Ralitsa Simeonova-Ganeva

HUMAN CAPITAL IN ECONOMIC GROWTH: A REVIEW OF THEORY AND EMPIRICS[1]

Human capital has been considered as a factor in the macroeconomic production function for the first time in the seminal work of Lucas (1988). Later on, it was also used as a regressor in the empirical analysis of Mankiw, Romer and Weil (1990). Over the past twenty years, economists have explored the relationship between economic growth and human capital in numerous theoretical and empirical studies. The current paper attempts to review and generalize the developments of the theoretical and empirical models during this period as well as to summarize main findings regarding the impact of human capital on economic growth.

JEL: E24, J24, N30, O11, O49

Modern economic theory explains economic growth as an outcome determined by technological change, accumulation of individual skills, and existing incentives under which economic decisions are being taken, including decisions to acquire physical and human capital.[2] Human capital stocks are considered a key production factor in the enterprise as well as in the economy as a whole. The accumulation of human capital leads to increased efficiency and productivity, and to more inventions. Thus it contributes significantly to growth on the micro- and macroeconomic levels.

Over the last decades numerous economic studies have focused on human capital, its accumulation and its impact on the economy. In the 50s and 60s of the last century Schultz, Mincer, and Becker, among others, coined and developed the term 'human capital', and studied its influence on economic development.[3] They explored into those specific activities which enhance skills and increase the production potential of the workforce, which is conducive to economic growth. Those activities they called *investments in human capital*.

The research focusing on the influence of human capital on growth relate also to the ideas underlying the models which describe the impact of technological progress. Major works which have later on found applications to the theory of

[1] I would like to thank Prof. Rositsa Chobanova and Prof. Rositsa Rangelova from the Economic Research Institute of the Bulgarian Academy of Sciences for their guidance and persistent support. I am deeply indebted to Dr. Kaloyan Ganev from Faculty of Economics and Business Administration at Sofia University for his valuable comments and criticism. In addition I thank the researchers, faculty and participants in the doctoral seminar and the scientific conference devoted to growth theory at the Bulgarian Academy of Sciences for their comments, questions and suggestions.

[2] *Jovanovic, B*. Growth Theory. Working Paper 7468, NBER Working Paper Series, National Bureau of Economic Research, 2000.

[3] *Becker, G*. Human Capital: A Theoretical and Empirical Analysis with Special Reference to Education, 3rd edition. NBER, The University of Chicago Press, 1993.

human capital are those of Arrow[4] and Romer[5]. Arrow explained the discovery of new ideas with the *learning-by-doing* process, as a consequence of the experience gained in production activity. Romer studied the role of scientific research on economic development.

In the late 80s of the 20th century the Solow model, considered the cornerstone of growth theory[6], was further developed by Lucas[7] using the human capital concepts, and to the traditional production factors a new key factor was added – *the human factor*.

After the UN introduced the System of National Accounts (SNA) as a standard of statistical reporting in a series of countries cross-country comparisons of statistical data became feasible. From the 70s until present research has intensified to foster the supply of comparable statistical information for almost all countries in order to facilitate the empirical estimation of various theoretical models, and in particular growth models.

In the early 90s Mankiw, Romer, and Weil[8] tried to answer the question whether the Solow model can be confirmed by international statistical data on about 100 countries. Following the approach introduced by Lucas and using the statistical series compiled by Summers and Heston[9], they complemented the production factors in the original model by variables describing the level of human capital in the various countries. After an econometric estimation of the improved model they managed to explain about 80% of the variance of income per capita in the countries considered, and their study was the first empirical proof of the validity of the neoclassical growth theory. In the twenty years to follow a number of economists studied theoretically and empirically the link between the variables representing the level of human capital, and economic growth.

In this paper an attempt to make a classification of modern economic growth models including human capital has been made. Models have been distinguished depending on the analytical approach used, as well as depending on the mechanism of human capital influence on economic growth. The focus has been put to econometric modeling and to empirical estimates of the effect which human

---

[4] *Arrow, K.* The Economic Implications of Learning by Doing. - The Review of Economic Studies, 1962, Vol. 29, N 3, p. 155-173.

[5] *Romer, P*. Endogenous Technological Change. - The Journal of Political Economy, 1990, Vol. 98, N 5, Part 2: The Problem of Development: A Conference of the Institute for the Study of Free Enterprise Systems, p. S71-S102.

[6] *Solow, R*. A Contribution to the Theory of Economic Growth - The Quarterly Journal of Economics, 1956, Vol. 70, N 1, p. 65-94.

[7] *Solow, R*. A Contribution to the Theory of Economic Growth - The Quarterly Journal of Economics, 1956, Vol. 70, N 1, p. 65-94.

[8] *Mankiw, G., D. Romer, & D. Weil*. A Contribution to the Empirics of Economic Growth. Working Paper 3541, NBER Working Paper Series, National Bureau of Economic Research, 1990.

[9] *Summers, R. & A. Heston*. A New Set of International Comparisons of Real Product and Price Levels Estimates for 130 Countries, 1950-1985. - Review of Income and Wealth, 1988, Vol. 34, N 1, p. 1-25.

capital has on economic growth. Here the main studies and results of both neoclassical and endogenous empirical models have been presented. Also, conclusions have been made from the theoretical and empirical modeling of growth and the role of human capital, and the appendices include tables summarizing the conclusions of selected models of growth and human capital.

