Human Capital and Macro-Economic Development: A Review of the Evidence

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SUPPLEMENTARY ONLINE APPENDIX

This Appendix illustrates the methodology underlying the development accounting exercises discussed in the paper. It provides first a discussion of the general setup in section S1, and then goes through various ways to measure human capital in sections S2-S7.

S1 Setup

The paper considers implementations of development accounting based on a Cobb-Douglas production function, which can be written in per worker terms as

$$y_c = A_c k_c^{\alpha} h_c^{1-\alpha}$$

where the subscript c indexes countries, y_c, k_c and h_c are GDP, physical and human capital per worker, and A_c denotes total factor productivity. Following Klenow and Rodríguez-Clare (1997) and many papers thereafter, output per worker is rewritten as a function of physical capital intensity, human capital and TFP,

$$y_c = \left(\frac{k_c}{y_c}\right)^{\frac{\alpha}{1-\alpha}} A_c^{\frac{1}{1-\alpha}} h_c \tag{S1}$$

The logic of using the formulation in (S1) for development accounting is as follows. Standard models of physical capital accumulation predict that an increase in h_c (as well as an increase in $A_c^{\frac{1}{1-\alpha}}$) induces a proportional increase in k_c and y_c, so that the capital to output

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ratio is unaffected. By performing counterfactuals where h_c is changed and $\frac{k_c}{y_c}$ is kept fixed, one can give "credit" to human capital for the variation in physical capital induced by it.[1]

Given that (S1) is multiplicative in h_c, the counterfactual GDP per worker with the US level of human capital can be computed without any data on physical capital or any calibration of α. In particular, for given measures of human capital h_c and h_{US}, the counterfactual relative output per worker for country c is given by

$$\frac{\tilde{y}_c}{y_{US}} = \frac{y_c/y_{US}}{h_c/h_{US}} \tag{S2}$$

where a value of 1 would imply that, everything else equal, equalizing human capital per worker would close the income gap between country c and the United States. This is the summary statistics used throughout the paper and this Appendix when presenting the development accounting results.

S2 Educational Attainment

Following Bils and Klenow (2000), human capital per worker is assumed to take the form

$$h_c = e^{\beta s_c} \tag{S3}$$

where s_c is the average years of schooling completed in country c. The logarithm of human capital per worker depends linearly on s_c, with β being the slope of this relationship.[2]

The calibration of β is based on microeconomic evidence on returns to education. Under the assumption of perfectly competitive labor markets, (S3) implies a log-linear relationship between wages and years of schooling. As discussed in the paper, reviews of the international evidence (Psacharopoulos, 1994; Psacharopoulos and Patrinos, 2004; Caselli et al., 2016) suggest a Mincerian return of 10%, or $\beta = 0.1$. The development accounting results are displayed in Table S1.

[1]The treatment of physical and human capital is asymmetric here, as human capital differences that arise as responses to pre-existing differences in technology or physical capital are not separately accounted for. Given that the paper considers several dimensions of human capital, it is unclear what model of human capital accumulation should be used to assess the strength of these responses. For this reason, no adjustment is implemented in this respect. Section 5 of the paper discusses more structural approaches that shed light on the link between endogenous human capital accumulation and productivity differences across countries.

[2]Several authors, including Hall and Jones (1999) and Caselli (2005), consider versions of (S3) where years of schooling enter non-linearly in the exponent, to match the fact that returns to schooling are often found to be different across levels of educational attainment. These modifications have limited impact on the development accounting results.

S3 Cognitive Skills

Human capital per worker is given by

$$h_c = e^{\beta s_c + \delta t_c}$$

where t_c is the measure of average cognitive skills discussed in the paper and δ is a parameter governing the conversion from this measure to human capital. The parameters β and δ can be calibrated as the coefficients of years of schooling and test performance in a regression that includes both as controls. Following Hanushek et al. (2017), these are set as $\beta = 0.08$ and $\delta = 0.17$. The development accounting results are displayed in Table S1.

S4 Health

Following Weil (2007), human capital per worker takes the form

$$h_c = e^{\beta s_c + \gamma r_c} \tag{S4}$$

where r_c is the average health status as proxied by the survival rate to the age of 65.

