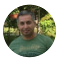
Long-Run Growth and Physical Capital-Human Capital Concentration

Article · January 1998

3 authors:


Nejat Erk
Cukurova University


Hasan altan Çabuk
Cukurova University


Sanlı Ateş
Cukurova University

Long-Run Growth and Physical Capital-Human Capital Concentration

Nejat ERK*

Çukurova University, Department of Economics, 01330 , Adana, Türkiye

H. Altan Çabuk**

Çukurova University, Department of Econometrics, 01330 , Adana, Türkiye

Sanlı ATEŞ***

Çukurova University, Department of Economics, 01330 , Adana, Türkiye

Abstract

This paper aims to explore physical capital (*K*) and human capital (*H*) absorption and diffusion effects on the long term economic growth where the early studies started with T.W. Schultz and G.S. Becker. Within the proposed hypothesis three alternative models will be tested for forty five developed and developing countries. The hypothesis also likes to explore whether above mentioned criteria's also can explain why on the overall developed countries has a relatively lower long-run economic growth rate vs. developing countries. In our first model, time series data for 1960-1990 for the selected forty five countries statistically verifies that the ratio of slopes (Per unit change in *K* and *H*) is high for the developed countries and small for the developing countries. In the second model growth (*g*) is related to k_{t-1} (capital concentration with respect to human capital = K_{t-1}/H_{t-1}). Empirical results show that an increase in k_{t-1} leads to statistically significant lower growth rates for all countries. Third model tests average growth rates of developed and developing countries at a cross-sectional level for $\bar{k}$ (average capital concentration with respect to human capital = the slope of *K* trend / the slope of *H* trend). Similar findings have been reached confirming our hypothesis.

1. Introduction

Economic growth theory had faced significant changes during the last fifty years. This in no way decreases the importance of different long term economic growth rates both for developed and developing countries. In fact, major economic literature concentrates on whether future growth rates will lead to a convergence or divergence of Per capita income which is an extension of "catch-up thesis" (Baumol, 1986; Barro, 1994; Jones, 1997). Besides these debates, consistency of low long-run growth rates of developed countries relative to developing countries needs to be explored to create rationale for the divergence or

[*] E-Mail: erk@pamuk.cc.cu.edu.tr ; WEB Site: http://pamuk.cc.cu.edu.tr/~erk/

[**] E-Mail: haltan@pamuk.cc.cu.edu.tr ; WEB Site: http://idari.cu.edu.tr/~haltan

[***] E-Mail: asanli@cu.edu.tr ; WEB Site: http://idari.cu.edu.tr/~asanli

convergence of Per capita income among countries. Introduction of human capital factor to economic growth theory is not new. But as in the case of *Ak* type models, human capital has been added to the production, economic growth and to the Hamiltonian functions with the assumption that this independent factor does not need any concentration with other factors of production. To clarify the concentration of k ($k=K/H$) concept, we should look into factors like technological absorption, diffusion, learning by doing and other endogenous factors, not reflected in traditional *Ak* type models. Existing technological level and improvements in it, needs similar improvements in human capital component in its broadest sense to stir up long term economic growth in all countries. Developing countries with relatively backward technologies and with low but appropriate human capital endowments have been able to capture high long term growth rates. On the contrary, developed countries with devastating technological improvements had not been able to capture high growth rates because of the relative inadequacy of human capital endowments. Thus, not the absolute sizes of K and H but their relative concentration values should be the key determinant of long term economic growth. In the empirical test section of our study, we will try to explore the improvements in economic growth theory for the post 1950 period. To verify our hypothesis, that for a given time interval higher k values will be represented by low growth rates which coincides with high Per capita income countries will be tested for time series and cross-sectional data.

The debate over complementarity and substitutability of inputs of output is not new. Thus the economic history of economic growth, looks at the nature of inputs to be used, as well as the mathematical functional form in explaining GDP growth. As in the case of Uzawa (1965) and Lucas (1988), there are economists incorporating k relationship, with z (gross average product of physical capital) trying to show the scarcity of human capital.

