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A new way to look at old issues: Worker education and regional economic growth

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Abstract

Human capital investments can improve economic growth in various ways. Nevertheless, existing studies have found that investing in human capital produces minimal returns. However, their results may have been affected by attenuation bias after the application of particular assessment adjustments. In addition, there is no evidence of causality in several studies. Accordingly, this study investigates the effects of human capital investment (in the form of workers' education) on economic growth. Data of 102 nations from 2000 to 2015 are used to discern the yearly effects on the development of services provided by educated workers. Micro-models of the supply of and demand for the services provided by educated workers are estimated with macro production technologies. The findings indicate a significant positive causality between the services provided by educated workers and economic performance, particularly when there is optimal education investment. Investment in education appears to be ideal at roughly three to six numbers of years of education in fields where enterprise-required skills are taught. Economies in which average workers have attained this education level and possess the skills needed by companies in the relevant locations maximize growth. As a result of the economic growth, employment increases for unemployed workers with the enterprise-required skills.

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1. Introduction

Researchers have long endeavored to understand the impact of human capital on overall economic growth, producing a significant body of research (Barro 1991, 2001, Benos and Zotou 2014, Breton 2013, Hanushek and Woessmann 2012, Hendricks 2002, Jones 2002a, and Vandenbussche *et al.* 2006). The relevance of this topic continues to grow as a result of evolving and innovative approaches to output production (Acemoglu *et al.* 2018, Chatterjee and González-Rivera 2018, and Toivanen and Väänänen 2016). This study re-evaluates how investing in human capital affects economic growth. Specifically, it uncovers certain relatedness existing among groups of countries in terms of their commitment to investing in human capital for economic growth.

The study contributes to the literature by finding latent groups of related economies and the effects of human capital investment on economic growth for each group. It presents a new intuitive approach to determining group heterogeneity in the effect of human capital investment on growth. The study also investigates whether the effect of human capital on growth is correlated with the rising demand for human capital services triggered by increased economic growth. The findings in this regard contribute to the literature on the relationship between human capital investment and employment creation. Historical data of 102 countries for the period 2000–2015 are used to explore the effects of investing in human capital on growth.

Human capital investments can improve economic growth in various ways. First, investing in human capital generates economic growth because the outcomes—ideas, information, and competencies—increase the demand for the inputs used in their production. In economies where workers have only basic capabilities, innovative approaches to production are restricted, and industrial growth is limited (Squicciarini and Voigtländer 2015). In such economies, operational costs are high and sales are minimal (Restuccia and Rogerson 2017). The acquisition of skills by workers reduces these costs and increases sales. Investing in human capital can enhance the workers' skills (Bell *et al.* 2019), leading to the adoption of new production approaches and the spread of innovative ideas across enterprises (Freire-Serén 2001). Firms capable of establishing and diffusing new processes realize increased benefits (Bertrand and Schoar 2003, and Bloom *et al.* 2013). In general, human capital investments generate externalities and demonstrate a spillover effect (Acemoglu and Angrist 2000, and Belenzon and Schankerman 2013).

Nevertheless, existing studies have found that investing in human capital produces minimal returns (Krueger and Lindahl 2001, and Portela *et al.* 2004). However, their results appeared to have been affected by the attenuation bias after the application of particular assessment adjustments (Acemoglu and Autor 2012). Hanushek and Woessmann (2008) and Oreopoulos and Salvanes (2011) used various assessment adjustments to derive comparative results. Cohen and Soto (2007) and Fuente and Doménech (2006) further attempted to overcome the problems of measurement in the Barro and Lee (2001) data in terms of educational attainment.

In addition, there is no evidence of causality in several studies (Bils and Klenow 2000); an exception is the study by Sianesi and Van Reenen (2000), which found reverse causation between investment in human capital and growth. Reverse causation suggests that an increase in economic growth can result from human capital investments, and economic growth increases can increase the demand for the services of educated workers. This identifies a simultaneity problem between the services of educated workers and growth. However, most approaches for finding group heterogeneity of an economic relationship do not adequately account for endogeneity, such as the approach by Liu *et al.* (2020). This study presents a new intuitive approach that first demonstrates how severe the effects of endogeneity and unobserved heterogeneity are in the relationship between human capital investments and growth. The next step is to select an estimator that sensibly accounts for the aforementioned problems to track the latent groups of related economies in terms of the effect that the services provided by educated workers exert on economic growth.

