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Unconditional convergence and the role of capital, labour and productivity

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connecting for impact

PWT version 11.0

- Release: October 7, 2025
- Period: 1950–2023
- Country coverage: Up to 185 countries
  - Somalia and South Sudan added
- New data: PPPs from ICP through 2021
- Focus on: 118 countries with TFP measures
- Joint work, supported by STEG

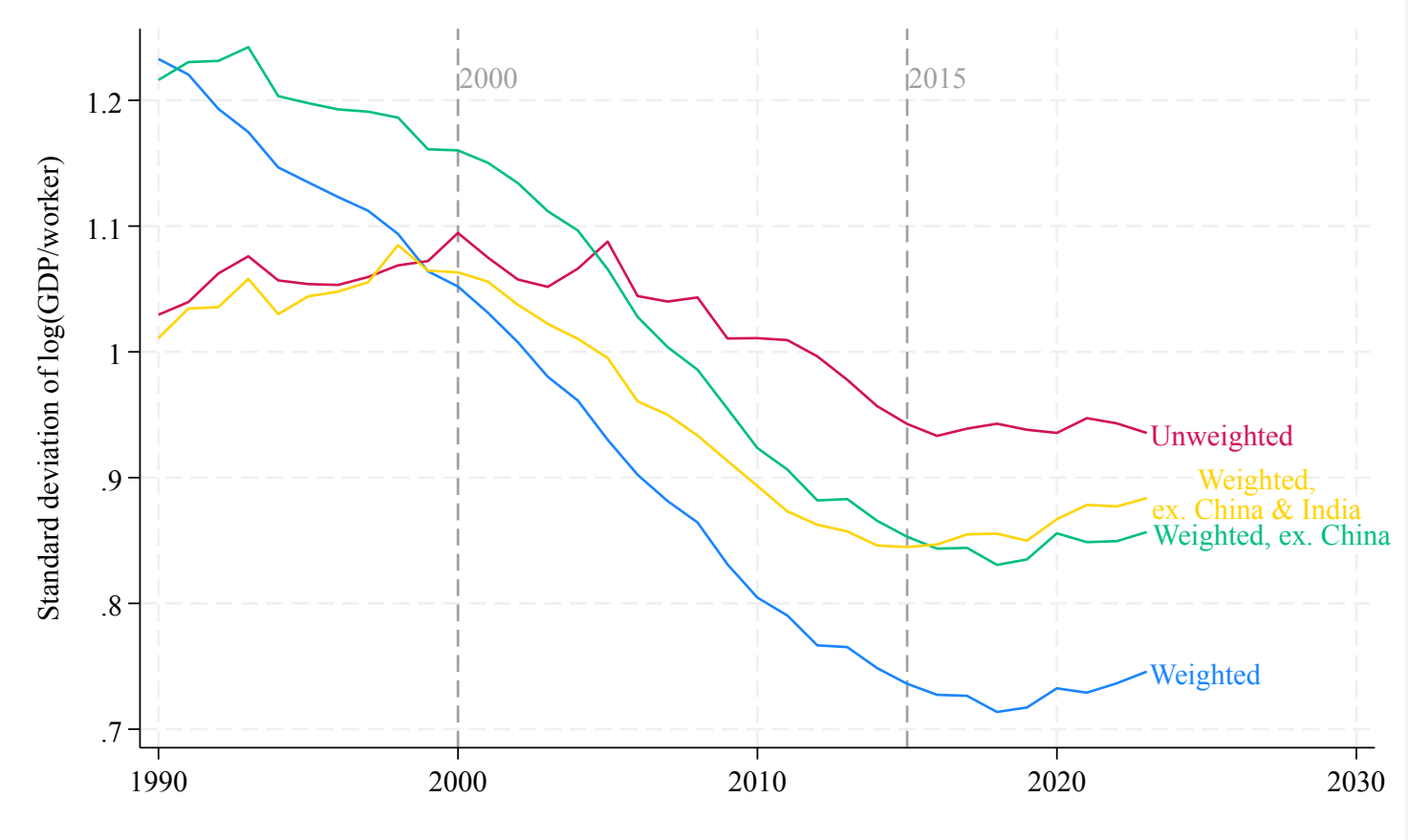
Plan for today

- Patterns of income convergence in recent decades
- How to account for this convergence pattern?
  - Development accounting in PWT
- Measurement challenges
  - Human capital (L)
  - Intangibles (K)
- Sectoral changes (A) (Inklaar, Marapin & Gräler, IMF EcRev 2024)

Convergence and Growth

- Standard story: convergence in income only conditional (e.g., Barro, EJ 2015)
- Decreasing income differences since 1990?
  - Unconditional convergence (Patel, Sandefur & Subramanian, JDevEc 2021)
  - Patel et al. (2025): "Several years ago, we celebrated a new era of unconditional convergence of global incomes. Since then, the trend has reversed.
- Sector level:
  - Manufacturing (Rodrik, QJE 2013) vs. Herrendorf Rogerson & Valentinyi (AER: Insights, 2025)
  - Agriculture (Inklaar & Marapin, 2025)

Cross-country dispersion in GDP/worker



- σ-convergence: dispersion in log(GDP/worker)
- 2000–2015 period saw strongest convergence

σ- and β-convergence

$\Delta\sigma$	σ (weighted)	σ (unweighted)	σ (weighted excl. China)	σ (weighted excl. China & India)
1990-2000	-0.181	0.065	-0.056	0.052
2000-2015	-0.316	-0.152	-0.307	-0.218
2015-2023	0.010	-0.007	0.004	0.039

	β (weighted)	β (unweighted)
1990-2000	0.015*	-0.005***
2000-2015	0.027***	0.007***
2015-2023	-0.002	-0.005

Note: *** p < 0.01, ** p < 0.05, * p < 0.10

- 2000–2015 period saw strongest convergence across measures

$$\frac{1}{s}\log\left(\frac{y_{i,t+s}}{y_{i,t}}\right) = \alpha - \left(\frac{1-e^{-\beta s}}{s}\right)\log(y_{i,t}) + \varepsilon_{i,t+s}$$

What can account for this convergence?