On the contrary, our attempt hypothesis that, increasing improvements in technology and a number of innovations is aggravating the difficulty of human capital substitutability with the existing technology. This dynamics is expected to be a more dominant retardant of economic growth at the growing stages of globalization. The key element that led to globalization of market seems to be low cost of information, know-how and technology transfer among regions and countries. But this in no means guarantee the absorption, diffusion and learning by doing of this product to every production element involved in the creation of GDP. Thus, given the increasing share of schooling, R&D and other innovative efforts in GDP in developing countries, the gap between technological improvements and human capital creation is widening in terms of absorption and diffusion of technological advances which are commercialized with short time lags due to increasing competition. The hypothesis put forward, if proven to be true, seems to have the potential to explain low growth rates of developed countries vs. developing countries. Developing countries, unlike developed ones have weaknesses and lags in technology transfer due to their imperfections in their domestic markets and human capital inadequacies. Thus, independent of cost advantages information, know-how and technology transfer creates an important lag in technology transfer towards developing countries. But as well known from "Catch-up Thesis" this brings in an advantage of mastery as well as diffusion, absorption and learning by doing of technology. Strikingly, this in no way guarantees that developing countries will catch the developed ones within the near future. As long as technological improvements and competition rules stays the same, any country converging in terms of income with the developed world will face similar problems, thus will be forced to lower their growth rates. In this respect, the difference in GDP reflecting development levels, should not be measured in cardinal terms but ordinal terms because the effort a country that has to put in for one percent incremental growth is not the same for a country facing $ 22,000 and $ 700. This in fact could be the possible explanation for structurally different growth rates among developed and developing countries.

Traditional human capital theory incorporates, educational (formal and informal), health and migration components. In our hypothesis widening of technology and human capital incorporates R&D and innovation, absorption, diffusion and learning by doing within the human capital component.

2. Recent Developments in Economic Growth Theory

Frank Ramsey's 1928 dated publication "A Mathematical Theory of Saving" could be named as the first contribution to the modern theory of economic growth. The developed theory aims to optimize the decision making process between different time spans. In 1950's R.F. Harrod and E.D. Domar had an attempt to turnaround the static Keynesian growth model to a dynamic model.

But unfortunately 1929 Great Depression reduced the popularity of above cited economic models and economists. 1950's also witnessed another important contribution to growth theory by R. M. Solow. The contribution of Solow to economic growth theory can be summarized as diminishing marginal returns on inputs and constant returns to scale which is very typical for *neoclassical* production functions. Advancements in the Solow's theory integrated with constant saving ratios had been utilized in developing the simplified general equilibrium model. *Neoclassical* features of the model depicts that relatively lower GDP holding countries will be facing faster growth rates. Solow reaches to this striking result, by looking at the capital factor which faces diminishing marginal returns. In other words, countries with low physical capital Per worker will have higher capital return ratios, thus will have higher growth rates where this occurrence will reflect to the incomes of developed countries. This type of convergence is known as absolute convergence in economic literature. The narrow degree of convergence stems from; stable nature of physical capital Per labor, savings rate, population growth rate and from the properties of production functions. Post 1980 studies by R.J. Barro (1991) and W.J. Baumol (1986) included initial human capital stocks and institutionalist factors to the growth models. One other important feature of *neoclassical* growth models is that discontinuities in technological advances will lower existing growth rates. The possible explanation for such an outcome goes back to diminishing marginal returns initiated by D. Ricardo and T. Malthus.

Starting from 1960's neoclassical theory has been transformed to endogenous growth models where technology had been endogenized with learning by doing and vintage approaches. In this respect, especially Arrow's contribution in 1962 is a milestone. In this model, individual innovations spread around the economy very fast due the fact that technology being a non competitive product. In cases where spread adjustment slows down, innovations will be transformed to be the product of the R&D sector where the market is imperfectly competitive. Inevitably, this brings in the need for some changes to the *neoclassical* growth models. The contribution to the *neoclassical* theory delayed till P.M. Romer's contribution to the theory in 1980's. But we should not omit the fact that D. Cass and T. Koopmans work in 1965 sets up the roots of household optimization decisions. While this new approach had examined the dynamics towards development phase, it did not go beyond conditional convergence. In this respect, endogenous nature of savings did not alter dependence of exogenous technological improvements on long term Per capita GDP growth.