Human capital investments can work in conjunction with other growth-enhancing elements such as investment in infrastructure or unobserved components such as social dispositions toward work and business and the robustness of property rights. In this study, I used country-specific fixed effects to control for potentially spurious relationships. The spillover effects suggest nonlinearities in the output effect of investments in human capital (Kalaitzidakis *et al.* 2001, and Kijek and Kijek 2020) and indicate that the size of the growth impact caused by human capital investment depends on reaching a critical investment threshold. This result suggests that a positive growth effect can impose a threshold on a country's human capital investment. This study investigates the existence of these nonlinearities in the growth effect and the extent of the investment threshold. The findings have consequences for public policy in terms of the optimum level of human capital investment to maximize output growth.

The remainder of this paper is organized as follows. Section 2 presents the data and important descriptions; Section 3 expands the model; and Section 4 discusses the findings. Section 5 concludes.

2. Data

This section examines the association between investments in human capital and economic growth. Data are sourced from 102 developed and developing countries for the period 2000–2015. Considering developed and developing countries provide a better coverage of the regional economies that is necessary in examining the effect of worker education on growth around the world. The 2000–2015 time frame is used because of incomplete data for some variables such as road networks. Again, the aim of this study is to re-evaluate how investing in human capital has affected regional economic growth in the recent decade. The data examined include the real gross domestic product (GDP), capital stock (K), total stock of workers (TSW), number of persons employed (NPE), and the overall population (POP).

Table 1–Description of study variables and summary statistics

	Description	Mean	Standard deviation	Minimum	Maximum
K[a]	Real capital stock at current prices in millions US$	2701.504	7350.058	4.055	86485.090
RDH[a]	Real deterioration of human capital, measured as the real depreciation rate	0.043	0.011	0.023	0.101
NPE[a]	Number of persons employed, a measure of the raw labor in millions	23.951	89.702	0.122	791.770
GDP[a]	Real GDP at constant prices in millions US$, a measure of economic output	717.046	1977.265	2.731	17126.860
PHC[a]	Price of human capital services, proxied by the price level of capital services	0.859	0.443	0.061	3.241
POP[a]	Population in millions	52.218	178.218	0.270	1397.029
HS[b]	Household size, measured as total contributing family workers in percent	7.111	8.966	0.013	48.473
TSW[b]	Total stock of workers, proxied by total labor force in millions	2470.505	8946.493	14.499	78707.32
MTL[b]	Main telephone lines	10624.020	33505.940	0.800	367786
TRN[c]	Total road network in kilometers	293.239	847.677	1.230	6586.623
EGC[d]	Electricity generating capacity in megawatts	43.362	139.818	0.007	1628.711
SEC[e]	Average duration of secondary schooling, a measure of human capital stock	3.302	1.563	0.130	8.410
USA	Dummy variable, United States	0.010	0.099	0	1
LOW	Dummy that is equal to 1 when SEC<2.5	0.335	0.472	0	1
MHIGH	Dummy that is equal to 1 when 2.5<SEC≤5.5	0.586	0.493	0	1
VHIGH	Dummy that is equal to 1 when SEC > 5.5	0.079	0.270	0	1

Sources: [a] Penn World Table 9.1 (Feenstra *et al.* 2015); [b] World Development Indicators 2019; [c] the World Road Statistics; [d] the United Nations Energy Statistics; and [e] Barro and Lee (2013).

Additional data include the average duration of secondary education (SEC), price of (human) capital services (PHC), real deterioration of human capital (RDH), and contributing family workers (HS). They also include measures of infrastructure services: main telephone lines (MTL), total road networks (TRN), and electricity generating capacity (EGC). The education variable can be observed at five-year intervals. Table 1 shows the variables used in the analysis and the specific rundown measurements; data sources are provided as footnotes.

The country-specific data was used to generate all missing information regarding human capital stock via the exponential growth procedure (EGP), in which the growth rate remains constant over a certain period. Starting from the stock of human capital in 2000, the growth rate is applied to the total initial stocks, along with any changes in the growth rate. Points are then computed using the R software for the periods 2000–2005, 2005–2010, and 2010–2015, taking the predicted stock for 2015 into account. Development in human capital stock occurs every year, causing an exponential growth. The infrastructure measure is constructed as a geometric mean of the MTL, TRN, and EGC, in accordance with Calderón *et al.* (2015).

Before commencing the modeling process, various broad midpoints are arranged, and the fundamental linkages are analyzed. Table 1 reveals the increase in education investment along with the calculated average real GDP for the 102 countries for 2000–2015. Real GDP increased from approximately US$ 3 million to US$ 17,127 million, which amounts to a mean growth of US$ 717 million over the 15-year period. This growth can be partially attributed to an increase in the education investment from 0.13 years to 8.41 years with a mean of 3.30 years over the 2000–2015 periods. A total of 1,632 observations were used, and the summary statistics for the other variables are also shown in Table 1. Overall, it can be concluded that there is a strong and positive association between education investment and economic growth, with a correlation coefficient of 0.64.