- Development accounting (e.g., Hsieh & Klenow, 2010):

$$\log\frac{y_j}{y_m} = \frac{\alpha}{1-\alpha}\log\left(\frac{k_j/y_j}{k_m/y_m}\right) + \log\frac{h_j}{h_m} + \frac{\log(A_j/A_m)}{1-\alpha}$$

- Compare between countries j and reference country m (typically, the US)
- Account for cross-country variation in α

Interpretation & presentation

How much of the differences in GDP/worker can be accounted for by differences in produced capital/output, human capital and TFP?

=> Three regressions:

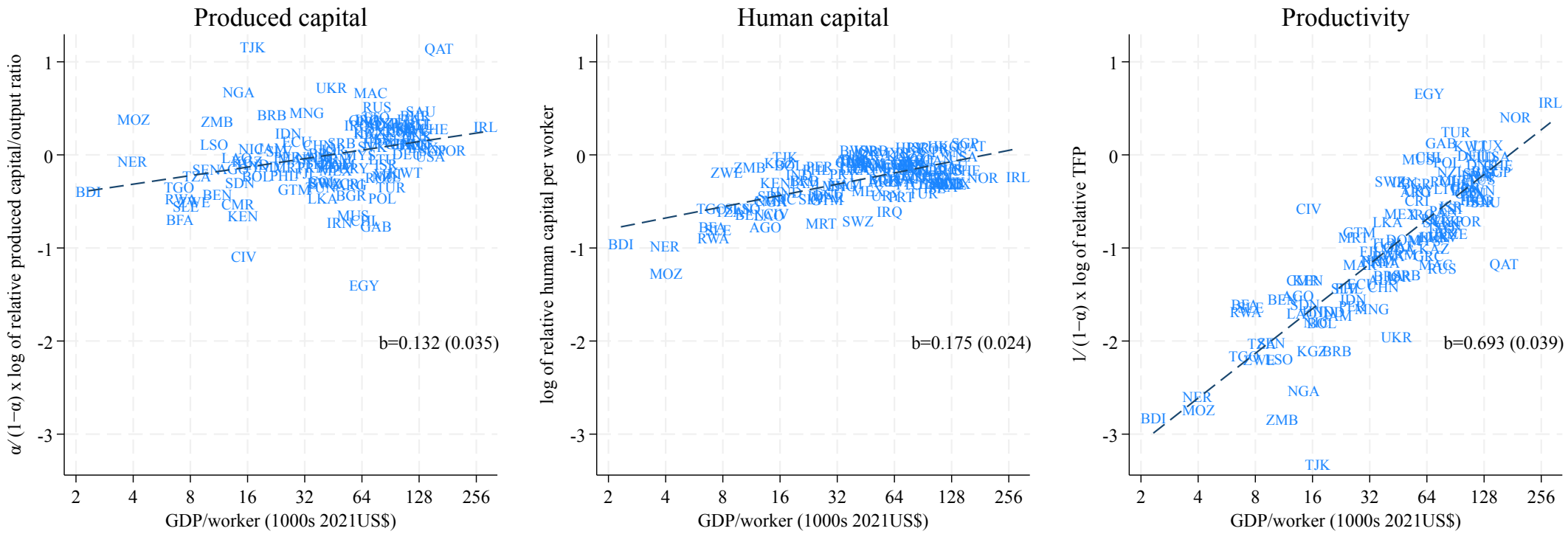
$$\frac{\alpha}{1-\alpha}\log\left(\frac{k_j/k_k}{y_j/y_k}\right) = \beta_0 + \beta_k \log\frac{y_j}{y_k} + \varepsilon_j$$

$$\log\frac{h_j}{h_k} = \beta_0 + \beta_h \log\frac{y_j}{y_k} + \varepsilon_j$$

$$\frac{\log(A_j/A_k)}{1-\alpha} = \beta_0 + \beta_A \log\frac{y_j}{y_k} + \varepsilon_j$$