The Modern Theory of Growth and Human Capital

The models of economic growth and human capital measure the direct and indirect effects of changes in the human capital stock on growth. The direct effects are related to labor productivity, and the indirect – to the changes in total factor productivity resulting from the increase or decrease of human capital.

The models of human capital influence on economic growth can be classified according to:

1. The analytical approach used:

1.1. Theoretical studies

1.1.1. Mathematical models

1.1.2 Non-technical analysis[10]

1.2. Empirical studies:

1.2.1. Studies focusing on human capital measurement

1.2.2. Growth accounting

1.2.3. Econometric models

2. The mechanism of influence of human capital on growth:

2.1. Neoclassical models

2.2. Endogenous models

Theoretical and Empirical Models

To distinguish theoretical from empirical studies is to some extent arbitrary. Alongside with mathematical models Many theoretical approaches are based on empirical observations, and many empirical analyses contain new approaches to theoretical modeling. Here we distinguish theoretical from empirical models on the basis of whether the main focus of the respective paper has been theoretical or empirical analysis.

The theoretical studies represent either an attempt to model mathematically the influence of human capital on growth, or a non-technical analysis of that influence:

- The mathematical models of growth define a functional relationship between human capital and growth, therefore we have the influence of human capital on growth is defined through parameters. These mathematical models are the starting point in empirical studies of the influence of human capital on growth using world or regional economic data. Among the main theoretical models are those of Lucas (1988), Becker, Murphy and Tamura (1990), Romer (1990), Jones (1996), etc.

[10] In other words, descriptive analysis in which no mathematical models is used in order to make it more accessible to a larger audience.

• The non-technical analysis includes an evidence-based substantiation and a discussion of policies and the effects of policies of governments and international organizations (such as the World Bank, UN, OECD, IMF, etc.) with respect to fostering economic growth through the enhancement of human capital in target countries or regions. Such studies are most often included in working documents of these organizations, as well as in review papers of leading economists such as Easterly (2002), Grossman and Helpman (2005), etc.

The empirical studies represent a comparison of the theoretical base with real-life observations on the world or regional economies, as well as numerical assessment of the direct and indirect influence of human capital on economic growth:

• The studies focused on human capital measurement lay the quantitative foundation of empirical estimates of human capital influence on growth. They include the compilation of panel data[11] on human capital, as well as the construction of various indices measuring human capital. The most notable studies in the area of human capital measurement are those of Kyriacou (1991), Barro and Lee (1993, 2000), Sala-i-Martin and Mulligan (1995, 2000), Woessmann (2000), etc.

• Growth accounting is a simplified approach for calculating the contribution to economic growth of each of the production factors in the macroeconomic production function. It is based on the Solow model, which has been modified and extended after the development of the human capital theory within growth theory, to reflect the dynamics of the human capital stock.[12] This approach includes relatively simplified calculations and leads to a quantitative assessment of the contribution of human capital to economic growth. Among the most notable studies measuring the contribution of human capital to growth are those of Dougherty and Jorgenson (1997), Hall and Jones (1999), etc.

• The econometric models make a quantitative assessment of the influence of human capital on economic growth on the basis of cross-sectional, time-series and panel data regressions. The main differences among the various econometric models stem from the differences in their specification, from differences in the data used, from differences in the groups of countries to which they relate, as well as to differences in human capital measurement. Precisely because of those differences the econometric estimates of the influence of human capital on growth most often differ in sign and magnitude. Among the most notable econometric models are those of Mankiw, Romer and Weil (1990), Benhabib and Spiegel (1994, 2002), Barro and Sala-i-Martin (1995), Islam (1995), Sachs and Warner (1995), Bils and Klenow (1996), Jones (1996), Barro (1998), Topel (1999), Pritchett (1999), de la Fuente and Domenech (2000, 2001, 2002), Hanuschek and Kimko (2000), Krueger and Lindahl (2001), Temple (2001), etc.

---

[11] Panel data – a combination of cross-sectional and time series for a group of/all countries.

[12] For further information of *Barro, R.* Notes on Growth Accounting. Working Paper N 6654, NBER Working Papers Series, National Bureau of Economic Research, 1998.

Neoclassical and Endogenous Models

Neoclassical and endogenous models are distinguished depending on the assumptions made with respect to the *technology* production factor. Although in all models technology is considered the most important determinant of economic growth, in the early neoclassical models of growth its dynamics was exogenously given for the economic systems considered. At a later stage of the development of growth theory technological change was linked to the behavioral characteristics of consumers and producers, and was endogenous to the economy, i.e. it was an endogenous production factor in that case. The provisional classification of models studying the influence of human capital on growth was made by Aghion and Howitt[13]. They distinguished the following two approaches in growth modeling:

- Neoclassical models: The approach introduced by Lucas, based on the human capital theory of Becker[14], who adopted the idea that growth was mainly determined by human capital accumulation, and the cross-country differences in growth rates were explained by the differences in their rates of human capital accumulation. Since this approach expanded the set of production factors in the macroeconomic production function of Solow, it is often called the *neoclassical* approach[15]. It encompasses the theoretical and empirical models of Lucas (1988), Becker, Murphy and Tamura (1990), Mankiw, Romer and Weil (1990), etc.
- Endogenous models: The approach introduced by Romer, based on the theory of Nelson and Phelps on technological diffusion[16]. It adopted the idea that the engine of growth is the human capital stock which determines the ability of economies to develop technologically. Therefore it is also called the *technological progress approach[17].* This group of models studies the linkage between total factor productivity (taken to represent technological development in a given economy), and the average level of human capital. Major endogenous models of human capital influence on economic growth are those of Romer (1990), Rebelo(1991), Benhabib and Spiegel (1994), de la Croix (2002), etc.

