alpha}} h_i A_i$$

- Holds MPK fixed – captures long-run capital adjustment in a wide class of models

Covariance metric

Klenow and Rodríguez-Clare (1997) covariance metric:

$$share_x \equiv \frac{\text{cov}(\log(x), \log(y))}{\text{var}(\log(y))}$$

Benefits:

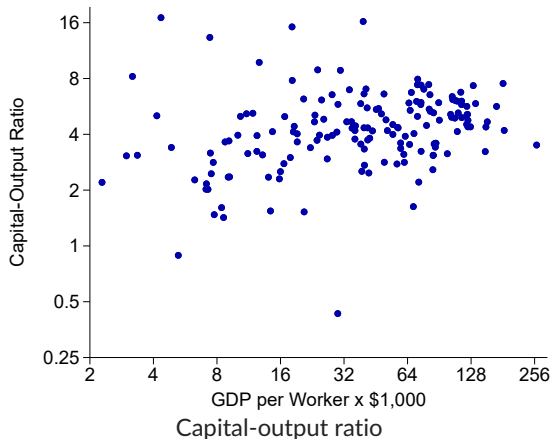
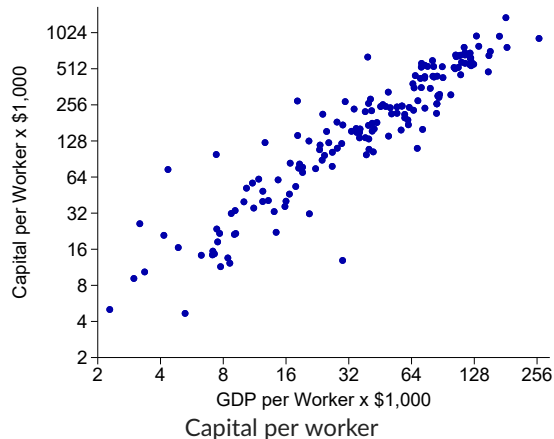
- Additive and order invariant (useful for combining results across studies)
- Rewards factors that both *vary* and *correlate* with y
- Easy to implement: regress $\log(x)$ on $\log(y)$

The world income distribution: summary statistics

	GDP per capita	GDP per worker
10th percentile	2,968	8,415
Median	17,073	41,452
Mean	26,868	56,687
90th percentile	61,942	122,006
var[log(y)]	1.34	1.02
90-10 ratio	20.9	14.5

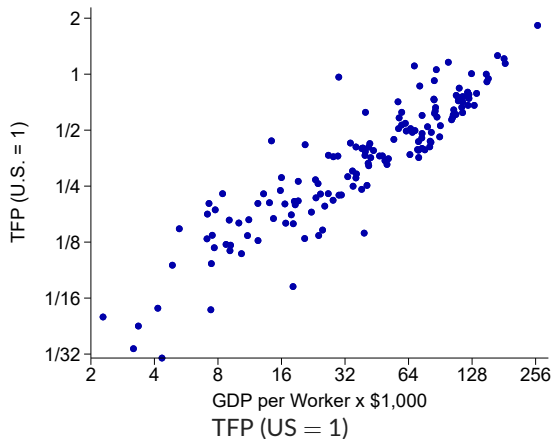
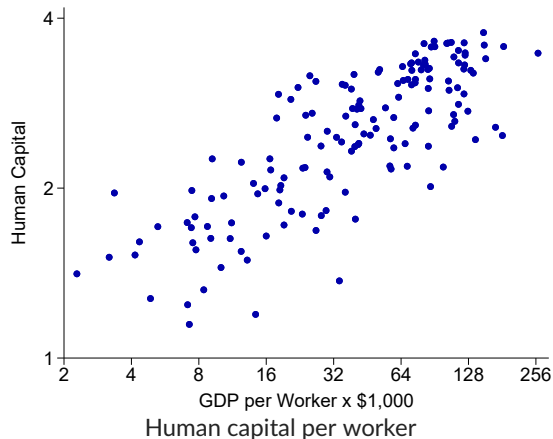
Note: GDP is measured in 2021 international dollars. The sample includes 153 countries for which data are available on GDP, employment, physical capital, and years of schooling. Source: Feenstra, Inklaar and Timmer (2025).

Baseline development accounting inputs: physical capital



- ▷ Slope of 1.13 for K/N ; just 0.13 for K/Y

Baseline development accounting inputs: human capital and TFP



- ▶ Classic accounting relies heavily on large, mysterious TFP gaps (slope 0.70)

Success of factors, baseline measures

Factor	share	std. err.	# countries
<i>Capital-per-worker specification</i>			
Physical capital, k^α	.377	.013	153
Human capital, $h^{1-\alpha}$	.155	.009	153
Human + physical capital	.531	.017	153
<i>Capital-output specification</i>			
Physical capital, $(K/Y)^{\alpha/(1-\alpha)}$	.066	.019	153
Human capital, h	.232	.014	153
Human + physical capital	.297	.026	153

Note: Source: Feenstra, Inklaar and Timmer (2025) and Barro and Lee (2013) augmented with World Bank (2026).

Success of factors, Caselli metrics

Caselli's metrics roughly agree with K/Y specification

Data	$\frac{\text{var}[\log(x)]}{\text{var}[\log(y)]}$	$\frac{x_{90}/x_{10}}{y_{90}/y_{10}}$	# countries
Caselli's data	0.39	0.34	94
Latest data	0.33	0.32	153

Note: Results are based on the metrics proposed by Caselli, which he labels $success_1$ and $success_2$. Source: first row: Caselli (2005); second row: data from Feenstra, Inklaar and Timmer (2025) and Barro and Lee (2013) augmented with World Bank (2026).

