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Human Capital and Economic Growth in India: The ARDL Approach

رأس المال البشري والنمو الاقتصادي في الهند :منهج ARDL

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Abstract

We used time series data on variables, real GDP, physical capital stock and human capital index of India to examine the relationship between these three variables oyer the period 1972-2019. The auto-regressive distributed lag (ARDL) model and the bound test of co-integration reveal that physical capital stock, human capital index and GDP are co-integrated only when GDP is used as the dependent variable. Moreover, the negative and statistically significant value of the coefficient of adjustment in the error correction model further reinforces that there is a long-run relationship between these variables. This long-run relationship also reveals that both physical capital stock and the human capital index positively impact GDP growth in India. Growth in the human capital index is not found to be dependent on either GDP or physical capital stock. Since the human capital index is constructed based on years of schooling and returns to education, we infer from it that education stimulates economic growth in India. Hence, India has reaped the benefits in the form of economic growth by adopting the policy of free and compulsory education for its populace.

Keywords: Human Capital, Physical Capital, Economic Growth, ARDL Model, Bound Test.

ملخص

لقد استخدمنا بيانات السلسلة الزمنية للمتغيرات، الناتج المحلي الإجمالي الحقيقي، ومخزون رأس المال الفيزيائي ومؤشر رأس المال البشري في الهند لفحص العلاقة بين هذه المتغيرات الثلاثة خلال الفترة 1972-2019 .أظهرت واختبار (ARDL) نموذج الخطأ الموزع الذاتي التأخيري حدود التكامل أن مخزون رأس المال الفيزيائي ومؤشر رأس المال البشري والناتج المحلي الإجمالي متكاملون فقط .عندما يتم استخدام الناتج المحلي الإجمالي كمتغير معتمد علاوة على ذلك، فإن القيمة السلبية والإحصائية المعنوية لمعامل التعديل في نموذج تصحيح الخطأ تعزز أكثر من ذلك أن هناك علاقة طويلة الأمد بين هذه المتغيرات .كما يكشف هذا العلاقة طويلة الأمد أن مخزون رأس المال الفيزيائي ومؤشر رأس المال البشري يؤثران إيجابياً على نمو الناتج المحلي الإجمالي في الهند .لم يتم العثور على نمو ري أن يكون معتمدًا علىxفي مؤشر رأس المال البش .الناتج المحلي الإجمالي أو مخزون رأس المال الفيزيائي حيث أن مؤشر رأس المال البشري يتم بناءه استنادًا إلى سنوات التعليم وعوائد التعليم، نستنتج من ذلك أن التعليم يحفز النمو الاقتصادي في الهند .وبالتالي، حققت الهند الفوائد في شكل نمو اقتصادي من خلال اعتماد سياسة التعليم المجاني والإلزامي لسكانها

،كلمات مفتاحية :رأس المال البشري، رأس المال الفيزيائي .اختبار الحدود ،ARDL النمو الاقتصادي، نموذج

Introduction

The economic growth of a nation hinges on its growth of the stock of physical, and human capital and the level of technology it uses in the production of goods and services. Growth in physical capital stock is generally considered an important determinant of economic growth but the growth theories predict that long-run sustained growth is not possible only through capital accumulation. The modern endogenous growth theories rely on human capital growth for long-run sustained growth in a country. Endogenous growth theorists consider knowledge, education, research and development as the key drivers of technological changes that sustain growth in a country.

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The attributes of workers that can potentially enhance their productivity in any productive activity are called human capital. Workers accumulate these attributes mostly through investments. Becker (1965) and Mincer (1984) developed the early human capital theories. These theories explain the role of human capital in the production process and the incentives to invest in skills, in the form of schooling, on-the-job investments, and training. Their analysis emphasizes the productivity-enhancing role of human capital.

Schultz (1961) and Nelson & Phelps (1966) provided an alternative perspective on human capital. According to their perspectives, the main role of human capital is not to enhance productivity in current tasks, but to help workers cope with changes, disruptions and especially the adoption of new technologies. Nelson and Phelps's (1966) perspectives on the role of human capital are significant in many cases. For instance, a number of empirical evidence suggests that more educated farmers are more likely to adopt new technologies and seeds (Foster & Rosenzweig, 1996).

Some growth literature with empirical evidence supports Nelson and Phelps' perspectives on human capital. This literature found a stronger correlation between economic growth and levels of human capital than between economic growth and changes in human capital. Benhabib and Spiegel (1994) suggest that this may be for the reason that the most important role of human capital is not to increase the productive capacity in current activities but to facilitate the adoption of new technology.

Human capital represents people's investment in acquiring skills, education and training that raise their productivity. The theory that explains the economic behaviour of people towards the acquisition of education and training as an investment is called human capital theory. Human capital theories given by Schultz (1971), Sakamota & Powers (1995), and Psacharopoulos & Woodhall (1985) are founded on the premise that education plays a key role and is essential for improving the productive efficiency of people engaged in economic activities.

Nelson & Phelps (1966) and Benhabib & Spiegal (1994) observed that labour force with more education has the ability to make innovations faster. Lucas (1988) and Mankiw et al., (1992) found that the increase in human capital enhances the productivity of other factor inputs which raises economic growth. Their models explain that the rate of economic growth depends on the rate of human capital accumulation. Narayan & Smith (2004) found that human capital, income and export are co-integrated when export is used as a dependent variable, but they are not co-integrated when human capital or income is used as a dependent variable.