This robust relationship correlates with the significant effects identified when aggregate output is regressed on human capital investment. Figure 1 shows the relationship between education investment and GDP per worker for a single year, 2015. A univariate cross-country regression of investment in education clarifies that it is responsible for approximately 86% of the variation in economic output, with investment in education appearing to be a major contributor to the overall output growth.

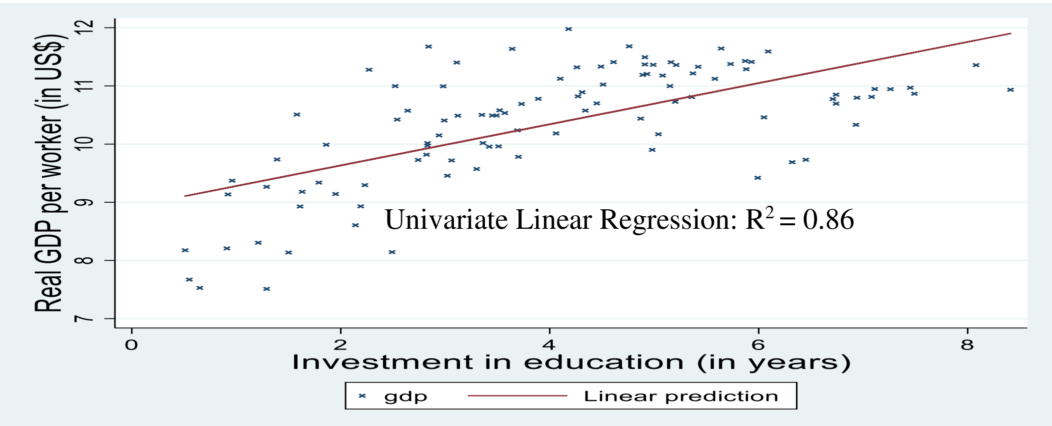

Fig. 1 Investment in education and real GDP per worker for 102 countries

3. Models

Consider a structural model of telecommunication investment used by Röller and Waverman (2001):

$$\log(GDP_{it}) = a_{0i} + a_1\log(K_{it}) + a_2\log(TLF_{it}) + a_3\log(PEN_{it}) + a_4 t + \varepsilon_{it}^1 \quad (1)$$

$$\log(PEN_{it} + WL_{it}) = b_0 + b_1\log(GDP_{it}/POP_{it}) + b_2\log(TELP_{it}) + \varepsilon_{it}^2 \quad (2)$$

$$\begin{aligned}\mathrm{Log}(TTI_{it}) = {} & c_0 + c_1\log(GA_{it}) + c_2 GD_{it} + c_3(1-USCAN).WL_{it} \\ & + c_4(1-USCAN)\log(TELP_{it}) + c_5(USCAN).\log(TELP_{it}) + \varepsilon_{it}^3\end{aligned} \quad (3)$$

$$\log\left(PEN_{it}/PEN_{i,t-1}\right) = d_0 + d_1\log(TTI_{it}) + d_2\log(GA_{it}) + \varepsilon_{it}^4 \quad (4)$$

where equation (1) specifies aggregate production as functions of physical capital stock (K); total labor force (TLF), a proxy for human capital stock; telecommunication stock, proxied by telephone penetration rate (PEN); and a linear time trend (t). It enables for country-specific fixed effects. Similarly, equation (2) presents real GDP per capita and telephone service price (TELP) as factors determining effective demand for telephone mainlines per capita, which is measured as telephone mainlines per capita plus waiting list per capita (WL). Waiting list per capita is combined with the penetration rate to capture telecommunication services' market clearing. This is because the service price of telephone cannot explain the available number of telephone mainlines at any moment in time. It is believed that there may be excess of telephone mainlines in some countries.

Again, the reduced-form equation (3) postulates that telecommunication infrastructure investment (TTI) is a function of country geographic area (GA), government real deficit (GD), the waiting list and price of telephone service. The *USCAN* is a dummy variable for the United States and Canada with respect to their supply-side reaction to waiting line and prices. In addition, equation (4) defines telecommunication infrastructure investment as the variation in the telecommunication infrastructure stock. With the presence of the micromodel of demand for and supply of telecommunication infrastructure in system (1)–(4), the telecommunications infrastructure is endogenized (Röller and Waverman 2001). That is, because equations (2), (3), and (4) includes the supply of and demand for telecommunication infrastructure, the telecommunications sector is endogenized. Again, note that equation (2) reflects the elasticity of telecommunication-service demand with respect to income.