Outline

- ① Overview of Basic Structure and Facts
- ② **Measures of the Labor Input**
- ③ Measurement of Physical Capital
- ④ The Constructive Approach to Human Capital
- ⑤ The Deductive Approach to Human Capital
- ⑥ Imperfect Substitution Between Skill Types
- ⑦ Other Advances and Open Areas
- ⑧ Conclusion

Labor input and development

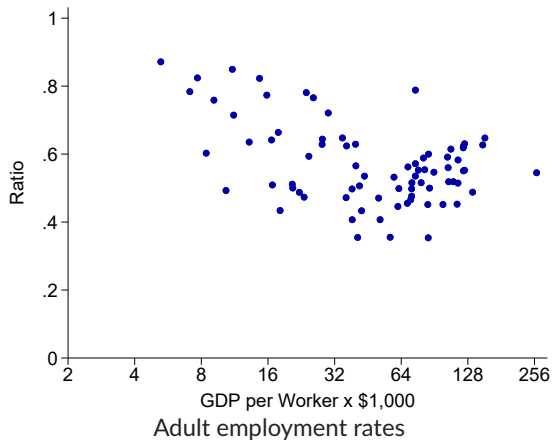
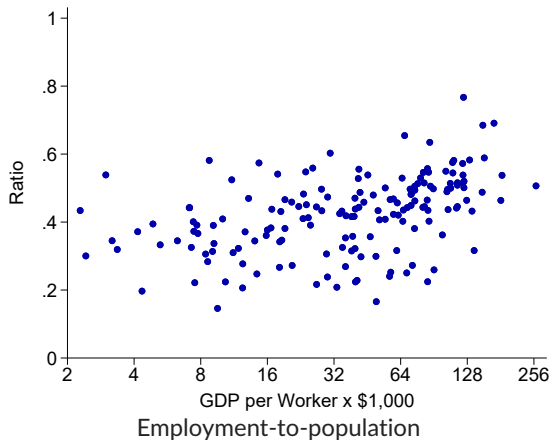
Do people in poor countries work less?

- ▷ Yes: gaps in GDP per capita $>$ gaps in GDP per worker
 - ▷ $\implies$ developed countries have more workers per capita

Due entirely to higher share of children in developing countries

- ▷ Adult employment rates higher in developing countries
- ▷ Share of children not useful as a proximate explanation, reinforces focus on GDP per worker

Labor input and development: workers per capita



New data: hours per worker

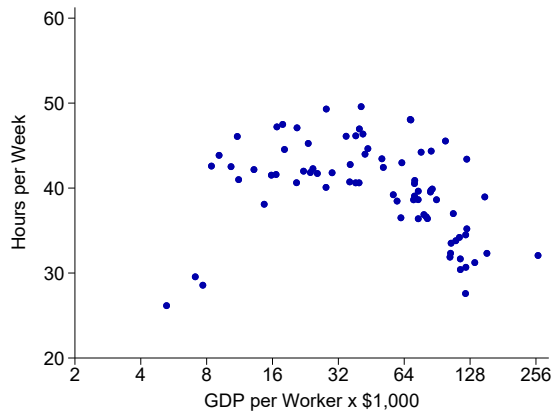
Wider availability of high-quality labor force surveys with data on hours worked

- ▷ Bick, Fuchs-Schündeln and Lagakos (2018): collect and harmonize data from 80 countries
- ▷ Gethin and Saez (forthcoming): 160 countries

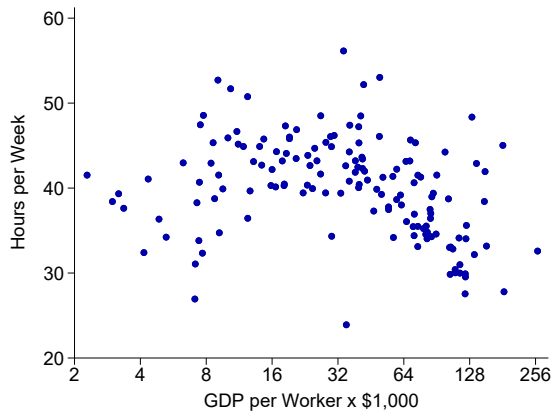
Main finding: more hours per worker in developing countries

- ▷ *Worsens* the development puzzle

Labor input and development: hours per worker



Bick, Fuchs-Schündeln and Lagakos (2018)



Gethin and Saez (forthcoming)

Success of factors revisited: labor

Puzzle is worse than previously thought

Factor	share	std. err.	# countries
<i>Capital-per-worker specification</i>			
Hours per worker, $n^{1-\alpha}$	-.031	.008	139
<i>Capital-output specification</i>			
Hours per worker, n	-.046	.012	139

Note: Source: Feenstra, Inklaar and Timmer (2025) and Gethin and Saez (forthcoming).

Outline

- ① Overview of Basic Structure and Facts
- ② Measures of the Labor Input
- ③ **Measurement of Physical Capital**
- ④ The Constructive Approach to Human Capital
- ⑤ The Deductive Approach to Human Capital
- ⑥ Imperfect Substitution Between Skill Types
- ⑦ Other Advances and Open Areas
- ⑧ Conclusion

Overview: what's new?

Classic measure: aggregate capital stock

- Constructed from past investment expenditures

Four areas of research:

- ① Capital services
- ② Natural vs. reproducible capital
- ③ Public capital
- ④ Intangibles

Capital services: a primer

Capital's contribution to output is the flow of services it provides, s_t

- The use of roads, factories, and equipment for the given period of time
- Roughly, their rental price

Traditional approach uses instead the total value of the capital stock, p_t

- Cumulated, depreciated investment expenditures

Linking capital services and stocks

No-arbitrage equation links s_t to p_t , required return on capital r , depreciation rate δ :

$$s_t = rp_t + \delta p_{t+1} - (p_{t+1} - p_t)$$

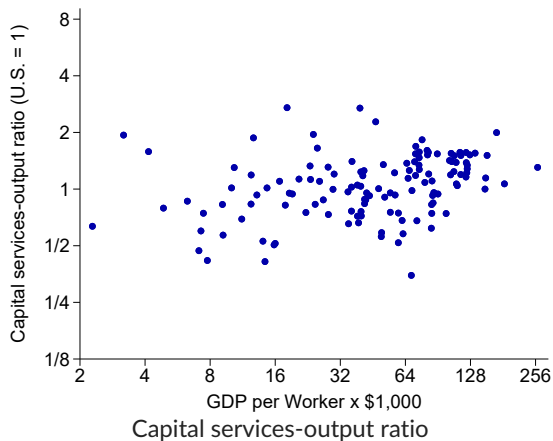
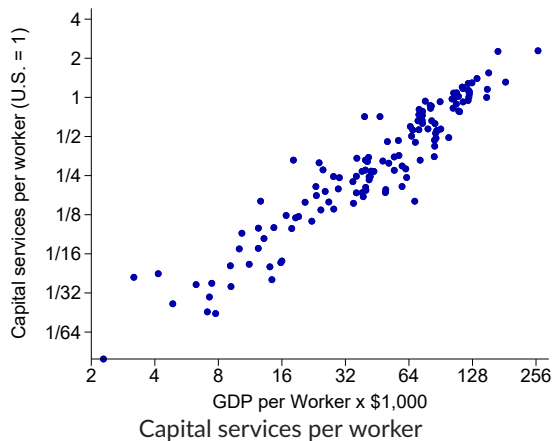
If $p_t = p_{t+1}$, then $s_t = p_t(r + \delta)$