Table 1 in the Appendices summarizes this classification.

Approaches in the Econometric Modeling of Human Capital Influence on Growth

The econometric modeling of growth matches the real-life observations of economic processes in the various countries to the theoretical findings of modern growth

[13] *Aghion, P., P. Howitt*. Endogenous Growth Theory. MIT, 1998, p. 327-356.

[14] *Becker, G*. The Economic Approach to Human Behavior. The University of Chicago Press, 1976.

[15] See for example *Krueger, A., M. Lindahl*. Education for Growth: Why and for Whom? - Journal of Economic Literature, 2001, Vol. 39, N 4, p. 1101-1136; *Woessmann, L.* Specifying Human Capital: A Review. Some Extensions, and Development Effects. Working Paper N 1007, Kiel Institute of World Economics, 2000, etc.

[16] *Nelson, R., E. Phelps*. Investment in Humans, Technological Diffusion, and Economic Growth. - The American Economic Review, 1966, Vol. 56, N 1/ 2, p. 69-75.

[17] See *Woessmann, L.* Specifying Human Capital: A Review, Some Extensions, and Development Effects. Working Paper N 1007, Kiel Institute of World Economics, 2000.

theory. The empirical estimates of the influence of human capital on growth become possible only after the construction of the above-listed measures of human capital. The present review systematically analyses and summarizes the influence of human capital on macroeconomic growth according to the various econometric studies.

The empirical testing of the influence of human capital on growth originated about twenty years ago, and the first major study in this area was that of Mankiw, Romer and Weil[18]. The econometric models of growth can in general be divided into regional models (*regional data sets analysis*)[19] and models studying a set of countries (*cross section of countries* or *cross-country regressions*).

The empirical analysis of various regions (e.g. the states of the USA, the Japanese prefectures, the EU Member States, etc.) focuses on the characteristics of economic growth[20] and the issues of convergence[21].

The regional studies devoted to human capital are based on microeconomic concepts. They include the study of its influence on the demand and supply of skilled labor, the wage formation in various sectors, the level of workforce mobility, etc.[22].

The macroeconomic study of the influence of human capital for a separate region requires the availability of time series of length at least 40-50 years, and such data is available for only a limited number of countries. Therefore, the empirical studies of growth determinants using time series regressions are yet to be developed[23]. This is the reason why, for the purposes of this paper, the review of econometric models below focuses on the cross-country models.

The cross-country empirical analysis studies the influence of various growth determinants, including human capital, based on the available statistical data on various countries. The analysis is performed through cross-sectional regressions[24], and later on through panel regressions[25]. These models can be distinguished on

---

[18] See *Mankiw, G., D. Romer, D. Weil*. A Contribution to the Empirics of Economic Growth. Working Paper N 3541, National Bureau of Economic Research, 1990.

[19] For more information concerning the empirical study of growth, see for example *Barro, R., X. Sala-i-Martin*. Economic Growth, 2nd edition. MIT Press, 2004.

[20] See for example *Kaldor, N*. Capital Accumulation and Economic Growth. - In: Lutz, F., D. Hague (eds.). The Theory of Capital: Proceedings of a Conference Held by the International Economics Association. New York: St. Martin's Press, 1961, p. 177-222; *Kuznets, S*. Modern Economic Growth: Findings and Reflections. - The American Economic Review, 1973, Vol. 63, N 3, p. 247-258, etc.

[21] See for example *Barro, R., X. Sala-i-Martin*. Convergence. - The Journal of Political Economy, 1992, Vol. 100, N 2, p. 223-251; *Barro, R., X. Sala-i-Martin, O. Blanchard, R. Hall*. Convergence Across States and Regions. - Brookings Papers on Economic Activity, 1991, Vol. 1991, N 1, p. 107-182, etc.

[22] See for example *Becker, G*. Human Capital: A Theoretical and Empirical Analysis with Special Reference to Education, 3rd edition. NBER, The University of Chicago Press, 1993.

[23] See *Greiner, A., W. Semmler, G. Gong*. The Forces of Economic Growth: A Time Series Perspective. Princeton University Press, 2005, p. 1-15.

[24] The regressions explain GDP growth for the countries studied for a specified point in time, and the explanatory values enter both with current values as well as with past values.

[25] The regressions explain GDP growth for the countries studied simultaneously through time-series and cross-sectional data on those countries.

the basis of the theoretical specification of the influence of human capital on growth[26] - 1) models based on the neoclassical production function; 2) models based on the endogenous theory of growth; 3) empirical models of growth determinants – growth regressions.

The first empirical studies of growth included human capital as a separate production factor in the neoclassical production function. In other words, the explained variable was GDP, or GDP growth, and the explanatory variables were the production factors labor, physical capital, and human capital. This approach assumed a direct influence of human capital on economic growth.

