Journal of Global Economics
ISSN: 2375-4389
Kim, J Glob Econ 2015, 3:4
DOI: 10.4172/2375-4389.1000156
Review Article
Open Access

Economic Growth: Education vs. Research

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Abstract

Barro and Sala-i-Martin analyzed the empirical determinants of growth. They used a cross-sectional empirical framework that considered growth from two kinds of factors, initial levels of steady-state variables and control variables (e.g., investment ratio, infrastructure). Recent literature suggests that education is important in determining steady-state growth. Sequeira Following Baumol, we also consider the growth regression. We extend the previous research for Asian countries of Kim to developed countries. Following the implications of semi-endogenous growth theory, we regressed output growth on a constant, one-year lagged output (initial income) and the determinants of steady-state income [investment rate, population growth, the quadratic (or linear) function of R&D intensity and human capital measured by years of schooling or enrollment rate in secondary school]. The regression suggests higher significance in research efforts. This contradicts with that of Sequeira, which asserts the speed is determined by only education, preference and technology parameter. The coefficients for the determinants of steady-state income, especially for the quadratic function of R&D intensity, are significant and occur in the expected direction. Our results suggests that adopting appropriate growth policy related with R&D, an economy can grow more rapidly through transition dynamics or changing fundamentals.

Keywords: R&D intensity; Growth regression; Convergence; Education

Background

Endogenous growth model stresses the role of education for sustained growth. Lucas presents human capital for explaining unlimited growth by increasing the efficiency of education. Jones also gives similar model incorporating human capital. So-called Lisbon Agenda set by EU features the growth gap between EU and the U.S. The first look at the European case reveals the deficit in tertiary education investment.

We examine simple model and derive important implications [1-5].

Some data exist on the relationship between research and development (R&D) and input to education (years to schooling, expenditures). R&D is presumably a very important input to the production function for knowledge. We can also see plots of R&D intensities showing increasing trends in the five most highly developed countries (G-5 countries) from the 1960s to 2005.[1] During this period, resources devoted to R&D (relative to GDP) steadily increased. Not only has the share of R&D in terms of goods increased, but the share in terms of labor has also increased.[2] We want to know the relationship between research input and human capital.

In Romer's endogenous growth model, physical capital itself is viewed as knowledge.[3] Knowledge is created via a R&D process [6]. In R&D based growth models, imperfect competition is necessary for compensating the rewards for successful innovations. Funke and Strulik argue that instead of R&D, only human capital affects steady-state growth. Sequeira develop this idea and derive the fact that education is most welfare improving. In this study, we seek this hypothesis by theoretical and empirical study. In addition, we compare the growth effect of research with that of human capital. We performed similar study using East Asian economies' data set [3].[4]

Mankiw, Romer and Weil belong to the latter group. In this study, we are interested in the second issue [7]. They included human capital into aggregate production function, and broad concept of physical capital, then find the speed of convergence to be relatively lower than that of Solow's. Mankiw, Romer and Weil have argued that the augmented Solow model is right in including diminishing returns and in forecasting the same rate of (efficiency) growth across countries. Aghion and Howitt, they include human capital into the category of capital as broad capital. With them, Lucas also emphasizes human capital accumulation as a source of growth [8].

Nelson and Phelps[5] and subsequent empirical work by Benhabib and Spiegel describe growth as being driven by the stock of human capital. Krueger and Lindahl provide the implication that human capital stocks only matter for catching up, since their correlation disappears when restricting to OECD countries. Hanushek and Woessmann emphasize the significance of the quality of education like conditional test score. Acemoglu delivers the issue of low-development traps by the complementarity between R&D and education investments [9,10]. Barro and Sala-i-Martin analyzed the empirical determinants of growth. They used an empirical framework that considered the growth from two kinds of factors: initial levels of steady-state variables

[1]In this paper, we consider Canada, France, Japan, UK, and US. Germany is substituted for Canada because of structural change of Germany in 1990s.

[2]The number of U.S. scientists and engineers engaged in R&D increased from about 0.75% of the labor force in 1993 to around 1% in the 2000s.

[3]Pioneering studies for growth and R&D were performed by Uzawa (1965), Shell (1966, 1967) and Phelps (1966).