Thus, in economic growth literature, both bi-directional and unidirectional causality is suggested between human capital and economic growth.

The neoclassical growth models brought the role of technology into prominence for long-run economic growth. However, since the technology is assumed to be exogenous, they do not explain the mechanism through which technological change takes place in an economy.

In contrast to neoclassical growth models, the endogenous growth models put forward some explanations for technological change which is thought to be the key to long-run economic growth in a country. Intellectual property rights, scale and quality of research and education are the most important factors which cause technological changes. Scientific research and education are complements and reinforce each other. They are fountainheads of all types of innovations in a country. For a country with a large educated population base, it is much easier to learn, disseminate and adopt any new knowledge or innovation. India is one of the few countries which have successfully developed a big educated population base by adopting the policy of free and compulsory education for all children till the age of 14.

Hence, we aim to analyze if India has reaped the benefits of high economic growth from the policy of expanding education by providing free and compulsory education to its populace.

The primary objective of this article is to test causal relationships between physical capital, human capital and real GDP by applying the bond test of co-integration and the model of error correction using time series data for India from 1972 to 2019. The article makes some unique contributions to the strand of existing empirical literature linking physical capital, human capital and real GDP. This research endeavour is expected to further the understanding of the nature of this relationship and assist in policy-making and its execution.

Firstly, it uses the modern econometric technique of the ARDL bound testing model developed by Pesaran & Shin (1999) and Pesaran et al., (2001) to examine the long-run relationship among the above three variables. Secondly, it uses the Penn World Table data on the human capital index which is much broader than any other measure of it, as a substitute for human capital. Finally, it uses time series observations which are long enough to validate the estimated parameters.

The remaining article is organized as follows. In section 2, we discuss the theoretical underpinning and empirical evidence related to the estimated models and discuss the relationship among the above three variables. In section 3, we describe the variables included and how they have been constructed, the data sources for these variables and the econometric methods of data analysis adopted. Section 4 covers results and discussion. Finally, we conclude the paper in section 5.

Literature Review

The Solow (1956) model is the principal model to understand the long-run economic growth and cross-country variations in income. The production function in this model is expressed as $Y_t = A_t F(K_t, N_t)$ where A_t is an exogenous variable that measures productivity and K_t and N_t denote capital stock and labour force respectively in period t. This production function is believed to show diminishing marginal product to each factor input but constant returns to scale. The model also assumes perfect competition in the input market.

Given the above-mentioned properties of production function together with Solow's (1956) model assumptions predicts a positive relationship between capital and output per worker and between technological change and output per worker. However, the sustained increase in output per worker is determined only by exogenous technological growth. Thus, in the neoclassical growth model, the government or policymakers have no role to play in promoting long-run growth.

Lucas (1988) and Loening (2004) highlighted the role of human capital as an independent factor of production in their endogenous growth models. Mankiw et al., (1992) used the modified Solow model to directly incorporate human capital, in production functions and emphasized the need to adjust the labour force for all types of qualitative changes as in the course of time they acquire and embody the human capital with them.

The neoclassical growth models assume that productivity rises entirely exogenously and is not caused by any factor included in the model. The fact is that endogenous growth models are also based on the assumed growth relationships. However, as compared to neoclassical growth models, endogenous growth theories propose a mechanism within the model that gives rise to returns to scale which can potentially outweigh the diminishing marginal product. Thus, productivity may be assumed to be dependent on even size of capital per worker. The increasing returns to scale might be realized by a firm as people learn collectively from the experience gained through learning by doing as new capital is added (Arrow, 1962). In the same way as the accumulation of capital has the potential to increase productivity, growth in inputs like human capital, skills and technical knowledge can trigger a rise in productivity and cause sustained long-run growth by generating increasing returns to scale.

One of the earliest studies on the connection between education and economic growth is by Lucas (1988). He proposed that the development of human capital, which is dependent on the amount of time people devote to learning new skills, is essential for economic growth. Rebelo (1991) expanded this concept by adding physical capital as a second input to the function of accumulating human capital. Romer's (1990) endogenous growth model makes the assumption that new ideas are results of human capital, which takes the form of knowledge. Investment in human capital therefore enhances physical capital, which in turn spurs economic growth. Benhabib & Spiegel (1994) identified human capital development as a source of economic progress.

Human capital, according to Mincer (1984), is essential for a nation to experience sustained economic growth and development since it is both the cause and the impact of growth and development. The Granger causality test was used by De Meulemeester & Rochat (1995) to determine whether there was a connection between higher education enrollments and economic growth in six nations (Australia, France, Italy, Japan, Sweden, and the United Kingdom) for various time periods between the year1885 and 1987. They discovered a short-run unidirectional causal relationship between higher education enrollment and economic growth in France, the United Kingdom, Sweden, and Japan as well as a bidirectional relationship in Italy and Australia.

Bils & Klenow (2000) also addressed the relationship between the above two variables and found that, in the cross-country correlation, the causal impact of education on economic growth is as strong as the reverse causation from economic growth to the acquisition of education. A uni-directional connection from education to economic growth in India was discovered by Pradham (2009) using annual data from year 1951 to 2002 and the error-correction modelling technique.

However, several studies (In & Doucouliagos, 1997; Asteriou & Agiomirgianakis, 2001; Bo-nai & Xiong-Xiang, 2006) also presented empirical evidence in support of a bi-directional correlation between education and economic growth.

