# Economic Growth in the Long Run

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# What We Do

Compute new measures of output per worker, physical capital per worker, human capital per worker

1. Original estimates of real output per worker for 168 countries
2. Original estimates of real physical capital per worker for 168 countries
3. Original estimates of schooling per worker for 168 countries
4. Original estimates of human capital per worker for 168 countries

# Literature & Sources

1. Klenow & Rodriguez-Clare (1997)
2. Hall & Jones (1999)
3. Baier, Dwyer & Tamura (2006)
4. Maddison Project (2014)
5. B. R. Mitchell (2003)
6. Morrisson & Murtin (2009)

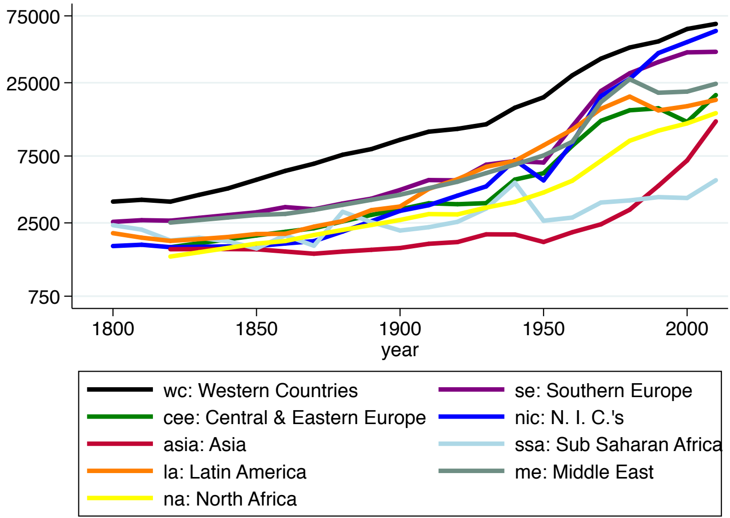
$$h_t = exp(.1E + g(\text{experience} = \chi)) \tag{1}$$

$$g(\chi) = .0495\chi - .0007\chi^2 \tag{2}$$

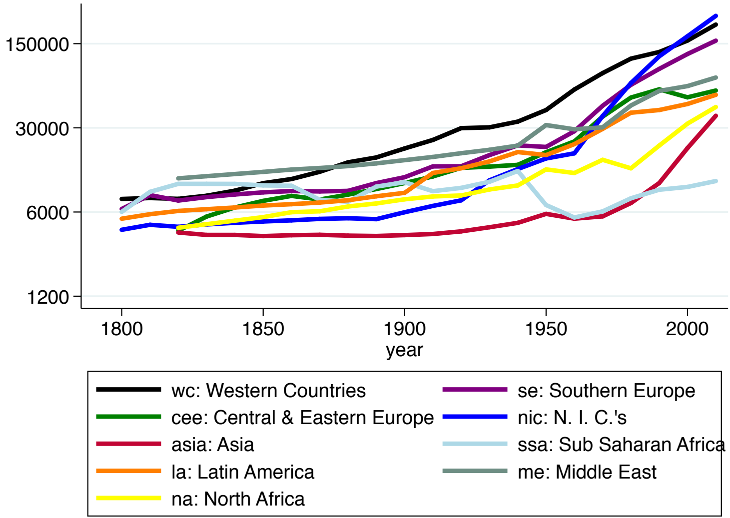
Nine Geographic Regions

- Western Countries
- Southern Europe
- Central & Eastern Europe
- Newly Industrialized Countries
- Asia
- Sub-Saharan Africa
- Latin America
- Middle East
- North Africa