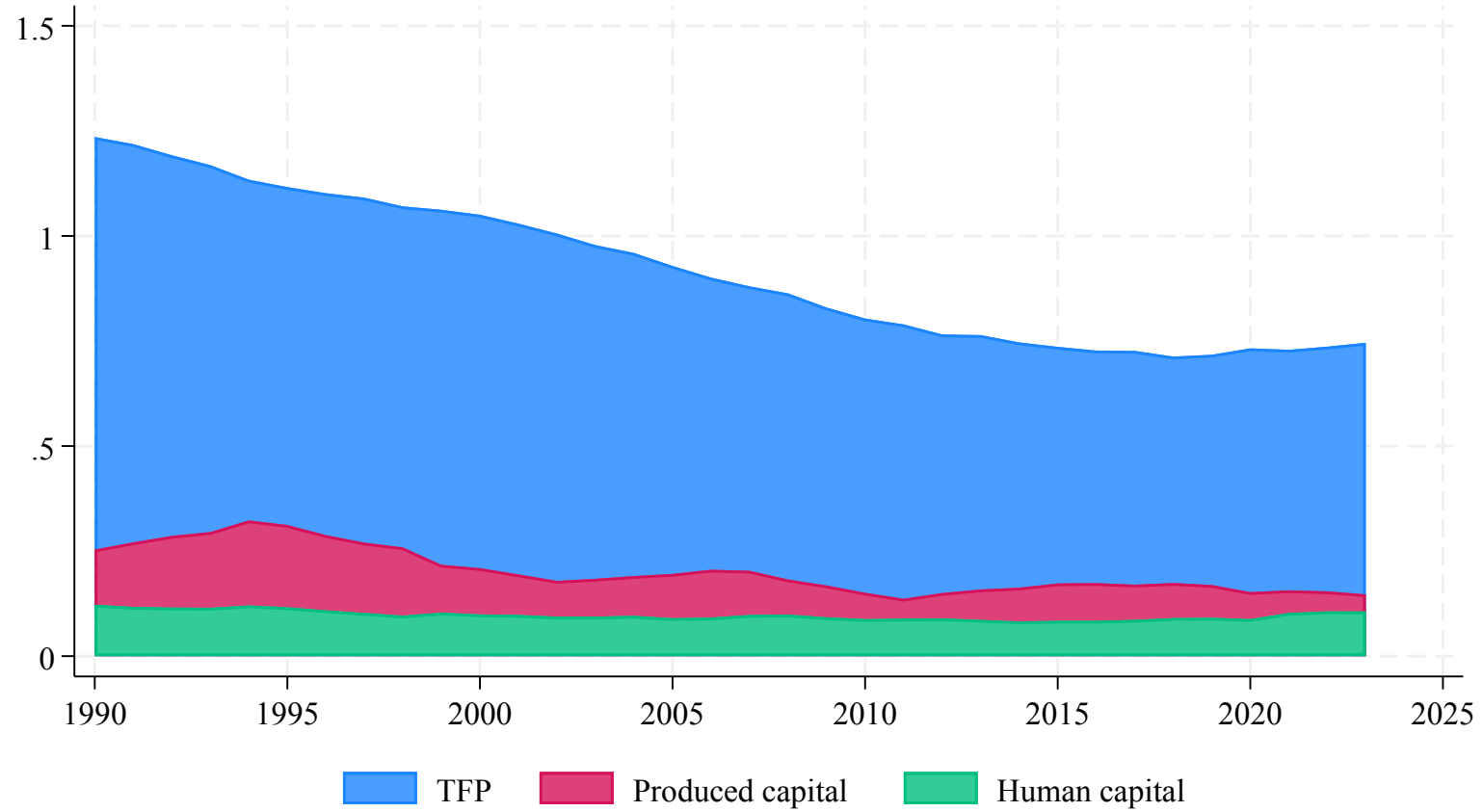
$$\beta_k + \beta_h + \beta_A = 1$$

Accounting results for 2021



Source: Penn World Table, PWT version 11.0, Feenstra et al. (*AER* 2015)
Notes: Shown are the 118 countries in PWT 11.0 for which TFP estimates can be made, omitted are Central African Republic and Venezuela.
Also shown is the slope coefficient and associated robust standard error.

Accounting results over time



Based on weighted dispersion in GDP/worker

- Estimate β_k, β_h and β_A for every year and multiply by σ
- TFP accounts for most of the observed convergence

GDP/worker convergence primarily from TFP

$\Delta\sigma$	Total	Produced capital	Human capital	TFP
Weighted				
1990-2000	-0.19	-0.02	-0.02	-0.14
2000-2015	-0.31	-0.02	-0.02	-0.28
2015-2023	0.01	-0.05	0.02	0.04
Unweighted				
1990-2000	0.08	-0.18	-0.04	0.29
2000-2015	-0.15	0.13	-0.01	-0.28
2015-2023	-0.01	-0.03	-0.01	0.04

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Measurements Challenges

Measuring produced capital, K

Investment in (non-financial) asset i accumulates with investment I and depreciates at rate δ:

$$K_{it} = (1 - \delta_i)K_{it-1} + I_t$$

Concerns:

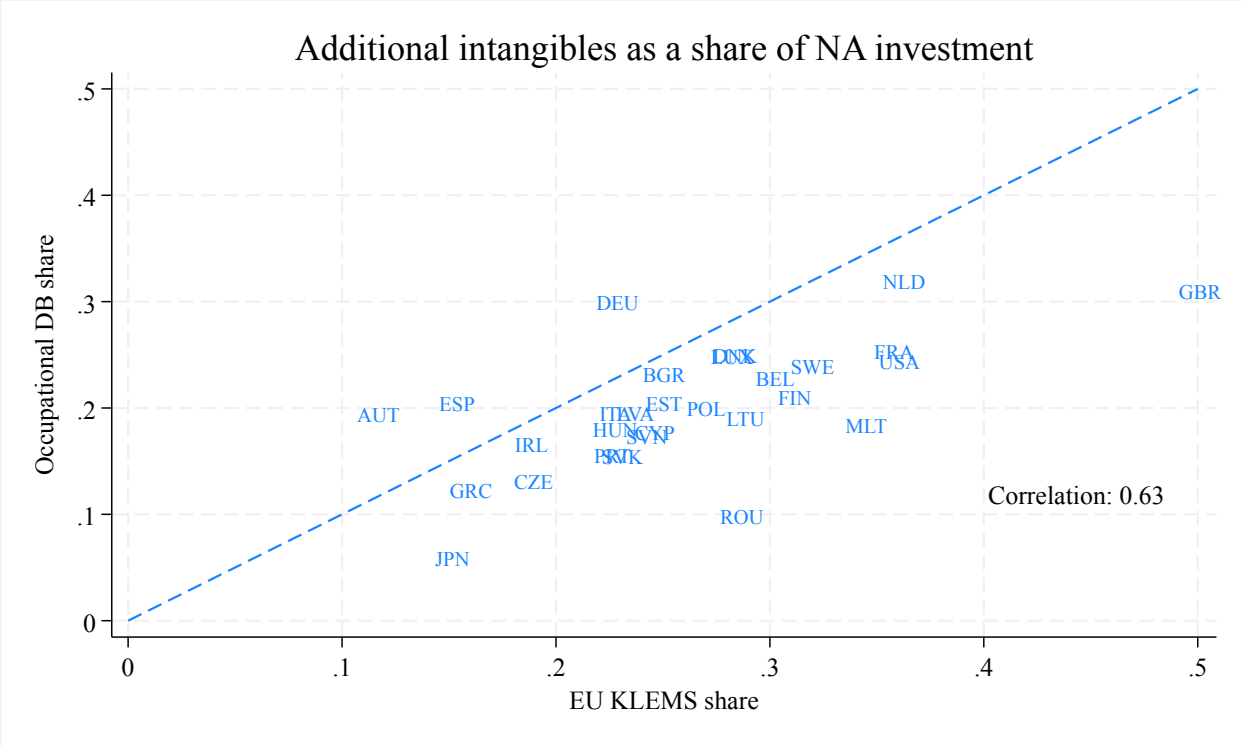
- Capturing quality change in high-tech goods => rely on US deflators
- Lack of data on natural resources, including land and subsoil assets (though see Freeman, Inklaar and Diewert, RoIW 2021)
- Capturing investment in all intangible assets (e.g., Haskel/Westlake, 2018)

Intangibles and the definition of capital

- What counts as investment National Accounts:
  - Equipment and structures
  - Software (since SNA1993)
  - R&D (since SNA2008)
- What should count as investment? => spending with expected returns >1 year (Corrado, Hulten & Sichel, CHS, 2005, 2009)
- CHS add:
  - New products in finance, new designs
  - Brand equity
  - Staff training
  - Organisational capital

Importance of intangibles

- Intangible investment: own-account investment for 58 countries
- First 29 countries
  - EU KLEMS & INTANProd (Release 2025; Bontadini, et al. 2023), EU, UK, Japan & US
- Additional 29 countries
  - Occupation Database (Kruse et al., 2024)
  - Imperfect measurement but comparable pattern



Development accounting impact

- Higher-income countries invest more in intangibles
  - Correlation of 0.7 between new intangibles share and log(GDP/worker); similar to Chen (2017)
- More intangible investment over time: 18% in 2000 => 21% in 2018
- Intangibles are produced, so $K \uparrow$ and $Y \uparrow$ => net effect TBD
- Including intangible can account for a small part of convergence in GDP/worker

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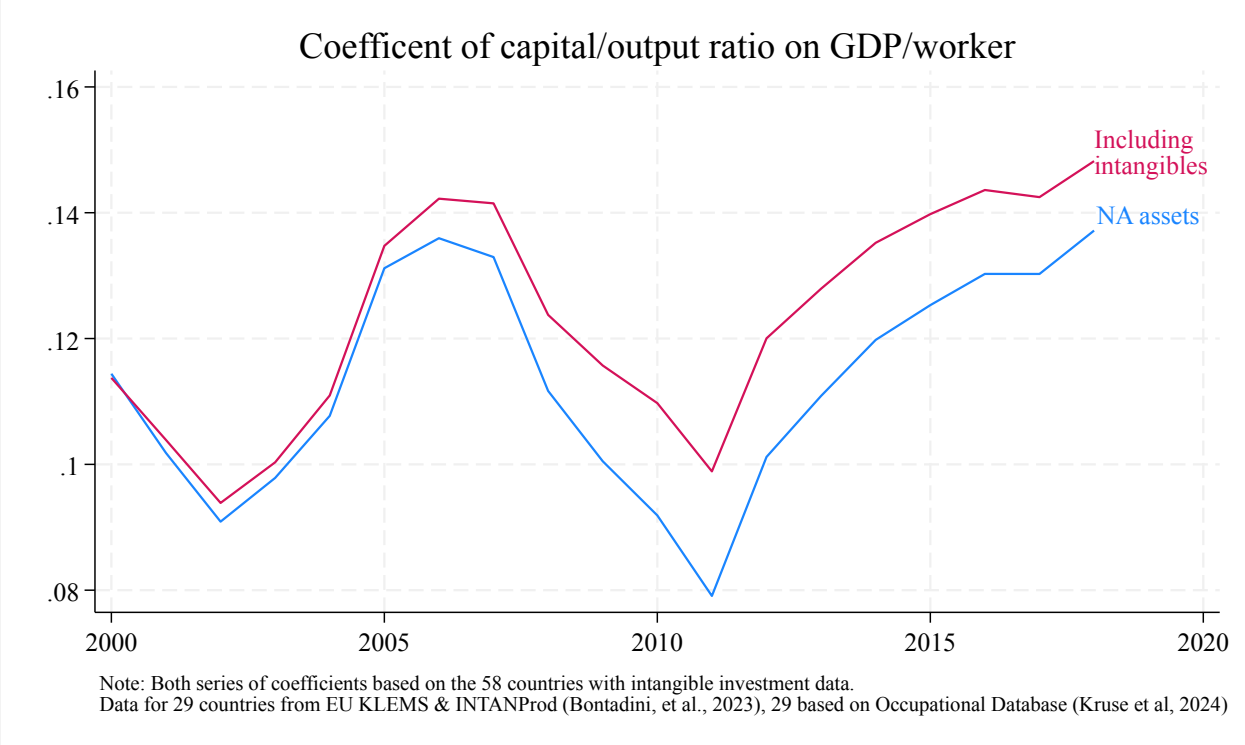