In both Pakistan and India, Abbas (2000) discovered a large and positive correlation between human and material capital. Using the impulse response function, Haldar & Mallik (2010) discovered that investments in education had a positive and statistically significant influence on investments in health and increase GNP per capita. Tamura (2006) discovered that the young adult death rate was favourably correlated with the fertility rate, and adversely correlated with both education level and rate of return from education.

Hanushek (2013) contends that raising educational standards help emerging countries prosper economically over the long term. According to Zang & Lihuan (2011), postsecondary education is more crucial for boosting China's economic growth than primary or secondary education.

An extensive data set on regional human capital and other characteristics from the 19th and 20th centuries was investigated by Diebolt & Hippe (2019), who discovered that historical regional human capital was a significant factor in explaining current regional differences in innovation and economic development. As a result, unidirectional as well as bidirectional interactions between y, pc, and hc are suggested by economic theories and empirical evidence.

Methodology

The time series data on Gross Domestic Product (GDP) at constant 2011 national prices (in mil. 2011 US$), Physical Capital (PC) stock at constant 2011 national prices (in mil. 2011 US$), and Human Capital (HC) index, based on years of schooling and returns to education for the period 1972-2019, are analyzed in this article. Each of these three variables was transformed into the natural log and denoted by the letters y, pc, and hc, respectively. The data on all of the aforementioned variables were compiled from the Penn World Tables, version 10.01 (Feenstra et al., 2015).

In order to test the long-term associations between y, pc, and hc, a three-step technique is used. Each variable is subjected to the Dickey-Fuller unit root test in the first stage. After estimating the auto-regressive distributed lag (ARDL) model, we perform the bound test of co-integration if the variables are integrated of a different order, but no variable is integrated of order two provided that they are also co-integrated. For the purpose of confirming the equilibrating relationships between them, we additionally estimate the ARDL error correction model (ECM). We, thereafter, use a variety of model adequacy tests.

To perform the bounds test of co-integration among the variables y, pc and hc, the conditional ARDL error correction model involving variables y, pc and hc are specified as follows:

$$\Delta y_t = a_{11} + b_{11}t + \sum_{i=1}^{p} \alpha_{i1} \Delta y_{t-i} + \sum_{i=1}^{p} \beta_{i1} \Delta pc_{t-i} + \sum_{i=1}^{p} \gamma_{i1} \Delta hc_{t-i} + \sigma_{11}y_{t-1} + \sigma_{12}pc_{t-1} + \sigma_{13}hc_{t-1} + u_{1t} \quad (1)$$

$$\Delta pc_t = a_{21} + b_{22}t + \sum_{i=1}^{p} \alpha_{i2} \Delta pc_{t-i} + \sum_{i=1}^{p} \beta_{i2} \Delta y_{t-i} + \sum_{i=1}^{p} \gamma_{i2} \Delta hc_{t-i} + \sigma_{21}pc_{t-1} + \sigma_{22}y_{t-1} + \sigma_{23}hc_{t-1} + u_{2t} \quad (2)$$

$$\Delta hc_t = a_{31} + b_{32}t + \sum_{i=1}^{p} \alpha_{i3} \Delta hc_{t-i} + \sum_{i=1}^{p} \beta_{i3} \Delta y_{t-i} + \sum_{i=1}^{p} \gamma_{i3} \Delta pc_{t-i} + \sigma_{31}hc_{t-1} + \sigma_{32}y_{t-1} + \sigma_{33}pc_{t-1} + u_{3t} \quad (3)$$

Hypotheses:

H_0: σ_{1j}=σ_{2j}= σ_{3j} (where j=1, 2, 3)

H_1: $\sigma_{1j} \neq \sigma_{2j} \neq \sigma_{3j} \neq 0$

Here, y is the log of real GDP, pc is the log of real physical capital stock, and hc is the human capital index. Δ is the first difference operator. For evaluating the significance of the lagged values of the variables, the F-test is used to examine long-run links between the variables. If a long-run association between the variables is present, the F-test identifies which variable needs to be normalized.

Based on the literature review and previous empirical research findings, we examine three different relationships, the first one with y as a dependent variable, the second one with pc as a dependent variable and the third one with hc as a dependent variable as follows:

$y_t = f_1(pc_t , hc_t)$ (4)

$pc_t = f_2(y_t , hc_t)$ (5)

$hc_t = f_2(y_t , pc_t)$ (6)

If the cointegration test suggests two cointegrating equations, we apply the vector error correction model to test the validity of these long-run relationships. Alternatively, the ARDL model will be applied if a single cointegrating equation is found with y as a dependent variable. Moreover, we also estimate the ARDL error correction model (ECM) which is specified below for checking the validity of the underlying long-run relationship:

$$\Delta y_t = a_{11} + b_{11}t + \sum_{i=1}^{p} \alpha_{i1} \Delta y_{t-i} + \sum_{i=1}^{p} \beta_{i1} \Delta pc_{t-i} + \sum_{i=1}^{p} \gamma_{i1} \Delta hc_{t-i} + \emptyset ECT_{t-1} + e_t \quad (7)$$