[4]Empirical studies for economic growth are classified into two areas. The first is explaining the difference between cross-country income levels. The second for between growth rates.Hall and Jones (1999), Klenow et al. (1997), Jones (2002) are standard examples of the former.

[5]Their model was already similar to the Schumpeterian approach.

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Received July 24, 2015; **Accepted** September 22, 2015; **Published** October 05, 2015

Citation: Kim BW (2015) Economic Growth: Education vs. Research. J Glob Econ 3: 156. doi:10.4172/2375-4389.1000156

and control variables (e.g., the ratio investment, infrastructure, life expectancy, degree of democracy etc.), using cross-sectional regression methods. Cross-country growth regressions concern the significant correlations between the growth rate of per capita income, the initial value of income, and structural variables [1,11]. Jones showed that U.S. growth rates do not exhibit large persistent changes, although the determinants of long-run growth highlighted by the endogenous growth model do exhibit these changes [12].[6]

Jones, Kim decomposed the growth rate of the US and South Korea considering education, and concluded that average growth rate consists of transition dynamics and long-run equilibrium growth rate [13]. This paper is organized: Section 2 devotes to search of previous studies and presents basic econometric models. Section-3 performs diverse estimation methods for detecting research effort on growth and get more reliable estimates for convergence. Section 4 summarizes and concludes.

Empirical Analysis: Growth Regression

Previous literatures

Many economists have recently presented sophisticated empirical analysis for cross-country growth regression, including Islam, Caselli, Esquivel, and Lefort, Cellini, and Barro and Sala-i-Martin [1,14-16].

These studies raise two basic methodological issues.

Jones shows conditional convergence by depicting growth rates and relative income levels of each country to that of the US. Relatively poorer countries compared with income levels of their own steady state incomes reveal high growth rate [4,5].

The first objection to Mankiw, Romer, and Weil is that they assume a country's initial efficiency is uncorrelated with the explanatory variables [7]. Islam solves this problem by using panel data. The estimates are different from previous cross-sectional results, implying that the fixed effects problem is serious. When fixed effects are substantial, OLS yields inconsistent and inefficient estimates. They cannot disentangle the individual effects from trend effects [14].

In this paper, we solve this problem further considering the endogeneity of RHS variables in growth regression by using Arellano and Bond's GMM estimation [17].

The second objection to standard growth regressions is that they assume a country's steady-state determinants are fixed over time. Cellini solves this problem by using co-integration and error-correction methods. We apply the same tools to test endogenous growth theory [16]. Sarno also takes ECM approach. He shows that long-run equilibriums of G7 countries follow nonlinear error corrections [18]. In addition, he asserts that there exist significant spillovers within the G7. However, he used R&D data for only measuring productivity (or technology). In contrast to this, in this paper, we explicitly consider R&D data in the framework of endogenous growth theory.

The third extension is that of Liu and Stengos [19]. They recognized the nonlinearity of the effects of education (enrollment in the secondary school) on growth rate, and used semi-parametric approach in growth regression.

[6]However, per capita output is proportional to the share of R&D in the population of an economy along a balanced growth path. The scale effect exhibited by the model is measured in levels, not in growth. This effect comes from the non-appropriable nature of knowledge. A larger economy provides more potential creators for knowledge.

In summary, these previous studies neglect the implication of Romer's endogenous growth theory. The growth of per capita income (or labor productivity) is associated with knowledge creation activity [20]. In this context, Ha and Howitt test the implication of Schumpeterian growth theory by co-integration and simulation. However, they do not use the standard growth equation setting.

Meanwhile, empirical growth studies use human capital variable for explaining cross-country income differences. MRW, Lucas and Jones, Romer are good examples [4,5]. In this study, we compare the effects of education with those of research and development. Benhabib and Spiegel show that growth is correlated with initial level of human capital.

In this paper, we incorporate related variables such as R&D intensity and R&D expenditures into previous neoclassical growth models. According to R&D based growth models, increase in R&D inputs enhances the rate of growth. We examine and test this hypothesis in this empirical study.

Economic growth models: exogenous vs. endogenous

Stylized facts for growth are summarized by Kaldor[7]. Where y97 is per capita GDP in 1997 (relative to the U.S.), g is the average annual growth rate, sK is the physical investment rate, n is the population growth rate, and y* is the steady state income per capita (relative to the U.S.) (Table 1).