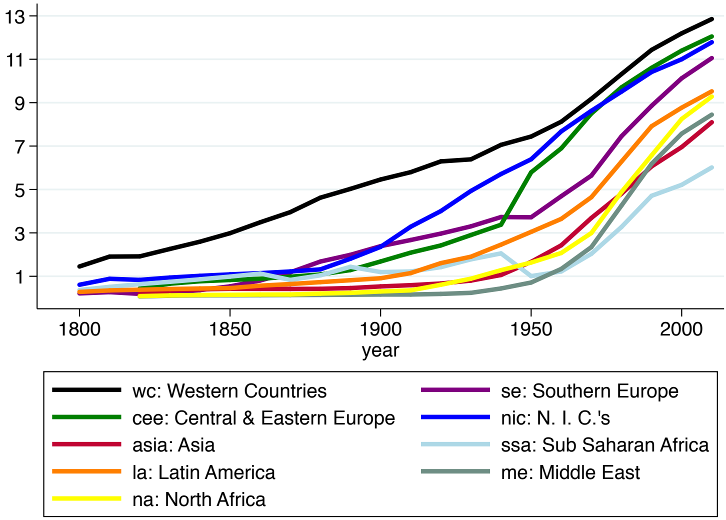
# Real Output per Worker



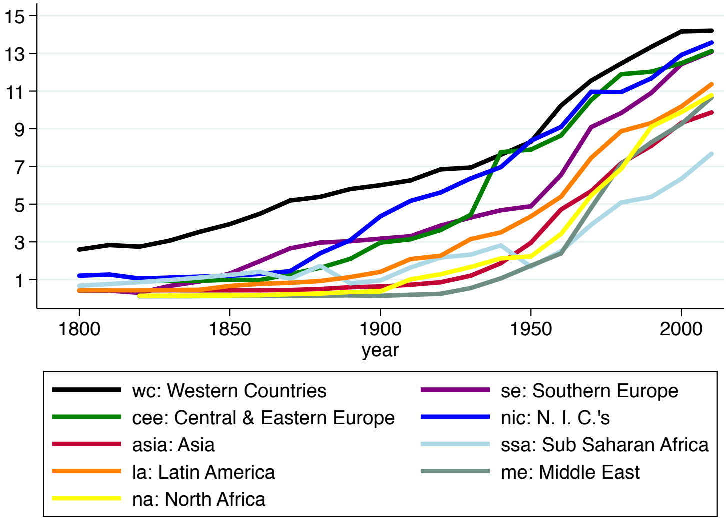
# Real Physical Capital per Worker



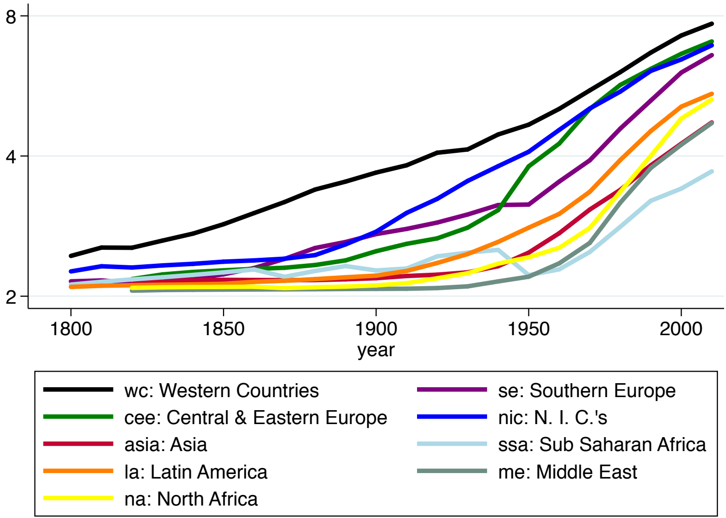
# Schooling per Worker



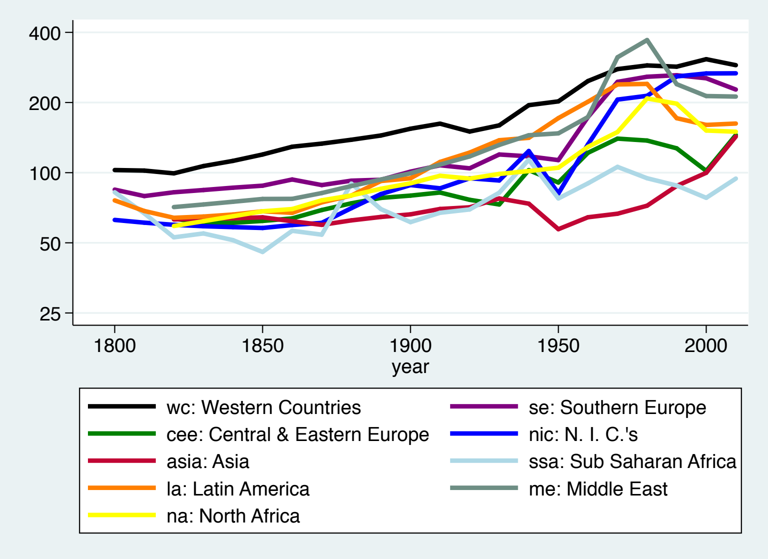
# Schooling per Young Worker



# Human Capital per Worker



# Total Factor Productivity



# Growth Accounting

Table: Growth Accounting: Labor Force - Duration Weighted

| | | Annualized Growth Rates | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Region | N | y | k | hc | x | tfp | $s_x$ | $s_{tfp}$ |
| World | 168 | 1.20% | 1.26% | 0.48% | 0.74% | 0.46% | 0.615 | 0.385 |
| WC | 18 | 1.34 | 1.54 | 0.50 | 0.84 | 0.50 | 0.626 | 0.374 |
| SE | 8 | 1.46 | 1.65 | 0.57 | 0.93 | 0.53 | 0.636 | 0.364 |
| CEE | 24 | 1.29 | 1.38 | 0.52 | 0.80 | 0.49 | 0.623 | 0.377 |
| NIC | 5 | 1.79 | 2.07 | 0.56 | 1.06 | 0.73 | 0.592 | 0.408 |
| Asia | 20 | 1.13 | 1.18 | 0.44 | 0.68 | 0.45 | 0.604 | 0.396 |
| SSA | 48 | 1.07 | 0.74 | 0.72 | 0.73 | 0.34 | 0.681 | 0.319 |
| LA | 28 | 1.08 | 1.14 | 0.49 | 0.70 | 0.38 | 0.651 | 0.349 |
| ME | 12 | 1.18 | 0.85 | 0.58 | 0.67 | 0.51 | 0.566 | 0.434 |
| NA | 5 | 1.25 | 1.31 | 0.50 | 0.77 | 0.48 | 0.613 | 0.387 |

# Variance Decomposition of Growth: Traditional

1. Egalitarian
   - Klenow & Rodriguez-Clare: KRC