Toda and Yamamoto Test of Causality

We estimate the Toda & Yamamoto (1995) test of causality between variables if they are cointegrated based on the aforementioned relationships. The extended VAR model, which serves as the foundation for this test, is defined as follows:

$$y_t = a_{11} + \sum_{i=1}^{p} \alpha_{i1} y_{t-i} + \sum_{i=p+1}^{p+d_{max}} \alpha_{i1} y_{t-i} + \sum_{i=1}^{p} \beta_{i1} pc_{t-i} + \sum_{i=p+1}^{p+d_{max}} \beta_{i1} pc_{t-i} + \sum_{i=1}^{p} \gamma_{i1} hc_{t-i} + \sum_{i=p+1}^{p+d_{max}} \gamma_{i1} hc_{t-i} + u_{1t} \quad (8)$$

$$pc_t = a_{21} + \sum_{i=1}^{p} \alpha_{i2} pc_{t-i} + \sum_{i=p+1}^{p+d_{max}} \alpha_{i2} pc_{t-i} + \sum_{i=1}^{p} \beta_{i2} y_{t-i} + \sum_{i=p+1}^{p+d_{max}} \beta_{i2} y_{t-i} + \sum_{i=1}^{p} \gamma_{i2} hc_{t-i} + \sum_{i=p+1}^{p+d_{max}} \gamma_{i2} hc_{t-i} + u_{2t} \quad (9)$$

$$hc_t = a_{31} + \sum_{i=1}^{p} \alpha_{i3} hc_{t-i} + \sum_{i=p+1}^{p+d_{max}} \alpha_{i3} hc_{t-i} + \sum_{i=1}^{p} \beta_{i3} y_{t-i} + \sum_{i=p+1}^{p+d_{max}} \beta_{i3} y_{t-i} + \sum_{i=1}^{p} \gamma_{i3} pc_{t-i} + \sum_{i=p+1}^{p+d_{max}} \gamma_{i3} pc_{t-i} + +u_{3t} \quad (10)$$

where d_{max} is the maximum order of integration of a variable among all the variables.

Results and Discussion

Stationarity & Unit Root Test

Augmented Dickey-Fuller (Dickey & Fuller, 1979) and KPSS (Kwiatkowski et al., 1992) unit root tests are applied on the time series data of each variable. Both the tests show that only y is stationary at the first difference while the other two variables are not stationary at either level or the first difference (table 1).

Table 1.
Conventional Stationarity Test

	ADF Test Statistic	KPSS Test Statistic
Variables	Constant & Trend	Constant & Trend
y	0.25934 [0]	0.267675*[6]
pc	-1.72430 [1]	0.163011**[6]
hc	-2.45066 [1]	0.261547*[6]
Δy	-8.63207*[0]	0.120007[11]
Δpc	-2.182730 [1]	0.218061*[6]
Δhc	-2.24624 [0]	0.172501**[5]

* Shows level of significance at 1% and ** at 5%.
Source: Author's own calculation.

However, all the three variables are found to be stationary at the first difference when we apply Zivot-Andrews (Zivot & Andrews, 1992) unit root test allowing for one break in both intercept & trend. Hence, we find that the ARDL modelling is appropriate for examining a long-run relationships between these variables (Table 2).

Table 2.
Zivot-Andrew Unit Root Test Allowing for One Break in Intercept & Trend

Variables	Intercept & Trend
y	-3.38985[0]
pc	-4.90381[1]
hc	-3.77950[1]
Δy	-9.22192*[0]
Δpc	-5.21705**[0]
Δhc	-5.80606*[0]

*& ** denote the level of significance at 1%. & 5% respectively. Lags selected by the BCI criterion are given in the brackets.
Source: Author's own calculation.

Cointegration Analysis

For applying the ARDL model, variables must be integrated maximum of order 1. We applied Augmented Dickey Fuller test on each variable for ascertaining the order of integration of each variable. The results show that each of series pc and hc is I(0) but y is I(1). Therefore, we proceed to next step for applying ARDL model involving the above three variables.

Under the second step, we apply bounds test on each of y, pc and hc with separately y and pc as a dependent variable for checking the presence of co-integration among the variables. The results of bounds test with F-statistic reveal that there is co-integration among the variables only when y is used as a dependent variable.

The F-statistic value of 7.43961 with y as the dependent variable is higher than the 5% I(1) critical bound. Because y is the dependent variable, the null hypothesis that there is no long-run link between y, pc, and hc is rejected. The F-statistic value of 3.85872 with pc as the dependent variable is below the 5% I(0) critical bound. Since pc is the dependent variable, we could not reject the null hypothesis that there is no long-term link between y, pc, and hc. Similar to this, the value of F-statistic 2.99925 with hc as the dependent variable is below the 5% I(0) critical bound. As a result, the test does not successfully refute the null hypothesis that there is no long-term link between the three variables (Table 3).

Table 3.
The F-Bounds Test of Co-integration with Unrestricted Constant and Restricted Trend

Null Hypothesis: There is No Level Relationships						
Dependent Variable	F-statistic Value	Signif.	I(0)	I(1)	Co-integration	Decision
Δy	7.43961	5%	3.43	4.26	Yes	Estimate Error Correction Model
Δpc	3.85872	5%	3.43	4.26	No	Estimate ARDL short-run Model
Δhc	2.99925	5%	3.43	4.26	No	Estimate ARDL short-run Model

Source: Author's own calculation.

Results of the ARDL Error Correction Model

For checking the validity of the ARDL model involving co-integrated variables, we estimate the ARDL (8, 4, 8) Error Correction model and apply the diagnostics check for the model adequacy. Table 4 displays the outcomes of the error correction model. For the confirmation of a long-run relationship between the three variables y, pc, and hc with y as the dependent variable, the value of the Error Correction Term (ECTt-1) coefficient ϕ in equation (7) must be negative and significant (Table 4).