Closed form solution of the slow models: We first consider a neoclassical growth model with exogenous technological progress. This enables us to understand endogenous growth theory more easily. The production technology for the final-goods sector (*Y*) is expressed by an aggregate Cobb-Douglas production function. The steady-state growth rate of *A* (technology) and output are constant and given by:

$$g_A = g_y \, (= g_k) \tag{1}$$

y: output per capita, *k*: capital per capita

This "Solow model with technological progress" predicts that growth rate is determined by the rate of exogenous technological change. While the two growth rate are the same in this Harrod-neutral technological progress case, $g_y = g_A + \alpha g_k$ in the Hicks-neutral technological progress case.

But, this model has fatal disadvantage that it cannot explain this source of "manna from heaven" (eg. Exogenous technological progress) Jones incorporates human capital into Solow model [4,5].

Along a balanced growth path, we get:

$$y^*(t) = (s_K / n + g_A + d)^{(\alpha/1-\alpha)}\, h\, A(t) \tag{2}$$

where y* is the steady state income per capita, s_K is the physical investment rate, g_A is the average annual growth rate of productivity, and *d* is the depreciation rate of physical capital.

hL=H

	y_{97}	y_{60}	g(60,97)	s_K	u	n	$(A_{90})\,A_{97}$
U.S.	1.000	1.000	0.0139	0.204	11.89	0.0096	(1.000)1.000
Korea	0.596	0.111	0.0594	0.326	10.56	0.0110	(0.435)0.750

Table 1: Fundamental parameter values.

[7]1958 Conference on capital accumulation.

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$h=\exp(\psi u)$

$Y=K^{\alpha}(AH)^{1-\alpha}$

where u is years of schooling, ψ is the return to education, *H* is total amount of human capital.

$y(t) = [(sK / n + gA + d) * (1 - e\text{-}\lambda t) + (y0 / A0) * (1 - \alpha / \alpha) * e\text{-}\lambda t] (\alpha/1\text{-}\alpha)\ h\ A(t)$ (3)

In this equation, we define a new parameter, the speed of convergence: $\lambda=(1 - \alpha)(n + g + d)$. In between t = 0 and t = ∞, income per capita is the weighted average of its initial and steady-state value. As the time goes on, the first term in the bracket has higher weight, since the exponent term *(1 - e-λt) increases.

Note that income per capita at any time (*t*) is written as a function of the parameters, percapita human capital and of the exogenous variable A(*t*).[8] This specification leads us to compare cross-country income differences, and gives insight into method for comparing growth rate differences. Neoclassical reference emphasizing (human) capital accumulation is Mankiw, Romer and Weil [7]. Theirs is an augmented version of the Solow model with human capital that slows down the convergence to the steady state by counteracting the effects of diminishing returns of physical capital.

a. Human capital: Lucas presents another version of endogenous model.

$Y=K^{\alpha}(hL)^{1-\alpha}$

$\Delta h=(1-u)h$

$\Delta h/h=g$

The increase in human capital per person (h) increases the steady-state income level, and increases growth rate. Human capital accumulates at a speed proportional to the stock of capital. Human capital affects current production, and current schooling time (1-u) affects the accumulation. Finally, education effort produces a positive growth rate in steady state.

We also examine the effects of human capital measured by years of schooling or school enrollment rate on the growth rates.

b. AK: Simultaneous accumulation of human and physical capital: Romer presents another version of endogenous model that consider learning by doing effect. This is called as AK model. Another model that explains non-existence of DRS is as follows [6]

$y=k^{0.5}h^{0.5}$

$\Delta k=sy$

$\Delta h=qy$

$\Delta k=1+(sq)^{0.5}$

The increase in saving rate and investment in human capital per person (h) increases the steady-state income level, and increases growth rate. We can see the saving and investment rate have growth effect as well as level effect.

c. Human capital and R&D in endogenous model: Sequeira presents another version of endogenous model.

