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EDUCATION, HEALTH, AND ECONOMIC DEVELOPMENT

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This paper examines the relationships of income with education and health using heterogeneous panel cointegration techniques to account for the potential cross-country heterogeneity in the effects of education and health. Our main results are: (i) education and health are, on average, income-enhancing; (ii) for different schooling levels, although primary education lowers income, both secondary and tertiary education raise income with larger impacts for the former than the latter, on average; (iii) there is considerable heterogeneity in the effects of education and health on income across countries; and (iv) the effect of education (health) on income tends to be greater (smaller) in countries with higher levels of development, greater (less) trade openness, less abundant natural resources, less corruption, higher levels of democracy, and a more homogeneous society.

Keywords: Education, Health, Economic Development, Heterogeneous Panels

1. INTRODUCTION

Poor countries have relatively low quality of labor—low education attainment and poor health status—in the form of human capital. Understanding the relationship between economic growth and both education and health is therefore a necessary step toward understanding the growth performance of poor countries. According to the human capital hypothesis, better education and improved health, albeit in themselves an end, are a means to achieve higher economic growth and development. More educated and healthier workers are more productive, better at adapting to new technologies, and much able to respond to new opportunities, and hence earn more than workers with opposite attributes. Microlevel evidence also shows that an individual's level of education and health determines his or her economic performance such as productivity and wages [Harmon et al. (2003), Behrman and Rosenzweig (2004), Bleakley (2007)]. At the macrolevel, most studies find a

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positive correlation of education and health with levels or growth rates of income. For instance, Barro (1991), Mankiw, Romer, and Weil (1992), Sala-i-Martin (1997), Temple (1999), (2001), and Wolff (2000), among others, find that enrollment, schooling, and/or literacy boost growth.[1] Pritchett and Summers (1996), Bloom, Canning, and Sevilla (2004), Lorentzen, McMillan, and Wacziarg (2007), Swift (2011), Bloom, Canning and Fink (2014), and Madsen (2016) support the positive contribution of health capital to economic growth or development.[2] Thus, there is a near consensus that education expansions or health improvements will make a country richer.

Drawing a macroeconomic conclusion directly from either the microlevel or macrolevel evidence is problematic, however. Microlevel studies do not resolve the question of whether differences in education and health are at the root of the large income differences across countries because they fail to incorporate externalities and control for general equilibrium effects of changes in population education and health. Educational externalities, for example, include the possibilities that educated workers may raise the productivity of their less educated coworkers, that there may be spillover effects from technical progress or knowledge accumulation arising from human capital investment, or that an environment with a higher average level of human capital may entail a higher incidence of learning from others. More education is also associated with better public health, better parenting, lower crimes, a better environment, wider political and community participation, and greater social cohesion, all of which are in turn likely to feed back into economic growth [please see, Sianesi and Van Reenen (2003), for detailed discussions]. As for externalities of health, better health is associated with better education outcome, more job experience, and higher saving and investment in education [Kalemli-Ozcan et al. (2000), Zhang et al. (2003)]. Improved health also allows parents to choose a low level of fertility, which limits the growth of total population and supports per capita gross domestic product (GDP) growth [Galor (2005)]. On the other hand, lower fertility also leads to higher investment in human and physical capital, and hence promoting economic growth and development, as a result of the quality–quantity trade-off [Becker et al. (1990), Tamura (1994, 1996), Murphy et al. (2008), Tamura et al. (2016)]. It is these externalities that provide economic justification for the public support of education and health initiatives. With reference to the success of microstudies in finding a positive effect of human capital on wage, Temple (1999) points out that it is worrying for the failure of current literature to discern this effect at the macrolevel.

On the other hand, macrolevel investigations, which can better arrest the equilibrium effect and potential externalities, are typically based on growth regressions in a cross-country setting or homogeneous panel data context and hence are subject to serious drawbacks in the estimation process including the endogeneity bias and country heterogeneity. The cross-country finding of a strong correlation between measures of education (health) and both the level and growth rate of income fails to establish a causal effect of education (health) on economic growth and development. Correlation evidence is seldom proof of causation. Observed correlation could derive from reverse causation (more growth would cause more education and better health) or common omitted variables bias (growth and both education and health outcomes may be driven by unobserved country-specific factors such as socio-political institutions). Panel estimation can account for unobserved time-invariant country-specific effects, but are not able to account for the heterogeneity in the relationship between education (health) and growth across countries. This heterogeneity arises possibly because, for example, schooling (health care) quality is not constant across countries, the efficiency in allocation of educational (health) resources differs among countries, or different schooling levels have unequal effects on grow, due to differential economic and institutional endowments across countries. As put forth by Temple (1999, 2001), pooling a number of heterogeneous countries with different economic and institutional frameworks as typical in the empirical literature may suffer from influential outliers and produce unsatisfactory estimates. Moreover, and perhaps more importantly, the homogeneous panel estimators used in these studies produce inconsistent and potentially misleading estimates when the slope coefficients differ across countries [Pesaran and Smith (1995)].

This paper revisits the issue and contributes to current empirical literature in the following dimensions. First, instead of treating education and health separately as typical in the literature, it assesses whether and how education and health affect economic development measured by real income per capita in one unified empirical framework.[3] Considering two important components of human capital in one unified empirical framework ensures that we do not erroneously overestimate the contribution of one component by mistakenly attributing to it the contributions of other component we omit. This is particularly important given potential complementarity between education and health: increased education promotes health knowledge and technology and leads to better health outcomes [Pritchett and Summers (1996), Brunello et al. (2016)] and improved health expands education and leads to better education outcomes [Kremer and Miguel (2004), Tamura (2006)].

Second, our main contribution is to estimate the average effect of education and health on income for the 50 countries using heterogeneous panel cointegration estimators. Such estimators are robust under cointegration to many of the problems inherent in cross-country and panel studies, including omitted variables, slope heterogeneity, and endogenous regressors [Pedroni (2007)]. We find that education and health are, on average, income-enhancing. It is also found that although primary education lowers income, both secondary and tertiary education raise income with larger impacts for the former than the latter.

As a third contribution, we examine the degree of heterogeneity in the effects of education and health across countries by providing estimates of the education-income and health-income coefficients for each of the 50 countries. We find that there is considerable heterogeneity in the effects of education and health on income across countries. We then investigate, as a final contribution, whether countries with certain similar characteristics benefit (lose) more, on average, from education and health than others by presenting heterogeneous panel estimates of

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the education-income and health-income coefficients for certain country groups. The data suggest that the effect of education (health) on income tends to be greater (smaller) in countries with higher levels of development, greater (less) trade openness, less abundant natural resources, less corruption, higher levels of democracy, and a more homogeneous society.

The remainder of the paper is composed of four sections. Section 2 describes the data and sets up the basic empirical model. Section 3 presents the empirical results. Section 4 concludes.

2. DATA AND METHODOLOGY

2.1. Data

Our data set is mainly taken from the World Development Indicators (WDI) (2014) of the World Bank. We include all countries with complete time series, resulting in a balanced panel with 1,400 observations and 50 countries for the period 1985–2012. Table A.1 lists the countries. As it is standard in the literature, economic development (ecodev_{it}) is measured by real GDP per capita. Education capital (education_{it}) is proxied by the gross enrollment rate of primary, secondary, and tertiary education whereas health capital (health_{it}) is proxied by the infant mortality rate, which describes the number of live-born infants who fail to reach the age of 1, and the child mortality rate, which describes the number of live-born infants who fail to reach the age of five, as well as life expectancy at birth as in Pritchett and Summers (1996), Acemoglu and Johnson (2007), and Lorentzen et al. (2007). These measures are readily available for a larger set of countries over a longer time period than other potential proxies such as average years of schooling and literacy. The use of the enrollment rate as a proxy is consistent with most of the literature examining the role of human capital on growth [Barro (1991), Mankiw et al. (1992), Bils and Klenow (2000), Ranis et al. (2000)]. As argued, many high- and middle-income countries have already achieved high levels of primary enrollment. For these countries, increases in education spending are unlikely to be allocated to primary education and thus higher education spending may not be associated with higher primary enrollment; in low-income countries, where primary enrollment rates are lower, greater priority may be given to primary education. Furthermore, Psacharopoulos (1994) indicates that low-income countries rely heavily on primary education and moderately on secondary education, whereas higher education seems to be more profitable in wealthy countries. Hence, to capture progress in building human capital for countries at different stages of development, we consider a combined enrollment rate, the sum of these three education enrollment rates, in the spirit of Baldacci et al. (2008).[4] The use of mortality is due to the fact that although it is desirable to account for both mortality and morbidity as a full measure of health capital, such data are not available. As a robustness check, we consider life expectancy, output of both mortality and morbidity. Nevertheless, given imperfect measures of education and health capital, the results should be

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interpreted with caution. All variables are in natural logarithm. Table 1 reports summary statistics.