The value of coefficient of the error correction is -0.99210 which is negative as expected and also statistically significant at 1%. Moreover, the absolute value of it is very close to 1. Hence, the results of the estimated Error Correction Model validate the long-run relationship among these three variables (Table 4).

It is advisable to look at the rate of adjustment in the ARDL model. In the table below, CointEq(-1) is used to represent the Error Correction Term (ECT), and its coefficient is -0.99210. It is negative and statistically significant at 1%. It implies that about 99.2% of the deviation from the long-run relationship is corrected within a period of one year. Further, the large value -5.91692 of t-statistic of this coefficient is significant at 1% (Table 4).

Table 4.
ARDL (8, 4, 8) Error Correction Regression with Restricted Constant and No Trend

Variable	Coefficient	Std. Error	t-Statistic	Prob.
D(Y(-1))	0.649981	0.145837	4.456906	0.0003
D(Y(-2))	0.385203	0.126835	3.037049	0.0074
D(Y(-3))	0.693082	0.129855	5.337342	0.0001
D(Y(-4))	0.256853	0.109971	2.335637	0.0320
D(Y(-5))	0.617502	0.106781	5.782899	0.0000
D(Y(-6))	0.291044	0.081085	3.589389	0.0023
D(Y(-7))	0.427118	0.079566	5.368079	0.0001
D(K)	1.496388	0.25584	5.848909	0.0000
D(K(-1))	-2.596669	0.352445	-7.36758	0.0000
D(K(-2))	1.041373	0.432721	2.406569	0.0278
D(K(-3))	-0.854532	0.36466	-2.34337	0.0315
D(HC)	3.619642	0.459079	7.884579	0.0000
D(HC(-1))	-4.543449	0.741394	-6.12825	0.0000
D(HC(-2))	2.490531	0.706831	3.523519	0.0026
D(HC(-3))	-0.745108	0.607399	-1.22672	0.2366
D(HC(-4))	-0.873996	0.491118	-1.77961	0.0930
D(HC(-5))	0.296343	0.557731	0.531336	0.6021
D(HC(-6))	-2.187674	0.626971	-3.48928	0.0028
D(HC(-7))	2.786586	0.450589	6.184315	0.0000
CointEq(-1)*	-0.992102	0.167672	-5.91692	0.0000
R-squared	0.903398			
Adjusted R-squared	0.811626			
Durbin-Watson stat	1.969814			

*Denotes level of significance at 1%.
Source: Author's own calculation.

The table below shows the findings of the long-term associations between the three variables. The pc and hc coefficients are positive as predicted and significant at 1%. As a result, pc and hc have a positive relationship with y. To put it another way, increasing physical and human capital has a favourable effect on economic growth (Table 5).

Table 5.
Levels Equation with y as Dependent variable (Model with Restricted Constant and no Trend)

Variable	Coefficient	Std. Error	t-Statistic	Prob.
pc	0.61536	0.05647	10.89666*	0.0000
hc	0.87709	0.15541	5.64374*	0.0000
c	3.33801	0.65571	5.09066*	0.0001

*Denotes significance at 1%.
Source: Author's own calculation.

The Diagnostic Check

First, we check to see if the model's residuals are homoscedastic and serially uncorrelated. To determine whether the model's residuals are serially uncorrelated, we perform the Breusch-Godfrey Serial Correlation LM Test. The null hypothesis of no serial connection is not rejected by the F-statistic's p-value of 0.4579. As a result, Table 6 shows that the errors are serially uncorrelated (Table 6).

Table 6.
Results of the Diagnostic Checks

Type of Test	Test Statistic	Value	df	Probability
Specification test	F-statistic	1.20647	(1, 16)	0.2883
Ramsey RESET (1)	Likelihood ratio	2.90787	1	0.0881
Ramsey RESET (2)	F-statistic	1.17253	(2, 15)	0.3364
	Likelihood ratio	5.81034	2	0.0547
Normality test	Jarque-Bera	3.22171		0.1997
Breusch-Godfrey Serial	F-statistic	0.82068	(2, 15)	0.4579
Correlation LM Test	Obs*R-squared	3.94528	2	0.1391
Breusch-Pagan-Godfrey Test of	F-statistic	0.76957	(22, 17)	0.7218
Heteroskedasticity	Obs*R-squared	19.9590	22	0.5856

Source: Author's own calculation.

Similarly, we use the Breusch-Pagan-Godfrey test of heteroskedasticity to see if there is heteroskedasticity in the residuals. That the errors are homoscedastic serves as the test's null hypothesis. The F-statistic has a value of 1.67301 and a corresponding p-value of 0.7218, neither of which even slightly rejects the null hypothesis. As a result, Table 6 shows that the residuals are homoscedastic.

We apply the Jarque-Bera test of normality on the residuals. Ede3r The value of the Jarque-Bera test statistic is 3.22171 which does not reject the null that the errors are normally distributed at 5% level of significance (Table 6).

For evaluating the stability of the model, we used the CUSUM test, which is based on the cumulative sum of the recursive residuals. It displays cumulative sum plots with 5% critical lines. If the graph of the cumulative total passes any of the two critical lines, this test shows parameter instability. The 5% significance lines are not crossed by the blue line graph. Hence, the model is found to be stable (Figure 1).