- Using stocks innocuous if r, δ similar across countries

Inklaar, Woltjer and Gallardo Albarrán (2019): neither holds

- Developing countries: higher required returns, lower depreciation rates (composition)
- Now available in PWT (ck)

Capital services and development



Success of factors revisited: physical capital

Factor	share	std. err.	# countries
<i>Capital-per-worker specification</i>			
Physical capital stock (cn)	.377	.013	153
Physical capital services (ck)	.376	.011	133
<i>Capital-output specification</i>			
Physical capital stock (cn)	.066	.019	153
Physical capital services (ck)	.065	.017	133

Note: Source: Feenstra, Inklaar and Timmer (2025).

Defining natural capital

Natural capital: land and its naturally occurring, economically relevant features

- ▷ Subsoil resources (petroleum, minerals), forests, cropland, pasture
- ▷ Excluded: urban land, scenic and tourism land (beaches)

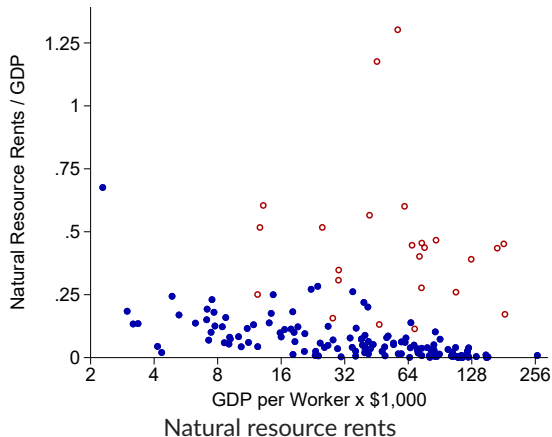
Excluded from PWT reproducible capital

- ▷ Not the result of past investment expenditures
- ▷ Contribution of good cropland, subsoil petroleum is distinct from tractors, oil rigs
- ▷ Could low natural capital account for low productivity?

Data on natural resource rents from World Bank make progress possible

- ▷ Monge-Naranjo, Sánchez and Santaaulàlia-Llopis (2019), building on Caselli and Feyrer (2007)

Natural resource rents uncorrelated with development



Data from Monge-Naranjo, Sánchez and Santaaulàlia-Llopis (2019); oil exporters in red

- Very important for minority of countries; on average, uncorrelated with development

What is public capital?

Public vs. private capital

- Public: roads, ports, courts, police stations
- Private: factories, trucks
- Summing them into “aggregate K ” has no clear meaning $\Rightarrow$ separate, complementary inputs

Efficiency of public investment, γ_i

- Bridges to nowhere, unfinished school buildings, funds siphoned off
- \$1 of public investment yields $\gamma_i < 1$ of usable public capital

Public capital

Public capital: capital financed by public investment expenditures

- Raises two distinct concerns

Concern 1: public spending may translate poorly into capital (Pritchett, 2000)

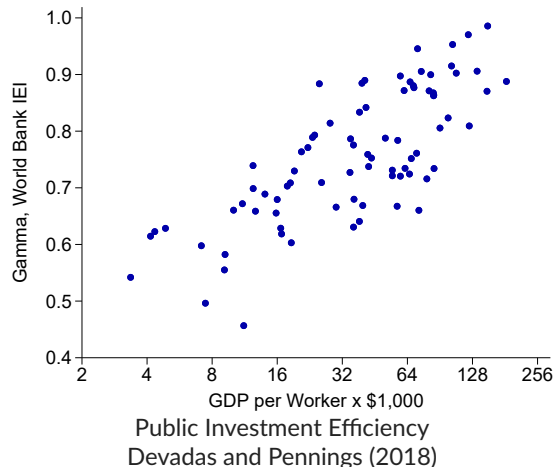
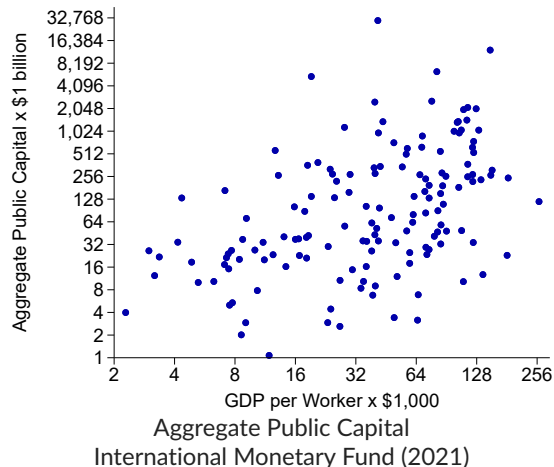
$$K_{i,t+1}^G = K_{i,t}^G(1 - \delta^G) + \gamma_i I_{i,t}^G$$

- New data: public investment, capital stocks by country (Cubas, 2020; International Monetary Fund, 2021)
- Efficiency measures γ_i (Devadas and Pennings, 2018; Kapsoli, Mogues and Verdier, 2023)

Concern 2: Public capital may be a separate, complementary input (Barro, 1990)

$$Y_i = (K_i^G)^\zeta (K_i^P)^\alpha (A_i L_i)^{1-\alpha}$$

Public capital and public investment efficiency



- ▶ Large gaps in public capital; half of public investment in poorest countries wasted