2.2. Methodology

To examine the long-run relationship of economic development (ecodev_{it}) with both education (education_{it}) and health capital (health_{it}), we follow common practice in panel cointegration studies to estimate a multivariate model of the form:

$$\text{ecodev}_{it} = \alpha_i + \beta_{1i}\text{education}_{it} + \beta_{2i}\text{health}_{it} + \varepsilon_{it}$$
$$i = 1, 2, ..., \quad Nt = 1, 2, ..., T. \qquad (1)$$

The coefficients $\beta_i' = (\beta_{1i}, \beta_{2i})$ in equation (1) can be interpreted as the respective long-run elasticity of economic development with respect to education and health capital. Moreover, we include country-specific fixed effects, α_i, to control for country-specific omitted factors that are relatively stable over time, such as geography and institutions.

Equation (1) assumes that there is a long-run relationship between economic development and education and health capital. Necessary conditions for this assumption to hold are that the individual time series for ecodev_{it}, education_{it}, and health_{it} are nonstationary or, more specifically, integrated of the same order and that ecodev_{it}, education_{it}, and health_{it} form a cointegrated system. If a cointegrating relationship exists among a set of nonstationary variables, then the same cointegrating relationship also exists in extended variable space. In other words, cointegration relationships are invariant to model extensions [Lütkepohl (2007)]. An important implication of finding cointegration is thus that no additional variables are required to produce unbiased parameter estimates.

Although adding further nonstationary variables to the model may result in further cointegrating relationships, the estimates of the original cointegrating equation, however, will not be significantly affected by the presence or absence of additional variables [Juselius (2006)]. This justifies considering small subsystems, such as equation (1). As a robustness check, we demonstrate this by re-estimating equation (1) using (log) physical capital as an additional explanatory variable.

In the presence of cointegration, the long-run effect of education and health on economic development can be estimated using the group-mean dynamic ordinary least squares (DOLS) and fully modified ordinary least squares (FMOLS) for heterogeneous cointegrated panels estimators suggested by Pedroni (2001). Both estimators allow for greater flexibility in the presence of heterogeneous cointegrating vectors. Moreover, the point estimates provide a more useful interpretation in the case of heterogeneous cointegrating vectors since they can be interpreted as the mean value of the cointegrating vectors, which does not apply to the within estimators. And, these group-mean estimators suffer from a much lower level of small sample-size distortion than is the case with the within-dimension estimators.

TABLE 1. Descriptive statistics

	Real GDP per capita	School enrollment	Primary enrollment	Secondary enrollment	Tertiary enrollment	Infant mortality	Child mortality	Life expectancy	Physical capital
Mean	8.9527	5.3621	4.6057	4.3347	3.2096	2.4843	2.6956	4.2834	12.8933
Median	9.2493	5.4271	4.6209	4.5275	3.5068	2.2721	2.4336	4.3129	13.0772
Std.	1.5026	0.3201	0.1688	0.5236	1.1316	1.0215	1.0736	0.1113	1.9000
Min.	5.1924	3.4001	3.2414	1.3366	−1.2188	0.5306	0.7885	3.8280	8.7101
Max.	11.1244	5.7995	5.0822	5.0698	4.7844	5.0093	5.5385	4.4200	17.6280
Obs.($N * T$)	1,400	1,400	1,400	1,400	1,400	1,400	1,400	1,400	1,242

Notes: School enrollment is the sum of gross enrollment rates of primary, secondary, and tertiary education. All variables are in natural logarithms except for human capital.

In general, group-mean estimators involve estimating separate regressions for each country and averaging the slope coefficients:

$$\hat{\beta}_1 = N^{-1}\sum_{i=1}^{N}\hat{\beta}_{1i} \quad \text{and} \quad \hat{\beta}_2 = N^{-1}\sum_{i=1}^{N}\hat{\beta}_{2i}. \tag{2}$$

The t-statistic is the sum of the individual t-statistics divided by the root of the number of cross-sectional units:

$$t_{\hat{\beta}_{1i}} = \sum_{i=1}^{N}\frac{t_{\hat{\beta}_{1i}}}{\sqrt{N}} \quad \text{and} \quad t_{\hat{\beta}_{2i}} = \sum_{i=1}^{N}\frac{t_{\hat{\beta}_{2i}}}{\sqrt{N}}. \tag{3}$$

The basic idea behind both the DOLS and FMOLS estimators is to account for possible serial correlation and endogeneity of the regressors. Thus, an important feature of these estimators is that they generate unbiased estimates for variables that are cointegrated, even with endogenous regressors. In addition, the estimators are also robust to the omission of variables that do not form part of the cointegrating relationship.

The FMOLS estimator employs a nonparametric correction to eliminate the endogeneity bias using ε_{it}, Δeducation, and Δhealth. However, the DOLS estimator employs a parametric correction for the potential endogeneity by augmenting equation (1) with leads, lags, and contemporaneous values of differenced education and health:

$$\begin{aligned}\text{ecodev}_{it} &= \alpha_i + \beta_{1i}\text{education}_{it} + \beta_{2i}\text{health}_{it} \\ &\quad + \sum_{j=-p_i}^{p_i}\varphi_j\,\Delta\text{education}_{it-j} + \sum_{j=-q_i}^{q_i}\phi_j\,\Delta\text{health}_{it-j} + v_{it}.\end{aligned} \tag{4}$$

A potential disadvantage of the DOLS procedure is that the estimates may be sensitive to the choice of the lead and lag structure. FMOLS requires fewer assumptions and tends to be more robust [Pedroni (2000)]. However, it is well known that in small T samples (like ours), the DOLS estimator performs better than FMOLS estimator. Thus, DOLS is our preferred estimation method. As a robustness check, we also consider FMOLS.

Since both the FMOLS and DOLS estimators may be biased in the presence of cross-section dependence,[5] we check the robustness of our results by using the common correlated effects (CCE) mean group (CCEMG) estimator of Pesaran (2006). It is a common practice in panel studies to use common time dummies to control for cross-sectional dependence through common time effects. The CCEMG estimator has the advantage that it allows for cross-section dependence arising from multiple unobserved common factors, and that it permits the individual responses to the common factors to differ across countries. The estimator involves augmenting the cointegrating regression, equation (1), with the cross-section averages of the dependent variable and the observed regressors as proxies for the unobserved common factors. Accordingly, the cross-sectionally augmented cointegrating regression is given by

$$\text{ecodev}_{it} = \alpha_i + \beta_{1i}\text{education}_{it} + \beta_{2i}\text{health}_{it} + \theta_{1i}\overline{\text{ecodev}_t} + \theta_{2i}\overline{\text{education}_t} + \theta_{3i}\overline{\text{health}_t} + \xi_{it}, \tag{5}$$

where $\overline{\text{ecodev}_t}$, $\overline{\text{education}_t}$, and $\overline{\text{health}}_t$ are the cross-section averages of ecodev$_{it}$, education$_{it}$, and health$_{it}$, respectively.

The CCEMG estimator is sufficiently general to allow for potentially nonstationary and/or nonlinear observables and unobservables, as well as idiosyncratic or global business cycle effects [Chudik et al. (2011)].

It is noted that the existence of a long-run relationship between income, education, and health does not exclude the possibility of long-run Granger-causality running from income to education and health. Next, we check the direction of causality. Since our data are stationary and cointegrated, as an alternative, we base the panel Granger-causality test on the panel vector error correction model (VECM). Specifically, we follow Herzer et al. (2012) in using a two-step procedure to test the direction of causality. In the first step, we employ the FMOLS estimate of the long-run relationship to construct the disequilibrium term:

$$\text{ec}_{it} = \text{ecodev}_{it} - (\hat{\alpha}_i + \hat{\beta}_{1i}\text{education}_{it} + \hat{\beta}_{2i}\text{health}_{it}). \tag{6}$$

In the second step, we estimate the following specification of VECM:

$$\begin{pmatrix} \Delta\text{ecodev}_{it} \\ \Delta\text{education}_{it} \\ \Delta\text{health}_{it} \end{pmatrix} = \begin{pmatrix} c_{1i} \\ c_{2i} \\ c_{3i} \end{pmatrix} + \sum_{j=1}^{J} \Gamma_j \begin{pmatrix} \Delta\text{ecodev}_{it-j} \\ \Delta\text{education}_{it-j} \\ \Delta\text{health}_{it-j} \end{pmatrix} + \begin{pmatrix} a_1 \\ a_2 \\ a_3 \end{pmatrix} \text{ec}_{it-1} + \begin{pmatrix} \varepsilon_{1i} \\ \varepsilon_{2i} \\ \varepsilon_{3i} \end{pmatrix}, \tag{7}$$

where the error-correction term ec$_{it-1}$ represents the deviation from the equilibrium and the adjustment coefficients a_1, a_2, and a_3 capture how ecodev$_{it}$, education$_{it}$, and health$_{it}$ respond to deviations from the equilibrium relationship.