1970's were the years where little had been contributed to growth theory and most contributions in economics focused on Monetarist, Neo-Keynesian and Rational Expectation theories. From mid 1980 's on, economists like P.M. Romer, R.E. Lucas, S.Rebelo, P.Aghion, P.Howitt, E.Helpman, G.M.Grossman focused on physical capital, human capital, R&D sector, externalities and imperfect competition factors in explaining the economic growth process which could be summarized under the heading of endogenous growth models. This development which could be named as "new endogenous economic growth theory" endogenizes technology (knowledge stock) through human capital. On the other hand, human capital variable had been omitted in the neoclassical models or simply been taken as manna from heaven. Romer's supporting efforts via increasing returns to the endogenous growth models enabled several endogenous growth models to be developed in the post 1980 period. These studies accept the following four elements as the major source of economic growth. First group involves profit seeking R&D sector (Romer, 1990; Grossman ve Helpman, 1991; Aghion and Howitt, 1992). Second group has physical capital and learning by doing models (Romer, 1986; Rebelo, 1991; d'Autume ve Michel, 1993). Third group involves human capital accumulation (Lucas, 1988; Jones, 1996), and the fourth group involves public investment under the endogenous economic growth theory (Barro, 1990). Common features of the above mentioned models stem from broadening the definition of capital and including increasing and decreasing returns to growth theory.

In the Solow growth models, every production factor works under decreasing returns, and growth in Per capita GDP is simply a function of technological improvements. In contrast, basic features of endogenous growth models come from the non existence of decreasing returns. *Ak* type endogenous growth model (Rebelo, 1991) has these features and the following simple structure;

(1) $$Y = AK$$

Here *A*, shows the technology level,; *K,* shows the technology, human capital, learning by doing level. Putting the function into factor income form, we get $y = Ak$. The model could also be expressed in terms of capital accumulation ratio;

(2) $$\gamma_k = \frac{\dot{k}}{k} = \frac{sf(k)}{k} - (n + \delta)$$

Here, γ_k, shows capital accumulation ratio; n shows increases in labor supply;δ, shows the depreciation. This equates the average productivity of capital to technological level $f(k)/k = A$. Re-defining the capital accumulation process;

(3) $$\gamma_k = sA - (n + \delta)$$

As long as we have a positive technology term (*A*), average and marginal productivity of capital will be a constant.. This makes the *sA* term a constant and if we like to have positive capital accumulation, $sA>(n+\delta)$ condition should hold. Thus without exogenous technological improvements it is possible to create capital accumulation. Under *Ak* type endogenous growth steady state equilibrium Per capita GDP, capital and consumption growth ratios are equal;

(4) $$\gamma = \gamma^* = sA - (n + \delta)$$

Although changes in population increase solely leads to level effect in Solow growth model, in endogenous growth models it is also possible to lead to growth effects. While it is technically possible to have convergence towards steady state condition, in *Ak* type models Per capita income growth being independent from Per capita income levels, does not permit such a convergence.. But Jones and Manuelli (1990), had merged , *Ak* type endogenous models with *neoclassical* growth models yielding $Y = F(K,L) = AK + BK^{\alpha}L^{1-\alpha}$. In this production function, marginal productivity of capital reaching to zero, while the capital amount goes to infinity, Inada conditions can not be fulfilled. In *Ak* type models return on capital is a constant. To overcome this problem, the narrow definition of capital should be improved. Enabling *K* to show human capital elements as well as physical capital could be a remedy to solve such a problem. .

An alternative, could be taking *K* as the source of learning by doing process as in the case of Arrow (1962) or Romer (1986). In these models, learning process which is created by physical capital investments, dissemination among the producers leading to an overall gain of the economy (positive externalities), thus, altering the decreasing returns process of physical capital to a constant returns stage. In this respect, physical capital becomes the engine of growth. In the Solow growth model, investments do not have economic growth effect. The structuralized nature of learning in endogenous growth models have been developed by Romer (1986). Production function then will look like;

(5) $$Y = AK^{\alpha+\beta}L^{1-\alpha}$$

Different from *neoclassical* growth models the function has a β coefficient as an exponential value for capital. This constant term reflects the spreading pace of knowledge accumulation to the rest of the economy. The rare case $\alpha+\beta=1$ shows the case where capital output ratios leads to steady growth. This *AK* type, is similar to savings driven economic growth process as in the case of endogenous economic growth models. The contribution of physical capital on economic growth has been tested empirically by, Romer (1987), De Long and Summers (1991, 1992). In this empirical study, explanatory power of share of investment in GDP has been tested against the economic growth rate. Barro and Lee (1994), in their empirical study found that % 1 increase in investment leads to a %0.12 increase in economic growth rate. On the contrary to Barro and Lee, Levine and Renelt (1992), asserts the weaknesses of the explanatory power of the above cited regression results.