$$1 = \frac{\sigma^2_{g_A} + \sigma_{g_x, g_A}}{\sigma^2_{g_y}} + \frac{\sigma^2_{g_A} + \sigma_{g_x, g_A}}{\sigma^2_{g_y}} \quad (3)$$

2. Capital Deepening: $\frac{k}{y}$
   - Klenow & Rodriguez-Clare: KRC2

$$1 = \frac{\sigma^2_{g_{\hat{A}}} + \sigma_{g_{\hat{x}}, g_{\hat{A}}}}{\sigma^2_{g_y}} + \frac{\sigma^2_{g_{\hat{A}}} + \sigma_{g_{\hat{x}}, g_{\hat{A}}}}{\sigma^2_{g_y}} \quad (4)$$

# Variance Decomposition of Growth: Alternatives

TFP growth induces factor accumulation

- Neoclassical growth model with exogenous technological progress
- Romer (1990), Acemoglu (several)

$$1 = \frac{(\sigma_{g_A} + \sigma_{g_x}\rho_{g_x,g_A})^2}{\sigma_{g_y}^2} + \frac{(1-\rho_{g_x,g_A}^2)\sigma_{g_x}^2}{\sigma_{g_y}^2} \qquad (5)$$

Factor accumulation induces TFP growth

- Romer (1986)
- Lucas (1988)
- Tamura (2002,2006)

$$1 = \frac{(\sigma_{g_x} + \sigma_{g_A}\rho_{g_x,g_A})^2}{\sigma_{g_y}^2} + \frac{(1-\rho_{g_x,g_A}^2)\sigma_{g_a}^2}{\sigma_{g_y}^2} \qquad (6)$$

# Variance Decomposition of Growth: Alternatives

3. TFP growth induces factor accumulation: average share

$$\bar{S}_{g_A} = \frac{(\sigma_{g_A} + \sigma_{g_x}\rho_{g_x,g_A})^2 + (1 - \rho^2_{g_x,g_A})\sigma^2_{g_A}}{2\sigma^2_{g_y}} \tag{7}$$

4. Factor accumulation induces TFP growth: average share

$$\bar{S}_{g_x} = \frac{(\sigma_{g_x} + \sigma_{g_A}\rho_{g_x,g_A})^2 + (1 - \rho^2_{g_x,g_A})\sigma^2_{g_x}}{2\sigma^2_{g_y}} \tag{8}$$