Success of factors revisited: public and private capital

Uncertainty about functional forms and parameters, but potentially important

Factor	share	std. err.	# countries
<i>Capital-per-worker specification</i>			
Private capital, $(k_i^P)^\alpha$	.406	.013	141
Public capital, $(K_i^G)^\zeta$, $\zeta = 0.10$	.085	.014	141
Public capital, $(\gamma_i K_i^G)^\zeta$, $\zeta = 0.10$	.098	.014	141
Public capital, $(\gamma_i K_i^G)^\zeta$, $\zeta = 0.20$	.196	.028	141
<i>Capital-output specification</i>			
Private capital, $(K_i^P / Y_i)^{\alpha/(1-\alpha)}$	.110	.020	141
Public capital, $(K_i^G)^{\zeta/(1-\alpha)}$, $\zeta = 0.10$	.127	.021	141
Public capital, $(\gamma_i K_i^G)^{\zeta/(1-\alpha)}$, $\zeta = 0.10$	.147	.021	141
Public capital, $(\gamma_i K_i^G)^{\zeta/(1-\alpha)}$, $\zeta = 0.20$	.294	.041	141

Note: Source: Feenstra, Inklaar and Timmer (2025) for GDP per worker; International Monetary Fund (2021) for public and private capital stocks; and Devadas and Pennings (2018) for public-capital efficiency.

Intangible capital

Intangible capital: long-lived, non-physical assets or resources that enhance productivity

- ▷ R&D, brand equity, organizational know-how

U.S. evidence: intangible capital similar in size to tangible capital stocks

- ▷ Important contributor to growth (Corrado, Hulten and Sichel, 2009)

Currently missing from international investment expenditures, capital stocks

- ▷ $\implies$ included in TFP
- ▷ More complete uptake of SNA 2008 important for systematic progress

Outline

- ① Overview of Basic Structure and Facts
- ② Measures of the Labor Input
- ③ Measurement of Physical Capital
- ④ **The Constructive Approach to Human Capital**
- ⑤ The Deductive Approach to Human Capital
- ⑥ Imperfect Substitution Between Skill Types
- ⑦ Other Advances and Open Areas
- ⑧ Conclusion

Constructive approach: overview

Classic measure equates human capital with years of schooling

▷ $h_i = \exp(0.1 \times S_i)$

One strand of research adds additional dimensions of human capital

- ▷ Education quality
- ▷ Experience
- ▷ Early childhood, parents, and culture
- ▷ Health

These dimensions are summed to *construct* a new, more expansive measure of human capital

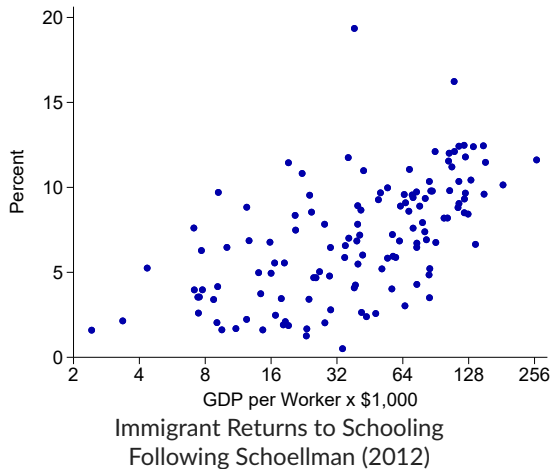
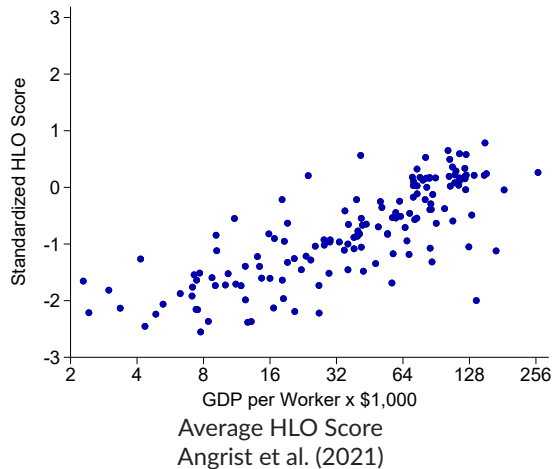
Education quality

Human capital generated per year of schooling

Three forms of evidence

- ① Cross-country test scores: Harmonized Learning Outcomes (Angrist et al., 2021)
- ② Rate of test score improvement (Kaarsen, 2014)
- ③ Returns to schooling of foreign-educated migrants (Schoellman, 2012)

Education quality measures



Valuing education quality

Extend the macro-Mincer approach:

$$h_i = \exp(0.1 \times S_i + \rho Q_i), \quad \rho = 0.20 \text{ (Angrist et al., 2021)}$$

Or let quantity and quality interact (Schoellman, 2012)

$$h_i = \exp \left[\frac{(S_i Q_i)^\eta}{\eta} \right], \quad \eta \approx 0.5$$

Experience

Human capital accumulated through work

- ▷ Typically proxied as potential experience = years since graduation $\approx$ age $- S - 6$

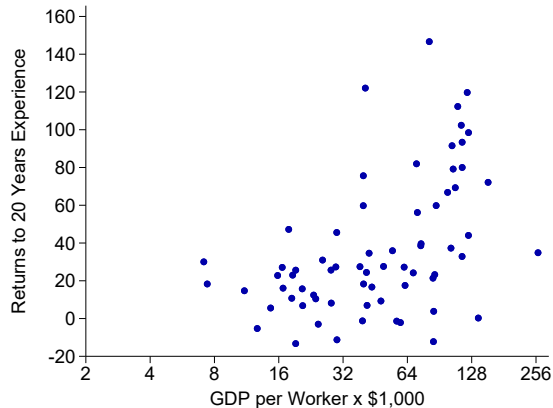
Early literature: no substantive differences

- ▷ Level of experience is similar: developing countries have younger workers, less schooling
- ▷ Returns to experience are similar