Implementing the development accounting exercise requires picking a value for γ. As discussed in the paper, one cannot rely directly on microeconomic evidence in this case, since the survival rate is an aggregate statistics and does not vary within countries. To make progress, Weil (2007) postulates a linear cross-country relationship between the survival rate r_c and average height v_c, $v_c = \alpha_r + \gamma_r r_c$, as well as a within-country log-linear relationship between wages and individual height,

$$\log w_{i,c} = \alpha_v + \beta s_{i,c} + \gamma_v v_{i,c} + \varepsilon_{i,c}$$

Since γ_r and γ_v can be estimated directly, one can identify γ in (S4) as $\gamma = \gamma_r \gamma_v$. The estimates in Weil (2007) imply $\gamma = 0.65$; moreover, β is set equal to 0.1 as before.[3] The development accounting results are displayed in Table S1.

[3]This is potentially problematic as educational attainment and health (or height) are likely to be positively correlated, and therefore the estimate of $\beta = 0.1$ from Mincerian regression without health controls might already partially reflect the effect of health. While the estimates Weil (2007) refers to for the calibration of γ are conditional on educational attainment, he does not report the corresponding estimates for the education controls. However, reasonable changes to the value of β do not massively affect the magnitude of the development accounting results.

S5 Experience

Following Lagakos et al. (2018), human capital per worker is

$$h_c = e^{\beta s_c + \phi_c(\theta_c)}$$

where θ_c is the average experience and $\phi_c(.)$ is a country-specific function, implying different returns to experience across countries. Since most countries in Lagakos et al. (2018)'s sample have between 15 and 19 years of average experience, the estimated returns for this category are used for the development accounting calculations.[4] The results are displayed in Table S2.

S6 Development Accounting with Migration Data

According to the model in Schoellman (2012), the relationship between human capital per worker and average years of schooling can be written as

$$h_c = e^{\frac{\beta s_c}{\eta}} \tag{S5}$$

where β is the Mincerian return for non-migrants (common across countries) and η is a parameter between 0 and 1, in equilibrium positively related to the elasticity of years of schooling with respect to education quality. Equation (S5) differs from the standard Mincerian specification in (S3) only because of the presence of η in the denominator of the exponent. Intuitively, if individuals go to school for longer when educational quality is higher, for a given gap in years of schooling we can infer a larger gap in human capital than what implied by the Mincerian return alone.

The key step for development accounting is the choice of η. Schoellman (2012) estimates this parameter from the observed cross-country relationship between average years of schooling and educational quality, proxied by immigrants' returns to education. He finds that $\eta = 0.5$, which implies that the resulting logarithm of human capital per worker is twice as large compared to when educational quality is not accounted for. The development accounting results based on (S5) are displayed in Table S2.

Hendricks and Schoellman (2018) exploit variation in wage gains at migration to provide an alternative quantification of human capital. Given the production function in (S1), the

[4] The calculations are based on returns to foreign experience from the baseline specification in Lagakos et al. (2018). The authors emphasize that this approach ignores that life-cycle wage growth also depends on the time allocated to human capital investment. They incorporate this aspect in an alternative exercise, disciplined by a Ben-Porath model of human capital accumulation. They find that the resulting contribution of experience in development accounting is marginally lower.

wage of a migrant from country c (and corresponding human capital h_c) when working in the US can be written as

$$w_{US,c} = (1-\alpha)\left(\frac{k_{US}}{y_{US}}\right)^{\frac{\alpha}{1-\alpha}} A_{US}^{\frac{1}{1-\alpha}} h_c \tag{S6}$$

while the pre-migration wage of the same worker is (S6) with k_{US}, y_{US} and A_{US} replaced by the corresponding quantities for country c. It follows that the wage gain upon migration is

$$\frac{w_{US,c}}{w_{c,c}} = \left(\frac{k_{US}/y_{US}}{k_c/y_c}\right)^{\frac{\alpha}{1-\alpha}} \left(\frac{A_{US}}{A_c}\right)^{\frac{1}{1-\alpha}}$$

so that the relative human capital per worker can be found as

$$\frac{h_{US}}{h_c} = \frac{y_{US}/y_c}{w_{US,c}/w_{c,c}}$$

The corresponding development accounting results are displayed in Table S2.

