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Education Quality and the Empirics of Economic Growth

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We extend Mankiw, Romer and Weil's (1992) classic paper by introducing differences in education quality (proxied by students' performance on the PISA test). This substantially reduces the role of human capital investment rates in explaining cross-country income differences. More importantly, the coefficient on this variable is now consistent with microeconomic evidence on returns to education.

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We extend Mankiw, Romer and Weil's (1992) classic paper by introducing differences in education quality (proxied by students' performance on the PISA test). This substantially reduces the role of human capital investment rates in explaining cross-country income differences. More importantly, the coefficient on this variable is now consistent with microeconomic evidence on returns to education.

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1 Introduction

The past few decades have seen the emergence of a literature that seeks to empirically understand why some countries are so much richer than others. To this day, Mankiw, Romer and Weil's (1992) paper – henceforth MRW – remains one of the most important contributions to the field. They estimate an augmented version of the Solow model, with both physical and human capital as inputs. The model is able to account for a large fraction of income per capita dispersion across countries. Furthermore, the implied estimated coefficients (factor shares in total income) are consistent with data from national accounts.

Nonetheless, their coefficient on human capital is large, especially in comparison to estimates of returns to education (see, for instance, Klenow and Rodriguez-Claire [1997] and Acemoglu [2009]). This may be due to omitted variables that are correlated with

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human capital and affect income differences directly, such as differences in education quality. The present paper addresses this issue, by incorporating education quality in MRW's model.

As in Hanushek (2013) and Hanushek and Woessman (2012), we use students' performance on a standardized international test (the PISA test) to measure education quality. Our results imply that such a variable is highly significant, and its inclusion leads to a substantial reduction in the coefficient of human capital. More importantly, this coefficient is now in line with estimates of returns to education from the literature.

Our work is related to other papers that consider alternative candidates for omitted factors in MRW's empirical strategy. For instance, Knowles and Owen (1995) and Ram (2007) include, respectively, health capital and IQ scores in MRW's regressions. Islam (1995) and Caselli, Esquivel and Lefort (1996) take into account countries' unobservable characteristics that do not change over time. Our results are especially related to those found by Hanushek (2013) and Hanushek and Woessman (2012). They estimate Barro-type regressions, with measures of both quantity and quality of human capital. As in our case, the quality variable is highly significant, and its inclusion renders the quantity variable insignificant.

The rest of the paper is organized as follows. In Section 2 we introduce the model and derive the equations to be estimated using cross-country data. Section 3 describes the data and discusses regression results. Section 4 concludes.

2 Model

We introduce education quality into MRW's augmented Solow model as a shifter to the technology of accumulating human capital. There is a single final output (Y), which is produced using physical capital (K), human capital (H) and labor (L) through a Cobb-Douglas technology. Specifically, $Y = K^{\alpha} H^{\beta} (AL)^{1-\alpha-\beta}$, where A and L grow at the constant rates g and n, respectively. A fraction s_k of output is invested in the accumulation of physical capital, while a fraction s_h is invested in human capital. Both inputs depreciate at the constant rate δ. Let $k = K/(AL)$ and $h = H/(AL)$. Education quality (Q) improves the technology of accumulating human capital. The laws of motion for k and h are thus given by:

$$\dot{k} = s_k k^{\alpha} h^{\beta} - (n + g + \delta)k$$
$$\dot{h} = Q s_h k^{\alpha} h^{\beta} - (n + g + \delta)h$$

In steady state, the levels of physical and human capital per efficiency worker are:

$$k^* = \left(\frac{s_k}{n+g+\delta}\right)^{\frac{1-\beta}{1-\alpha-\beta}} \left(\frac{Qs_h}{n+g+\delta}\right)^{\frac{\beta}{1-\alpha-\beta}} \tag{1}$$

$$h^* = \left(\frac{s_k}{n+g+\delta}\right)^{\frac{\alpha}{1-\alpha-\beta}} \left(\frac{Qs_h}{n+g+\delta}\right)^{\frac{1-\alpha}{1-\alpha-\beta}} \tag{2}$$

Following Caselli (2005), we set $Q = \exp\{\phi_\tau \tau\}$, where τ is the country's PISA score. We then substitute equations (1) and (2) into the production function and take logs to find the steady-state income per worker:

$$\begin{aligned} \ln\left(\frac{Y}{L}\right) &= \ln(A) + \frac{\alpha}{1-\alpha-\beta}\ln(s_k) + \frac{\beta}{1-\alpha-\beta}\ln(s_h) \\ &\quad - \frac{\alpha+\beta}{1-\alpha-\beta}\ln(n+g+\delta) + \frac{\beta}{1-\alpha-\beta}\phi_\tau \tau \end{aligned} \tag{3}$$