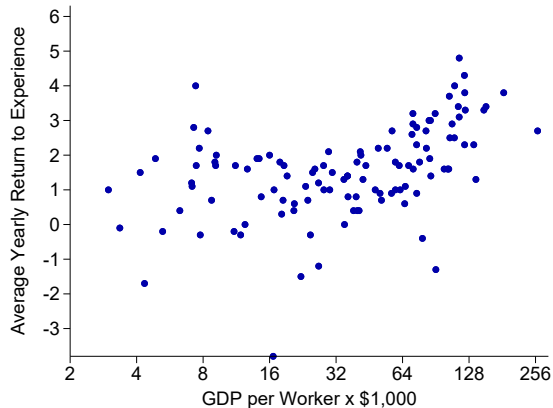
Revision is about better data

- ▷ Returns to experience higher in developed countries (Lagakos et al., 2018b; Jedwab et al., 2023)
- ▷ Returns to experience are portable, probably reflect human capital (Lagakos et al., 2018a)
- ▷ Potential mechanism: less training in developing countries (Ma, Nakab and Vidart, 2024)

Returns to potential experience



Immigrants
Lagakos et al. (2018a)



Non-migrants
Jedwab et al. (2023)

Early childhood, parents, and culture

Early childhood environment

- ▶ Refugees: no effect on adult outcomes from an additional year of early childhood abroad (Schoellman, 2016)

Parents

- ▶ Large gaps in test scores for children at start of school (Singh, 2020)
- ▶ Second-generation immigrants “inherit” parental-origin test scores; fades with time (De Philipps and Rossi, 2021)

Culture

- ▶ Migrants from richer countries are more productive in Sweden (Ek, 2024)
- ▶ Mechanism: migrants from richer countries have culture of autonomy, sort to non-routine jobs

Health

Health: height as broad proxy

- ▷ 3.4% return per cm; richest and poorest countries differ by up to 15 cm (Weil, 2007)
- ▷ Little new work on aggregate health stocks since – open area

Summing up

Goal: add dimensions to construct total human capital

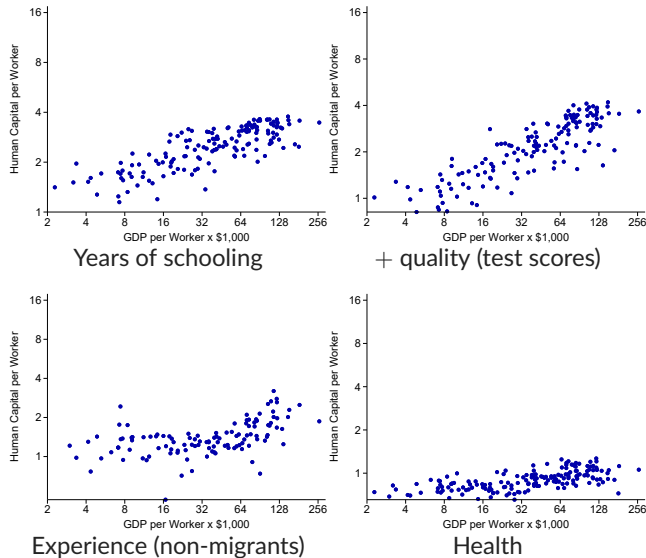
Concern: double-counting

- Test score differences reflect parents and culture, not just school systems (Singh, 2020; De Philippis and Rossi, 2021)
- Health affects years of schooling (Weil, 2007)

Approach

- Add years of schooling, test scores, experience, health
- Each constructed to limit double-counting
- Development accounting not well-suited to identify causal effects

Human capital stocks revisited



Total human capital



Success of factors revisited: human capital

Factor, x	share	std. err.	# countries
<i>Capital-per-worker specification</i>			
Years of schooling	.155	.009	153
... + schooling quality (test scores)	.245	.012	142
... + schooling quality (immigrants)	.240	.020	123
Experience (non-migrants)	.103	.017	109
Experience (immigrants)	.154	.033	65
Health	.064	.006	152
Human capital (years + quality + experience + health)	.437	.026	106
<i>Capital-output specification</i>			
Years of schooling	.232	.014	153
... + schooling quality (test scores)	.367	.018	142
... + schooling quality (immigrants)	.360	.030	123
Experience (non-migrants)	.154	.026	109
Experience (immigrants)	.231	.049	65
Health	.095	.010	152
Human capital (years + quality + experience + health)	.655	.039	106

Note: Sources, by row: (1): Barro and Lee (2013) augmented with World Bank (2026); (2): Harmonized Learning Outcomes from Angrist et al. (2021), valued at 20 percent per standard deviation; (3): own estimates following Schoellman (2012); (4): Jedwab et al. (2023); (5): Lagakos et al. (2018a); (6): height at age 19 from NCD-RisC (2020, 2026), converted into human capital following Weil (2007). Throughout, GDP per worker is taken from Feenstra, Inklaar and Timmer (2025).

Outline

- ① Overview of Basic Structure and Facts
- ② Measures of the Labor Input
- ③ Measurement of Physical Capital
- ④ The Constructive Approach to Human Capital
- ⑤ **The Deductive Approach to Human Capital**
- ⑥ Imperfect Substitution Between Skill Types
- ⑦ Other Advances and Open Areas
- ⑧ Conclusion

Comparing approaches: overview

Constructive approach: expands on classic measurement

- ▷ Adds additional dimensions

Deductive approach: useful check

- ▷ Evidence on wage changes of cross-country migrants
- ▷ Infer importance of human capital as a residual
- ▷ Don't have to specify dimensions of human capital

Deductive approach

Cross-country migrants convey useful information (Hendricks, 2002)

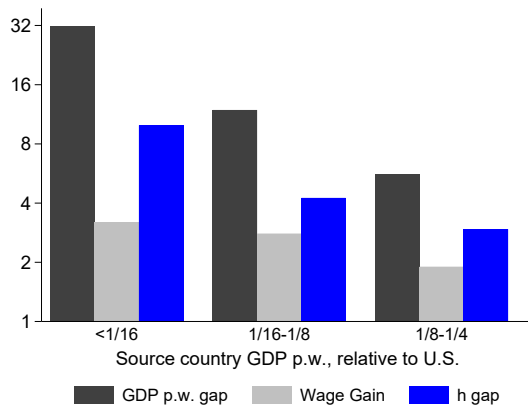
- ▷ Carry their portable human capital to countries with new physical capital, TFP
- ▷ Challenge: selection, skill transfer, discrimination

New strategy: wage changes of migrants (Hendricks and Schoellman, 2018)