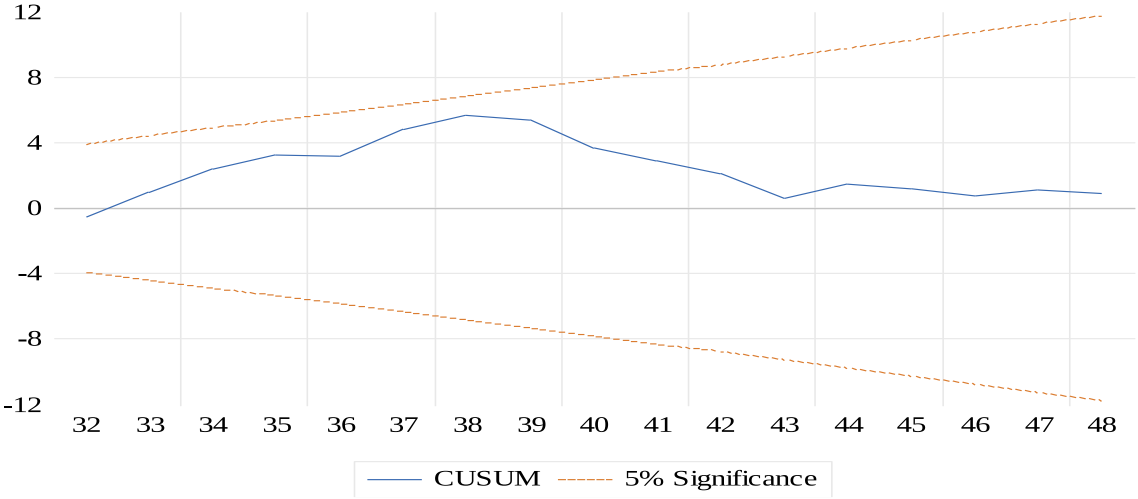

Figure 1. CUSUM Test of Model Stability
Source: Author's own construction.

Similarly, CUSUM of Squares test of model stability also reveals model stability as the middle blue line graph remains well within the 5% significance lines (Figure 2).

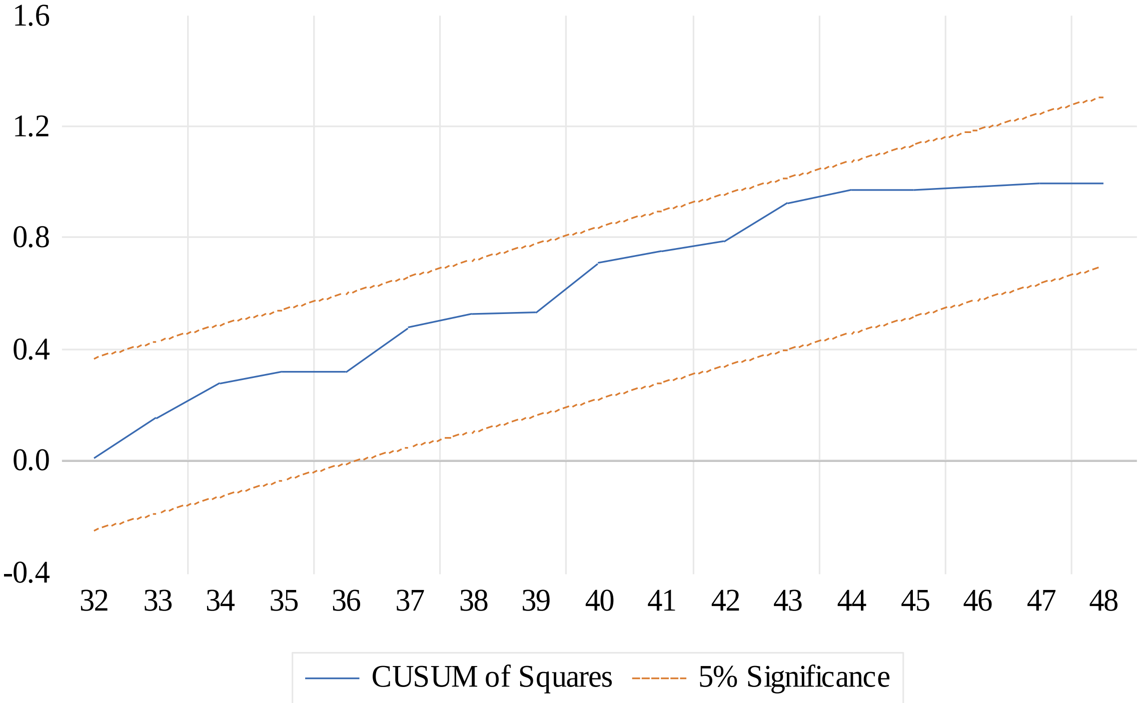

Figure 2. CUSUM of Squares Test of Model Stability
Source: Author's own construction.

Thus, we discover a long-run unidirectional relationships among y, pc and hc. Both pc and hc have a positive and significant effects on y. Besides factor accumulation through raising saving rate, increases in total factor productivity, driven by, among others, knowledge and technology transfers due to trade openness fueled the largest part of India's GDP growth (World Bank, 2018). Our findings also conform to it. However, our findings are not in agreement with the endogenous model of growth of Romer (1990) which argues that investments in human capital encourage growth in physical capital and boost economic growth. Our findings show that investments in human capital stimulate economic growth however its inverse is not true against the assertion of Mincer (1984) who argues that human capital is both cause and effect of economic growth and development. Bils & Klenow (2000) examined the causality and suggested that the causation from economic growth to acquisition of education and that from education to economic growth are equally important in the cross-country association. Some other studies (In & Doucouliagos, 1997; Asteriou & Agiomirgianakis, 2001; Bo-nai & Xiong-Xiang, 2006), however, found evidence in support of a bi-directional relationships between economic growth and human capital.