If a long-run relationship between the variables exists, according to the Granger representation theorem at least one of the adjustment coefficients must be nonzero. A significant error-correction term also suggests long-run Granger-causality, and thus long-run endogeneity [Hall and Milne (1994)], whereas a nonsignificant adjustment coefficient implies weak exogeneity and no long-run Granger-causality running from the independent to the dependent variable(s). We hence test for weak exogeneity of ecodev$_{it}$, education$_{it}$, and health$_{it}$, and thus for long-run Granger-noncausality between ecodev$_{it}$, education$_{it}$, and health$_{it}$. Since all variables in the model, including ec$_{it-1}$, are stationary (because the level variables are integrated of order 1 and cointegrated), a conventional likelihood ratio test can be used to test the null hypothesis of weak exogeneity, $H_0 : a_{1,2,3} = 0$.

3. EMPIRICAL RESULTS

3.1. Integration and Cointegration

The first step in the empirical analysis is to examine the time series properties of the data. To this end, we use the panel unit root test in heterogeneous panels of Im et al. (2003) (hereafter IPS). The IPS test can lead to spurious inferences in the presence of cross-section dependence. Particularly, the cross-section independence test of Pesaran (2004) (hereafter CD) indicates a significant cross-section correlation. Therefore, we also employ the cross-sectionally augmented IPS test proposed by Pesaran (2007) (hereafter CIPS) to check whether all variables are integrated of order 1. The results, which are reported in Table A.2, demonstrate that it is reasonable to suggest all variables follow I(1) processes. We then turn to examine the existence of a long-run relationship among the variables. We use the standard panel cointegration test of Pedroni (2000, 2004). A potential problem with this test is that it does not allow for cross-sectional dependence. Therefore, we also test for cointegration in the presence of possible cross-section dependence by using a two-step residual-based procedure in the style of Holly et al. (2010). Specifically, in the first step, we employ the CCE estimation procedure of Pesaran (2006), i.e., by augmenting the cointegrating regression (1) with the cross-sectional averages of the dependent and independent variables as proxies for the unobserved factors. In the second step, we compute the residuals of the individual CCE long-run relations, and apply the CIPS test to the computed residuals, including an intercept. This allows us to account for unobserved common factors that could be correlated with the observed regressors in both steps. The results of the tests, which are reported in Table A.3, support the long-run cointegrating relationship among economic development, education, and health. Moreover, Pedroni's (2001) test for the null of slope homogeneity indicates substantial heterogeneity across countries (panel B).

Table A.4 reports the panel Granger-causality test results. The error correction terms are significantly different from zero in each equation, implying that the null hypothesis of weak exogeneity can be rejected for ecodev_{it}, education_{it}, and health_{it} at the 1% level. Thus, the weak exogeneity tests suggest that all variables are endogenous in the long run, from which it can be concluded that the statistical long-run causality indeed runs from education_{it}, and health_{it}, to ecodev_{it}, from ecodev_{it} to education_{it}, and health_{it}, and from $\text{ecodev}_{it}(\text{health}_{it})$ to $\text{health}_{it}(\text{education}_{it})$. Better education and improved health are both a cause and consequence of economic development. Similarly, education is both a cause and effect of health, which does not contradict the prediction of Pritchett and Summers (1996), Brunello et al. (2016), Kremer and Miguel (2004), and Tamura (2006). More importantly, the found two-way causality validates our use of DOLS and FMOLS estimators.

3.2. Long-Run Relationship

Having established a cointegration relationship among these variables, and considering heterogeneity in the long-run effect of education and health on economic development across these countries, we use the group-mean DOLS and FMOLS estimators suggested by Pedroni (2001). The estimation results are reported in the first four columns of Table 2. As can be seen, better education and improved health are associated with higher income. The respective estimate on school enrollment and on infant mortality is positive and negative, both of which are statistically significant.

However, both DOLS and FMOLS estimates could be biased in the presence of cross-section dependence due to unobserved, common time-specific factors. To control for such factors, we re-estimate the regressions using cross-sectionally demeaned data (i.e., by subtracting cross-section means from the observed data). This is equivalent to using the residuals from regressions of each variable on time dummies in place of the original variables. As can be seen from columns 3 and 4 of Table 2, better education and improved health contribute to faster economic development. The respective estimate on school enrollment and on infant mortality is positive and negative, with relatively smaller magnitudes, and both are of statistical significance. However, the use of demeaned data assumes that the cross-section dependence is due to a single common source and that the response to the common factor is the same for all countries. This may bias the results [Pedroni (2007)]. To allow for cross-section dependence that potentially arises from multiple unobserved common factors and to permit the individual responses to these factors to differ across countries, we experiment with the CCEMG estimator in column 5 of Table 2. We find qualitatively similar results as before. The respective estimated coefficient on school enrollment and on infant mortality remains positive and negative, and both are statistically significant.

In the remaining columns of Table 2, we report also estimates from the within-dimension DOLS estimator of Kao and Chiang (2000) and FMOLS estimator of Phillips and Hansen (1990), both assume homogeneous slope coefficients for all countries. As can be seen, both estimators provide qualitatively similar results as above. Given, however, that the effects of education and health on income differ across countries, the results of the pooled within-dimension estimator (which assumes homogeneous coefficients) should be interpreted with caution. On the other hand, because the CCEMG estimator is intended for the case where the regressors are exogenous and fails to account for the endogeneity of education and health, we continue our robustness analysis using the DOLS and FMOLS estimators.

As argued, the correlation between increased human capital and income may sometimes be hidden in the cross-country data by a number of unrepresentative observations [Temple (1999, 2001)]. To verify that the respective estimated effect of education and health on income is not due to individual outliers, we re-estimate the DOLS regression by excluding one country at a time from the sample. The

TABLE 2. Estimates on education and health capital

	Heterogeneous models					Homogeneous models			
	DOLS raw data	FMOLS raw data	DOLS demeaned data	FMOLS demeaned data	CCEMG	DOLS raw data	FMOLS raw data	DOLS demeaned data	FMOLS demeaned data
School enrollment	0.4372**	0.4040**	0.1992**	0.1416**	0.4785**	0.5825**	0.3969**	0.3836**	0.2661**
	(9.50)	(8.69)	(14.55)	(13.94)	[2.79]	(7.66)	(5.62)	(5.48)	(3.77)
Infant mortality	−0.5208**	−0.4877**	−0.2664*	−0.3301**	−0.2193*	−0.3331**	−0.3993**	−0.0829*	−0.1654**
	(−34.66)	(−39.67)	(−1.70)	(−5.21)	[−2.01]	(−12.35)	(−14.12)	(−1.85)	(−3.44)

Notes: The number of leads and lags in the individual DOLS regressions was determined by the Schwarz criterion with a maximum of three lags. The values in the parentheses (brackets) are the t-values (z-values) of corresponding coefficient estimates. ** and * denote significant at 1% and 10% levels, respectively.

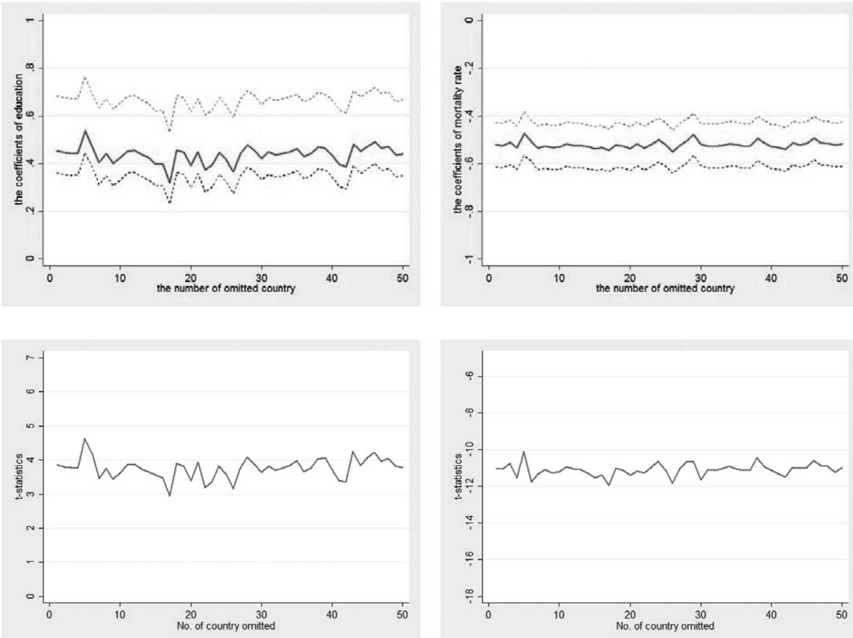

FIGURE 1. DOLS estimation with single country excluded from the sample.

sequentially estimated group-mean coefficients along with their 95% confidence intervals and t-statistics are presented in Figure 1. As the education (health) coefficients are relatively stable between 0.3196 (−0.5504) and 0.5374 (−0.4729) and always significant at the 1% level, we conclude that the estimated effect is not the result of individual outliers.