S7 Imperfect Substitution

The aggregate human capital stock is a combination of two types of workers, skilled and unskilled, so that human capital per worker can be written as

$$h_c = \left[(h_{S,c} l_{S,c})^{\frac{\varepsilon-1}{\varepsilon}} + (h_{U,c} l_{U,c})^{\frac{\varepsilon-1}{\varepsilon}}\right]^{\frac{\varepsilon}{\varepsilon-1}} \tag{S7}$$

where $l_{S,c}$ and $l_{U,c}$ are the shares of skilled and unskilled workers in the labor force, and $h_{S,c}$ and $h_{U,c}$ represent the amount of labor services supplied by a given skilled and unskilled worker. The aggregator in (S7) features a constant elasticity of substitution equal to ε. Assuming perfectly competitive labor markets, the wage ratio between skilled and unskilled workers (skill premium) is

$$\frac{w_{S,c}}{w_{U,c}} = \left(\frac{h_{S,c}}{h_{U,c}}\right)^{\frac{\varepsilon-1}{\varepsilon}} \left(\frac{l_{S,c}}{l_{U,c}}\right)^{-\frac{1}{\varepsilon}} \tag{S8}$$

The key observation is that, while $l_{S,c}/l_{U,c}$ is substantially higher in rich countries, $w_{S,c}/w_{U,c}$ is relatively flat across countries (Caselli and Coleman, 2006; Jones, 2014; Rossi, 2017). According to (S8), for the range of values for ε estimated in the empirical literature, this implies that $h_{S,c}/h_{U,c}$ is higher in rich countries, i.e. that skilled workers are relatively more "efficient" in those countries.

Human capital per worker is computed from (S7), where $h_{S,c}/h_{U,c}$ is backed out from

(S8) using $\varepsilon = 1.5$ as estimated by Ciccone and Peri (2005), and where, following the baseline exercise in both Jones (2014) and Caselli and Ciccone (2019), $h_{U,c}$ is assumed not to vary across countries. Skill premia are constructed as in Jones (2014): the wage for each level of eduational attainment is imputed using Mincerian returns, and $w_{S,c}$ and $w_{U,c}$ are computed as weighted averages across the educational categories belonging to the skilled and unskilled groups.[5] The skilled category includes workers with some tertiary education.

The counterfactual based on Jones (2014)'s thought experiment is then computed using (S2). To implement the counterfactual suggested by Caselli and Ciccone (2019), one needs to compute the level of human capital per worker that would result if the shares of skilled and unskilled labor were equalized with those of the United States,

$$h_c^{US} = \left[(h_{S,c} l_{S,US})^{\frac{\varepsilon-1}{\varepsilon}} + (h_{U,c} l_{U,US})^{\frac{\varepsilon-1}{\varepsilon}} \right]^{\frac{\varepsilon}{\varepsilon-1}}$$

where $h_{H,c}$ and $h_{U,c}$ are treated as technological parameters and kept fixed. The counterfactual relative GDP per worker is then given by

$$\frac{\tilde{y}_c}{y_{US}} = \frac{y_c / y_{US}}{h_c / h_c^{US}}$$

The development accounting results based on both counterfactuals are displayed in Table S2.

[5]As in Jones (2014), the Mincerian return is 13% for countries with an average of completed years of schooling of 4 less, 10% for countries between 4 and 8 and 7% for countries above 8.

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Tables

Table S1: Development Accounting: Educational Attainment, Cognitive Skills and Health

		Educational Attainment		Educational Attainment & Cognitive Skills		Educational Attainment & Health	
	y_c/y_{US}	h_c/h_{US}	$\tilde{y}_c/y_{US}$	h_c/h_{US}	$\tilde{y}_c/y_{US}$	h_c/h_{US}	$\tilde{y}_c/y_{US}$
15^{th} Percentile (Ghana)	0.06	0.51	0.11	2.13	0.12	0.44	0.13
30^{th} Percentile (Philippines)	0.14	0.59	0.23	1.88	0.26	0.53	0.26
45^{th} Percentile (Brazil)	0.24	0.56	0.44	1.97	0.48	0.54	0.46
60^{th} Percentile (Argentina)	0.40	0.67	0.59	1.62	0.65	0.66	0.60
75^{th} Percentile (New Zealand)	0.56	0.81	0.69	1.17	0.66	0.83	0.67
90^{th} Percentile (France)	0.80	0.76	1.06	1.22	0.98	0.77	1.03

Notes: The Table shows development accounting results when human capital is measured as educational attainment, as a combination of educational attainment and cognitive skills (as measured by test scores) and as a combination of educational attainment and health (as measured by the survival rate to age 65). y_c/y_{US} and h_c/h_{US} denote GDP and human capital per worker in country c, relative to the corresponding quantities in the United States. $\tilde{y}_c/y_{US}$ denotes the counterfactual relative GDP per worker in country c with the US level of human capital per worker. GDP per worker is taken from version 9.0 of the Penn World Tables (Feenstra et al., 2015), educational attainment from Barro and Lee (2013), average test scores from Hanushek and Woessmann (2012a) and Hanushek and Woessmann (2012b), and the survival rate is computed from the World Development Indicators (World Bank, 2019).