Toda and Yamamoto Causality Test

We run the VAR model for choosing the best lags using the lag order selection criteria before performing this causality test. The majority of the lag selection criteria (Table 7) advise including 3 lags. The VAR (3) model is augmented by the highest level of integration discovered between the variables for this causality test. Hence, we estimate an expanded VAR (4) model by adding lags equal to the maximum order of integration to each variable for the Toda & Yamamoto (1995) test of causality (Table 8).

Table 7.
VAR Lag Order Selection Criteria

Lag	LogL	LR	FPE	AIC	SC	HQ
0	125.0803	NA	6.2555	-5.6781	-5.5552	-5.6328
1	414.8391	525.6091	9.0319	-18.7367	-18.2452	-18.5554
2	463.8899	82.1314	5.1761	-20.5995	-19.7394*	-20.2823
3	476.3102	19.0637*	4.4980*	-20.5995	-19.5298	-20.3054*
4	481.4321	7.14684	5.5604	-20.5995	-18.9808	-19.9891
5	491.5379	12.6909	5.5830	-20.5995	-18.6636	-19.9046

* Indicates lag order selected by a criterion.
Source: Author's own calculation.

Table 8.
Results of Toda & Yamamoto (1995) Causality Test

Hypothesis	Chi-sq	df	Prob.	Inference
hc does not Granger-cause y	15.96215	4	0.0031*	Causality from hc to y
pc does not Granger-cause y	9.270363	4	0.0547***	Causality from pc to y
y does not Granger-cause hc	2.625963	4	0.6222	No causality from y to hc
pc does not Granger-cause hc	4.493356	4	0.3433	No causality from pc to hc
y does not Granger-cause pc	4.811609	4	0.3072	No causality from y to pc
hc does not Granger-cause pc	3.474789	4	0.4817	No causality from hc to pc

*and **** show level of significance at 1% and 10% respectively.
Source: Author's own calculation.

Conclusion

Time series data on three variables namely, real GDP, physical capital stock and human capital index for India over the period 1972-2019 were used for examining the relationships among them. The Autoregressive Distributed Lag (ARDL) model was chosen after applying the various stationary tests. The ARDL model combined with the bound test of co-integration confirm that physical capital stock, human capital index and GDP are co-integrated only when GDP is used as a dependent variable. Additionally, the error correction model within the ARDL model's framework's negative and statistically significant value of the adjustment coefficient further substantiates the validity of the long-run relationship between the aforementioned variables with GDP as the dependent variable. Toda & Yamamoto (1995) causality test accounting for the maximum order of integration also reveals that the causality runs from both physical capital stock and human capital index towards the real GDP in India over the period 1972-2019. The reverse causality is not found either from GDP to human capital index or from GDP to physical capital stock. Since, human capital index is constructed by including years of schooling and returns to education, we infer that education has been stimulating economic growth in India during the period 1972-2019. Hence, India has reaped the benefits of high economic growth from expanding education by adopting the policy of free and compulsory education for its populace.

Bibliographic references

Abbas, Q. (2000). The Role of Human Capital in Economic Growth: A Comparative Study of Pakistan and India. The Pakistan Development Review, 39(4), 451-473. DOI: https://doi.org/10.30541/v39i4IIpp.451-473

Arrow, K.J. (1962). The economic implications of learning by doing. Review of Economic Studies, 29, 155-73. https://doi.org/10.2307/2295952

Asteriou, D., & Agiomirgianakis, G.M. (2001). Human capital and economic growth: time series evidence from Greece. Journal of Policy Modeling, 23, 481-89. https://doi.org/10.1016/S0161-8938(01)00054-0

Becker, G.S. (1965). A theory of the allocation of time. Economic Journal, 75, 493–517. https://doi.org/10.2307/2228949

Benhabib, J., & Spiegel, M. (1994). The role of human capital in economic development: evidence from aggregate cross-country data. Journal of Monetary Economics, 34, 143-173. https://doi.org/10.1016/0304-3932(94)90047-7

Bils, M., & Klenow, P.J. (2000). Does schooling cause growth? American Economic Review, 90, 1160-1183. https://www.aeaweb.org/articles?id=10.1257/aer.90.5.1160

Bo-nai, F., & Xiong-Xiang, L. (2006). A study on the rate of contribution of education investment to the economic growth in China. Higher Education Press and Springer-Verlag, Front. Educ, 4, 521-532. https://doi.org/10.1007/s11516-006-0027-y

De Meulemeester, J.L., & Rochat, D. (1995). Causality analysis of the link between higher education and development. Economics of Education Review, 14, 351-61. https://doi.org/10.1016/0272-7757(95)00015-C

Dickey, D.A.., & Fuller, W.A. (1979). Distribution of the estimators for autoregressive time series with a unit root. Journal of the American Statistical Association, 74(366), 427. https://doi.org/10.2307/2286348