We also check the robustness of our results to the inclusion of physical capital and time trends. Physical capital is obtained from the Feenstra et al. (2013) Penn World Table Version 8.0. The result of this exercise is reported in Table 3. As expected, the estimates do not change substantially when considering physical capital and time trends. The respective estimated coefficient on school enrollment and on infant mortality remains positive and negative, and both are statistically significant.

In Table 4, we examine whether our findings are robust to alternative measures of health, different samples, and time periods. The first four columns confirm that improved health contributes to larger income. The respective estimate on infant mortality and child mortality is negative and statistically significant. And, the estimate on life expectancy is positive that is also of statistical significance. Moreover, all coefficients suggest that education has a beneficial effect on real income as the estimate on school enrollment is positive that is of statistical significance. In the last eight columns, we extend our period back to 1970, which leaves 40 countries in the sample, and re-do the estimation based on this new sample for

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TABLE 3. Robustness checks with individual physical capital and time trends

	DOLS raw data	FMOLS raw data	DOLS demeaned data	FMOLS demeaned data
Panel A: Adding physical capital				
School enrollment	0.4569**	0.3312**	0.2510**	0.1238**
	(13.67)	(6.87)	(9.72)	(7.33)
Infant mortality	−0.4929**	−0.4124**	−0.3254**	−0.2232**
	(−12.89)	(−30.61)	(−12.67)	(−13.35)
Physical capital	0.0374**	0.0130**	0.0956**	0.1086**
	(18.56)	(11.48)	(18.21)	(19.62)
Panel B: With time dummy				
School enrollment	0.5553**	0.3414**	0.2405**	0.1238**
	(15.81)	(9.26)	(8.00)	(7.33)
Infant mortality	−0.3839**	−0.3882**	−0.5906**	−0.2233**
	(−15.36)	(−14.65)	(−10.97)	(−13.35)
Physical capital	0.0267**	0.0528**	0.0644**	0.1086**
	(21.52)	(16.93)	(15.05)	(19.62)

Notes: The number of leads and lags in the individual DOLS regressions was determined by the Schwarz criterion with a maximum of three lags. The values in the parentheses (brackets) are the t-values (z-values) of corresponding coefficient estimates. ** and * denote significant at 1% and 10% levels, respectively.

the period 1970–2012 and 1985–2012. We find quite robust results. The signs and significance remain for education and health estimates and for both periods, albeit differences in the magnitudes.

Thus, it can be concluded that the effect of education and health on income is robust to the possible presence of cross-sectional dependence, potential outliers, different specifications of the empirical model, different measures of health, and different samples and time periods. More importantly, our data imply that though complements, education, and health indeed play a different role in shaping human capital and have different effects on the real economy. Although improving either education or health raises income, promoting both allows countries to benefit more from human capital accumulation, on average.

In Table 5, we check whether there are differences in the response of income to different levels of education. Previous studies, which use disaggregated levels of schooling, find that primary and secondary enrollment generally has a positive effect on economic growth, as opposed to tertiary education [Self and Grabowski (2004), Pereira and St. Aubyn (2009)]. As mentioned, this differential effect could be one important source of heterogeneity in the education–income relationship. Panel A of Table 5 indicates that primary education enrollment is income-decreasing. The estimate on primary education enrollment is negative and statistically significant. Panels B and C suggest that both secondary and tertiary education enrollment are income-increasing, with stronger impacts of secondary education than tertiary education. The estimates on both secondary and tertiary

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TABLE 4. Robustness checks with alternative measures of health capital and different samples

	1985–2012 (50 countries)				1970–2012 (40 countries)				1985–2012 (40 countries)			
	DOLS raw data	FMOLS raw data	DOLS demeaned data	FMOLS demeaned data	DOLS raw data	FMOLS raw data	DOLS Demeaned data	FMOLS demeaned data	DOLS raw data	FMOLS raw data	DOLS demeaned data	FMOLS demeaned data
Panel A: Infant mortality												
School enrollment	0.4372**	0.4040**	0.1992**	0.1416**	0.3083**	0.3427**	0.1374**	0.2431**	0.1027**	0.1733**	0.1621**	0.2093**
	(9.50)	(8.69)	(14.55)	(13.94)	(5.64)	(6.41)	(4.95)	(7.11)	(6.33)	(6.23)	(10.21)	(11.09)
Infant mortality	−0.5208**	−0.4877**	−0.2664*	−0.3301**	−0.4919**	−0.4811**	−0.1880**	−0.1528**	−0.5705**	−0.5190**	−0.2005*	−0.4039**
	(−34.66)	(−39.67)	(−1.70)	(−5.21)	(−36.59)	(−40.67)	(−3.95)	(−2.71)	(−36.31)	(−37.71)	(2.21)	(−4.55)
Panel B: Child mortality												
School enrollment	0.4382**	0.4116**	0.1019**	0.1836**	0.2865**	0.3439**	0.1078**	0.2728**	0.0929**	0.1713**	0.1029**	0.1262**
	(11.52)	(8.40)	(13.18)	(13.35)	(5.55)	(6.74)	(3.94)	(6.50)	(8.28)	(5.68)	(8.64)	(9.39)
Child mortality	−0.4844**	−0.4546**	−0.1446*	−0.1871**	−0.4798**	−0.4641**	−0.1907**	−0.1358**	−0.5565**	−0.4982**	−0.1337*	−0.1321**
	(−36.33)	(−39.47)	(−2.32)	(−7.44)	(−36.44)	(−39.71)	(−3.62)	(−2.70)	(−37.28)	(−37.63)	(2.51)	(−3.50)
Panel C: Life expectancy												
School enrollment	0.5449**	0.5863**	0.4062**	0.3805**	0.6325**	0.6870**	0.1235**	0.1284**	0.3727**	0.5446**	0.2144**	0.2224**
	(11.59)	(15.68)	(13.37)	(13.79)	(14.58)	(14.68)	(9.81)	(8.81)	(9.26)	(14.44)	(7.72)	(8.89)
Life expectancy	4.3818**	4.6439**	4.3004**	3.4526**	4.5835**	4.5685**	0.1427**	0.9374**	4.7690**	4.5918**	3.4258**	3.0171**
	(28.22)	(30.55)	(11.26)	(10.10)	(30.81)	(34.28)	(2.75)	(7.03)	(28.28)	(28.82)	(10.65)	(9.95)

Notes: The number of leads and lags in the individual DOLS regressions was determined by the Schwarz criterion with a maximum of three lags. The values in the parentheses (brackets) are the t-values (z-values) of corresponding coefficient estimates. ** and * denote significant at 1% and 10% levels, respectively.

TABLE 5. Robustness checks with alternative measures of education capital and different samples