$\Delta h=ah_h+bhn^{1-c}$

[8]Jones (2002b).

h: human capital per person, h_h: schooling, bhn^{1-c} : learning with varieties

$\Delta Y/Y=(r^*-\rho)/\theta$

In his model, steady-state growth in output is not affected by research activities but only human capital and technology(and preferences) parameters.

The increase in human capital per diversity(h/n) increases the steady-state growth of innovations and interest rate. We examine the effects of human capital measured by years of schooling on the growth rate and compare it with research efforts in simple calibration.

Data of Simple Calculation

The data set consists of several macroeconomic variables (GDP per capita, R&D expenditures, and TFP growth rate) observed for 25 years (1975-2000) in South Korea that is a member of OECD. They were obtained from the IFS and OECD. Because of missing data for some of the variables, we obtained fewer than 25 observations (only 7 points) (Table 1).

Where *y97* is per capita GDP in 1997 (relative to the U.S.), *g* is the average annual growth rate, s_K is the physical investment rate, *n* is the population growth rate, and y* is the steady state income per capita (relative to the U.S.) (Table 2).

Data of Growth Regression

The data set consists of panel data of several macroeconomic

	Years of schooling	SR	h	(A/h)	(h/A)	(S/X)2	y*	g
1975	6.600	0.470	1.935	0.517	1.935	1.770	3.425	
1980	7.600	0.560	2.138	0.468	2.138	1.770	3.785	0.105
1985	8.600	2.300	2.363	0.423	2.363	1.770	4.183	0.105
1990	9.500	1.720	2.586	0.387	2.586	1.770	4.577	0.094
1995	10.300	2.560	2.801	0.357	2.801	1.770	4.958	0.083
1997	10.560	2.570	2.875	0.348	2.875	1.770	5.089	0.026
2000	10.600	2.390	2.886	0.346	2.886	1.770	5.109	0.004

Table 2: Fundamental parameter values.

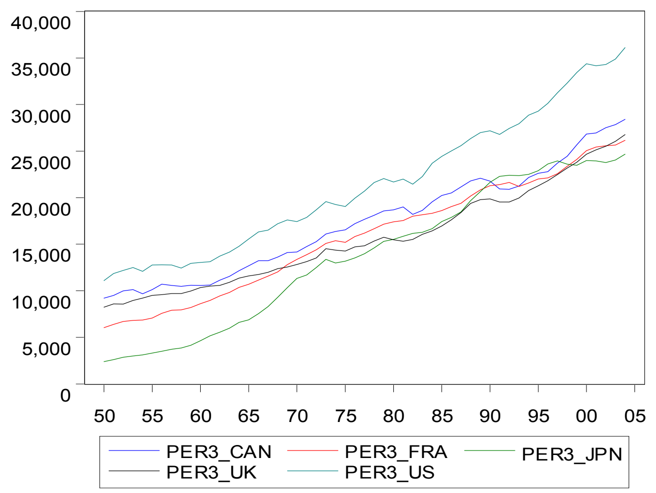

Figure 1: The Trend of Per Capita Income(y) (%).

Citation: Kim BW (2015) Economic Growth: Education vs. Research. J Glob Econ 3: 156. doi:10.4172/2375-4389.1000156

variables (GDP per capita, R&D expenditures, and TFP growth rate) observed for 59 years (1948-2006) in G-5 countries (U.S., Japan, Canada, France, and the U.K) (Figure 1).

Growth regression: Semi-endogenous economic growth model and convergence

In general, for "wide and short" panel data as in our study, a fixed effects estimation model is used. In this paper, we use the fixed effects method not because of the data structure, but because of the data generating process.

Consider a growth regression of the form:

$$y(t) - y(t - 1) = \alpha + \beta\, y(t - 1) + \gamma X(t) + \varepsilon \qquad (4)$$

Here, $y^*(t) = a+bX$, and X is the (row-vector of) determinant of steady-state income, (investment rate, population growth, productivity growth, depreciation rate, etc.).

We estimated the growth regression model by fixed or random effects panel regression with the restriction that each individual country effects exists. In this regression we include the level variable of R&D investment (S_R) and human capital (**H**).[9] Their coefficients are positive and significant. We can find that the growth effect of research effort is larger than human capital. Human capital is measured by years of schooling (**H**, Penn Table) or enrollment in secondary school. **SEC**, Liu and Stengos[10] These data can be obtained from Barro and Lee (Table 3) [19,21].[11]

We can see that research has greater effect than degree of education measured by years of schooling or school enrollment rate. A 1% increase in the rate of the square of research intensity causes an 0.02% change in the per capita income.