Diebolt, C., Hippe, R. (2019). The long-run impact of human capital on innovation and economic development in the regions of Europe. Applied Economics, 51, 542-563. https://doi.org/10.1080/00036846.2018.1495820

Feenstra, R.C, Robert, I., Marcel, P.T. (2015). The next generation of the Penn world table. American Economic Review, 105, 3150-3182. available for download at www.ggdc.net/pwt

Foster, A., & Rosenzweig, M. (1996). Technical change and human capital returns and investments: evidence from the green revolution. American Economic Review, 86, 931-953. https://www.jstor.org/stable/2118312

Haldar, S.K, & Mallik, G. (2010). Does human capital cause economic growth? A case study of India. International Journal of Economic Sciences and Applied Research, 3, 7-25. http://ijbesar.teiemt.gr/docs/volume3_issue1/human_capital.pdf

Hanushek, E. A. (2013). Economic growth in developing countries: the role of human capital. Economics of Education Review, 37, 204-212. https://doi.org/10.1016/j.econedurev.2013.04.005

In, F., & Doucouliagos, C. (1997). Human capital formation and US economic growth: a causality analysis. Applied Economics Letters, 4, 329-31. https://www.tandfonline.com/doi/ref/10.1080/758532603?scroll=top

Kwiatkowski, D., Phillips, P.C.B, Schmidt, P., & Shin, Y. (1992). Testing the Null Hypothesis of Stationarity Against the Alternative of a Unit Root. Journal of Econometrics, 54, 159-178.

Loening, J.L. (2004). Time series evidence on education and growth: the case of Guatemala 1951-2002. Revista de análisis economic, 19. https://acortar.link/CeOwFR

Lucas, R.E. Fr. (1988). On the mechanics of economic development. Journal of Monetary Economics, 22, 3-42. https://doi.org/10.1016/0304-3932(88)90168-7

Mankiw, G., Romer, D., Weil, D. (1992). A contribution to the empirics of economic growth. Quarterly Journal of Economics, 107, 407-438. https://doi.org/10.2307/2118477

Mincer, J. (1984). Human capital and economic growth. Economics of Education Review, 3, 195-205. https://doi.org/10.1016/0272-7757(84)90032-3

Narayan, P.K., & Smyth, R. (2004). Temporal causality and the dynamics of exports, human capital and real income in China. International Journal of Applied Economics, 1, 24-45. https://ssrn.com/abstract=2084677

Nelson, R., & Phelps, E. (1966). Investment in humans, technological diffusion and economic growth. American Economic Review, 56, 69-75. https://www.jstor.org/stable/1821269

Pesaran, M.H., Shin, Y., & Smith, R. (2001). Bounds testing Approaches to the analysis of level relationships. Journal of Applied Econometrics, 16, 289-326. https://www.jstor.org/stable/2678547

Pesaran, M.H., & Shin, Y. (1999). An autoregressive distributed lag modelling approach to co-integration analysis. In S. Strom (ed). Econometrics and Economic Theory in the 20th Century: The Ragnar Frisch Centennial Symposium, Cambridge University Press, Cambridge. https://acortar.link/skNyt5
Pradham (2009). Education and economic growth in India: Using error correction modelling. International Research Journal of Finance and Economics, 25. https://mpra.ub.uni-muenchen.de/48524/
Psacharopoulos, G., & Woodhall, M. (1985). Education for development: An analysis of investment choice. Oxford University Press: Washington.
Rebelo, S.T. (1991). Long-run policy analysis and long-run growth. Journal of Political Economy, 99(3), 500-521. https://doi.org/10.1086/261764
Romer, P.M. (1990). Endogenous technological change. Journal of Political Economy, 98(5), 71-101. https://doi.org/10.1086/261725
Sakamota, A., & Powers, P.A. (1995). Education and the dual labour market for Japanese men. American Sociological Review, 60, 222-246.
Schultz, T.W. (1971). Investment in Human Capital: The Role of Education and of Research. New York: Free Press. https://doi.org/10.2307/1237858
Schultz, T.W. (1961). Investment in human capital. The American Economic Review, 51, 1-17. https://www.jstor.org/stable/1818907
Solow, R.M. (1956). A contribution to the theory of economic growth. Quarterly Journal of Economics, 70, 65-94. https://doi.org/10.2307/1884513
Tamura, R. (2006). Human capital and economic development. Journal of Development Economics, 79(1), 26-72. https://doi.org/10.1016/j.jdeveco.2004.12.003
Toda, H.Y., & Yamamoto, T. (1995). Statistical inference in vector autoregressions with possibly integrated processes. Econometrics Journal, 66, 225-250.
Vaganova, O., Rudenko, I., Markova, S., Smirnova, Z., & Kutepov, M. (2019). The use of educational video materials in educational process of a higher educational institution. Amazonia Investiga, 8(22), 216-222. Retrieved from https://www.amazoniainvestiga.info/index.php/amazonia/article/view/308
World Bank. (2018). India development update: India's growth story. New Delhi. Retrieved from https://acortar.link/hwKV56
Zang, C., & Lihuan, Z. (2011). The composition of human capital and economic growth: evidence from China using dynamic panel data analysis. China Economic Review, 22, 165-171. https://doi.org/10.1016/j.chieco.2010.11.001
Zivot, E., & Andrews, D.W.K. (1992). Further evidence on the Great Crash, the Oil-Price shock, and the unit-root hypothesis. Journal of Business and Economic Statistics, 10(3), 251-270. https://doi.org/10.2307/1391541