If the regressed economies can be examined under the assumption of steady state equilibrium, the functional relationship will be inconsistent with the *neoclassical* economic growth assumptions. Reason being, economic growth effect of saving and investment can be only realized if the economy is not under steady state equilibrium.. These growth rates, after the non-existence of convergence, which is the phase where steady equilibrium has been reached (Mankiw, Romer and Weil, 1992). Grossman and Helpman (1991), ties the investment growth interaction to technology creation in the R&D sector. Thus, their endogenous economic growth model will have the following form.

$$(6) \qquad \frac{\dot{K}}{Y} = \frac{\alpha\gamma_Y}{r+\gamma_Y}$$

Here γ_Y, shows the national income growth as a result of resources devoted to R&D; α shows capital-national income elasticity and; r shows the discount factor. The model shows the contribution of physical capital to long term economic growth.

Human capital factor is another key factor frequently discussed effecting the economic growth process. Lucas (1988, 1990), argues the importance of human capital with respect to physical capital. He asserts that, investment to the education sector creates positive externalities which enables increasing returns. Under steady state equilibrium, Per capita income increase should lead to equal to Per capita human capital increases. Romer (1990), makes the distinction between rival and non-rival environments for inputs of production. Production function with these two inputs if written in the following form ($F(D,X)$), copying argument, states that doubling of non-rival inputs will be increasing output in larger amounts.. This argument relies on the assumption that, X is a rival and reproducible input while D is non-rival and having no replacement input cost. D being a productive input, F function can not be written in a concave form. In other words, $F(\lambda D,\lambda X) > \lambda F(D,X)$. This argument is not very new in economic growth literature. Solow (1956) accepts the case of externalities; Arrow accepts the case as learning by doing (1962); Lucas accepts the case as (1988) nonrival and non-excludable goods..

To sum up within the recent economic literature, Romer (1990) argues that increasing returns stems from the externalities in R&D sector. For him, endogenous economic growth models can be examined under two alternatives. The first one, asserts that existing knowledge is the source of human capital which disappears by death. The second one is, basic technology knowledge that is passed over generations which shows continuity in itself. At an empirical level we see that years of schooling is taken as a measure for human capital (Barro, 1991; Barro and Lee, 1993; Tallman and Wang, 1994).

3. The Formal Model

As hypothesized above in the introduction section, the slow Per capita GDP growth rates in the developed countries vs. higher Per capita GDP growth rates in the developing countries could be verified by the spread between technology and human capital existence. For the hypothesis to hold, k is expected to have an inverse relationship for developed and developing countries Per capita GDP growth rates. Meaning that we expect a relatively smaller k for the developing world and a relatively higher k values for developed world. Or the measurement could be turned around to the relationship between growth rates between developed and developing countries. This time setting growth (g) rate as the dependent variable, we expect k to be lower for high growth rates (vice versa is also true) . In testing the formal model, we have the following assumptions;

- Labor human capital is far more important than the labor itself in the production process.
- Technological change is a function of physical capital growth.
- Human capital measured with Barro-Lee data permits human capital in its broadest definition.
- Human capital and physical capital factors show complementarity

4. Findings of the Study

In this study, we have used time series data for the 1960- 1990 period covering 45 developed and developing countries. The variables incorporated to the models are physical capital stock (K_t)[1], human capital stock (H_t)[2], k_t defined as capital concentration with respect to human capital (K_t/H_t), Per capita GDP (y_t)[3] and Per capita GDP growth rates (g_t)[4]. Among these variables, K_t, y_t and g_t are expressed in terms of US dollars, but H_t data is an index of schooling developed from Barro-Lee data. To have a chance of comparison, all physical capital stock and human capital data has been indexed for Turkish data (Turkey 1960 = 100).

[1] K_t data set have been obtained from Summers-Heston data set, http://www.nuff.ac.uk/Economics/Growth/summers.htm
[2] H_t data set have been obtained from Barro-Lee data set http://www.nuff.ox.ac.uk/Economics/Growth/barlee.htm
[3] y_t data have been obtained World Bank Data 95 CD-ROM
[4] g_t have been computed using y_t data set.