In order to clarify further the mechanism by which human capital affects growth, in the later studies the empiricists used an endogenous specification of human capital influence on growth through the specification of a direct relationship between human capital and total factor productivity. In such cases the influence of human capital on growth was indirect and was carried out through the improvement of total factor productivity.

Along with these two approaches, there exists a third one – growth-regressions, also called *Barro regressions*[27]. This approach consists in the econometric estimation of the existence and magnitude of influence of a number of demographic, social, political, and economic factors on growth, such as population growth, child mortality rate, expected longevity, corruption level, civil freedoms, ethnical structure and diversity, political system, market development, etc. Among these variables the quantity and quality of educational attainment are also present.

Table 2 of the Appendices presents some of the major econometric studies of human capital influence on economic growth, the data sources and the human capital measures that they use, as well as the conclusion of those studies.

The influence of human capital on growth in the cross-sectional and neoclassical econometric models

Mankiw, Romer and Weil studied the degree to which the Solow model explains the differences in income in the various countries[28]. They compared the econometric estimates of two model specifications in which human capital was present, respectively not present, as a variable. Based on the results obtained they found that the inclusion of human capital reduces the magnitude of influence of physical capital and increases the explanatory power of the model with respect to cross-country income differences to 80 % (based on R^2). Despite the strong

[26] See *Krueger, A., M. Lindahl*. Education for Growth: Why and for Whom? - Journal of Economic Literature, 2001, Vol. 39, N 4, p. 1101-1136.

[27] Named after Robert Barro, who has a significant contribution to the development of this approach. See for example Economic Growth in a Cross Section of Countries. - Quarterly Journal of Economics, 1991, Vol. 106, N 2, p. 407-443; Determinants of Economic Growth: A Cross-Country Empirical Study. MIT Press, 1997, etc.

[28] See *Mankiw, G., D. Romer, D. Weil*. Op. Cit.

influence of human capital the authors concluded that the higher educational attainment leads to short-term, and not long-term, growth.

Mankiw, Romer and Weil modified the Solow model to include the human capital stock as a separate production factor:

$$Y(t) = K(t)^{\alpha} H(t)^{\beta} (A(t)L(t))^{1-\alpha-\beta} \quad (1)$$

The changes in physical and human capital was determined by the share of output invested in the respective type of capital (s_K and s_h), by the rate of depreciation of capital (δ), and by the exogenous levels of technological advancement and population growth (g and n):

$$\begin{aligned} \dot{k}(t) &= s_K y(t) - (n + g + \delta)k(t) \\ \dot{h}(t) &= s_h y(t) - (n + g + \delta)h(t) \end{aligned} \quad (2)$$

The regression analysis was based on the following relationship expressing the linkage between income per capita and the increases in physical and human capital, and population growth:

$$\ln\left(\frac{Y(t)}{L(t)}\right) = \ln A(0) + gt - \frac{\alpha+\beta}{1-\alpha-\beta}\ln(n+g+\delta) + \frac{\alpha}{1-\alpha-\beta}\ln(s_K) + \frac{\beta}{1-\alpha-\beta}\ln(s_h) \quad (3)$$

As a measure of investment in human capital they used secondary-school enrollment rates of working-age population, and the empirical analysis included running cross-sectional regressions. As a result of econometric estimation they reached the following specific relationship between income and physical capital, human capital, and labor:

$$Y = K^{\frac{1}{3}} H^{\frac{1}{3}} L^{\frac{1}{3}} \quad (4)$$

In general, the empirical analysis corroborated the conclusions of the Solow model but only when the influence of human capital in the production process is made distinct. This modified model managed to explain the cross-country income differences as a consequence of the differences in savings, education, and population growth. Thus, they confirmed empirically the significance of human capital for economic growth.

Later on the positive influence of human capital on economic growth was corroborated by a number of authors who used various measures to ascertain its empirical significance in economic growth.

Barro[29] discovered a positive relationship between the enrollment rates and the real growth of per capita income. Another positive relationship established as a result of his empirical analysis was that between human capital and the share of investment in GDP. He included a variable reflecting the cross-country differences in the quality of education, the ratio between the number of students and the number of teachers. It was found that there is a negative relationship between economic growth for the period 1960-1985 and the ratio between the number of students and the number of teachers in primary education in 1960. In other words, the higher the number of students per teacher, the lower the magnitude of influence of education on growth. The analogical relationship in secondary education was found to be statistically insignificant.

Sachs and Warner[30] also established a positive influence of secondary-school enrollment rates in an extended neoclassical model including also variables standing for natural resources available to the countries.

Azariadis and Drazen[31] showed empirically a statistically significant influence of literacy in 1960 on the ratio between the 1980 and the 1960 per capita income based on a static regression analysis.

Barro and Sala-i-Martin[32] made inferences with respect to the role of the educational attainment of men and women to economic growth based on growth regressions. They found that the initial human capital stock mattered for growth only with respect to male education. An increase of the average secondary education length for men by 0.68 years led to an increase in growth by 1.1 percentage points a year. An increase by 0.09 years in the average tertiary education length of men led to an increase in annual average growth by 0.5 percentage points. Both secondary and tertiary education of women had negative or zero influence on growth. The latter they interpreted as insufficient utilization of females' human capital in the labor markets of most countries. Primary education for both women and men had no statistically significant influence on growth. Another conclusion which Barro and Sala-i-Martin made in this empirical analysis was that public expenditure on education have a positive effect on growth.