# Results

Table: Variance Decomposition of Growth: Plausible Bounds

| Region | N | $\frac{\sigma_{g_x,g_y}}{\sigma^2_{g_y}}$ | $\frac{\sigma_{g_A,g_y}}{\sigma^2_{g_y}}$ | $\frac{\sigma_{g_{\hat{x}},g_y}}{\sigma^2_{g_y}}$ | $\frac{\sigma_{g_{\hat{A}},g_y}}{\sigma^2_{g_y}}$ | $\bar{S}_{g_x}$ | $\bar{S}_{g_A}$ | $x_{bdt}$ | $A_{bdt}$ |
|---|---|---|---|---|---|---|---|---|---|
| World | 168 | .45 | .55 | .18 | .82 | .45 | .55 | .22 | .78 |
| WC | 18 | .30 | .70 | -.04 | 1.04 | .33 | .67 | .46 | .54 |
| SE | 8 | .42 | .58 | .14 | .86 | .50 | .50 | .50 | .50 |
| CEE | 24 | .67 | .33 | .51 | .49 | .65 | .35 | .28 | .72 |
| NIC | 5 | .16 | .84 | -.25 | 1.25 | .22 | .78 | .64 | .36 |
| Asia | 20 | .57 | .43 | .36 | .64 | .57 | .43 | .40 | .60 |
| SSA | 48 | .43 | .57 | .14 | .86 | .44 | .56 | .37 | .63 |
| LA | 28 | .41 | .59 | .11 | .89 | .42 | .58 | .22 | .78 |
| ME | 12 | .44 | .56 | .16 | .84 | .49 | .51 | .44 | .56 |
| NA | 5 | 1.26 | -.26 | 1.38 | -.38 | .70 | .30 | .84 | .16 |

# Results

Table: Variance Decomposition of Growth: Plausible Bounds

| Region | N | $\frac{\sigma_{g_X,g_Y}}{\sigma^2_{g_Y}}$ | $\frac{\sigma_{g_A,g_Y}}{\sigma^2_{g_Y}}$ | $\frac{\sigma_{g_{\hat{X}},g_Y}}{\sigma^2_{g_Y}}$ | $\frac{\sigma_{g_{\hat{A}},g_Y}}{\sigma^2_{g_Y}}$ | $\bar{S}_{g_X}$ | $\bar{S}_{g_A}$ |
|---|---|---|---|---|---|---|---|
| larger regions | | | | | | | |
| (1) WC & NIC | 23 | .29 | .71 | -.06 | 1.06 | .32 | .68 |
| (2): (1) & SE | 31 | .41 | .59 | .12 | .88 | .48 | .52 |
| (3): (2) & NA | 36 | .42 | .58 | .14 | .86 | .47 | .53 |
| (4); (3) & Asia | 56 | .45 | .55 | .18 | .82 | .47 | .53 |
| (5): (4) & LA | 84 | .42 | .58 | .14 | .86 | .44 | .56 |
| (6); (5) & SSA | 132 | .42 | .58 | .13 | .87 | .44 | .56 |
| (7): (6) & $ME_{not\ opec}$ | 135 | .42 | .58 | .13 | .87 | .44 | .56 |
| (8): (7) & CEE | 159 | .45 | .55 | .18 | .82 | .45 | .55 |

# Intergenerational human capital accumulation

$$h_{15,it} = A\bar{h}_t^{\rho_{it}}\left(\frac{h_{25,it-10} + h_{35,it-10}}{2}\right)^{\beta-.1\rho_{it}} exp(.1E_{it-10} + g(\chi_{it-10})) \quad (9)$$

$$\rho_{it} = 0 : \text{ no spillovers} \quad (10)$$

$$\rho_{it} = \min\{.35, \frac{E_{it-10}}{30}\} \quad (11)$$

# Intergenerational Elasticity of Earnings

Table: Estimates of Intergenerational Elasticity of Earnings: $\beta$

| Country | Links | Estimate range | Median range | Source |
|---|---|---|---|---|
| USA | father & sons | [.146, .495] | .327 | T 4 Olivetti & Passerman |
| USA | father & sons | [.261, .535] | .355 | T 4.2 Grawe |
| Canada | father & sons | [.110, .256] | .211 | T 4.3 Grawe |
| Germany | father & sons | [-.280, .313] | .065 | T 4.4 Grawe |
| UK | father & sons | [.344, .814] | .579 | T 4.5 Grawe |
| Malaysia | father & sons | [.283, .791] | .537 | T 4.6 Grawe |
| USA | parents & sons | [.302, .521] | .343 | T 5.5 Mayer & Lopoo |
| USA | father & sons | [.106, .416] | .368 | T 3 Lefgren, et al |
| multiple | father & children | [.110, .600] | .400 | T 7.5 Mulligan |
| multiple | father & sons | [-.044, .707] | .356 | T 4 & app. Bjorklund & Jantti |