Model 1

This model estimates overall linear trends for the variables K_t and H_t for 45 developed and developing countries for the period of 1960-1990. This model incorporates the following equations that are estimated using least squares (LS) both for developed and developing countries.

$$
\begin{aligned}
K_t &= \alpha_k + \beta_k . t + \varepsilon_t \\
H_t &= \alpha_h + \beta_h . t + \nu_t
\end{aligned}
\tag{7}
$$

Table 1 shows LS parameter estimates for equation (7). To remove the autocorralation problems for some countries we have used Cochrane-Orcutt iterative LS method. Linear trends for all countries have significant positive slope values, while having the expected sign. Examining Table 1, the slope parameter estimates for K_t and H_t variables, for developing countries slope values of the K variable are relatively high with respect to slope values of developing countries. Foreseen hypothesis states that developing countries β_k / β_h ratios values are expected to be declining while the same ratios for the developed countries are expected to be increasing. Table 2 shows the values of β_k / β_h parameter estimate ratios for each country which confirms our hypothesis putting forward high Per capita GDP countries have relatively high β_k / β_h. All statistical tests seem to be statistically significant. In Table 2, this ratio in developing countries like USA, Germany, Canada and Italy relatively high in value, while in developing countries like Chile, Dominic Republic, Colombia and Swaziland is relatively low. This also verifies our previously stated hypothesis.

Taking k_t values from Table 2 and defining, countries Per capita GDP less than 4000 US Dollars as developing countries and higher than 4000 US Dollars to test Spearman rank correlations between Per capita income and k_t ratio gives us higly significant 94% rank correlation for 1990. Similar significant findings for every other five years have been given in Table 3. Parallel to our findings high significant rank correlation values clearly shows that developed and developing countries when ranked according to the Per capita GDP shows similar rank for k_t values. Although 94% rank correlation value reflects a very high statistical significance, very low unexplained relationship could be explained with lower industrial base countries having service sector dominant in GDP creation.

Table 1. *K*-Trend and *H*-Trend Parameter Values in Developed and Developing Countries

Developed Countries	β_k	T-Stat	β_h	T-Stat
Australia	18.69	47.94	2.19	9.48
Austria	9.58	46.63	5.84	28.12
Belgium	9.67	37.92	1.44	6.63
Canada	38.55	30.71	0.90	3.95
Denmark	6.21	45.20	1.22	12.57
Finland	7.28	36.86	3.94	19.68
France	64.84	54.67	3.83	41.01
Germany	187.80	26.36	1.56	42.76
Greece	7.08	34.09	5.86	29.82
Hong Kong	2.79	34.67	6.90	46.99
Iceland	0.21	27.99	4.15	352.64
Ireland	2.42	35.09	3.07	54.52
Israel	2.91	38.39	4.94	15.41
Italy	47.00	46.85	2.94	36.64
Japan	180.40	31.16	4.78	10.11
Korea, Republic of	24.43	16.25	9.94	24.82
Netherlands	13.12	45.23	6.34	12.47
Norway	3.81	17.56	4.61	37.21
Portugal	3.87	37.44	4.10	26.69
Spain	28.96	38.70	6.09	27.31
Sweden	10.43	53.35	3.50	12.48
Switzerland	13.82	43.18	5.65	9.69
United Kingdom	33.60	58.62	2.33	14.65
United States	267.16	85.08	6.60	17.28

Developing Countries	β_k	T-Stat	β_h	T-Stat
Argentina	9.95	26.58	4.62	34.03
Chile	2.32	21.52	3.22	26.62
Colombia	9.10	28.08	3.68	13.53
Dominican Republic	1.04	21.53	3.25	27.07
Ecuador	4.06	19.82	6.33	15.54
Guatemala	0.69	23.60	3.18	19.72
Honduras	0.45	24.87	4.45	17.23
India	41.61	28.13	4.44	59.06
Jamaica	0.20	7.37	3.92	85.59
Kenya	0.53	15.59	4.29	22.30
Malawi	0.14	22.79	2.17	18.44
Mauritius	0.08	11.45	4.67	31.07
Mexico	33.16	27.38	6.36	26.82
Panama	1.12	29.76	5.92	15.89
Peru	4.16	38.98	6.15	21.77
Philippines	5.20	29.92	5.67	23.40
Swaziland	0.10	17.16	4.61	17.29
Turkey	13.98	26.61	3.27	46.94
Venezuela	9.51	21.57	5.65	12.37
Zambia	0.11	4.11	4.07	20.17
Zimbabwe	0.69	6.69	2.48	12.16