Hall and Jones[33] discovered through the estimation of growth regressions that the educational attainment affected positively income per worker. Besides that, there was a strong positive relationship between the share of population speaking

---

[29] *Barro, R*. Economic Growth in a Cross Section of Countries. - Quarterly Journal of Economics, 1991, Vol. 106, N 2, p. 407-443.

[30] See *Sachs, J., A. Warner*. Natural Resources Abundance and Economic Growth. Center for International Development and Harvard Institute for International Development, Harvard University, 1997.

[31] See *Azariadis, C., A. Drazen*. Threshold Externalities in Economic Development. - The Quarterly Journal of Economics, 1990, Vol. 105, N 2, p. 501-526.

[32] See *Barro, R., X. Sala-i-Martin*. Economic Growth, 1st edition. MIT Press, 1995.

[33] *Hall, R., C. Jones*. The Productivity of Nations. Working Paper N 5812, National Bureau of Economic Research, 1996.

English (and a weaker positive relationship between the share of population speaking other international languages) and income per worker.

Topel[34] established a positive influence of educational attainment on growth. His empirical estimates showed that a year increase in the average number of years of education of the labor force in a given country led to an increase in its income per worker from 5 to 15%.

Temple[35] also confirmed the positive linkage between educational attainment and growth.

Jones[36] found out that educational attainment the current educational attainment of workers affects positively their future productivity. He analyzed the interpretation of the human capital variables used by other authors and questioned the usefulness of percentage changes in educational attainment as an explanatory variable in growth regressions. Instead he suggested using educational attainment levels. To support this claim he showed that educational attainment is bounded from above due to the natural characteristics of saturation of educational attainment among the population. For example, in some developing countries educational attainment increases from an average of one year education length to two years average education length which means a 100% increase in educational attainment, while in the developed countries with well-educated populations educational attainment increased at very low rates due to approaching the highest possible level.

Hanushek and Kimko[37] used qualitative (and not quantitative) measures of human capital. They constructed measures of workforce quality based on the results from international tests of knowledge skills of pupils in the area of mathematics and natural sciences. They found out that the quality of the labor force had a positive influence on economic growth.

Barro[38] also used the results from international tests of knowledge skills of pupils and included them in growth regressions alongside variables relating to educational attainment. He confirmed the positive significance of educational quality to growth. Besides that, he discovered that the positive influence of education on growth was present only in developing countries, and only related to the educational attainment of men. In higher-income countries this relationship was weak or statistically insignificant.

---

[34] See *Topel, R.* The Labour Market and Economic Growth. – In: Ashenfelter, O., D. Card (eds.).The Handbook of Labour Economics. North Holland, Amsterdam, 1999.

[35] Temple, J., "Growth Effects of Education and Social Capital in the OECD Countries", OECD Economic Studies No. 33, OECD, 2001.

[36] *Jones, C*. Human Capital, Ideas and Economic Growth. Conference Paper, VIII Villa Mondragone International Economic Seminar on Finance, Research, Education, and Growth in Rome on June 25-27, 1996.

[37] See *Hanushek, E., D. Kimko*. Schooling, Labour-Force Quality, and the Growth of Nations. - The American Economic Review, 2000, Vol. 90, N 5, p. 1184-1208.

[38] See *Barro, R*. Education and Economic Growth. Research Paper, Harvard University, 2001.

Sala-i-Martin, Doppelhofer and Miller[39] estimated cross-sectional growth regressions but analyzed the robustness of empirical estimates on the basis of Bayesian Averaging of Classical Estimates[40]. As a result of this analysis they discovered that among the variables strongly positively influencing growth were the primary-school enrollment rates. A weakly positive influence on growth had the share of population speaking a foreign language, and public expenditure on education and higher-education enrollment rates did not affect growth.

Bils and Klenow[41] also studied the role of human capital but based on the direction of influence between human capital and growth. To this end they studied first the impact of educational attainment and enrollment rates in growth regressions and found it to be positive. After that they calibrated a theoretical general-equilibrium model, in which the cause-and-effect relationship between education and growth was specified, and showed that the significant econometric estimates of the influence of education on growth cannot be explained. It came out, however, that there was a direct influence from growth to education but not vice versa.

One of the most significant critiques of the influence of human capital on growth was the empirical analysis of Pritchett[42], who rejected the existence of a positive influence of human capital on economic growth. He used human capital measures in a Mincer regression and found out that neither the increase in enrollment rates, nor the increase in educational attainment had a statistically significant effect on growth.

Pritchett interpreted this contradiction by proposing three possible explanations for the lack of effects on growth from increasing the education level. In his opinion these explanations were not mutually exclusive and could be due to imperfections of the educational system, of the labor market, and of the institutional environment. First, the quality of education could be so low that it would not lead to increasing workers' skills and productivity. In other words, not only quantity, but quality also matters. Second, the increase in the supply of skilled labor under an unchanged demand might lead to a sharp slump in the returns to education. Third, the existence of a specific institutional environment can engage human capital into economically inefficient activities which do not contribute to economic growth.