Based on (3), we estimate the following equation for a cross-section of countries:

$$\ln\left(\frac{Y_i}{L_i}\right) = a + \gamma_k \ln(s_{ki}) + \gamma_h \ln(s_{hi}) + \gamma_n \ln(n_i + g + \delta) + \gamma_\tau \tau_i + \varepsilon_i \tag{4}$$

where a is a constant (which captures the component of parameter A that is common to all countries) and ε_i is an error term (which captures features of parameter A that are heterogeneous across countries). The index i identifies a country in our cross-section. MRW estimate this same equation, but without the PISA score as a regressor.[1]

We call equation (4) the unrestricted regression model, since it does not impose any constraint on the parameters. MRW also estimate a restricted model, which takes into account constraints that arise from their augmented version of the Solow model. Specifically, we can rewrite (3) as follows:

$$\begin{aligned} \ln\left(\frac{Y}{L}\right) &= \ln(A) + \frac{\alpha}{1-\alpha-\beta}[\ln(s_k) - \ln(n+g+\delta)] + \\ &\quad \frac{\beta}{1-\alpha-\beta}[\ln(s_h) - \ln(n+g+\delta)] + \frac{\beta}{1-\alpha-\beta}\phi_\tau \tau \end{aligned}$$

In our case, the restricted regression model to be estimated is then:

[1] Following MRW, we assume that $g + \delta$ does not vary across countries. Specifically, $g + \delta = 5\%$.

$$\ln\left(\frac{Y_i}{L_i}\right) = a + \lambda_k[\ln(s_{ki}) - \ln(n_i + g + \delta)] + \lambda_h[\ln(s_{hi}) - \ln(n_i + g + \delta)] + \lambda_\tau \tau_i + \varepsilon_i \quad (5)$$

Equation (5) also allows us to recover estimates for parameters α, β and ϕ_τ.

3 Data and regression results

To keep our results as comparable as possible to MRW, we follow their empirical strategy very closely. Data for s_k (investment as a share of GDP) and Y/L (output per working-age person) come from the Penn World Table, version 7.1 (PWT 7.1).[2] As for the human-capital investment rate (s_h), we combine gross enrollment rates from UNESCO with school-age population shares from the World Bank databank.[3] Population growth rates are also from the World Bank databank.

We first replicate MRW's main exercise. Table 1 displays the results, with unconstrained regressions in the upper panel and constrained regressions in the lower panel. Column (1) reproduces MRW's main result. They use data from a cross-section of 98 non-oil countries for the period 1960-1985, based on an earlier version of the Penn World Table (mark 4). Their dependent variable is the log of Y/L in 1985. As for independent variables, they use averages over the period 1960-1985.[4]

We then undertake this same exercise, but with data from PWT 7.1. The results are in column (2). In this case, from the 98-country original sample, we were able to find 91 countries, which we use in our estimation. Column (3) displays estimates for a more recent period (1990-2010), once more with data from PWT 7.1. Here, the dependent variable is the log of Y/L in 2010, while averages of right-hand side variables over the whole period serve as regressors. In this case, we could find data for 87 of the 98 countries from the original MRW sample.

Notwithstanding differences in magnitudes across columns, the message is broadly the same. The key variables are statistically significant, and their signs are compatible with those implied by the augmented Solow model. Furthermore, estimates from the restricted model (implied α and β) are consistent with factor shares from national accounts, which

[2] Y/L is real GDP (from PWT 7.1) divided by population aged 15-64 (from the World Bank).

[3] Specifically, the human capital investment rate (s_h) is the secondary gross enrolment rate (from UNESCO) multiplied by the share of population between ages 15-19 (from the World Development Indicators - Health and Population Statistics).

[4] To compute such averages we use data whenever available within the time frame considered. Data on Y/L, investment rates and population growth rates are available on a yearly basis, while data on schooling are available every five years.

put the labor share at approximately 2/3. Adjusted R-squares are sizeable, meaning that the model can account for a large fraction of the income disparity across countries.

We now introduce data on education quality. We take a subsample of 37 countries, which are present in MRW's sample and have data on PISA scores in 2009.[5] Table 2 exhibits regression results. Columns (1) and (2) report estimates for periods 1960-1985 and 1990-2010, respectively, without including the PISA score as a regressor. Coefficients in column (1) are similar to those in Table 1, although less precisely estimated (which is expected given the smaller sample size). In column (2), the coefficient on physical capital falls in magnitude (especially in the unrestricted regression) and becomes statistically insignificant, while the coefficient on human capital rises in magnitude. Nonetheless, the estimated coefficients are still consistent with the augmented Solow model. The implied α's are similar to those obtained for a larger sample in Table 1.