	1985–2012 (50 countries)				1970–2012 (40 countries)				1985–2012 (40 countries)			
	DOLS raw data	FMOLS raw data	DOLS demeaned data	FMOLS demeaned data	DOLS raw data	FMOLS raw data	DOLS demeaned data	FMOLS demeaned data	DOLS raw data	FMOLS raw data	DOLS demeaned data	FMOLS demeaned data
Panel A: Primary education enrollment												
Primary enrollment	−0.8833**	−0.5183*	−0.5637**	−0.5490**	−0.3158**	−0.2756*	−0.2052**	−0.1071**	−1.4137**	−0.7966**	−0.1628**	−0.2559**
	(−5.75)	(−2.20)	(−6.31)	(−5.59)	(−3.14)	(−2.03)	(2.58)	(3.90)	(−7.46)	(−3.21)	(−7.25)	(−8.91)
infant mortality	−0.6290**	−0.6186**	−0.3461**	−0.5014**	−0.5765**	−0.5787**	−0.1625**	−0.2375**	−0.6084**	−0.6006**	−0.2827**	−0.1642*
	(−82.19)	(−90.84)	(−16.37)	(−17.13)	(−104.57)	(−109.94)	(−8.72)	(−8.20)	(−79.40)	(−82.03)	(2.71)	(2.46)
Panel B: Secondary education enrollment												
Secondary enrollment	0.5422**	0.4187**	0.3328**	0.3536**	0.2883*	0.2166**	0.2097**	0.2199**	0.3960**	0.2262**	0.3325**	0.3315**
	(11.57)	(8.37)	(14.56)	(12.68)	(2.10)	(3.35)	(5.95)	(6.98)	(9.56)	(5.61)	(14.73)	(13.17)
Infant mortality	−0.4667**	−0.5368**	−0.2343**	−0.3014**	−0.5527**	−0.5469**	−0.1309**	−0.1044**	−0.4418**	−0.5134**	−0.1483**	−0.1393**
	(−66.49)	(−63.15)	(−16.24)	(−10.16)	(−55.69)	(−60.15)	(−5.09)	(−4.43)	(−59.56)	(−57.20)	(−6.40)	(−5.33)
Panel C: Tertiary education enrollment												
Tertiary enrollment	0.1406**	0.2079**	0.1458**	0.2052**	0.1825**	0.1720**	0.1660**	0.1592**	0.1139**	0.1976**	0.1207**	0.1598**
	(14.31)	(15.23)	(30.41)	(27.50)	(10.06)	(10.65)	(22.72)	(4.38)	(13.13)	(13.86)	(14.39)	(31.67)
Infant mortality	−0.4472**	−0.3402**	−0.0775	−0.0310**	−0.3703**	−0.3714**	−0.0976*	−0.0633*	−0.4018**	−0.3088**	−0.0911*	−0.0712*
	(−24.10)	(−28.80)	(−0.78)	(−3.01)	(−25.34)	(−32.68)	(1.67)	(−9.64)	(−25.33)	(−27.07)	(2.09)	(1.69)

Notes: The number of leads and lags in the individual DOLS regressions was determined by the Schwarz criterion with a maximum of three lags. The values in the parentheses (brackets) are the t-values (z-values) of corresponding coefficient estimates. ** and * denote significant at 1% and 10% levels, respectively.

education enrollment are positive and statistically significant, with larger magnitudes for the former than the latter. The evidence is robust to different samples and periods, and stands in sharp contrast to the microlevel evidence of the highest return to primary education. However, the finding is complementary and consistent with Barro (1991) and Mankiw et al. (1992) that emphasize a special development role of secondary and higher education. In addition, all coefficients on infant mortality suggest that health has a beneficial effect on real income as the estimate on infant mortality is negative that is also of statistical significance.

3.3. Individual Country Estimates

The results reported thus far indicate that education and health have, on average, a positive long-run effect on income. This finding for the sample as a whole does not imply, however, that education and health exert positive effects on real income in each individual country. The individual country DOLS point estimates on education and health (using the original specification) are presented in Table 6. Although these estimates must be interpreted with caution given the relatively limited number of observations for each country, it can be concluded that there is considerable heterogeneity in the effects of education and health on income across countries. The education (health) coefficients range from −4.4683 (−2.8704) in China to 3.9394 (0.9291) in Lithuania. With respect to estimates of different schooling levels, the primary education coefficient ranges from −19.2397 in Ireland to 4.9593 in Poland, the secondary education coefficient from −1.3657 in Poland to 7.5709 in Kazakhstan, and the tertiary education coefficient from −0.7545 in Thailand to 1.2833 in Ireland.

Accordingly, there are large cross-country differences in the impact of education and health on income that are not captured in standard cross-country and panel regressions. Moreover, although most studies obtain a positive coefficient on education, we find that for 22 out of 50 countries, an increase in education is associated with a decrease in income. Thus, a substantial portion of countries does not gain from education. Concerning schooling levels, we find that for 26 out of 50 countries, an increase in primary education is associated with a decrease in income; for 19 out of 50 countries, an increase in secondary education is associated with a decrease in income; and for 19 out of 50 countries, an increase in tertiary education is associated with a decrease in income. Such variations in the education–income nexus may arise, as suggested by Pritchett (2001), because of heterogeneous education quality, difference in gaps between demand for and supply of education, and different institutional quality, both economic and political, that affect the efficacy of education for each country. The extent and mix of these three phenomena vary from country to country and hence the actual economic impact of education. Particularly, as pointed out by Pritchett (2001), the impact of education might fall short of what is hoped because the institutional/governance environment is sufficiently perverse, the marginal returns to education fall rapidly as the supply

TABLE 6. Individual country DOLS estimates, 1985–2012

Country	Education coefficients	Health coefficients	Primary education coefficients	Secondary education coefficients	Tertiary education coefficients
Austria	−0.3585*	−0.4352**	−1.4064**	0.1641	−0.1469**
Belgium	0.0058	−0.3745**	0.1316	0.0078	0.2760*
Bulgaria	0.1506	−1.0425**	0.2356	0.7877**	−0.0971**
Burkina Faso	0.1912	0.0699	0.4399**	0.5860*	−0.4814**
China	−4.4683**	−2.8704**	−1.8116**	1.2991**	−0.2828
Colombia	−1.2644	−1.2714	−1.7625**	1.2436	0.4778
Cuba	2.0307**	0.1429	−2.2254	3.3531**	0.4083**
Cyprus	0.2211	−0.2802**	0.3967*	0.1867	0.1632**
Czech Republic	2.2697**	0.1255	2.0028	2.0732*	0.8474**
Denmark	1.0623**	−0.0391	0.9672	0.4354**	0.3729**
Finland	−0.2861	−0.6486**	−3.4622*	−0.3118	−0.0299
France	−0.4651	−0.3922**	0.1959	−0.1836	−0.0527
Greece	0.3624*	−0.3011**	0.6308*	0.3559	−0.2489
Hungary	1.0692	−0.0817	−2.0236**	1.5087*	0.5182**
Iceland	2.3250*	0.2626	1.5232	−0.6147	0.4963*
Indonesia	2.2914*	0.0638	−7.1379*	1.4893*	0.0672
Ireland	6.2040**	0.6200	−19.2397**	1.8194	1.2833**
Israel	−0.4989*	−0.4944**	−0.1123	−0.5042**	−0.2754
Italy	−0.0209	−0.2692*	1.0256	1.7852**	0.0890
Japan	2.7012**	0.2797	1.3114	1.8426**	0.4072*
Jordan	−0.1200	−0.7253*	−2.7140**	0.4017	−0.7470*
Kazakhstan	3.5548**	0.1482*	3.8656**	7.5709**	0.8312**
Republic of Korea	2.5152**	−0.6185**	−8.6921**	1.7467*	0.6262**
Lao PDR	−0.0357	−1.4952**	0.3271**	−0.1348**	−0.0246
Latvia	1.5038*	−0.5763*	−1.3238*	1.6042**	0.1803
Lithuania	3.9394**	0.9291**	−3.1246**	1.9785**	1.0370**
Malawi	0.1755**	−0.3657**	0.1507**	0.1889**	−0.0369
Malta	−1.5349**	−1.2963**	−0.8843**	−0.5840*	0.0910**
Mauritania	−0.4234*	−2.6549**	−0.1610	−0.3044**	0.1223
Mauritius	1.2560	−0.5474	−0.9775*	0.9292**	0.2588**
Mexico	−0.0953	−0.2676**	0.8688	−0.1255	−0.0790
Morocco	0.5459**	−0.2186*	−0.2326	0.6210**	0.1298
Nepal	0.1874*	−0.3482**	0.2427**	0.0457	−0.0208
Netherlands	−0.1852	−0.7150**	0.8120	−0.1565	−0.0140
New Zealand	−0.8092	−0.6128*	−0.9193	−0.5735*	−0.1823
Norway	0.8282**	−0.2113**	1.1459	0.2997	0.3557**
Oman	0.1963	−0.2164**	0.1629	0.2058	0.0052
Panama	−1.1678**	−1.8862**	−2.1657**	−0.1367	−0.2306*
Poland	−0.9585	−0.8671**	4.9593**	−1.3657**	−0.4584*
Portugal	0.4971**	−0.1812**	1.2994*	0.1647**	0.2228**
Romania	2.4319**	0.0366	0.2697	1.3311**	0.0135

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Table 6. Continued

Country	Education coefficients	Health coefficients	Primary education coefficients	Secondary education coefficients	Tertiary education coefficients
Slovenia	2.9217**	0.4593*	1.1746	−1.7217	0.6597**
Spain	−1.8235	−0.8911**	−3.4035**	−0.7676	0.3027
Sweden	−0.2254**	−0.4694**	−0.9240**	−0.1696**	0.1370**
Switzerland	−1.2255*	−0.7967**	−0.6429**	−0.8560	0.6127**
Thailand	−2.2146**	−1.9210**	−3.1114**	0.1545	−0.7545**
Tunisia	−0.9127*	−0.8845**	−0.6684**	−0.2194*	−0.1385*
Turkey	−1.2832**	−0.8101**	−0.4280	−0.2764*	0.1088
United Kingdom	0.5112	−0.4732	1.2948	−0.7509	0.1467
United States	0.2900	−0.6288**	−0.0434	0.6858	0.0857

Note: ** and * denote significant at 1% and 10% levels, respectively.

expands while demand for educated labor is stagnant, or education/schooling quality might be so low it does not raise cognitive skills or productivity.