Thus Pritchett explained the lack of influence of education on economic growth in many countries, as well as the lack of an effect of public investment in education. He did not deny the role of human capital but showed that its positive

---

[39] See *Sala-i-Martin, X., G. Doppelhofer, R. Miller*. Determinants of Long-Term Growth: A Bayesian Averaging of Classical Estimates (BACE) Approach. Working Paper, Columbia University, 2003.

[40] For more information on the robustness analysis of estimates, see for example *Barro, R., X. Sala-i-Martin.* Economic Growth, 2nd edition. MIT Press, 2004, p. 541-566.

[41] *Bils, M., P. Klenow*. Does Schooling Cause Growth or the Other Way Round? Working Paper N 6393, National Bureau of Economic Research, 1998.

[42] *Pritchett, L*. Where Has All the Education Gone? Policy Research Working Paper N 1581, World Bank, 1996.

influence could be manifested only when there is a favorable economic and institutional environment.

The interpretation of Pritchett was corroborated to some extent also by Hall and Jones[43] who discovered that after adding variables describing the social infrastructure in growth regressions, the influence of educational attainment diminishes and explains only partially the income-per-capita differences.

Krueger and Lindahl[44] stated the hypothesis that the inability to establish a positive linkage between human capital and growth was due to human capital measurement errors. To prove this they used the results from a statistical study of two independently constructed series of international educational figures on the average number of years of study, as a result of which it came out that the correlation between the two series was very low.

De la Fuente and Domenech[45] also found out statistical deficiencies in one of the most frequently used data on educational attainment – the Barro and Lee dataset[46]. They revised the data and established a strong and statistically significant influence of human capital on the income level and on economic growth.

The other critiques of the neoclassical static models relate to the way of specifying the influence of human capital on economic growth, as well as to the assumption of identical production functions for all studied countries in the static regressions.

The influence of human capital on growth in the endogenous models and in the panel growth regressions

Benhabib and Spiegel[47] searched for an empirical proof of two alternative approaches to modeling the influence of human capital on growth – a neoclassical, and an endogenous one. The difference between these approaches is in determining the mechanism of influence of human capital on growth. In the neoclassical approach the education of the labor force influences growth directly:

---

[43] See *Hall, R., C. Jones*. Why Do Some Countries Produce So Much More Output Per Worker Than Others? - The Quarterly Journal of Economics, 1999, Vol. 114, N 1, p. 83-116.

[44] See *Krueger, A., M. Lindahl*. Education for Growth in Sweden and the World. Working Paper N 7190, National Bureau of Economic Research, 1999; Education for Growth: Why and for Whom? - Journal of Economic Literature, 2001, Vol. 39, N 4, p. 1101-1136.

[45] See *De la Fuente, A., R. Domenech*. Human Capital in Growth Regressions: How Much Difference Does Data Quality Make? Instituto de Analisis Economico (CSIC), Barcelona, 2000.

[46] See *Barro, R., J. Lee*. International Comparisons of Educational Attainment. - Journal of Monetary Economics, 1993, Vol. 32, No. 3, p. 363-394; International Data on Educational Attainment: Updates and Implications. Working Paper N 7911, National Bureau of Economic Research, 2000; International Measures of Schooling Years and Schooling Quality. - American Economic Review, Papers and Proceedings, 1996, Vol. 86, N 2, p. 218-223.

[47] See *Benhabib, J., M. Spiegel*. The Role of Human Capital in Economic Development: Evidence from Aggregate Cross-Country and Regional U.S. Data. Working Paper N 9224, C.V. Starr Center for Applied Economics, New York University, 1992.

$$(5) \qquad \frac{\dot{Y}}{Y} = f\left(., H\right)$$

In the endogenous approach the better-skilled workforce is more capable and more inventive in the implementation and use of better technologies, and therefore contributes to the increase of total factor productivity. The influence of human capital on growth is indirect and is assessed based on the following relationship:

$$(6) \qquad \frac{\dot{A}}{A} = f\left(H\right)$$

In the empirical estimation of the two theoretical approaches the authors used as a measure of the human capital stock the projections of the average years of schooling made by Kyriacou[48]. These projections were based on the statistical relationship between educational attainment and the enrollment rates in the educational system for past periods.

The empirical estimation showed that there is no direct statistically significant relationship between human capital and growth when the neoclassical specification was used, but established a statistically significant positive influence of human capital in the endogenous model. Thus Benhabib and Spiegel contributed to the specification of the mechanism in which human capital affects economic growth and confirmed empirically the positive influence of the human capital stock on total factor productivity (the technological level).

Islam[49] also compared empirical estimates of a neoclassical and an endogenous econometric model but for the first time used a different econometric tool – panel regressions. The main critique of Islam towards the static regression models was that they are based on the assumption of identical production functions in the countries studied. By introducing the panel approach he allowed for differences in the production functions of the countries. This became possible thanks to the econometric techniques of panel analysis which estimate the unobserved individual *country effects*. He modified the specification of Mankiw, Romer and Weil and used the ideas of Benhabib and Spiegel for an endogenous model. Both models were transformed into dynamic ones with panel data and with country effects included. In the empirical estimation of the neoclassical model, unlike the case of the static models, in the panel growth regressions educational attainment as a measure of human capital came out to be statistically insignificant. In the empirical estimation of the endogenous model Islam established a positive

[48] See *Kyriacou, G*. Level and Growth Effects of Human Capital: A Cross-Country Study of the Convergence Hypothesis. Economic Research Reports 19-26, C.V. Starr Center for Applied Economics, New York University, 1991.