Table S2: Development Accounting: Educational Attainment and Experience

		Educational Attainment		Educational Attainment & Experience	
	y_c/y_{FR}	h_c/h_{FR}	$\tilde{y}_c/y_{FR}$	h_c/h_{FR}	$\tilde{y}_c/y_{FR}$
15^{th} Percentile (Ghana)	0.07	0.68	0.10	0.27	0.26
30^{th} Percentile (Philippines)	0.17	0.78	0.22	0.26	0.66
45^{th} Percentile (Brazil)	0.31	0.74	0.41	0.39	0.78
60^{th} Percentile (Argentina)	0.50	0.89	0.56	0.38	1.32
75^{th} Percentile (Greece)	0.72	0.96	0.75	0.44	1.63
90^{th} Percentile (France)	1	1	1	1	1

Notes: The Table shows development accounting results when human capital is measured as educational attainment and as a combination of educational attainment and experience. y_c/y_{FR} and h_c/h_{FR} denote GDP and human capital per worker in country c, relative to the corresponding quantities in France. $\tilde{y}_c/y_{FR}$ denotes the counterfactual relative GDP per worker in country c with the France level of human capital per worker. GDP per worker is taken from version 9.0 of the Penn World Tables (Feenstra et al., 2015), educational attainment from Barro and Lee (2013), and returns to experience from Lagakos et al. (2018).

Table S3: Development Accounting: Migrants

		Schoellman (2012)		Hendricks & Schoellman (2018)	
	y_c/y_{US}	h_c/h_{US}	$\tilde{y}_c/y_{US}$	h_c/h_{US}	$\tilde{y}_c/y_{US}$
15^{th} Percentile (Ghana)	0.06	0.26	0.22	0.10	0.56
30^{th} Percentile (Philippines)	0.14	0.35	0.39	0.24	0.59
45^{th} Percentile (Brazil)	0.24	0.32	0.78	0.34	0.72
60^{th} Percentile (Argentina)	0.40	0.45	0.88	0.60	0.66
75^{th} Percentile (New Zealand)	0.56	0.65	0.86	0.92	0.61
90^{th} Percentile (France)	0.80	0.57	1.39	0.92	0.87

Notes: The Table shows development accounting results when human capital is measured using the approaches of Schoellman (2012) and Hendricks and Schoellman (2018). y_c/y_{US} and h_c/h_{US} denote GDP and human capital per worker in country c, relative to the corresponding quantities in the United States. $\tilde{y}_c/y_{US}$ denotes the counterfactual relative GDP per worker in country c with the US level of human capital per worker. GDP per worker is taken from version 9.0 of the Penn World Tables (Feenstra et al., 2015).

Table S4: Development Accounting: Imperfect Substitution

		Jones (2014)		Caselli & Ciccone (2019)	
	y_c/y_{US}	h_c/h_{US}	$\tilde{y}_c/y_{US}$	h_c^{US}/h_{US}	$\tilde{y}_c/y_{US}$
15^{th} Percentile (Ghana)	0.06	0.14	0.41	1.38	0.04
30^{th} Percentile (Philippines)	0.14	0.27	0.51	1.04	0.13
45^{th} Percentile (Brazil)	0.24	0.21	1.16	1.03	0.24
60^{th} Percentile (Argentina)	0.40	0.17	2.29	1.21	0.33
75^{th} Percentile (New Zealand)	0.56	0.57	0.98	0.95	0.59
90^{th} Percentile (France)	0.80	0.27	2.91	1.03	0.77

Notes: The Table shows development accounting results with imperfect substitution between skilled and unskilled labor, following the alternative approaches of Jones (2014) and Caselli and Ciccone (2019). y_c/y_{US} and h_c/h_{US} denote GDP and human capital per worker in country c, relative to the corresponding quantities in the United States. h_c^{US}/h_{US} denotes the counterfactual relative human capital per worker in country c with the US shares of skilled and unskilled labor. $\tilde{y}_c/y_{US}$ denotes the counterfactual relative GDP per worker in country c with either the US shares and relative efficiency of skilled and unskilled labor (Jones (2014)'s approach), or the US shares and country c's relative efficiency of skilled and unskilled labor (Caselli and Ciccone (2019)'s approach). GDP per worker is taken from version 9.0 of the Penn World Tables (Feenstra et al., 2015), while the shares of skilled and unskilled labor are computed from Barro and Lee (2013).