Similarly, although most studies obtain a positive coefficient on health, we find that for 11 out of 50 countries, an increase in health is associated with a decrease in income per capita. Thus, a substantial portion of countries does not gain from health, consistent with Acemoglu and Johnson (2007) and Young (2005). According to Acemoglu and Johnson (2007), population health may increase output per capita through a variety of channels, including more rapid human capital accumulation or direct positive effects on total factor productivity; however, improved health also leads to greater population (both directly and also potentially indirectly by increasing total births as more women live to childbearing age), which reduces capital-to-labor and land-to-labor ratios, thus depressing income per capita. Hence, how health affects economic development depends upon which effect dominates. If the benefits from improved health are limited and if some factors of production such as land are supplied inelastically, improved health might impede economic development.

3.4. Subsample Results

It is thus important to know why some countries lose or benefit from education expansions and health improvements, from a policy perspective. Since the reasons are complex and multifactorial in individual country cases, we abstract from the individual country estimates and present panel estimates for certain country groups. This allows us to assess whether countries with certain characteristics benefit (lose) more, on average, from education and health than others. In other words, we try to identify possible factors that determine the effect of education and health on income on average across countries (though not necessarily in each country).

Toward the end, we divide our sample into groups of countries with high and low income, high and low trade openness, high and low natural resource abundance, high and low levels of corruption, high and low levels of democratization, and high and low levels of ethnic fractionalization. Although the criteria on which these classifications are based may change over time, the following analysis assumes only that the country composition of the groups, and thus the classification itself, is relatively stable.

In panel A of Table 7, we present separate DOLS estimates for developing and advanced countries (according to World Bank (2014) classification) (listed in Table A.1). This exercise allows one to check whether the contribution of education and health is larger in developing countries than in advanced countries. As indicated, school enrollment has, on average, a positive and statistically significant impact on income, with a larger impact in advanced countries than in developing countries. This is in sharp contrast with the common view that schooling returns are generally higher in less developed countries than in more developed countries because of diminishing returns [Krueger and Lindahl (2001)]. As for health variables, both infant and child mortality have a negative and significant impact on income, whereas life expectancy has a positive and significant impact, with larger magnitudes in developing countries than in advanced countries. All these suggest that better health status increases income with a larger impact in low-income countries than high-income ones, consistent with Bhargava et al. (2001) and Weil (2007) finding that health's beneficial effect on GDP is stronger among poor countries. The data substantially reinforce the conclusions of McDonald and Roberts (2002) that health capital is more important at low incomes and education capital is more important at high incomes.

In terms of different levels of education, the data seem in line with previous contributions that the impact of increases in various levels of education greatly depends on the level of a country's development, with tertiary education being the most relevant for more advanced countries such as Organization for Economic Cooperation and Development (OECD) [Petrakis and Stamatakis (2002)]. Specifically, although primary education has a negative and significant impact on real income, both secondary and tertiary education have a positive and significant impact on real income with larger magnitudes for the former than the latter, in low-income countries. As for high-income countries, primary education has a negative and significant effect, secondary education has a minor impact, and tertiary education has a positive and significant effect. Clearly, secondary education is more important for low-income countries to develop whereas growth in high-income countries depends mainly on tertiary education. This does not contradict the finding of Cohn and Addison (1998) that wealthy OECD countries have higher rates of return on university education than the poorer ones, and of Petrakis and Stamatakis (2002) that secondary education contribute significantly to growth in developing nations, whereas tertiary education contributes significantly to growth in developed market economies.

TABLE 7. DOLS estimates for subsamples

	Alternative education capital measures						Alternative health capital measures					
	(1)		(2)		(3)		(4)		(5)		(6)	
	Primary enrollment	Infant mortality	Secondary enrollment	Infant mortality	Tertiary enrollment	Infant mortality	School enrollment	Infant mortality	School enrollment	Child mortality	School enrollment	Life expectancy
Panel A: Economic development												
Low	−0.9057**	−0.7198**	0.9673**	−0.4948**	0.0020**	−0.7699**	0.0904**	−0.8062**	0.0436**	−0.7317**	0.4230**	4.7982**
	(−3.57)	(−51.21)	(16.41)	(−50.89)	(3.92)	(−24.43)	(5.76)	(−24.40)	(6.34)	(−24.79)	(6.46)	(14.63)
High	−0.8671**	−0.5633**	0.2343	−0.4280*	0.2410**	−0.2135**	0.6884**	−0.3142**	0.7239**	−0.3053**	0.6405**	4.0802**
	(4.51)	(−64.34)	(1.21)	(−42.79)	(15.45)	(−10.85)	(7.57)	(−24.75)	(9.73)	(−26.62)	(9.72)	(24.60)
Panel B: Trade												
Low	−0.5556*	−0.5269**	0.3588**	−0.3486**	0.0867**	−0.4190**	0.1526**	−0.5051**	0.1803**	−0.4690**	0.3177**	3.2866**
	(−2.39)	(−58.47)	(8.74)	(−46.25)	(9.08)	(−15.44)	(6.88)	(−24.31)	(8.68)	(−26.11)	(8.40)	(19.55)
High	−1.3358**	−0.7700**	0.7955**	−0.6300**	0.2151**	−0.4676**	0.8304**	−0.5426**	0.7943**	−0.5056**	0.8587**	5.8941**
	(−6.07)	(−58.11)	(7.58)	(−48.23)	(11.42)	(−18.50)	(6.57)	(−24.91)	(7.58)	(−25.38)	(8.00)	(20.58)
Panel C: Natural resource abundance												
Low	−1.1138**	−0.5848**	0.3787**	−0.3673**	0.1728**	−0.3515**	0.5335**	−0.4382**	0.5398**	−0.4345**	0.8097**	5.6553**
	(−7.47)	(−35.46)	(5.59)	(−33.99)	(15.44)	(−18.77)	(7.26)	(−30.03)	(9.11)	(−32.16)	(10.32)	(28.21)
High	−0.2906	−0.6462**	0.9626**	−0.5054**	0.0578*	−0.6932**	0.1898**	−0.7334**	0.1769**	−0.6127**	0.4420**	1.1069**
	(1.12)	(−74.74)	(12.90)	(−57.16)	(2.28)	(−15.44)	(6.31)	(−17.34)	(7.17)	(−17.09)	(7.22)	(8.09)

TABLE 7. Continued

	Alternative education capital measures						Alternative health capital measures					
	(1)		(2)		(3)		(4)		(5)		(6)	
	Primary enrollment	Infant mortality	Secondary enrollment	Infant mortality	Tertiary enrollment	Infant mortality	School enrollment	Infant mortality	School enrollment	Child mortality	School enrollment	Life expectancy
Panel D: Corruption												
Low	−1.0699**	−0.4898**	0.1230	−0.3902**	0.2110**	−0.1814**	0.4858**	−0.3269**	0.5090**	−0.3250**	0.5503**	3.8022**
	(−4.03)	(−56.39)	(0.16)	(−40.32)	(10.79)	(−8.28)	(3.33)	(−23.19)	(4.50)	(−24.76)	(8.75)	(23.96)
High	−0.8451**	−0.6437**	0.9597**	−0.4496**	0.0906**	−0.6250**	0.4271**	−0.5653**	0.4305**	−0.5255**	0.5417**	4.8553**
	(−5.05)	(−51.67)	(16.76)	(−45.06)	(8.02)	(−20.84)	(10.10)	(−22.34)	(12.04)	(−22.95)	(6.51)	(15.27)
Panel E: Democracy												
Low	−1.6288**	−0.6283**	1.2225**	−0.4724**	−0.0002**	−0.8108**	0.0253**	−0.9651**	0.1328**	−0.6608**	0.5295**	4.5275**
	(−5.63)	(−34.45)	(18.29)	(−58.72)	(5.67)	(−16.37)	(9.68)	(−18.90)	(12.20)	(−15.46)	(6.30)	(26.50)
High	−0.5845**	−0.5442**	0.2338*	−0.3140**	0.2233**	−0.2153**	0.6125**	−0.3223**	0.6443**	−0.3130**	0.5542**	4.0877**
	(−3.88)	(−69.19)	(2.08)	(−21.62)	(12.21)	(−14.01)	(4.82)	(−28.71)	(5.84)	(−30.38)	(8.66)	(11.62)
Panel F: Ethnic fractionalization												
Low	−0.9098**	−0.6089**	0.4091**	−0.4386**	0.2386**	−0.2369**	0.7370**	−0.3512**	0.7937**	−0.3381**	0.7181**	4.2748**
	(−6.43)	(−53.38)	(7.46)	(−47.76)	(16.10)	(−10.11)	(7.28)	(−22.64)	(10.00)	(−23.66)	(11.18)	(22.31)
High	−0.8545	−0.6290**	0.6864**	−0.4927**	0.0345**	−0.6749**	0.1126**	−0.7046**	0.0530**	−0.6429**	0.3573**	4.4973**
	(−1.60)	(−62.68)	(8.93)	(−46.31)	(3.90)	(−24.26)	(6.14)	(−26.46)	(6.22)	(−27.82)	(5.09)	(17.51)

Notes: The values in the parentheses are the *t*-values of corresponding coefficient estimates. ** and * denote significant at 1% and 10% levels, respectively.