- ▷ Small wage change $\implies$ small role for country $(K/Y, A) \implies$ large role for h
- ▷ Large wage change $\implies$ large role for country $\implies$ small role for h
- ▷ Same migrant in two countries reduces concerns about selection

Deduce the importance of human capital

Human capital, deductive approach



Poorest countries: wage gains ($3.2\times$) are small relative to GDP per worker gaps ($31.8\times$)

- ▶ Human capital accounts for $1 - \frac{\log(3.2)}{\log(31.8)} = 66$ percent
- ▶ Similar to constructive approach

Outline

- ① Overview of Basic Structure and Facts
- ② Measures of the Labor Input
- ③ Measurement of Physical Capital
- ④ The Constructive Approach to Human Capital
- ⑤ The Deductive Approach to Human Capital
- ⑥ **Imperfect Substitution Between Skill Types**
- ⑦ Other Advances and Open Areas
- ⑧ Conclusion

Incorporating skill supply and skill-biased technology

Canonical model of labor economics (Katz and Murphy, 1992)

$$L_i = \left(z_{u,i} L_{u,i}^{\frac{\sigma-1}{\sigma}} + z_{s,i} L_{s,i}^{\frac{\sigma-1}{\sigma}} \right)^{\frac{\sigma}{\sigma-1}}$$

Supply of each type of labor:

$$L_{u,i} = N_{u,i} h_{u,i}$$

$$L_{s,i} = N_{s,i} h_{s,i}$$

Elasticity of substitution $\sigma \in [1, 2]$

- Relative supply, skill bias of technology matter (Goldin and Katz, 2008)

Relative skill efficiency

Observed skill premium:

$$\omega_i \equiv \frac{w_{s,i} h_{s,i}}{w_{u,i} h_{u,i}} = \frac{z_{s,i}}{z_{u,i}} \left(\frac{h_{s,i}}{h_{u,i}} \right)^{\frac{\sigma-1}{\sigma}} \left(\frac{N_{s,i}}{N_{u,i}} \right)^{-\frac{1}{\sigma}}$$

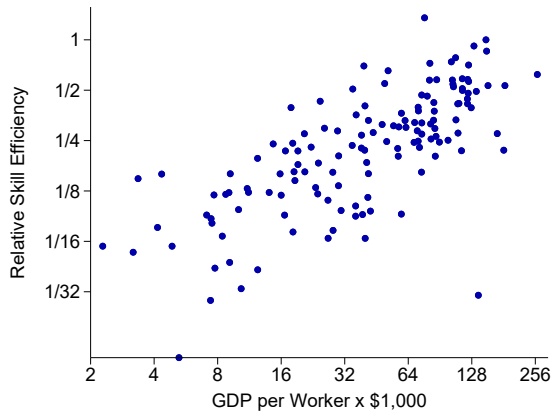
Developing countries have much lower relative supply of skilled labor

- ▶ Force towards much higher values of ω_i
- ▶ Available evidence: ω_i is flat or slightly declining with development (Banerjee and Duflo, 2005; Rossi, 2022)

Developed countries must have much higher relative efficiency of skilled labor (Rossi, 2022)

$$\frac{z_{s,i}}{z_{u,i}} \left(\frac{h_{s,i}}{h_{u,i}} \right)^{\frac{\sigma-1}{\sigma}}$$

Relative skill efficiency



- ▷ $16\times$ higher in developed countries ($\sigma = 1.5$)

Sources of relative skill efficiency

Skill efficiency captures two effects

- ▷ Relative human capital of skilled workers $h_{s,i}/h_{u,i}$
- ▷ Skill bias of technology $z_{s,i}/z_{u,i}$
- ▷ Disagreement about which matters quantitatively (Caselli and Coleman, 2006; Jones, 2014)

Additional data needed

- ▷ Returns to schooling of immigrants
- ▷ Trade data

Result: Majority (67–91 percent) due to skill bias of technology

Imperfect substitution and development accounting

Imperfect substitutes $\implies$ labor aggregator may matter much more

- Simple example: assume $z_{u,i} = h_{u,i} \equiv 1$

Express labor aggregator in terms of observables:

$$L_i = N_{u,i}^{\frac{1}{1-\sigma}} (N_{u,i} + \omega_i N_{s,i})^{\frac{\sigma}{\sigma-1}}$$

- Note: mixes quantity, quality of skilled labor & skill bias of technology
- Imperfect substitution + quantity alone *lowers* role for aggregator (Caselli and Ciccone, 2013)

Importance of imperfect-substitutes labor aggregator

Potentially important accounting implications, sensitive to σ

Factor	share	std. err.	# countries
<i>Capital-per-worker specification</i>			
Aggregator, $\sigma = 1.2$	.668	.056	139
Aggregator, $\sigma = 1.5$	.345	.026	139
Aggregator, $\sigma = 2.0$	.237	.017	139
<i>Capital-output specification</i>			
Aggregator, $\sigma = 1.2$	1.001	.085	139
Aggregator, $\sigma = 1.5$	.517	.039	139
Aggregator, $\sigma = 2.0$	.356	.025	139

Note: Source: own calculation using educational attainment data from Barro and Lee (2013) augmented with World Bank (2026); Feenstra, Inklaar and Timmer (2025).

Correlation suggests endogenous mechanism

High correlation among skilled labor share, skill bias of technology, human capital of skilled worker

- ▷ Suggests endogenous response or co-determination
- ▷ Previous slide: can be quantitatively important in aggregate

Similar idea may apply to other dimensions of human capital

- ▷ Complementarity between technology and culture or experience human capital?