[49] See *Islam, N*. Growth Empirics: A Panel Data Approach. - The Quarterly Journal of Economics, 1995, Vol. 110, N 4, p. 1127-1170.

influence of educational attainment on total factor productivity which corroborated the assumptions of Benhabib and Spiegel with respect to the role of human capital in economic growth.

Barro and Sala-i-Martin[50] applied the panel approach to growth regressions, and alongside the traditional social and economic factors they included quantitative and qualitative measures of human capital – educational attainment and the results from the tests of knowledge skills of pupils. It came out that the influence of the quality of education was much stronger than that of the quantity. They reaffirmed the positive influence of education on growth but, like in the static regressions, it was present only in secondary and tertiary education of men. In this case however they found out that public expenditures on education have no effect on growth.

Conclusion

The main difference between the theoretical approaches to the estimation of the influence of human capital on economic growth consists in the assumptions concerning the mechanisms for human capital creation. In the first models human capital was formed through the production function[51]. In the next stage of theory development the human capital accumulated at present depends on the human capital of the previous and the next generations, the human capital of teachers, the efforts of parents and teachers, the innate skills and talents, etc.[52]. Besides that, by analogy to physical capital, human capital depreciates.

The increase in the human capital stock is related to a positive effect on economic growth, due to its direct involvement in the macroeconomic production function as a separate production factor. We can summarize that in the theoretical studies human capital affects the present output in the following ways:

- The time that individuals devote to human capital formation affects the time that individuals devote to work;
- The internal effect of the increased human capital stock leads to increased labor productivity of individuals;
- The external effect of the increased human capital stock leads to increased productivity of all production factors;

---

[50] See *Barro, R., X. Sala-i-Martin*. Economic Growth, 2nd edition..., p. 511-541.

[51] See for example *Lucas, R*. On the Mechanics of Economic Development. - Journal of Monetary Economics, 1988, Vol. 22, p. 3-42; Rebelo, S. Long Run Policy Analysis and Long Run Growth. Working Paper N 3325, NBER Working Paper Series, National Bureau of Economic Research, 1990, etc.

[52] See for example *Becker, G., K. Murphy, R. Tamura*. Human Capital, Fertility, and Economic Growth. - Journal of Political Economy, 1990, Vol. 98, N 5, part II, p. S12-S37; *Kremer, M., J. Thomson*. Young Workers, Old Workers, and Convergence. Working Paper N 4827, NBER Working Paper Series, National Bureau of Economic Research, 1994; *Jones, C.* Human Capital, Ideas and Economic Growth. Conference Paper, VIII Villa Mondragone International Economic Seminar on Finance, Research, Education, and Growth in Rome on June 25-27, 1996, etc.

- The human capital stock is directly linked to technological advancement, which in turn determines growth.

Other interesting conclusions related to the influence of human capital on growth are:

- The economies with more hard-working individuals grow at higher rates since the time devoted to work as well to the accumulation of physical and human capital affects positively economic growth;
- The increase of the human capital stock leads to an increase in income per capita but is related to a negative effect on the propensity of individuals to have more children;
- There are two equilibrium states which follow from the linkage between the human capital stock and growth: the first features an economy with families having many children; in the second equilibrium the economy is characterized with small-numbered families and considerable accumulations of human capital.

In the empirical growth studies the linkage between human capital and economic growth has been repeatedly proved. Nevertheless, there are studies which do not find statistically significant effects of human capital on economic growth. The possible explanations for the lack of influence of increasing educational attainment on growth are related both to the specific economic and institutional environment in some countries and to the deficiencies of the statistical and econometric approaches applied.

The specific economic and institutional environment can be characterized with deficiencies in the educational system and in the labor market. First, the quality of education can be so low that it does not lead to improvements in workers' skills and productivity. Second, the increased supply of skilled labor under no changes in demand can lead to a sharp decline in the level of returns from education. Third, the institutional environment can engage human capital in economically inefficient activities which do not contribute to growth.

The used approaches for human capital specification and measurement are not always the most appropriate ones. In most cases economists encounter limits in the scope and quality of available educational data, while almost always these data are related to quantitative educational characteristics and do not reflect the quality of education in the different countries and periods.

The used econometric approaches for estimation of the effect of human capital can influence the obtained results. We can summarize that the panel regressions reflect more precisely reality that the static ones since they are based on the assumption of different production functions across countries.

We can conclude that the results from econometric studies of neoclassical and endogenous growth models clearly show that the mechanism of influence of human capital on growth is still not definitely specified in empirical terms. Such specification is to be done after widening the scope and improving the quality of statistical data, as well as in the course of the future endogenous growth theory developments.