The aim of this study is to endogenize the human capital investment similar to the endogenous telecommunication infrastructure in the system of (1)–(4). To do it, a structural model is envisaged within a production function framework in which investment in human capital is endogenized. A micromodel showing the supply of and demand for human capital, which is evaluated using macro production models, is specified. In this approach, investment in human capital is endogenized and the previously identified reverse causality is controlled. Country-specific fixed effects are added to solve the aforementioned spurious associations. Equation (1) is modified so that the macro activity of a nation is interfaced with its stock of capital (K), infrastructure index (INFR), the number of persons in employment (NPE), and the quantity of human capital. Human capital stock, rather than investment in human capital, enters the aggregate output production function because individual companies demand human capital, instead of investment in capital. However, human capital demand by enterprises is feasible when there is a supply of capital by families, which is possible through investment in capital.

The following dynamic simultaneous equations that relates to equations (1)–(4) is specified to explain economic growth with endogenous investment in human capital:

$$\log(GDP_{it}) = a_{i0} + \sum_{j=0}^{4} a_{1j}\log\left(K_{i,t-j}\right) + \sum_{j=0}^{4} a_{2j}\log\left(INFR_{it-j}\right) + a_3(SEC_{it}) + \sum_{j=1}^{3}\theta_j\log\left(GDP_{i,t-j}\right) + \varepsilon_{it}^{1} \quad (1')$$

$$\log(SEC_{it}/SEC_{i,t-1}) = b_{i0} + \sum_{j=0}^{1} b_{1j}\log\left(K_{i,t-j}\right) + \sum_{j=0}^{1} b_{2j}\log\left(RDH_{i,t-j}\right) + \sum_{j=0}^{1} b_{3j}\log(TSW_{it}) + \gamma\log(SEC_{it-1}/SEC_{i,t-2}) + \varepsilon_{it}^{2} \quad (2')$$

$$\log(SEC_{it}) = c_{i0} + \sum_{j=0}^{1} c_{1j}\log\left(PHC_{i,t-j}\right) + \sum_{j=0}^{1} c_{2j}\log\left(\frac{GDP}{POP}\right)_{it-j} + \delta\log\left(SEC_{i,t-1}\right) + \varepsilon_{it}^{3} \quad (3')$$

$$\log(TSW_{it}) = d_{i0} + \sum_{j=0}^{1} d_{1j}\log\left(HS_{i,t-j}\right) + \varphi\log\left(TSW_{i,t-1}\right) + \sum_{j=0}^{1} d_{2j}\, USA.\log\left(PHC_{i,t-j}\right) + \sum_{j=0}^{1} d_{3j}\,(1-USA).\log\left(PHC_{i,t-j}\right) + \varepsilon_{it}^{4} \quad (4')$$

where definitions of the variables are provided in Table 1.

SEC is the average duration of secondary education, which is used as a proxy for human capital (see e.g., Barro 2001). Although this measure of human capital is better than the other measures grounded in investment amounts (Kalaitzidakis *et al.* 2001), it is not reflective of the variances in the quality of human capital in different countries and different periods. The stock of human capital service used by enterprises is a determinant of the total output in equation (1'). As a result of the previously identified econometric complexities, country-fixed effects are allowed in the total output equation (1').

Equation (4') presents the supply of human capital as the overall stock of labor within a country. Based on this available stock of labor, firms recruit an optimal SEC amount of human capital service, which determines the overall productivity in the output equation (1'). The stock of human capital is embodied in the entire workforce in an economy. From this stock supply, firms recruit the SEC. The supply of human capital at a given time cannot be clarified using the price of human capital. There could be an overabundance of supply in some countries based on this price, meaning that a certain proportion of human capital could lack employment for an extended period prior to finding a job.

Unfortunately, the price of human capital for all the countries being considered could not be accessed. Therefore, the measure utilized is the capital service price level. Furthermore, a dummy for the United States is used because of the country's reaction to prices on the supply side. As suppliers of human capital in the United States are predominantly driven by private markets, the price elasticity of supply is expected to be different. The human capital price level for the United States differs from that of other nations (see, e.g., Feenstra *et al.* 2015) for an in-depth explanation of the data. Similarly, the size of the household, *HS*, affects the supply of human capital.

Differences in market characteristics and functions of company managers around nations render it challenging to clearly demonstrate the demand side of human capital in economies. Therefore, it is logical to develop an operational model for human capital demand. Since the activities of businesses fundamentally differ among nations, the potential to conceive a specific model remains limited. One approach could be to recognize enterprises' optimal production methods and accept that the volume of human capital service that yields outputs at the least cost is fully explicated by the price of human capital per worker, *PHC*; the income per capita, *GDP/POP*; as well as the volume of human capital required in the previous year, SEC_{t-1}. This is shown in equation (3').