Outline

- ① Overview of Basic Structure and Facts
- ② Measures of the Labor Input
- ③ Measurement of Physical Capital
- ④ The Constructive Approach to Human Capital
- ⑤ The Deductive Approach to Human Capital
- ⑥ Imperfect Substitution Between Skill Types
- ⑦ **Other Advances and Open Areas**
- ⑧ Conclusion

Other advances

Capital-labor substitutability

- ▶ Caselli (2005): capital & labor account for more if they are complements
- ▶ Recent plant-level estimates strongly suggest elasticity < 1 (Oberfield and Raval, 2021)
- ▶ Aggregate elasticity likely larger; value uncertain

Sectors

- ▶ Caselli (2005), Restuccia, Yang and Zhu (2008): Agriculture is uniquely unproductive
 - ▶ $\frac{90-10 \text{ ratio in ag}}{90-10 \text{ ratio in non-ag}} = \frac{43.5}{4.5} = 9.7$
- ▶ New GGDC data on sectoral PPPs reduce the gap (Boppart et al., 2025)
 - ▶ $\frac{38.5}{11.9} = 3.2$
- ▶ Data point to CES production function in ag (Chen, 2020; Boppart et al., 2025)

Other advances

Firm productivity

- ▶ Management quality accounts for 1/3 of TFP variation (Bloom, Sadun and Van Reenen, 2017)
- ▶ Firm-embedded productivity accounts for 28–34 percent of productivity differences (Burstein and Monge-Naranjo, 2009; Alviarez, Cravino and Ramondo, 2023)

Distributional accounting

- ▶ Microdata used to quantify effects of expansion of education on evolution of income distribution
- ▶ Expansion dampened global inequality (Gethin, 2025)

Outline

- ① Overview of Basic Structure and Facts
- ② Measures of the Labor Input
- ③ Measurement of Physical Capital
- ④ The Constructive Approach to Human Capital
- ⑤ The Deductive Approach to Human Capital
- ⑥ Imperfect Substitution Between Skill Types
- ⑦ Other Advances and Open Areas
- ⑧ **Conclusion**

Conclusion

New measurement pushes inputs from 30% → 55–70% of GDP per worker differences

- ▷ Hours deepen the puzzle (–5%)
- ▷ Physical capital unchanged or slightly smaller (7%)
- ▷ Human capital much larger (58–66%); constructive and deductive approaches agree

Many open questions

- ▷ Revisiting assumptions, improving existing measures
- ▷ Some important dimensions remain highly uncertain (public capital, imperfect substitution)

Emphasize limitations

- ▷ Needs external evidence on input gaps and how to scale them
- ▷ Proximate, not root, causes; no direct policy levers

- Alvarez, Vanessa, Javier Cravino, and Natalia Ramondo.** 2023. "Firm-Embedded Productivity and Cross-Country Income Differences." *Journal of Political Economy*, 131(9): 2289–2327.
- Angrist, Noam, Simeon Djankov, Pınar K. Goldberg, and Harry A. Patrinos.** 2021. "Measuring human capital using global learning data." *Nature*, 592(7854): 403–408.
- Banerjee, Abhijit V., and Esther Duflo.** 2005. "Growth Theory through the Lens of Development Economics." In *Handbook of Economic Growth*. Vol. 1A, , ed. Philippe Aghion and Steven N. Durlauf, Chapter 7, 473–552. Elsevier.
- Barro, Robert J.** 1990. "Government Spending in a Simple Model of Endogenous Growth." *Journal of Political Economy*, 98(5): S103–S125.
- Barro, Robert J., and Jong Wha Lee.** 2013. "A New Data Set of Educational Attainment in the World, 1950–2010." *Journal of Development Economics*, 104: 184–198.
- Bick, Alex, Nicola Fuchs-Schündeln, and David Lagakos.** 2018. "How Do Hours Worked Vary With Income? Cross-Country Evidence and Implications." *American Economic Review*, 108(1): 170–199.
- Bils, Mark, and Peter J. Klenow.** 2000. "Does Schooling Cause Growth?" *American Economic Review*, 90(5): 1160–1183.

- Bloom, Nicholas, Raffaella Sadun, and John Van Reenen.** 2017. "Management as a Technology?" NBER Working Paper No. 22327.
- Boppart, Timo, Patrick Kiernan, Per Krusell, and Hannes Malmberg.** 2025. "The Macroeconomics of Intensive Agriculture." mimeo, University of Minnesota.
- Burstein, Ariel T., and Alexander Monge-Naranjo.** 2009. "Foreign Know-How, Firm Control, and the Income of Developing Countries." *Quarterly Journal of Economics*, 124(1): 149–195.
- Caselli, Francesco.** 2005. "Accounting for Cross-Country Income Differences." In *Handbook of Economic Growth*. Vol. 1A, , ed. Philippe Aghion and Steven N. Durlauf, Chapter 9, 679–741. Elsevier.
- Caselli, Francesco.** 2016. "Accounting for Cross-Country Income Differences: Ten Years Later." Background Paper: World Development Report 2017.
- Caselli, Francesco, and Antonio Ciccone.** 2013. "The contribution of schooling in development accounting: Results from a nonparametric upper bound." *Journal of Development Economics*, 104: 199–211.
- Caselli, Francesco, and James Feyrer.** 2007. "The Marginal Product of Capital." *Quarterly Journal of Economics*, 122(2): 535–568.

- Caselli, Francesco, and Wilbur John Coleman, II.** 2006. "The World Technology Frontier." *American Economic Review*, 96(3): 499–522.
- Chen, Chaoran.** 2020. "Technology Adoption, Capital Deepening, and International Productivity Differences." *Journal of Development Economics*, 143: 102388.
- Corrado, Carol, Charles Hulten, and Daniel Sichel.** 2009. "Intangible Capital and U.S. Economic Growth." *Review of Income and Wealth*, 55(3): 661–685.
- Cubas, German.** 2020. "Public Capital and Economic Development." *Economic Journal*, 130(632): 2354–2381.
- De Philippis, Marta, and Federico Rossi.** 2021. "Parents, Schools and Human Capital Differences Across Countries." *Journal of the European Economic Association*, 19(2): 1364–1406.
- Devadas, Sharmila, and Steven Pennings.** 2018. "Assessing the Effect of Public Capital on Growth: An Extension of the World Bank Long-Term Growth Model." World Bank, Development Economics Development Research Group Policy Research Working Paper 8604.

Ek, Andreas. 2024. "Cultural Values and Productivity." *Journal of Political Economy*, 132(1): 295–335.

Feenstra, Robert C., Robert Inklaar, and Marcel P. Timmer. 2015. "The Next Generation of the Penn World Table." *American Economic Review*, 105(10): 3150–3182.

Feenstra, Robert C., Robert Inklaar, and Marcel P. Timmer. 2025. "Penn World Table 11.0." Groningen Growth and Development Centre. <https://doi.org/10.34894/FABVLR>.