Table 4 shows that there are causalities from main variables of interest (R&D efforts, lagged dependent values).[12] This solves the *problem of endogeneity* partially, since some lagged variables Grenger-cause the dependent variables. Whenever the zero-conditional-mean assumption holds for an explanatory variable, we say it is *exogenous*. In general, a lagged dependent variable model with serial correlation reveals the *endogeneity problem*. Regression with growth on left-hand side and education on right-hand side raises this problem, too. One way to deal with is to use instrumental varibles (IV) or to proceed to 2SLS. In special, Bils and Klenow emphasize this problem in cross-country panel regressions for TFP growth equation [22]. We can use sophisticated econometric methods like by Arellano and Bond [17], but we postpone this performance to future research.

Contrary to Hausmann and Rodrik, Shleifer and Vishny stress the greater scope for government failure in LDCs, where controls on governments are relatively weaker. We considered the government consumption ration(G)[13] as control variables, then estimation results show that the effects of research are smaller, even being negative. The analysis may consider other control variables, such as entrepreneurship and venture capital, and possibly other variables dealing with regulation, in the spirit of Shleifer's works [23] (Table 5). Shleifer shows the regression output of TFP Growth Equation (Research s_R *vs.* Education SEC). This shows that the effects of research efforts are larger and significant (Table 6), but insignificant when being controlled by the stock of existing human capital (Tables 3-6).

Vandenbussche, Aghion and Meghir consider a panel data of 22 OECD countries over 1960-2000 [24]. They find that the fraction of the working-age population with higher education is significant in explaining TFP growth. Aghion, Bouston, Hoxby and Vandenbussche find that an additional $1,000 in research education spending raises growth rate by 0.27% [25]. The more growth enhancing it becomes to invest in higher (research type) education and the less growth enhancing to emphasize lower education (eg. two years college). These results approximately support our panel regression outcomes.

Summary and Limitations

The increase in human capital increases the level of steady-state income, and increases transition-dynamic growth rate. The contribution of this paper is that it explicitly consider R&D and human capital variables in growth regression. In convergence regression, income growth is regressed on initial income and steady-state income levels. We show that the steady-state income level depends not only on the investment rate and population growth, as in Solow model, but

Dependent Variable: LOG(y)											
Method: Pooled Least Squares			**Method: Pooled EGLS (Cross-section random effects)**								
Variable	Coefficient	Prob.	Variable	Coefficient	Prob.	Coefficient	Prob.	Coefficient	Prob.	Coefficient	Prob.
C	0.74	0.00	C	0.55	0.00	0.23	0.00	0.29	0.00	0.15	0.00
LOG(y(-1))	0.96	0.00	LOG(y(-1))	0.96	0.00	0.98	0.00	0.97	0.00	0.99	0.00
LOG(X)	0.05	0.40									
LOG((SR)*(SR))	**0.02**	**0.02**	LOG((SR))	**0.04**	**0.02**	**0.02**	**0.09**				
LOG(SEC)	**0.01**	**0.01**		**0.01**	**0.12**			**0.00**	**0.40**		
LOG(S_K)	0.02	0.02									
LOG(H)										0.00	0.98

Table 3: Growth regression including human capital and R&D.

[9] We use the data for years of schooling and refer to Mincerian wage equation.

[10] We can also estimate the growth regression model by SUR (seemingly unrelated regression) with the strong restriction that each coefficient is the same across countries and over time. This estimation is a GLS (generalized least squares) procedure. The result shows that most coefficients are significant.(omitted)

[11] Human capital affects the steady-state income level, and indirectly leads to the change in growth rates. Hall and Jones(1999) presented "development accounting", which decomposes the income levels into the factors of physical capital, human capital and productivity.(Klenow and Rodriguez-Clare, 1997) MRW(1992) argue that when we include human capital, the speed of convergence decreases, since the elasticity of output to capital increases. Benhabib and Spiegel(1994) show that growth is related with the initial level of human capital.