Table 2. *k* Ratio in Developed and Developing Countries

Developed Countries	*k*	Developing Countries	*k*
Australia	8.53	Argentina	2.15
Austria	1.64	Chile	0.72
Belgium	6.72	Colombia	2.47
Canada	42.83	Dominican Republic	0.32
Denmark	5.09	Ecuador	0.64
Finland	1.85	Guatemala	0.22
France	16.92	Honduras	0.10
Germany	120.16	India	9.37
Greece	1.21	Jamaica	0.05
Hong Kong	0.40	Kenya	0.12
Iceland	0.05	Malawi	0.07
Ireland	0.79	Mauritius	0.02
Israel	0.59	Mexico	5.21
Italy	15.98	Panama	0.19
Japan	37.76	Peru	0.68
Korea, Republic of	2.46	Philippines	0.92
Netherlands	2.07	Swaziland	0.02
Norway	0.83	Turkey	4.27
Portugal	0.94	Venezuela	1.68
Spain	4.75	Zambia	0.03
Sweden	2.98	Zimbabwe	0.28
Switzerland	2.45		
United Kingdom	14.45		
United States	40.51		

Table 3. Overall Spearman's Rho Values For Per capita income and *k* Values

Variables	Spearman's Rho
$y60$ and β_k / β_h	0.932
$y65$ and β_k / β_h	0.930
$y70$ and β_k / β_h	0.940
$y75$ and β_k / β_h	0.939
$y80$ and β_k / β_h	0.949
$y85$ and β_k / β_h	0.952
$y90$ and β_k / β_h	0.947

Note: Spearman's rho values cover 45 countries

Model 2

Parallel to our findings where Per capita income increase leads to a high k_t value, our main hypothesis leads us to test whether Per capita GDP growth rates shows an inverse relationship with k_t variable. Our main hypothesis cited above will be handled by using both time series and cross-sectional data. The model which uses time series data will be estimated in this section and the model which uses cross-sectional data will be estimated under model three. To test the inverse relationship between g and k_{t-1}, we have formulated a mathematical model to confirm our hypothesis. The formulated model has been selected among alternatives for which fits best to the existing data. our chosen model among alternatives is stated mathematically as follows (equation (8)). The parameter estimates are shown in Table 4.

(8) $$g_t = f(k_{t-1}) = \alpha + \beta . \ln(1/k_{t-1}) + u_t$$

The model has been estimated using time series data for the 45 countries individually. Selected 33 out of 45 countries have statistically significant results, while the remaining 12 countries have the expected parameter sign, but volatility in GDP growth makes the estimate statistically insignificant.

Table 4. β Coefficient Values for Developed and Developing Countries (1961-1990)

Developed Countries	**Coefficient**	R^2	F-Stat	T-Stat	**Developing Countries**	**Coefficient**	R^2	F-Stat	T-Stat
Australia	2.16	0.0250	1.74	1.32	Argentina	5.12	0.1059	3.32	1.82
Austria	1.77	0.1156	4.79	2.19	Dominican Republic	3.12	0.0291	1.87	1.36
Belgium	2.81	0.1136	4.72	2.17	Ecuador	6.41	0.1368	5.59	2.36
Canada	1.22	0.0125	1.37	1.17	Guatemala	6.88	0.1253	5.15	2.27
Denmark	2.78	0.0764	3.40	1.84	Honduras	5.13	0.0472	2.43	1.56
France	3.40	0.3161	14.40	3.79	Jamaica	11.58	0.0832	3.63	1.91
Germany	1.38	0.0321	1.96	1.40	Malawi	1.33	0.0034	1.10	1.05
Greece	6.69	0.3824	18.95	4.35	Mexico	5.24	0.2610	11.24	3.35
Hong Kong	3.38	0.0266	1.79	1.02	Panama	6.56	0.2221	9.28	3.05
Iceland	1.75	0.0014	1.04	1.02	Peru	20.77	0.2137	8.88	2.98
Israel	5.27	0.1919	7.89	2.81	Philippines	5.58	0.0424	2.29	1.51
Italy	3.45	0.1237	5.10	2.25	Swaziland	7.23	0.0484	2.48	1.57
Japan	3.57	0.3876	19.35	4.39	Turkey	1.83	0.0015	1.04	1.02
Netherlands	4.63	0.2395	10.13	3.18	Zimbabwe	8.81	0.0307	1.92	1.39
Norway	12.78	0.1015	4.28	2.07					
Spain	4.74	0.2607	11.22	3.35					
Sweden	2.64	0.1415	5.78	2.40					
Switzerland	3.23	0.0809	3.55	1.88					
United States	2.01	0.0243	1.72	1.31					

All parameters of the estimates for all 33 countries have the right sign. This confirms that all estimated equations have negative slopes showing k_t increases leads to growth rate decreases for all countries. This finding verifies our main hypothesis in explaining differential growth rates for developed and developing countries. To strengthen our findings, growth elasticies with respect to k_t have been calculated using 1960-90 averages for all countries to show overall growth response of k_t changes for individual countries. Overall yearly growth elasticity for 33 countries is given in Table 5. The following Table showing high elasticity values for developed countries and low elasticity values for developing countries confirm our main hypothesis once more.