Measuring human capital, h

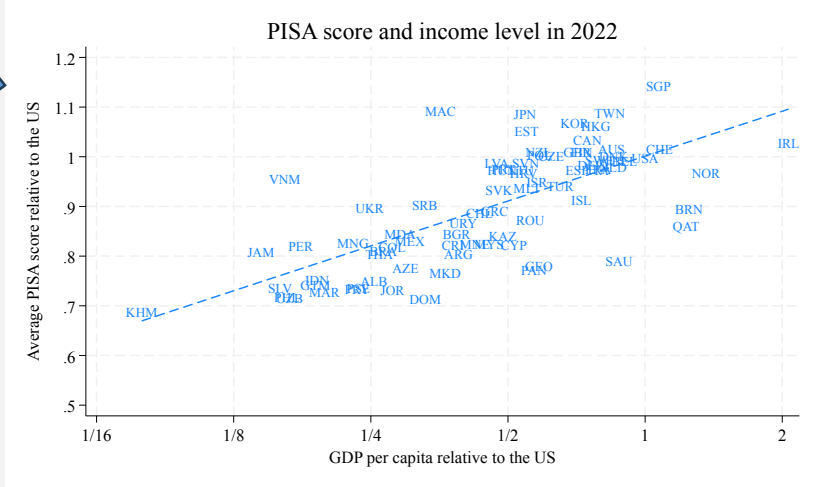
- Average years of schooling s with assumed rates of return ϕ, and
- Average hours worked w:

$$h = w \times s^{\phi}$$

Measuring human capital, h

Concerns:

- Years of schooling ≠ quality of schooling (Angrist et al., Nature 2021)
- Rates of return to schooling vary across countries and over time (Patrinos et al. 2024, doi: 10.15185/izawol.278.v2)
- Human capital accumulated on the job is not measured (Lagakos et al., JPE 2018)



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Learning-adjusted years of schooling

- Follow World Bank's Human Capital Index approach

$$LAYS_{it} = Q_{it} \times s_{it}$$

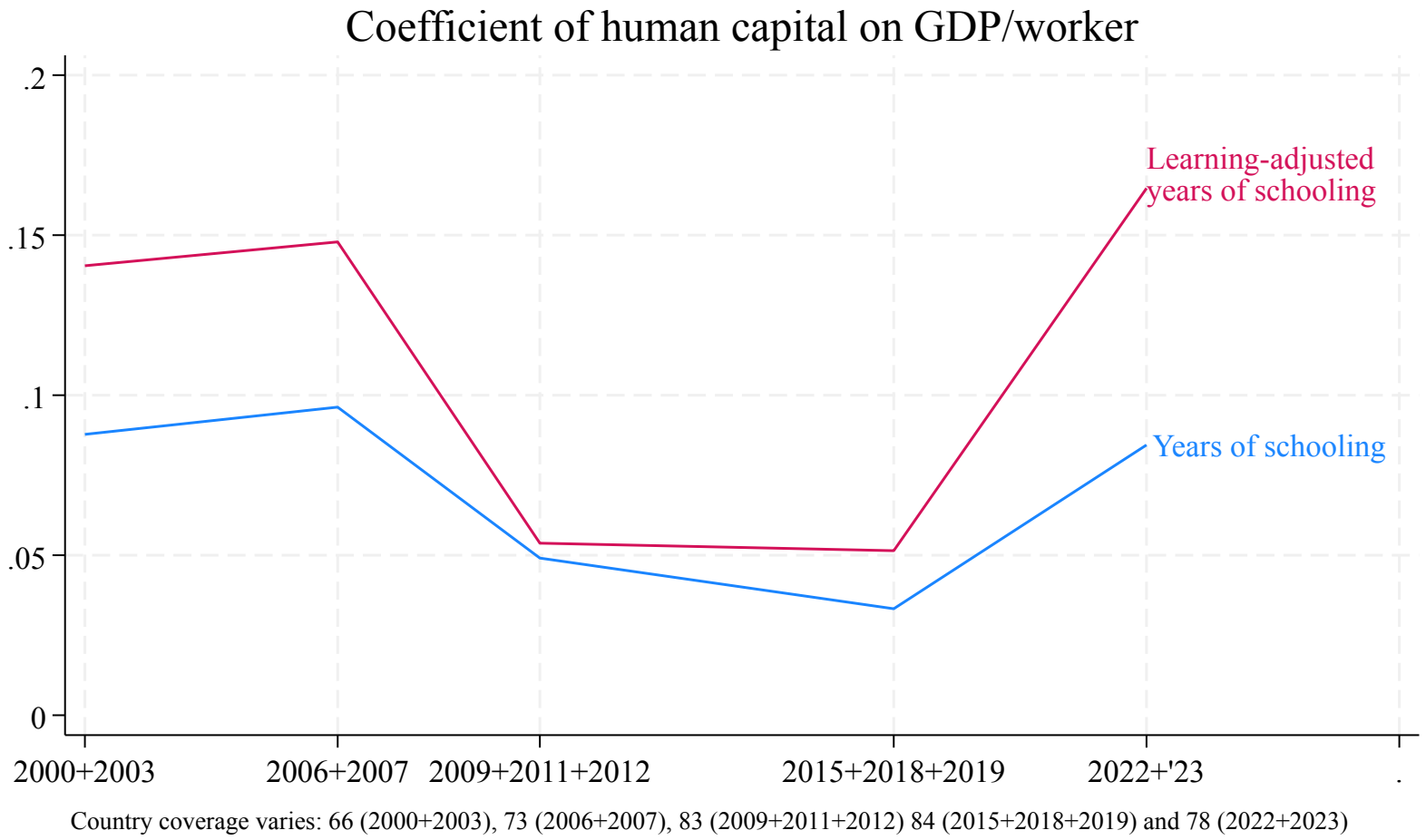
Where:

$$Q_{it} = HLO_{it}/625$$

HLO=Harmonised Learning Outcome from Angrist et al. (2021)

- Use Angrist et al. (2021) data from PISA and TIMSS
  - Add PISA 2022 and TIMS 2019 & 2023
- Correlation Q_{it} and log(GDP/worker): 0.55
- No time trend in Q_{it}

Outcomes new approach human capital



Country coverage varies: 66 (2000+2003), 73 (2006+2007), 83 (2009+2011+2012) 84 (2015+2018+2019) and 78 (2022+2023)

- Combine Q_{it} from different waves/tests to increase cross-section
- Human capital accounts for more of income differences, but no role in convergence

Sectoral TFP analysis

TFP variation across countries and time

- Productivity covers substantial part of convergence over time
  - Technology and resource allocation (e.g., Hsieh & Klenow, AEJ Macro 2010)
  - Partly mismeasured inputs
- Understanding productivity gaps?

  ⇒From aggregate development accounting to a sectoral perspective (Inklaar, Marapin & Gräler, IMF EcRev 2024)
- Understanding productivity convergence across time

Sectoral TFP analysis

Based on Inklaar, Marapin and Gräler (IMF EcRev, 2024)

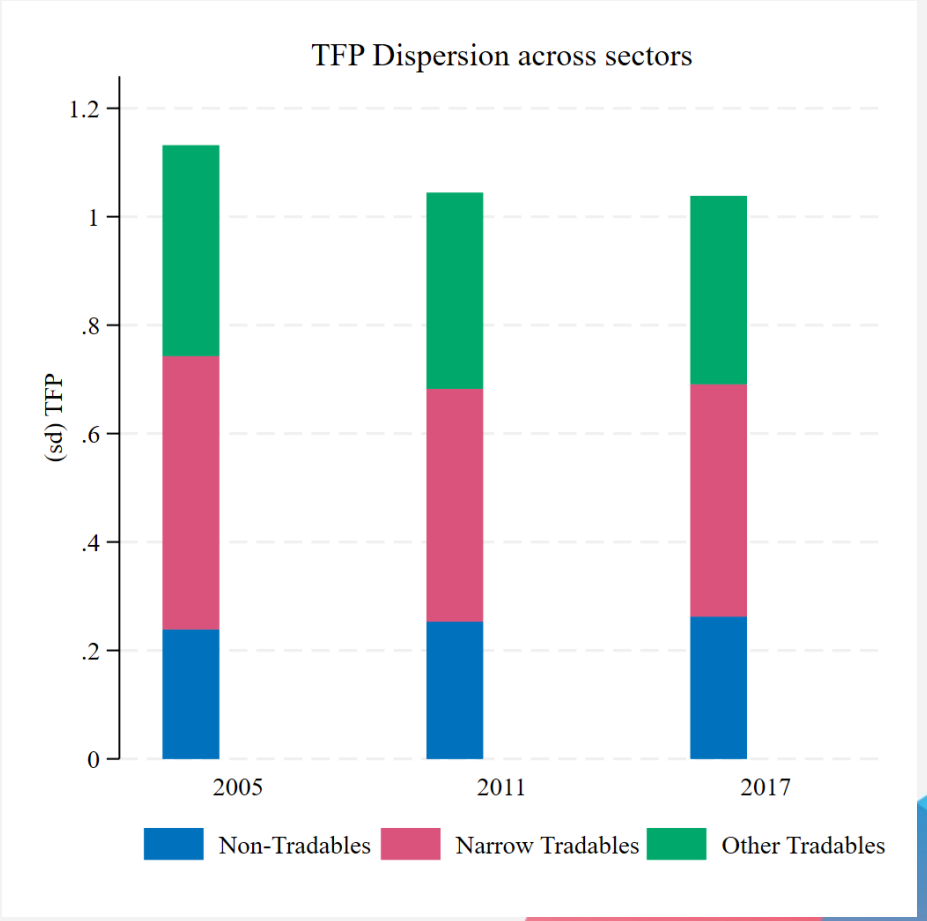
1. Develop new measures of relatives prices for sectoral (gross)output, intermediate inputs and value added
   - 84 countries
   - 12 sectors
   - 2005, 2011 & 2017
2. Development accounting for 12 sectors and relevant combinations of sectors
   - Traded vs. non-traded key distinction