Equation (2') shows investments in human capital in the form of a production equation, in which human capital production is determined by the input of physical capital, *K*; the input of labor stock, *TSW*; the rate at which human capital deteriorates, *RDH*; and past human capital investments, (SEC_{t-1}/SEC_{t-2}).

The supply and demand conditions in equations (2')–(4') cause the human capital investment to be endogenized, similar to the case of telecommunications infrastructure investment. The generalized method of moments (GMM) approach was used to obtain estimations of equations (1')–(4') for the 102 nations. Table 2 shows the numerical estimations. Note that "The focus of the empirical analysis is not on the estimation of demand and supply relationships in the telecommunications industry" (Röller and Waverman 2001 p. 918). As equation (1') is a modified version of the original equation (1), to implement this study's hypotheses, equations (2), (3), and (4) in the startup model are abstracted from.

4. Results and interpretation

Table 2 shows the results of the regression of human capital investment on economic growth. The ordinary least squares (OLS) method is used in Column 1, which does not account for fixed effects or reverse causality. In Column 2, the least squares dummy variable (LSDV) approach is used, which controls for fixed effects but not feedback causality. The GMM process is used in Column 3, which solves for fixed effects as well as simultaneity.

The capital variable, *K*, is introduced into the structure log (capital per worker). It has profound significance for the growth regression: the estimated coefficient is 0.299 (t-statistic of 3.03), whereas the OLS mean estimate is 0.350 (t-statistic of 6.59). This indicates that the capital per worker is robustly and positively correlated with the GDP per worker. The estimations produced by these methods are, to a certain extent, similar to the result of Romer (1990) that "in many countries, the portion of income paid to capital is around 33%" (p.25), implying that these estimations are not to be ignored (see also Gollin 2002).

INFR, the infrastructure variable, is included in the output regression to reflect the extent to which infrastructure services can be accessed, in line with Calderón *et al.* (2015). The estimated coefficient is fundamentally positive at 0.095 (t-statistic = 3.06) and representative of growth regressions. In the OLS method, the mean *INFR* was calculated as 0.087 (t-statistic = 2.73). This indicates a significant and positive relationship between the rise in infrastructure services and the output per worker. For example, the coefficient size implies that if infrastructure services increase by 10%, there will be approximately

1% rise in GDP per worker annually. Such elasticities replicate the returns to infrastructure, as demonstrated by Calderón *et al.* (2015).

Furthermore, the regressions include a specific relationship connecting previous and present growth for long-term horizons. For example, GDP_{t-1} denotes the output per worker in the previous year. The estimated coefficient for the previous growth is 0.909 (t-statistic = 8.90). In Column 1, the estimate is 1.003 (t-statistic = 13.70). Although these results suggest divergent growth, the estimates for the GMM estimator are considerably superior to those of the OLS estimator. The estimate for past growth fell from 1.003 in the OLS method to 0.793 in the LSDV technique (see Columns 1 and 2). The GMM estimate for the previous GDP per worker lies between these estimates. It makes, in line with Bond (2002), the estimator superior to the former two estimators.

The results of the human capital variable (*SEC*) are provided in Column 1. The growth elasticity is estimated to be 0.002 (t-statistic = 1.15), which is, as expected, insignificant but positive. The estimated value of 0.002 and the LSDV estimate of 0.004 mirror the findings of previous research that did not consider endogeneity seriously while investigating the effect of human capital on economic growth (Krueger and Lindahl 2001, and Portela *et al.* 2004). While human capital services do not necessarily have a very large impact on output per worker, this estimated value is not sufficient according to the "growth power" predicted by Romer (1990, pp.18–21). This could possibly be because the attenuation bias remains unaddressed. Another potential factor could be the presence of misleading relationships, requiring a fixed-effects estimation. The ambiguous evidence of previous growth (GDP_{t-1} in Column1) further implies spurious correlations.

The results in Table 2 are also estimations of investments in human capital and the associated supply and demand. Although they are not the main focus of this research, efforts were made to control for them, as would be considered sensible. The results exhibit relative robustness, but the results in Column 3 are the key focus. Human capital demand has a significant inverse relationship with the price of human capital (*PHC*), and size of the point estimate suggests that the demand is not elastic. Real GDP per capita, *GDP/POP*, is positive and significantly affects the demand for the services of educated workers. This income effect confirms the hypothesized existence of feedback causality between human capital and growth, and implies that investing in human capital generates employment for unemployed workers that possess the skills required by enterprises, but not for all types of unemployed workers. The demand in the previous year, SEC_{t-1}, is positively and significantly correlated with that in the current year.