Table 5. Average Elasticity's of Per Capita GDP Growth with Respect to *k*

Developed Countries	Average Elasticity	Developing Countries	Average Elasticity
Australia	1.045	Argentina	10.971
Austria	0.516	Dominican Republic	1.281
Belgium	0.897	Ecuador	2.971
Canada	0.420	Guatemala	9.498
Denmark	1.086	Honduras	5.751
France	1.116	Jamaica	7.911
Germany	0.475	Malawi	0.295
Greece	1.659	Mexico	0.991
Hong Kong	0.393	Panama	3.262
Iceland	0.491	Peru	22.976
Israel	1.510	Philippines	3.746
Italy	0.966	Swaziland	1.055
Japan	0.630	Turkey	0.680
Netherlands	1.667	Zimbabwe	1.920
Norway	4.173		
Spain	1.152		
Sweden	1.191		
Switzerland	1.386		
United States	1.020		

Model 3

This model uses cross-sectional data to estimate equation (9). We expect the same inverse relationship between g and $\bar{k}$ ($\bar{k}$ =β_k / β_h) in the model as given in equation (9). The same equation has been estimated for developed countries and developing countries and for all countries. All estimates are statistically significant and have the right sign, given in Table 6.

Table 6. Cross-Sectional $\beta_{\bar{k}}$ Coefficients
for Average Growth Rates and $\bar{k}$

	Coefficient	R^2	F-Stat	T-Stat
Developed Countries	0.311	0.1076	2.78	1.67
Developing Countries	0.114	0.5125	21.02	4.58
Overall	0.122	0.2174	12.22	3.50

(9) $$g = f(\bar{k}) = \beta_{\bar{k}}\left(\frac{1}{\bar{k}}\right)$$

By using the third model, we have also computed the growth elasticity's with respect to $\bar{k}$ of both developed and developing countries. Growth elasticity with respect to $\bar{k}$ yielding higher growth elasticity's for developing countries confirm our main hypothesis too.

Table 7. Growth Elasticities
For Developed and Developing Countries
(Using Equation (9))

	Growth Elasticity
Developed Countries	0.0055
Developing Countries	0.1107

5. Conclusion

We began this paper with the modest goal, namely to test the hypothesis whether capital concentration with respect to human capital has an inverse relationship with growth rates and positive relationship with Per capita GDP. To test and estimate the relationship three alternative models have been used. All model estimates using both cross sectional and time series data are statistically significant and has the hypothesized sign. The predictions completely matches with Solow's (1956) early predictions. Non the less, the technique completely differs in terms of the independent variables employed and with the new dimension it brings in to the comlimentarity of kt which further increases the importance of human capital development especially for developed nations. Thus, not solely the size of fixed capital formation but the size of human capital stock which complements it is as important for faster economic growth rates. . Given the statistically significant estimates we have to take into consideration some shortcomings related to our statistical estimations. Human capital as data involved in the model has a years of schooling focus, not fully reflecting R&D, technology absorption, diffusion, learning by doing and innovation capabilities. Human capital measurement measured in terms of years of schooling does not show similarity among nations. Approximation of physical capital growth for technological advancement might have some weaknesses by itself. Data collection difficulties for the tested variables restricted us to 31 years which avoids further dynamic time series analysis in testing the hypothesis. For further research same hypothesis could be tested at a firm or sectoral level to explain overall success rate of firms involved. If proven to be true, not only the high tech machinery and equipment that the firm possesses but the high caliber human resource endowment will be setting the overall firm success under similar competitive environments.

References

Aghion, P.; P. Howitt (1992) "A Model of Growth Through Creative Destruction" *Econometrica*, 60(2), 323-351.

Arrow, K.J. (1962) "The Economic Implications of Learning by Doing" Review of Economic Studies, 29, 155-173.

Barro, R.J. (1990) "Government Spending in a Simple Model of Endogenous Growth" *Journal of Political Economy*, 98(5), S103-S125.

Barro, R.J. (1994) *Economic Growth and Convergence*, International Center for Economic Growth, San Francisco, California.