[12] Cumming, Johan, and M. Zhang (2014) apply causality tests to the problem of the impact of Entrepreneurship.

[13] Data are obtained from Penn-World Tables version 6.1.(Summers and Heston, 1991).

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Pairwise Granger Causality Tests			
	Sample: 1948 2007		
	Lags: 2		
	Null Hypothesis:	F-Statistic	Prob.
CAN	y -> SR(R&D)	4.18	0.03**
	SR(R&D) -> y	1.74	0.21
FRA	y -> SR(R&D)	0.83	0.45
	SR(R&D) -> y	0.97	0.40
JAP	y -> SR(R&D)	2.40	0.12
	SR(R&D) -> y	3.18	0.07*
UK	y -> SR(R&D)	4.12	0.04**
	SR(R&D) -> y	0.25	0.79
US	y -> SR(R&D)	13.60	0.00**
	SR(R&D) -> y	0.40	0.68
KOR	y -> SR(R&D)	4.92	0.02**
	SR(R&D) -> y	2.42	0.12
Pairwise Granger Causality Tests			
	Lags: 1		
	Null Hypothesis:	F-Statistic	Prob.
CAN	y -> y(-1)	6.00E+25	0**
	y(-1) -> y	4.63616	0.0362**
UK	y -> y(-1)	2.10E+26	0**
	y(-1) -> y	5.07065	0.0288**
FRA	y -> y(-1)	1.60E+25	0**
	y(-1) -> y	4.35874	0.0419**
US	y -> y(-1)	4.40E+28	0**
	y(-1) -> y	1.69039	0.1995
JAP	y -> y(-1)	NA	NA
	y(-1) -> y	16.9346	0.0001**

Table 4: Granger causality tests.

Dependent Variable: LOG(y)				
Sample (adjusted): 1999 2006				
Variable	**Coefficient**	**Std. Error**	**t-Statistic**	**Prob.**
C	0.03	0.50	0.06	0.95
LOG(y(-1))	1.01	0.04	28.36	0.00**
LOG(n+0.075)	0.08	0.11	0.76	0.45
LOG((SR)*(SR))	-0.03	0.01	-2.50	0.02**
LOG(SEC)	0.01	0.01	0.60	0.56
LOG(H)	-0.02	0.04	-0.57	0.57
LOG(G)	-0.02	0.06	-0.28	0.78
Fixed Effects (Period)				

Table 5: Fixed Effects Panel Estimation Considering Government.

also on the R&D share and education, as in Jones' semi-endogenous growth model.

A permanent increase in the R&D share and human capital temporarily increases the growth rate in the process of transition dynamics. We show that R&D is more important than education empirically.

In future study, we need to consider the following problems in growth model. First, we need to extend endogenous model to derive our conclusion that research is more important. Second, for standard error, we need to consider the relationship between the speed of convergence and the regression coefficient estimate in growth regression. Third, we can add the data for developing countries and see what changes occur in the estimation results. Fourth, we omitted the process of

Dependent Variable: %Δ(TFP)				
Sample (adjusted): 1986 2006				
Variable	**Coefficient**	**Std. Error**	**t-Statistic**	**Prob.**
C	148.40	78.74	1.88	0.06*
LOG(y(-1))	-9.92	6.18	-1.60	0.11
LOG((SR)*(SR))	6.03	3.60	1.67	0.10*
LOG(SEC)	1.12	5.47	0.21	0.84
Fixed Effects (Period)				
Variable	**Coefficient**	**Std. Error**	**t-Statistic**	**Prob.**
C	866.50	507.28	1.71	0.10*
LOG(y(-1))	-43.58	36.06	-1.21	0.24
LOG(n+0.075)	1.42	106.81	0.01	0.99
LOG((SR)*(SR))	-1.34	10.50	-0.13	0.90
LOG(SEC)	7.04	8.91	0.79	0.44
LOG(H)	-64.51	40.45	-1.59	0.12
LOG(G)	-120.83	64.23	-1.88	0.07*

Table 6: TFP Growth equation (Research s_R *vs.* Education SEC).

accumulation in human capital and need consider this variable in the growth regression. Finally, Liu and Stengos captured the nonlinear structure of growth regression, and this approach is necessary in future research [19].

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