In panel B of Table 7, we split the sample into a subsample of countries with high-trade openness and countries with low-trade openness (listed in Table A.1). Trade openness is measured by the sum of exports and imports as a percentage of GDP from the WDI (2014). Education and health increase real income with a stronger impact in countries with greater trade openness. The evidence that trade intensifies the positive link of health and education with income is in line with Levine and Rothman (2006) showing that trade improves infant and child mortality, Feenstra and Hanson (1997) finding that opening up trade can increase returns to skill in both rich and poor nations, and Kim and Kim (2000) that international trade, combined with education, can have a positive growth effect by allowing workers to move easily to, and specialize in, the industry with the greatest productivity. In other words, trade not only improves levels and growth rates of income but also increases understanding of the germ theory of disease and the value of immunizations as well as the value of literacy and science.

Regarding different levels of education, although primary education has a negative and significant impact on real income, both secondary and tertiary education have a positive and significant impact on real income with larger magnitudes for the former than the latter and for countries with greater trade openness than for counties with less trade openness. It agrees with arguments of Barro (2001) that human capital facilitates the absorption of superior technologies from leading countries and this technology-absorption effect is especially important at the secondary and higher education levels.

In panel C of Table 7, we consider the possibility that the effect of education and health depends on the extent of natural resource abundance [measured by natural resource rent from WDI (2014)]. The logic behind this is simple: Natural resources are a curse on the levels and growth rates of income because natural resource booms reduce the returns to human capital and hence crowd out investment in schooling and education [Gylfason et al. (1999)], or because vast natural resource endowment leads to overconfidence and a false sense of economic security, which leads to underinvestment in human capital [Gylfason (2001)]. However, other studies hold that countries that have successfully evaded the resource curse tend to have a higher level of human capital, which makes possible the management of natural resources in ways that encourage the absorption of technology and development of valuable new economic sectors [Stijns (2006), Kurtz and Brooks (2011)]. As illustrated, when counties are divided into high- versus low-natural-resource-abundance subgroups (listed in Table A.1), both education and health indicators are income increasing. Education has a larger impact in countries with lower natural resource abundance, whereas health has a greater effect in countries with higher natural resource abundance. Countries with less natural resource abundance benefit more from education but gain less from health. Regarding different schooling levels, resource-abundant countries lose less from primary education but gain more from secondary education and benefit less from tertiary education.

In panel D of Table 7, we estimate separate coefficients for the countries with more corruption and for the countries with less corruption (listed in Table A.1).

Corruption is measured by control of corruption from the International Country Risk Guide. Several studies show that corruption has impacts on education and health outcomes. Corruption would reduce returns to education [Heyneman et al. (2008)] and lead to a misallocation of skills away from productive activities [Fershtman et al. (1996)]. Corruption lowers the ability of the government to raise revenues and decreases the availability of public funds for education and health [Mauro (1998)]. Evidence also shows that corruption leads to low child and infant mortality rates [Gupta et al. (2002)], reduces adult literacy and average years of schooling [Kaufmann et al. (1999)], and depresses investment in education [De la Croix and Delavallade (2009)]. Our estimates clearly suggest that health is income-increasing with a larger effect in countries with more corrupt governments than counties with less corrupt governments. Our evidence also indicates that education is income-increasing but with a larger effect in countries with less corrupt government than in countries with more corrupt governments. Regarding to different levels of schooling, high corrupt countries gain more from secondary and tertiary education and lose less from primary education.

Because democracy is typically more responsive to the social concerns of civil society, more democratic countries are conducive to policies that generate growth-enhancing public goods and services such as education and health care [Kaufman and Segura-Ubiergo (2001), Brown and Hunter (2004)], rather than narrow redistribution of private goods to a few supporters [Acemoglu and Robinson (2006)]. Evidence also shows that greater levels of democracy lead to lower infant and child mortality [Navia and Zweifel (2003)] and better education attainment [Tavares and Wacziarg (2001)]. In panel E, we report separate estimates for the countries with high levels of democratization and for the countries with low levels of democratization (also listed in Table A.1). The extent of democratization is proxied by the Polity2 index sourced from the Polity IV database. Education increases real income with a larger effect for more democratic countries than for less democratic countries. Health also increases income but with a stronger impact in less democratic countries than in more democratic countries. More democratic countries benefit more from education but gain less from health improvement. In light of different education levels, less democratic countries lose more from primary education but gain more from secondary and tertiary education.

Finally, we split the sample into countries with high ethnic fractionalization and countries with low ethnic fractionalization (listed in Table A.1). In circumstances of high fractionalization, elites or those in power may be less willing to invest in public goods such as education and health that benefit the entire population. Evidence also indicates that ethnically diverse countries have achieved lower rates of economic growth and worse educational and health outcomes as well as reduced investment in infrastructure when compared with countries that are ethnically homogenous [Easterly and Levine (1997), La Porta et al. (1999)]. The indicator of ethnic fractionalization is obtained from Alesina et al. (2003). According to the results in panel F of Table 6, the estimated beneficial effect of education on income is considerably larger for more homogeneous countries than for more heterogeneous countries. By contrast, the estimated beneficial effect of health on income is considerably larger for more heterogeneous countries than for more homogeneous countries. Besides, it is also found that more homogenous countries lose more from primary education, gain less from secondary education, and benefit more from tertiary education than more heterogeneous countries.

Overall, the subsample exercise indicates that (i) improving education and health raise income in each subgroup. This implies that our finding is robust to alternative samples; (ii) however, in terms of magnitudes, the incoming-increasing effect of education is larger in countries with greater trade openness, less abundant natural resources, lower corruption, higher levels of democracy, and a less ethnic-diverse society, and consequently higher development levels. In other words, greater trade openness, less abundant natural resources, lower corruption, higher levels of democracy, and a less ethnic-diverse society, and hence higher development levels lead to more positive (beneficial) effects of education on income. It is consistent with Pritchett's (2001) augments. On the other hand, the income-increasing effect of health seems to be greater in countries with greater trade openness, more abundant natural resources, higher corruption, lower levels of democracy, and a more ethnic-diverse society. That said, greater trade openness, more abundant natural resources, higher corruption, lower levels of democracy, a more ethnic-diverse society, and low development levels cause more negative (beneficial) effects of health on income. Hence, economic and political institutions and endowments determine the effect of education and health on income; and (iii) smaller income-increasing effects of health for richer countries could arise because richer (poorer) countries tend to have healthier (weaker) workers; therefore, any improvement in health may have smaller (larger) impacts on economic development because of diminishing returns to health capital. On the contrary, poor (rich) countries have lower (higher) education capital, an addition of education should have larger (smaller) impacts; however, poor (rich) countries also appear to have lower (better) education quality, less (more) job opportunities, and weaker (better) institutions. As a result, education may have greater net effects in high-income countries than in low-income ones. The finding is consistent with the view that countries grow more rapidly when education and other skills are more abundant [please see, Becker et al. (1990), for discussions].

4. CONCLUSION

This paper examines the nature of the income effect of education and health using dynamic panel cointegration techniques that are specifically designed to deal with the inability of previous studies to adequately account for the heterogeneity in the relationship between education (health) and income across countries. Employing data for 50 developed and developing countries over the period from 1985 to 2012, we find that both education and health raise income, on average. It is also found that the favorable income effect of schooling can be attributed mainly to secondary and tertiary education.