In column (3), we add the 2009 PISA scores to the regression, using the same data as in column (2). The coefficient on this variable is positive and highly significant. Moreover, the coefficient on human capital investment becomes much smaller in magnitude and loses significance. In particular, in the unconstrained regression, the point estimate is cut by more than half when one includes the education quality measure in the regression. The coefficient on physical capital investment becomes negative. The inclusion of the PISA score also considerably increases the adjusted R-squared.

For the sake of robustness, we estimate the model using five alternative time frames, always with a set of countries that have data on PISA scores: 1975-2000, 1980-2000, 1985-2000, 1985-2010 and 1995-2010. The results are similar to those shown in Table 2: the inclusion of PISA scores reduces both the magnitude and significance of the coefficient of s_h. Further, the coefficient on PISA scores is always positive and highly significant ($p < 0.01$).[6]

3.1 Relation with microeconomic evidence on returns to schooling

Based on the development accounting methodology, Acemoglu (2009, p.90-96) constructs bounds for the role of human capital in accounting for cross-country income differences.

[5] We take the simple average between Science and Math scores and divide by 10. Our quality measure thus ranges from 0 to 100 (since PISA scores go from 0 to 1000). This strategy is similar to the one employed by Caselli (2005).

[6] Regression results are not shown for these cases. We use data on Y/L from the last year of the time frame, and averages over the whole period of estimation for s_k, s_h and n. When the last year of the period is 2010, we use PISA scores from 2009; when the period ends in 2000, we use PISA scores from 2000.

In this approach, human capital stocks are seldom measured using a Mincerian specification. Particularly, country i's stock of human capital (per worker) is given by $\exp\{\phi u_i\}$, where u_i is the average number of schooling years of the adult population in country i, and ϕ is the returns to education parameter. Considering only differences in human capital stocks, the income ratio between two countries i and j is $\exp\{\phi(u_i - u_j)\}$.

Acemoglu (2009) considers two values for the returns to education parameter, based on microeconomic evidence: 0.06 and 0.10. In MRW's sample of 98 countries, the maximum difference in average years of schooling is 11.3.[7] This implies that the country with the highest education level would be between $\exp\{0.06 \times 11.3\} = 2.0$ and $\exp\{0.10 \times 11.3\} = 3.1$ times richer than the country with the lowest education level. These two values are displayed in Table 3 (row 1).

How do MRW's findings on the effect of human capital compare with these bounds? In MRW's original sample, the lowest and highest values of s_h are 0.4 and 12, respectively. Using the coefficient of s_h from column (1) of Table 1, this implies that (everything else constant) the income difference between the country with the highest and the country with the lowest schooling would be more than ninefold. Specifically,

$$\exp\{0.65 * [\ln 12 - \ln 0.4]\} = 9.1,$$

which far exceeds the upper limit proposed by Acemoglu, based on microeconomic evidence on returns to education. Rows 2 and 3 in Table 3 display the results of this same exercise, but using the other two estimates for the coefficient of s_h from Table 1. The fourth row uses data from MRW but for the smaller sample of countries (as in column (1) of Table 2). In all three cases, we observe the same pattern: the estimated coefficients of s_h are too large, generating income differences that are inconsistent with microeconomic evidence.

We next present the results for our smaller sample for the more recent period (1990-2010), which allows for the inclusion of PISA scores as a regressor (see row 5 of Table 3). In this case, we use estimated coefficients of s_h from columns (2) and (3) of Table 2. Without including PISA scores as a control, we continue to obtain coefficients that are above the upper bound implied by microeconomic evidence. However, the inclusion of scores leads to a decrease in the coefficient of s_h, which now falls within the bounds. The estimated effect of human capital on income disparity is actually quite close to the lower bound.

[7] Data on years of schooling are from Barro and Lee (2013). In this exercise, we use average years of schooling from persons aged 15 or older. We always use data on years of schooling from the last year of the period considered (1985 in the MRW sample).

We implement the same exercise for the five alternative time frames considered for robustness. In none of the cases does the regression without PISA as a control produce estimates that fall within the bounds. As for estimates including the PISA scores, although we cannot always place the effect of human capital inside the interval, values are much closer to the upper bound. The only exception is that displayed in the last row of the table (for the period 1995-2010). Figure 1 illustrates these results by displaying the six cases in Table 3 for which we have estimates with and without the inclusion of education quality as a control.

4 Conclusion

MRW's classic paper estimates an augmented version of the Solow model by considering differences in physical and human capital investment rates to understand the income disparity across countries. Consistently with the model, they find both investment rates to be highly significant, while their magnitudes are compatible with national income accounts data on factor shares. Nonetheless, their coefficient on human capital investment is too large, producing income differences across countries that are inconsistent with microeconomic evidence on returns to education. This may be due to omitted factors, which are potentially correlated with investment rates while affecting income disparity directly.