# Intergenerational human capital accumulation

$$H_{it} = \sum_{j=1}^{5} s_{j,t} h_{j,t} \tag{12}$$

$$x_1 = x_{15-24} \tag{13}$$

$$x_2 = x_{25-34} \tag{14}$$

$$x_3 = x_{35-44} \tag{15}$$

$$x_4 = x_{45-54} \tag{16}$$

$$x_5 = x_{55-64} \tag{17}$$

$$x = s,\ h \tag{18}$$

# Human capital in country i

$$h_{15,it} = A\bar{h}_t^{\rho_{it}}(\frac{h_{25,it-10} + h_{35,it-10}}{2})^{\beta-.1\rho_{it}} exp(.1E_{it-10} + g(\chi_{it-10})) \quad (19)$$

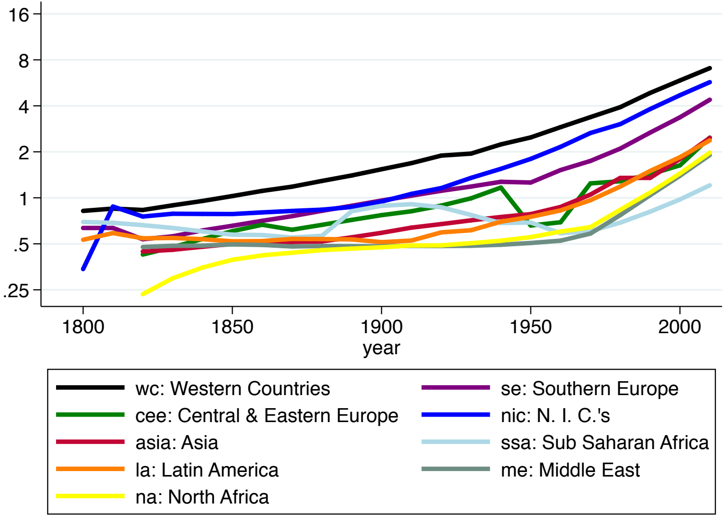
$$h_{25,it} = h_{15,it-10} exp(g(\chi_{15,it-10} + 10) - g(\chi_{15,it-10})) \quad (20)$$

$$h_{35,it} = h_{25,it-10} exp(g(\chi_{25,it-10} + 10) - g(\chi_{25,it-10})) \quad (21)$$

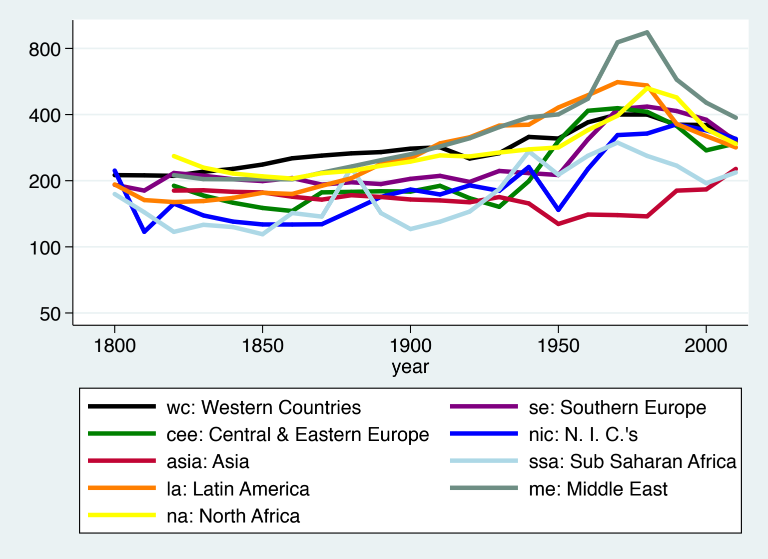
$$h_{45,it} = h_{35,it-10} exp(g(\chi_{35,it-10} + 10) - g(\chi_{35,it-10})) \quad (22)$$

$$h_{55,it} = h_{45,it-10} exp(g(\chi_{45,it-10} + 10) - g(\chi_{45,it-10})) \quad (23)$$