The price and supply of human capital are significantly and directly related. The point estimate is less than unity, which suggests that the supply is not elastic across nations. In the United States, the supply exhibits perfect inelasticity as the price remains constant. Household size, *HS*, is significant in explaining the supply of human capital, and the supply in the previous year is positively associated with human capital supply in the current period. Again, capital *K* leads to growth in human capital production. However, the rate at which human capital deteriorates, *RDH*, significantly and negatively affects production. Furthermore, the labor stock, *TSW*, leads to increases in human capital production, which confirms that human capital investment makes services of educated workers available for hire for enterprises. Moreover, previous human capital investments (SEC_{t-1}/SEC_{t-2}) lead to considerable growth in human capital production.

To investigate whether there is any change in the estimated effect of human capital on output per worker after controlling for spurious relationships and endogeneity, Equation$(1')$ was re-evaluated, taking into account country-specific fixed effects; the results are shown in Column 3. The determined effect of commitment to investing in education to output per worker is fundamentally transformed. The estimated elasticity increases to 0.021 (t-statistic = 2.08), suggesting growth effects that are considerably more plausible than previous estimations. This indicates that an additional year of schooling yields a considerable average increase in GDP per worker. In particular, if all other factors remain constant and simultaneity and fixed effects are considered, the mean growth in GDP per worker due to an additional year spent in education is 2.1% per annum.

In general, more plausible estimations were obtained by addressing the issue of simultaneity as well as misleading relationships. Overall, the GMM outcomes show an increased growth effect of education, similar to previous studies that applied varying corrections (Acemoglu and Autor 2012, Hanushek and Woessmann 2008, and Oreopoulos and Salvanes 2011). In addition, Colclough et al. (2010) explain the differences in the results. The representation of fixed effects with no reverse causality does not solve

Table 2–Average duration of secondary education and real GDP per worker: Developed and developing countries–Dynamic estimates of Equations (1')–(4') [a]: (2000–2015)

Variable	Column1		Column2		Column3[b]		Column4[b]	
	Estimate	*T*-value	Estimate	*T*-value	Estimate	*T*-value	Estimate	*T*-value
Output equation								
K	0.350	6.59	0.371	6.58	0.299	3.03	0.312	4.02
INFR	0.087	2.73	0.082	2.41	0.095	3.06	0.091	2.75
SEC	0.002	1.15	0.004	0.65	0.021	2.08	—	—
*LOW*SEC*	—	—	—	—	—	—	0.018	0.99
*MHIGH*SEC*	—	—	—	—	—	—	0.037	2.02
*VHIGH*SEC*	—	—	—	—	—	—	0.031	2.16
GDP_{t-1}	1.003	13.70	0.793	9.49	0.909	8.90	0.919	10.47
Demand equation								
GDP/POP	0.034	0.97	0.005	0.13	0.184	2.06	0.184	2.06
PHC	−0.036	−1.57	−0.009	−0.50	−0.362	−2.50	−0.362	−2.50
SEC_{t-1}	1.021	117.32	1.148	36.66	1.049	27.00	1.049	27.00
Supply equation								
HS	0.004	1.74	0.006	2.66	0.006	2.28	0.006	2.28
*(1-USA*PHC*	−0.010	−1.99	−0.001	−0.28	0.025	2.13	0.025	2.13
TSW_{t-1}	0.998	1199.38	0.983	138.84	0.983	84.69	0.983	84.69
Investment equation								
K	0.005	0.84	0.004	0.59	0.052	2.04	0.052	2.04
RDH	−0.027	−0.68	−0.070	−1.38	−0.781	−4.14	−0.781	−4.14
TSW	−0.045	−3.04	−0.018	−0.87	0.117	2.02	0.117	2.02
SEC/SEC_{t-1}	0.914	42.10	0.811	34.71	0.614	6.92	0.614	6.92

[a] Columns 1 and 2 report estimates from OLS and LSDV sequentially, and Columns 3 and 4 present the GMM estimates of the effects of education investment on GDP per worker.
[b] The number of instruments is 63 and 87 for Columns 3 and 4, respectively, which include the exogenous and first-order predetermined variables in the equations; lag of the dependent variable was not used as instrument in a particular equation. The forward orthogonal demeaning (FOD) transformation was used (Hsiao and Zhou 2017).

the assessment bias (see Column2). An increased impact is identified when controlling for simultaneity as well as country-fixed effects.