Sectoral TFP analysis

- Multilateral Tornqvist index

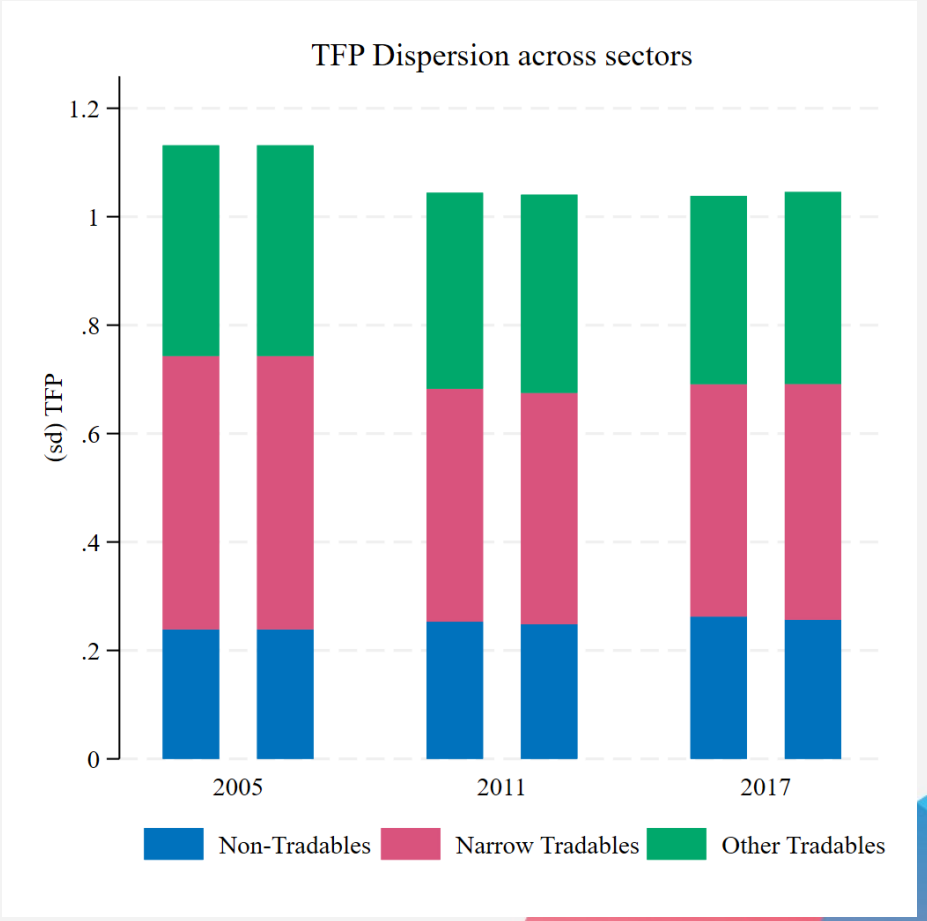
$$\log A_j^T = \frac{1}{2}\sum_i \left(V_{ij}^T + \overline{V_{ij}^T}\right)\left(\log A_{ij}^T + \overline{\log A_{ij}^T}\right)$$

- Decrease in TFP variation
  - Decrease in Traded (-0.07)
  - Decrease in Other (-0.03)
  - Increase in Non-Traded (-0.02)



Sectoral TFP analysis

- Two components:
  - Between-group (structural change)
  - Within-group (productivity convergence)
- Counterfactual analysis
  - Value added shares 2005
- Within-group TFP convergence drives pattern



Takeaways

- Strong income convergence 2000-2015; levelled off post-2015
- TFP accounts for most observed convergence
- Measurement improvements (intangibles, quality-adjusted human capital): explain more variation in levels, limited impact on convergence
- Sectoral analysis: TFP convergence concentrated in traded sectors, driven by within-group productivity changes

Measuring produced capital, K

- Investment in (non-financial) asset i accumulates with investment I and depreciates at rate δ:

$$K_{it} = (1 - \delta_i)K_{it-1} + I_t$$

- Each asset's marginal product can be approximated by its rental price, p_{it}^K, based on the asset price p_{it}^N, the rate of return R, the depreciation rate and asset's (5-year average) price change π:

$$p_{it}^K = p_{it-1}^N R_t + p_{it}^N \delta_i - p_{it-1}^N \times \bar{\pi}_{it}$$

- R is chosen so that capital income = GDP – labor income – resource rents

Intangible investment from occupation data (1)

- Occupation Database: 13 occupations, 2000–2018
  - 56 countries (Kruse et al., 2024), including high-income and LAC & Asia
  - 11 African countries (work in progress)
- Employment & compensation shares by industry => aggregate using total employment by industry (OECD Trade in Employment Data, ASUT Database)
- Include only countries with full time series and capital/TFP data in PWT => 58 countries

Appendix table C3: Classification of occupations

Occupational grouping	Description	ISCO 88 codes
1	Legislators	[11]
2	Managers	[12–13]
3	Engineering professionals	[21, 31]
4	Health professionals	[22, 32]
5	Teaching professionals	[23, 33]
6	Other professionals	[24, 34]
7	Clerical support workers	[41–42]
8	Personal service workers	[51, 910, 912–916]
9	Sales workers	[52, 911]
10	Craft workers and machine operators	[71–74, 81–82, 93]
11	Agricultural workers	[60-61, 92]
12	Other, including armed forces	[01-03, 90,99]
13	Drivers	[83]

Intangible investment from occupation data (2)

- R&D workers ➔ engineering professionals, already in SNA
- Brand/design/new products ➔ other professionals
- Organization capital ➔ managers
- Deflate investment by GDP deflator; GDP PPP for cross-country comparison
- Standard CHS depreciation:
  - Brand (55%) & Design/new products (20%) => 30%
  - Organization capital: 40%
- Adjust GDP for additional investment

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So why is the role of sectors not resolved yet?