# Human Capital per Worker



# Total Factor Productivity



# New Human Capital

Table: Growth Accounting: $\beta = .375$ & $\rho > 0$ Labor Force - Duration Weighted

| | | Annualized Growth Rates | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Region | N | y | k | hc | x | tfp | $s_x$ | $s_{tfp}$ |
| World | 168 | 1.20% | 1.26% | 0.95% | 1.05% | 0.14% | 0.880 | 0.120 |
| WC | 18 | 1.34 | 1.54 | 0.96 | 1.15 | 0.19 | 0.857 | 0.143 |
| SE | 8 | 1.46 | 1.65 | 1.14 | 1.31 | 0.15 | 0.897 | 0.103 |
| CEE | 24 | 1.29 | 1.38 | 0.92 | 1.07 | 0.22 | 0.830 | 0.170 |
| NIC | 5 | 1.79 | 2.07 | 1.53 | 1.71 | 0.08 | 0.955 | 0.045 |
| Asia | 20 | 1.13 | 1.18 | 0.93 | 1.02 | 0.11 | 0.900 | 0.100 |
| SSA | 48 | 1.07 | 0.74 | 0.96 | 0.89 | 0.18 | 0.831 | 0.169 |
| LA | 28 | 1.08 | 1.14 | 0.73 | 0.87 | 0.21 | 0.801 | 0.199 |
| ME | 12 | 1.18 | 0.85 | 0.92 | 0.89 | 0.28 | 0.759 | 0.241 |
| NA | 5 | 1.25 | 1.31 | 1.12 | 1.18 | 0.07 | 0.944 | 0.056 |

# New Human Capital

Table: Variance Decomposition of Growth: $\beta = .375$ & $\rho > 0$

| Region | N | $\frac{\sigma_{g_x, g_y}}{\sigma^2_{g_y}}$ | $\frac{\sigma_{g_A, g_y}}{\sigma^2_{g_y}}$ | $\frac{\sigma_{g_{\hat{x}}, g_y}}{\sigma^2_{g_y}}$ | $\frac{\sigma_{g_{\hat{A}}, g_y}}{\sigma^2_{g_y}}$ | $\bar{S}_{g_x}$ | $\bar{S}_{g_A}$ | $x_{bdt}$ | $A_{bdt}$ |
|---|---|---|---|---|---|---|---|---|---|
| World | 168 | .95 | .05 | .92 | .08 | .94 | .06 | .22 | .78 |
| WC | 18 | .99 | .01 | .98 | .02 | .99 | .01 | .46 | .54 |
| SE | 8 | .95 | .05 | .93 | .07 | .95 | .05 | .50 | .50 |
| CEE | 24 | 1.00 | .00 | .99 | .01 | .98 | .02 | .28 | .72 |
| NIC | 5 | 1.03 | -.03 | 1.04 | -.04 | .97 | .03 | .64 | .36 |
| Asia | 20 | .93 | .07 | .90 | .10 | .91 | .09 | .40 | .60 |
| SSA | 48 | .92 | .08 | .88 | .12 | .92 | .08 | .37 | .63 |
| LA | 28 | .94 | .06 | .91 | .09 | .92 | .08 | .22 | .78 |
| ME | 12 | .89 | .11 | .83 | .17 | .80 | .20 | .44 | .56 |
| NA | 5 | 1.02 | -.02 | 1.03 | -.03 | .98 | .02 | .84 | .16 |

# New Human Capital

Table: Variance Decomposition of Growth: $\beta = .375$ & $\rho > 0$

| Region | N | $\frac{\sigma_{g_X,g_Y}}{\sigma^2_{g_Y}}$ | $\frac{\sigma_{g_A,g_Y}}{\sigma^2_{g_Y}}$ | $\frac{\sigma_{g_{\hat{X}},g_Y}}{\sigma^2_{g_Y}}$ | $\frac{\sigma_{g_{\hat{A}},g_Y}}{\sigma^2_{g_Y}}$ | $\bar{S}_{g_x}$ | $\bar{S}_{g_A}$ |
|---|---|---|---|---|---|---|---|
| larger regions | | | | | | | |
| (1) WC & NIC | 23 | 1.02 | -.02 | 1.03 | -.03 | .98 | .02 |
| (2): (1) & SE | 31 | .95 | .05 | .93 | .07 | .95 | .05 |
| (3): (2) & NA | 36 | .95 | .05 | .92 | .08 | .94 | .06 |
| (4); (3) & Asia | 56 | .93 | .07 | .90 | .10 | .91 | .09 |
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| (7): (6) & $ME_{\text{not opec}}$ | 135 | .94 | .06 | .91 | .09 | .94 | .06 |
| (8): (7) & CEE | 159 | .96 | .04 | .93 | .07 | .96 | .04 |

# Conclusion

New long run data

- Inputs, human & physical capital, explain 61% of long run growth
- Variance decomposition of growth rates: inputs plausibly explain 15-50%

Intergenerational human capital accumulation

- Inputs, human & physical capital, explain 90% of long run growth
- Variance decomposition of growth rates: inputs plausibly explain 95%