Gethin, Amory. 2025. "Distributional Growth Accounting: Education and the Reduction of Global Poverty, 1980–2019." *Quarterly Journal of Economics*, 140(4): 2571–2618.

Gethin, Amory, and Emmanuel Saez. forthcoming. "Global Working Hours." *Quarterly Journal of Economics*.

Goldin, Claudia, and Lawrence F. Katz. 2008. *The Race between Education and Technology*. Cambridge, MA:Harvard University Press.

Gollin, Douglas. 2002. "Getting Income Shares Right." *Journal of Political Economy*, 110(2): 458–474.

Hall, Robert E., and Charles I. Jones. 1999. "Why Do Some Countries Produce So Much More Output Per Worker Than Others?" *Quarterly Journal of Economics*, 114(1): 83–116.

- Hendricks, Lutz.** 2002. "How Important Is Human Capital for Development? Evidence from Immigrant Earnings." *American Economic Review*, 92(1): 198–219.
- Hendricks, Lutz, and Todd Schoellman.** 2018. "Human Capital and Development Accounting: New Evidence from Wage Gains at Migration." *Quarterly Journal of Economics*, 133(2): 665–700.
- Hsieh, Chang-Tai, and Peter J. Klenow.** 2010. "Development Accounting." *American Economic Journal: Macroeconomics*, 2(1): 207–223.
- Inklaar, Robert, Pieter Woltjer, and Daniel Gallardo Albarrán.** 2019. "The Composition of Capital and Cross-country Productivity Differences." *International Productivity Monitor*, 36: 34–52.
- International Monetary Fund.** 2021. "IMF Investment and Capital Stock Dataset, 1960–2019." Prepared by the Expenditure Policy Division, Fiscal Affairs Department. Available at <https://infrastructuregovern.imf.org/content/dam/PIMA/Knowledge-Hub/dataset/IMFInvestmentandCapitalStockDataset2021.xlsx>. Downloaded July 3, 2026.

- Jedwab, Remi, Paul Romer, Asif Islam, and Roberto Samaniego.** 2023. "Human Capital Accumulation at Work: Estimates for the World and Implications for Development." *American Economic Journal: Macroeconomics*, 15(3): 191–223.
- Jones, Benjamin F.** 2014. "The Human Capital Stock: A Generalized Approach." *American Economic Review*, 104(11): 3752–3777.
- Kaarsen, Nicolai.** 2014. "Cross-Country Differences in the Quality of Schooling." *Journal of Development Economics*, 107: 215–224.
- Kapsoli, Javier, Tewodaj Mogues, and Geneviève Verdier.** 2023. "Benchmarking Infrastructure Using Public Investment Efficiency Frontiers." IMF Working Paper 23/101.
- Katz, Lawrence F., and Kevin M. Murphy.** 1992. "Changes in Relative Wages, 1963–1987: Supply and Demand Factors." *Quarterly Journal of Economics*, 107(1): 35–78.
- Klenow, Peter J., and Andrés Rodríguez-Clare.** 1997. "The Neoclassical Revival in Growth Economics: Has It Gone Too Far?" In *NBER Macroeconomics Annual 1997.*, ed. Ben S. Bernanke and Julio J. Rotemberg, 73–103. MIT Press.

Lagakos, David, Benjamin Moll, Tommaso Porzio, Nancy Qian, and Todd Schoellman. 2018a. "Life-Cycle Human Capital Accumulation Across Countries: Lessons from U.S. Immigrants." *Journal of Human Capital*, 12(2): 184–215.

Lagakos, David, Benjamin Moll, Tommaso Porzio, Nancy Qian, and Todd Schoellman. 2018b. "Life-Cycle Wage Growth across Countries." *Journal of Political Economy*, 126(2): 797–849.

Ma, Xiao, Alejandro Nakab, and Daniela Vidart. 2024. "Human Capital Investment and Development: The Role of On-the-job Training." *Journal of Political Economy: Macroeconomics*, 2(1): 107–148.

Monge-Naranjo, Alexander, Juan Sánchez, and Raül Santaeuilàlia-Llopis. 2019. "Natural Resources and Global Misallocation." *American Economic Journal: Macroeconomics*, 11(2): 79–126.

NCD-RisC. 2020. "Height and body-mass index trajectories of school-aged children and adolescents from 1985 to 2019 in 200 countries and territories: a pooled analysis of 2181 population-based studies with 65 million participants." *The Lancet*, 396(10261): 1511–1524.

NCD-RisC. 2026. "Height Data Downloads."

<https://www.ncdrisc.org/data-downloads-height.html>. Accessed July 13, 2026.

Oberfield, Ezra, and Devesh Raval. 2021. "Micro Data and Macro Technology." *Econometrica*, 89(2): 703–732.

Prescott, Edward C. 1998. "Needed: A Theory of Total Factor Productivity." *International Economic Review*, 39(3): 525–551.

Pritchett, Lant. 2000. "The Tyranny of Concepts: CUDIE (Cumulated, Depreciated, Investment Effort) Is Not Capital." *Journal of Economic Growth*, 5(4): 361–384.

Restuccia, Diego, Dennis T. Yang, and Xiaodong Zhu. 2008. "Agriculture and Aggregate Productivity: A Quantitative Cross-Country Analysis." *Journal of Monetary Economics*, 55(2): 234–250.

Rossi, Federico. 2022. "The Relative Efficiency of Skilled Labor across Countries: Measurement and Interpretation." *American Economic Review*, 112(1): 235–266.

Schoellman, Todd. 2012. "Education Quality and Development Accounting." *Review of Economic Studies*, 79(1): 388–417.

Schoellman, Todd. 2016. "Early Childhood Human Capital and Development." *American Economic Journal: Macroeconomics*, 8(3): 145–174.

Singh, Abhijeet. 2020. "Learning More with Every Year: School year productivity and international learning divergence." *Journal of the European Economic Association*, 18(4): 1770–1813.

Weil, David N. 2007. "Accounting for the Effect of Health on Economic Growth." *Quarterly Journal of Economics*, 122(3): 1265–1306.

World Bank. 2026. "Education Statistics (EdStats)." Available online at <https://datatopics.worldbank.org/education/>. Accessed January 22, 2026.