The key focus of this study is to assess the effect of investing in human capital on economic growth, and to examine whether the growth equation is nonlinear. To investigate whether the increased growth effects are associated with a restriction on the investments in human capital of a public economy, the overall output equation (1') is reformulated as follows:

$$\log(GDP_{it}) = a_{i0} + \sum_{j=0}^{4} a_{1j}\log(K_{i,t-j}) + \sum_{j=0}^{4} a_{2j}\log(INFR_{i,t-j}) + \sum_{j=1}^{3}\theta_j \log(GDP_{i,t-j}) + (a_3 LOW_{it} + a_4 MHIGH + a_5 VHIGH_{it}).SEC_{it} + \varepsilon_{it}^{1} \qquad (1'')$$

where *LOW*, *MHIGH*, and *VHIGH* are dummy variables associated with low, moderately high, and very high investments in education, respectively (Table 1). The mean investment made by the 102 nations in education is approximately 3 years (see Table 1). Investment durations that fall below this mean are categorized in the low range (investment in education between the mean and medium, which forms roughly 33.5% of the sample). Investment years above the mean are categorized in the high range (i.e., investment in education between the mean and maximum investments). It is possible to further categorize increased investments in education in the moderately high range (an investment that moves from the mean toward the midpoint to the maximum, accounting for about 58.6% of the sample), while the remaining 7.9% of the sample until the highest investment of 8.410 years is categorized as being extraordinarily high (a precise definition is provided in Table 1).

Table 3–Group-wise estimation results [a]

Country	Mean	Country	Mean	Country	Mean
GROUP 1	**0.018**	**GROUP 2**	**0.037**	Denmark	4.870
African countries = 17		**African countries = 6**		Estonia	5.017
Benin	1.576	Botswana	3.147	Finland	3.806
Burundi	0.461	Egypt	2.807	France	5.014
Cameroon	1.742	Gabon	3.090	Greece	3.610
Central African Rep	1.078	Mauritius	3.382	Hungary	3.894
Cote d'Ivoire	1.272	South Africa	2.969	Iceland	4.127
Kenya	1.441	Tunisia	2.507	Ireland	3.977
Lesotho	1.326	**American countries = 10**		Israel	4.514
Mauritania	0.814	Argentina	2.660	Italy	4.548
Morocco	1.711	Barbados	3.375	Latvia	5.057
Mozambique	0.278	Canada	4.982	Lithuania	5.074
Namibia	1.329	Chile	3.764	Luxembourg	4.268
Niger	0.392	Colombia	3.111	Netherlands	4.531
Rwanda	0.617	Jamaica	3.751	Norway	4.482
Senegal	0.555	Mexico	3,101	Poland	3.415
Sierra Leone	1.157	Panama	3.272	Romania	3.971
Togo	1.854	Peru	3.225	Russian Fed.	4.968
Zimbabwe	1.966	Venezuela	2.571	Serbia	4.138
American countries = 10		**Asian countries = 12**		Slovak Rep	4.373
Bolivia	2.398	China	2.740	Slovenia	4.994
Brazil	2.264	India	2.569	Spain	3.899
Costa Rica	2.198	Iran	3.649	Sweden	5.091
Dominican Rep.	2.474	Japan	4.658	Switzerland	4.929
Ecuador	2.327	Jordan	3.739	United Kingdom	4.929
Guatemala	0.980	Korea, Rep	4.971	**Oceania countries = 3**	
Honduras	1.554	Kuwait	3.020	Australia	4.727
Nicaragua	1.894	Malaysia	4.399	Fiji	3.181
Paraguay	2.269	Mongolia	4.918	New Zealand	3.900
Uruguay	2.353	Qatar	2.794	**GROUP 3**	**0.031**
Asian countries = 5		Saudi Arabia	2.950	**American Countries = 1**	
Indonesia	1.937	Sri Lanka	4.050	United States	5.506
Iraq	2.199	**European countries = 31**		**Asian countries = 3**	
Lao PDR	1.372	Austria	5.218	Kazakhstan	6.637
Philippines	2.491	Belgium	4.236	Kyrgyz Rep	5.872
Thailand	2.086	Bulgaria	4.267	Tajikistan	6.180
European countries = 2		Croatia	4.168	**European countries = 2**	
Portugal	2.417	Cyprus	4.043	Germany	6.413
Turkey	2.094	Czech Rep	4.870	Moldova	5.730

[a] The mean for each group is the effect of investing in education on growth. For a specific country, it is the mean education investment. Groups 1_3 are for low, moderately high, and very high levels of education investments, respectively. The total number of countries is 102.