Barro, R.J.; J-W, Lee (1994) "Sources of Economic Growth" *Carnegie-Rochester Conference Series on Public Policy.*

Baumol, W.J. (1986) "Productivity Growth, Convergence, and Welfare: What the Long-Run Data Show" *American Economic Review*, 76(5), 1072-1085.

d'Autume, A.; P. Michel (1993) "Endogenous Growth in Arrow's Learning by Doing Model" *European Economic Review*, 37, 1175-1184.

De Long, J.B.; L.H. Summers (1992) "Equipment Investment and Economic Growth: How Strong Is the Nexus?" *Brooking Papers on Economic Activity, 2*, 157-211.

Grossman, G.M.; E. Helpman (1991) *Innovation and Growth in the Global Economy*, MIT Press, Cambridge, Mass.

Jones, C.I. (1996) "Human Capital, Ideas, and Economic Growth" *Paper have been obtained by via of Internet, internet address: http://www-leland.stanford.edu/~chadj/.*

Jones, C.I. (1997) "Convergence Revisited" *Journal of Economic Growth*, 2(2), 131-153.

Jones, L.E.; R.E. Manuelli (1990) "A Convex Model of Equilibrium Growth: Theory and Policy Implications" *Journal of Political Economy*, 98(5), 1008-1038.

Levine, R.; D. Renelt (1992) "A Sensivity Analysis of Cross-Country Growth Regressions" *American Economic Review*, 82(4), 942-963.

Lucas, R.E. Jr. (1988) "On the Mechanics of Economic Development" *Journal of Monetary Economics*, 22, 3-42.

Lucas, R.E. Jr. (1990) "Why Doesn't Capital Flow from Rich to Poor Countries?" *American Economic Review*, 80(2), 92-96.

Mankiw, N.G.; D. Romer; D.N. Weil (1992) "A Contribution to the Empirics of Economic Growth" *Quarterly Journal of Economics*, 107(2), 407-437.

Rebelo, S.T. (1991) "Long-Run Policy Analysis and Long-Run Growth" *Journal of Political Economy*, 99(3), 500-521.

Romer, P.M. (1986) "Increasing Returns and Long-Run Growth" *Journal of Political Economy*, 94(5), 1002-1037.

Romer, P.M. (1987) "Growth Based on Increasing Returns Due to Specialization" *American Economic Review*, 77(2), 56-62.

Romer, P.M. (1990) "Endogenous Technological Change" *Journal of Political Economy*, 98(5), S71-S101.

Solow, R.M. (1956) "A Contribution to the Theory of Economic Growth" *Quarterly Journal of Economics*, 70, 65-94.

Uzawa, H. (1965) "Optimum Technical Change in an Aggregative Model of Economic Growth" *International Economic Review*, 6, 18-31.

Tallman, E.W.; P. Wang (1994) "Human Capital and Endogenous Growth Evidence from Taiwan" *Journal of Monetary Economics*, 34, 101-124.

Özet

Uzun Dönemli Büyüme ve Fiziksel Sermaye-Beşeri Sermaye Yoğunlaşması

Bu çalışma T.W. Schultz ve G.S. Becker tarafından önceleri başlatılan fiziki sermaye (K), beşeri sermaye (H), massetme ve yayılma etkilerinin uzun dönem ekonomik büyüme üzerine etkilerini araştırmaktadır. Önerilen hipotez çerçevesinde üç alternatif model 45 gelişmiş ve gelişmekte olan ülke için test edilmiştir. Diğer taraftan, yine ileri sürülen hipotez çerçevesinde, gelişen ülkelerin, gelişmekte olan ülkelere oranla, karşılaştırmalı olarak, neden daha düşük büyüme hızlarına sahip oldukları da sınanmıştır. İlk modelde, 1960-1990 dönemi baz alınarak, 45 ülkeye ilişkin K ve H değişkenlerinin istatistiksel anlamlı trend tahminlerinden elde edilen eğim oranları, gelişmiş ülkeler için yüksek, gelişmekte olan ülkeler için düşük elde edilmiştir. İkinci modelde, büyüme (g) ile k_{t-1} (beşeri sermayeye göre sermaye yoğunlaşması) ilişkilendirilmiştir.. Ampirik bulgular k_{t-1} ile büyüme arasında istatistiki açıdan anlamlı ters bir ilişkinin var olduğunu ortaya koymaktadır. Üçüncü modelde, kesit çalışmaları çerçevesinde, büyüme oranları ile $\overline{k}$ (beşeri sermayeye göre ortalama sermaye yoğunlaşması) ilişkisi araştırılmıştır ve hipotezimizi destekleyen benzer sonuçlara ulaşılmıştır.