Here we consider a candidate for omitted variable: differences in education quality, as proxied by students performance on a standardized international test – the PISA test. We take a subset of 37 countries from the original MRW sample, for which we have data on test scores. For the period 1990-2010, the inclusion of data on education quality reduces substantially the coefficient on human capital, which is now in line with microeconomic evidence on returns to education. In particular, the income disparity implied by human capital investment differences falls within the bounds proposed by Acemoglu (2009). As a robustness check, we consider different time frames in our estimation. Although estimates do not always fall inside the interval proposed by Acemoglu, they are usually much closer to the upper limit relative to cases in which PISA scores were not included in the regression.

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Table 1: Regressions results - Full sample

	MRW database	PWT 7.1	
	1960-1985	1960-1985	1990-2010
Unrestricted regression:			
Constant	6.84***	0.76	−3.40*
	(1.18)	(1.33)	(1.49)
$ln(s_k)$	0.70***	0.42**	1.07***
	(0.13)	(0.15)	(0.20)
$ln(n+g+\delta)$	−1.75***	−2.76***	−4.48***
	(0.42)	(0.48)	(0.47)
$ln(s_h)$	0.65***	0.92***	0.79***
	(0.07)	(0.08)	(0.14)
Adj. R-sq	0.78	0.76	0.79
Restricted regression:			
Constant	7.85***	4.48***	3.46***
	(0.14)	(0.22)	(0.27)
$ln(s_k) - ln(n+g+\delta)$	0.74***	0.48**	1.31***
	(0.12)	(0.16)	(0.21)
$ln(s_h) - ln(n+g+\delta)$	0.66***	0.97***	1.09***
	(0.07)	(0.08)	(0.14)
Adj. R-sq	0.78	0.74	0.74
Observations	98	91	87
Implied α	0.31***	0.20***	0.39***
	(0.04)	(0.06)	(0.05)
Implied β	0.27***	0.40***	0.32***
	(0.03)	(0.04)	(0.04)

Notes: ***, **, and * indicate significance at the 0.1%, 1%, and 5% levels, respectively. Standard errors in parentheses.

Table 2: Regressions results - Subsample (countries with PISA scores)

	MRW database	PWT 7.1	
	1960-1985	1990-2010	1990-2010
Unrestricted regression:			
Constant	7.45***	−1.29	−1.04
	(1.47)	(1.80)	(1.18)
$ln(s_k)$	0.65*	0.10	−0.64*
	(0.27)	(0.43)	(0.30)
$ln(n+g+\delta)$	−1.62**	−3.76***	−1.11
	(0.46)	(0.62)	(0.57)
$ln(s_h)$	0.72**	1.26*	0.56
	(0.23)	(0.56)	(0.38)
PISA score (τ)			0.09***
			(0.01)
Adj. R-sq	0.59	0.49	0.78
Restricted regression:			
Constant	8.05***	4.34***	1.41*
	(0.26)	(0.60)	(0.53)
$ln(s_k) - ln(n+g+\delta)$	0.71**	0.80	−0.43
	(0.23)	(0.43)	(0.31)
$ln(s_h) - ln(n+g+\delta)$	0.74**	2.14***	0.86*
	(0.22)	(0.55)	(0.38)
PISA score (τ)			0.10***
			(0.01)
Adj. R-sq	0.60	0.35	0.75
Observations	37	37	37
Implied α	0.29**	0.20*	-0.30
	(0.09)	(0.10)	(0.30)
Implied β	0.30***	0.54***	0.60***
	(0.08)	(0.09)	(0.16)
Implied ϕ	–	–	0.12
	–	–	(0.06)

Notes: ***, **, and * indicate significance at the 0.1%, 1%, and 5% levels, respectively. Standard errors in parentheses.

Table 3: Maximum effect of human capital on income disparity across countries

	Estimated Model					Microeconometric evidence	
				Estimated effect of schooling PISA included?		Acemoglu (2009) bounds	
	Period	Source	# countries	No	Yes	Min	Max
	Main regressions results						
1	1960-1985	MRW	98	9.1	-	2.0	3.1
2	1960-1985	PWT 7.1	91	22.9	-	2.0	3.1
3	1990-2010	PWT 7.1	87	6.7	-	2.0	3.1
4	1960-1985	MRW	37	2.9	-	1.7	2.3
5	1990-2010	PWT 7.1	37	2.5	1.5	1.5	2.0
	Robustness checks						
6	1975-2000	PWT 7.1	30	5.6	2.7	1.6	2.2
7	1980-2000	PWT 7.1	30	4.6	2.2	1.6	2.2
8	1985-2000	PWT 7.1	30	4.2	2.0	1.6	2.2
9	1985-2010	PWT 7.1	38	3.1	1.7	1.5	2.0
10	1995-2010	PWT 7.1	36	2.1	1.2	1.5	2.0

Figure 1: Maximum effect of human capital on income disparity across countries