The country-specific fixed effect is considered in Equation (1"). No base is provided, because the focus is on evaluating the actual growth effects of the investments; in other words, the significance and signs of a_3, a_4, and a_5. For example, when a_3 is positive and significant, but a_4 and a_5 are negative, a "diminishing returns" hypothesis is supported. However, if the signs are reversed (i.e., $a_4 > 0$ and $a_5 > 0$), the evidence supports an "ideal investment" hypothesis, in that the impact might be relatively insignificant for low investment levels. It is instructive to state that human capital investment in this context reflects the number of years spent acquiring the right types of skills required by enterprises. Once there is a mismatch between the skill composition of workers and the skills companies require in an economy, the services of such workers become insignificant for maximizing economic growth.

In Table 2, segment 4 shows the evaluation results of Equations (1''), (2'), through to (4'). The point estimations for real capital, *K*; infrastructure, *INFR*; as well as previous economic growth, GDP_{t-1}, retain significance and are within the sizes formally deemed to be satisfactory. Significantly, a worker who has made a considerable investment in education and has been educated to possess the right types of skills needed by enterprises within a nation yields an annual output of 3.7% (t-statistic = 2.02), which is significantly greater than the previously mentioned average output effect of 2.1%. By contrast, a worker whose investment in education is lacking produces 1.8% (t-statistic = 0.99) GDP, which is below that of a worker that makes high investments in education.

However, the extra GDP obtained disappears when the investment in education exceeds the optimal amount required to produce the highest economic growth. For example, the findings indicate that a worker with a very high education investment contributes 3.1% (t-statistic = 2.16) annually to GDP growth in the long term, which is less than that of a worker with moderate investment in education. This implies that the growth effect of human capital services rises: At a constant annual rate when there is less than three years of educational investment; at an increasing annual rate for roughly three to six years of educational investment; and at a diminishing annual rate for around eight years. This indicates that the annual contribution of human capital service to economic growth is greater in a nation whose workers have, on average, at least a minimum of roughly three number of years of education and a maximum of close to eight years of education in the curriculum wherein the right skills needed most for production in that location are taught.

The findings clearly reveal that the effect of human capital services on economic growth for a moderately high level of investment is greater than twice that with a low level of investment. In particular, human capital investments can reach an "optimum level." In this study, this optimum level equates to a mean investment of three to six years, which incorporates the mean investment in human capital for countries in Group 2 of Table 3. The mean investment in education for countries in Group 3 roughly exceeds the ideal education investments, and that for countries in Group 1 it is generally below the threshold level (see Table 3).

In this case, the findings indicate that an expansion of human capital investments by Group 1 countries yields a greater effect on overall growth. Therefore, African and other countries in Group 1 can grow their economies by investing in human capital, similar to China, Japan, and other countries in Group 2, assuming that human capital is significantly improved. In the United States and other countries in Group 3, education investment generates a diminishing growth effect. This does not imply that countries in Group 2 have grown larger than countries in other groups. It only implies that education has contributed more to the economic growth of the former countries than it has to the growth in the latter countries over the past one and a half decade. Overall, Table 3 groups countries according to similarities among them with respect to the relationship between investments in human capital and economic growth. This illustrates the importance of group heterogeneity in the effect of investing in education on economic growth.

5. Conclusion

This study aimed to investigate the relationship between human capital investment and economic performance. A model was estimated in which human capital investment is endogenized by developing a micro model that shows the demand for and supply of human capital investment. To observe the effects across economies, macro production technology was used to assess the micro model. After controlling for simultaneity and fixed effects, a causal relationship was observed between the stock of human capital and the overall output. Given the three levels of human capital investments, a threshold level is reached, indicating that the highest returns on education are achieved at moderately high levels of investment. This implies that increased investments in human capital have a greater effect on growth in only a certain group of economies.

The overwhelming growth of the Chinese economy, which is traceable to the 1999 Chinese educational policy, can serve as a practical example to these results. The policy massively increased higher education attendance in that year and the high annual rate of education attainment continued for over fifteen years. Coupled with the fact that Chinese higher institutions have a track record of teaching students hard skills, there was a large influx of educated workers into the Chinese labor market, which is the secret of the Chinese economic growth in recent times. As a result of such growth, employment has increased for Chinese graduates from technical or quantitative majors, but not for graduates who lack hard as well as soft skills–strong communication, analytical and managerial skills–that are required by companies (McKinsey 2013, and Tsang 2000). Accordingly, it is recommended that nations should adopt policies that strongly encourage higher education attendance and curricula that can appropriately match workers' skills with the types of skills enterprises require. This would expand economic growth of nations and increase employment of workers.

Identifying the most suitable group number for such returns is important but was not considered in this research. Doing so would help better understand the growth effects and consistency of group memberships. An educational curriculum that would better match workers' skills with the types of skills needed by companies was also not examined, which would clarify the presence of growth effects.

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