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Our results also indicate that there are, in fact, large cross-country differences in the effect of education and health on income. In order to explain such heterogeneity, we also estimate the education–health–income relationship for several groups of countries to check whether countries with similar characteristics benefit more, on average, from education (health) than countries without these characteristics. Our results suggest that the effect of education on income is higher in countries at the later stages of economic development, whereas the effect of health on income is higher in countries at the early stages of economic development. Our evidence further points out that the income effect of education tends to be greater in countries with greater trade openness, less abundant natural resources, lower corruption, higher levels of democracy, and a less ethnic-diverse society, and consequently higher development levels. To the contrary, the income effect of health seems to be higher in countries with greater trade openness, more abundant natural resources, higher corruption, lower levels of democracy, and a more ethnic-diverse society.

Thus, although low-income countries may benefit more from health improvements, they can also gain more from education, particularly secondary, over time when certain country-specific factors change. Specifically, reforms aimed at bettering natural resource management and improving quality of political institutions can help countries to exploit more gains from education in the long run.

NOTES

1. Some studies find weak or even negative effects of education. Benhabib and Spiegel (1994) and Delgado et al. (2014) find that education is not statistically significant, whereas Caselli et al. (1996) and Pritchett (2001) show a negative effect of education on output growth.

2. Counter evidence also exists. McDonald and Roberts (2002) and Hartwig (2010) reject the hypothesis that life expectancy is a statistically significant explanatory variable for economic growth in high-income countries. Acemoglu and Johnson (2007) even show that health improvements have negative effects on income per capita. Similarly, Young (2005) finds that the decline in population resulting from HIV/AIDS may increase income per capita despite significant disruptions and human suffering caused by the disease.

3. As argued by Hall and Jones (1999), the income level captures the differences in long-run economic performance that are most directly relevant to welfare as measured by the consumption of goods and services. Also, Mankiw et al. (1992) suggest that differences in growth rates across countries are mostly transitory, whereas explaining differences in levels is an important issue in economic development.

4. The best measures would be in terms of the output of education such as the literacy rate or test scores, but due to the difficulties of obtaining such measures, input measures tend to be used. Furthermore, data on education, particularly average years of education, are seldom available in annual periodicity. This is probably one of the reasons cross-country regressions have been the main empirical tool in this field.

5. Cross-section dependence may arise due to spatial correlations, spillover effects, omitted global variables, and common unobserved shocks. Cross-section correlation can potentially induce serious bias in the estimates because the impact assigned to an observed covariate in reality confounds its impact with that of the unobserved processes [Pesaran (2006)].

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APPENDIX : COUNTRY LIST AND CROSS-SECTION DEPENDENCE, UNIT ROOT, COINTEGRATION, AND HETEROGENEITY TESTS

TABLE A.1. Country list and classification

Country	Classification						Country	Classification					
Austria	2	4	5	8	10	11	Lithuania	2	4	5	7	10	11
Belgium	1	4	5	8	10	12	Malawi	1	3	6	7	9	12
Bulgaria	2	4	5	7	10	12	Malta	2	4	5	7	10	11
Burkina Faso	1	3	6	7	9	12	Mauritania	1	4	6	–	–	12
China	1	3	6	7	9	11	Mauritius	1	4	5	–	–	12
Colombia	1	3	6	7	9	12	Mexico	1	3	6	7		12
Cuba	1	3	5	7	9	12	Morocco	1	3	5	7	9	12
Cyprus	2	4	5	8	10	11	Nepal	1	3	6	–	–	12
Czech Republic	2	4	5	7	10	11	Netherlands	2	4	5	8	10	11
Denmark	2	4	5	8	10	11	New Zealand	2	3	5	8	10	12
Finland	2	3	5	8	10	11	Norway	2	3	6	8	10	11
France	2	3	5	8	10	11	Oman	2	4	6	7	9	12
Greece	2	3	5	8	10	11	Panama	1	4	5	7	9	12
Hungary	1	4	5	8	10	11	Poland	2	3	5	7	10	11
Iceland	2	3	5	8	10	11	Portugal	2	3	5	8	10	11
Indonesia	1	3	6	7	9	12	Romania	1	3	6	7	9	11
Ireland	2	4	5	8	10	11	Slovenia	2	4	5	7	10	11
Israel	2	3	5	8	10	12	Spain	2	3	5	8	10	12
Italy	2	3	5	7	10	11	Sweden	2	3	5	8	10	11
Japan	2	3	5	8	10	11	Switzerland	2	3	5	8	10	12
Jordan	1	4	5	7	9	12	Thailand	1	4	5	7	9	12
Kazakhstan	1	4	6	7	9	12	Tunisia	1	4	6	7	9	11
Republic of Korea	2	3	5	7	9	11	Turkey	1	3	5	7	9	11
Lao PDR	1	3	6	–	–	12	United Kingdom	2	3	5	8	10	11
Latvia	2	4	5	7	10	12	United States	2	3	5	8	10	12

Notes: The number “1” (“2”) indicates that the country included in the subsample is developing (advanced). The number “3” (“4”) indicates that the country included in the subsample has lower (greater) trade openness. The number “5” (“6”) indicates that the country included in the subsample has lower (higher) natural resource abundance. The number “7” (“8”) indicates that the country included in the subsample has lower (greater) corruption. The number “9” (“10”) indicates that the country included in the subsample has lower (higher) democracy. The number “11” (“12”) indicates that the country included in the subsample has lower (larger) ethnic fractionalization.

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TABLE A.2. Pesaran's CD and panel unit root tests

	Real GDP per capita	School enrollment	Primary enrollment	Secondary enrollment	Tertiary enrollment	Infant mortality	Child mortality	Life expectancy	Physical capital
CD	149.41**	144.30**	3.89**	74.73**	154.40**	175.95**	176.28**	163.80**	150.77**
IPS: level	4.29	5.59	−1.35*	0.66	2.64	12.37	8.13	−19.74**	13.70
Difference	−16.24**	−15.58**	−16.36**	−17.17**	−16.49**	−7.40**	−3.42**	−25.55**	−8.46**
CIPS: level	−1.62	−1.79	−1.69	−1.68	−1.56	−1.43	−1.22	−1.84	−1.06
Difference	−3.25**	−3.56**	−3.65**	−3.66**	−3.60**	−2.40**	−1.97*	−3.98**	−2.98**
Obs. ($N * T$)	1,400	1,400	1,400	1,400	1,400	1,400	1,400	1,400	1,242

Note: ** and * denote significance at the 1% and 10% levels, respectively.

TABLE A.3. Cointegration and heterogeneity tests

	Real income and health capital			Real income and education capital		
	Infant mortality	Child mortality	Life expectancy	Primary enrollment	Secondary enrollment	Tertiary enrollment
Panel A: Cross-section dependence and cointegration tests						
Pesaran (2004)						
CD test statistics	27.63**	25.53**	14.06**	12.83**	33.95**	22.47**
Holly et al. (2010)						
CIPS: level	−3.20**	−3.12**	−3.40**	−3.20**	−3.10**	−3.50**
Difference	−4.73**	−4.78**	−5.15**	−4.74**	−4.73**	−4.91**
Pedroni (2000, 2004)						
Group ρ	2.94**	2.93**	3.82**	3.31**	2.97**	2.73**
Panel ADF	−2.21*	−2.34*	0.04	−1.64	−2.15*	−1.73*
Group ADF	−2.27*	−2.45*	−0.26	−2.01*	−2.38*	−2.44*
Panel B: Heterogeneity test						
Test statistic	677.00**	691.63**	616.75**	820.44**	792.64**	920.42**

Note: ** and * denote significance at the 1% and 10% levels, respectively.

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TABLE A.4. Weak exogeneity/long-run causality tests

Panel A: Alternative education capital

	Primary enrollment and infant mortality weak exogeneity of			Secondary enrollment and infant mortality weak exogeneity of			Tertiary enrollment and infant mortality weak exogeneity of		
	Real GDP per capita	Primary enrollment	Infant mortality	Real GDP per capita	Secondary enrollment	Infant mortality	Real GDP per capita	Tertiary enrollment	Infant mortality
$\chi^2(1)$	97.08**	178.88**	37.60**	90.12**	125.71**	24.29**	125.96**	112.06**	31.45**

Panel B: Alternative health capital

	School enrollment and infant mortality weak exogeneity of			School enrollment and child mortality weak exogeneity of			School enrollment and life expectancy weak exogeneity of		
	Real GDP per capita	School enrollment	Infant mortality	Real GDP per capita	school enrollment	Child mortality	Real GDP per capita	School enrollment	Life expectancy
$\chi^2(1)$	125.28**	162.26**	57.06**	123.75**	140.04**	53.78**	126.24**	188.41**	56.48**

Notes: The number of degrees of freedom ν in the standard $\chi^2(\nu)$ tests correspond to the number of zero restrictions. The number of lags was determined by the general-to-specific procedure with a maximum of three lags. ** and * denote significance at the 1% and 10% levels, respectively.

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