Measuring sectoral productivity is hard

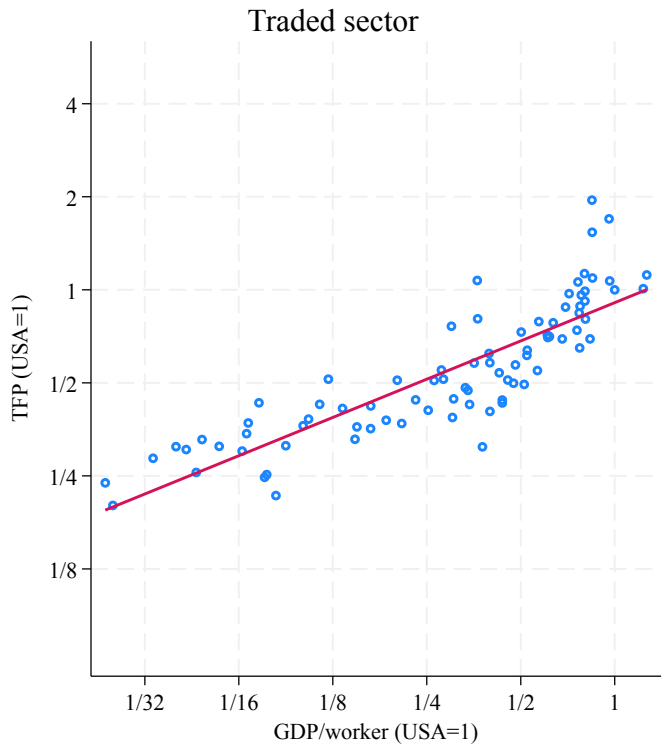
- Theory is not new (Caves, Christensen, Diewert, ECMA 1982)
- Trade-off in empirical literature: country coverage vs. measurement sophistication (e.g., Fadinger et al. AEJ: Macro 2022 for 38 countries)
- Development accounting benefits from broad coverage

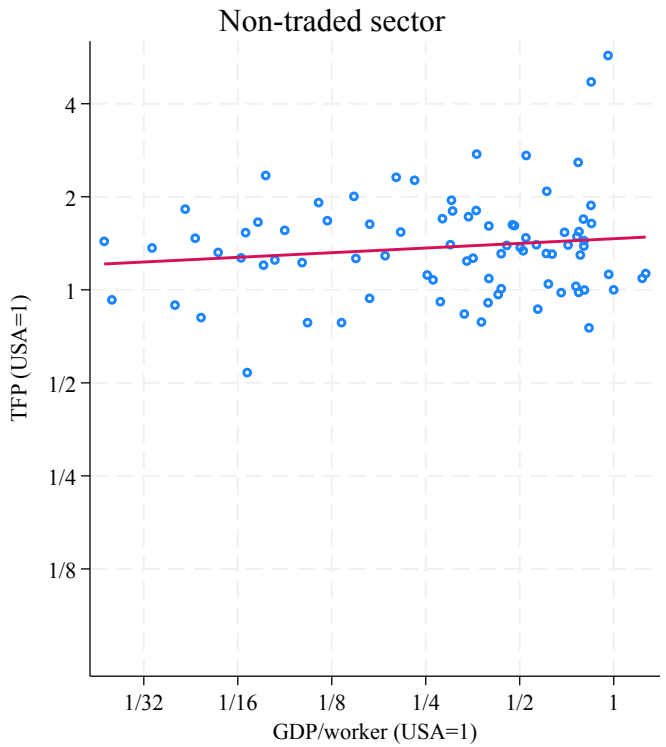
Measuring sectoral productivity

Measurement area	Previous approach	This paper
Industry output	Final expenditure price	Sectoral value added price
Labor input	Efficient labor allocation	Observed employment data
Production function	Cobb-Douglas	Törnqvist
Capital input	Efficient capital allocation	Robust findings to using observed capital data for half the sample

Sectoral TFP and GDP/worker differences

Group	Productivity level γ^i
Broad traded	0.409
	[0.377–0.441]
Narrow traded	0.380
	[0.336–0.423]
Non-traded	0.032
	[−0.016–0.079]
Agriculture	0.582
	[0.518–0.646]
Non-agriculture	0.255
	[0.218–0.292]
Manufacturing	0.366
	[0.305–0.426]
Non-manufacturing	0.342
	[0.300–0.383]
Consumption	0.363
	[0.322–0.403]
Investment	0.242
	[0.160–0.324]





Figures show average TFP levels for each country in the two sectors

$$\log\left(A_{j,t}^{i}\right) = \alpha^{i} + \gamma^{i}\log\left(y_{j,t}\right) + \delta_{t} + \varepsilon_{j,t}^{i}$$