6.11.2009

Appendix

Table 1

Classification of selected main studies of the impact of human capital on economic growth

Criterion	Types of studies	Subtypes	Authors
Analytical approach	Theoretical	Mathematical models	Lucas (1988); Becker, Murphy & Tamura (1990); Romer (1990); Rebelo (1991); Kremer & Thomson (1994); Barro & Sala-i-Martin (1995, 2004); Jones (1996); Aghion & Howitt (1998); de la Croix & Michel (2002), etc.
		Non-technical analysis	Regular thematic and review reports of the World Bank, UNDP, UNESCO, OECD, European Commission and others; Easterly (2002); Helpman (2004), etc.
	Empirical	Studies focused on the measurement of human capital	Summers & Heston (1988, 1991); Azariadis & Drazen (1990); Lau, Jamison & Louat (1991); Kyriacou (1991); Barro & Lee (1993, 1996, 2000); Mulligan & Sala-i-Martin (1995, 2000); Nehru, Swanson & Dubey (1995); Woessmann (2000); Hanushek & Kimko (2000); Bils & Klenow (2000); de la Fuente & Domenech (2000, 2002); Krueger & Lindahl (2001); Koman & Marin (2005); de la Fuente & Jimeno (2005), etc.
		Счетоводство на растежа	Dougherty & Jorgenson (1996); Hall & Jones (1996, 1999); Barro (1998); Jorgenson, Ho & Stiroh (2003), etc.
		Econometric models	Mankiw, Romer & Weil (1990, 1992); Barro (1991, 1997, 1998, 1999, 2001); Barro & Sala-i-Martin (1991, 1992, 1995, 2004); Benhabib & Spiegel (1994, 2002); Islam (1995); Jones (1996); Hall & Jones (1996, 1999); Sachs & Warner (1997); Bils & Klenow (1998, 2000); Topel (1999); Pritchett (1999); de la Fuente and Domenech (2000, 2001, 2002); Matovu (2000); Hanishek & Kimko (2000); Krueger & Lindahl (2001); Temple (2001); Stevens & Weale (2003), etc.
Direct or indirect impact of human capital	Neoclassical models - direct impact		Lucas (1988); Becker, Murphy & Tamura (1990); Mankiw, Romer & Weil (1990); Kremer & Thomson (1994); Barro & Sala-i-Martin (1995, 2004), etc.
	Endogenous models - indirect impact		Romer (1990); Rebelo (1991); Benhabib & Spiegel (1994); Aghion & Howitt (1998); de la Croix & Michel (2002), etc.

Table 2

Selected key econometric findings of the impact of human capital on economic growth

Authors (Year)	Data used and sample of countries included in the analysis	Approach used in modeling the effect of human capital	Educational indicators used in the estimation of the impact	Main findings
1	2	3	4	5
Mankiw, Romer & Weil (1990)	Summers & Heston (1988) and UNESCO statistics on education; Three samples including respectively 98, 75 and 22 developed and developing countries	Neoclassical approach	Secondary school enrollment rates	An addition of human capital to the macroeconomic production function in the Solow model can lead to explaining almost 80% of the cross-country variation of the income per capita.
Azariadis & Drazen (1990)	Summers & Heston (1988); 71 developed and developing countries	Growth regressions	Literacy rate of the population	There is positive impact of literacy on the relative change of income per capita.
Barro (1991)	Summers & Heston (1988) and UN and World Bank statistics on education; 98 developed and developing countries	Neoclassical approach	Literacy rate; school enrollment rates; students-teachers ratio	There is a positive impact of enrollment rates on growth. There is a negative or no impact of students-teachers ration on growth.
Benhabib & Spiegel (1994)	Summers & Heston (1991) and estimates of human capital stocks done by Kyriacou (1991); 78 developed and developing countries	Neoclassical and endogenous approach	Educational attainment	There is no relation between human capital and growth in testing a neoclassical model. There is a positive impact of human capital on growth in testing an endogenous model.
Barro & Sala-i- Martin (1995)	Summers & Heston (1991) and Barro & Lee (1994); developed and developing countries	Neoclassical approach; growth regressions	Educational attainment	Only the educational attainment of men has positive impact on growth. Primary school enrollment has no significant impact. Public expenditures have positive compact on growth.
Islam 1995)	Summers & Heston (1988) and Barro & Lee (1993); three different samples of 22, 67 and 79 developed and developing countries	Neoclassical and endogenous approach; cross-section and panel data regressions	Educational attainment; school enrollment rates	No significant impact of human capital on growth was found in testing a neoclassical model. Positive influence of both attainment and enrollment on total factor productivity (endogenous approach) was confirmed.
Jones (1996)	Summers & Heston (1991) and Barro & Lee (1993); 78 developed and developing countries	Neoclassical approach	Educational attainment	The percentage increase in the educational attainment has no relation to growth but its level determines growth.

Table 2 (continuous)

1	2	3	4	5
Hall & Jones (1996)	Summers & Heston (1991) and Barro & Lee (1993); 80 developed and developing countries	Growth regressions	Educational attainment; percentage of the population speaking international languages	Human capital variables determine income per worker. There is strong effect of speaking English as a foreign language on the income per worker. There are slighter effects in speaking other international languages.
Sachs & Warner (1997)	Summers & Heston (1991) and Barro & Lee (1993); 70 developed and developing countries	Neoclassical approach	School enrollment rates	Secondary school enrollment rates have a positive impact on growth.
Bils & Klenow (1998)	Summers & Heston (1991) and Barro & Lee (1996); 93 developed and developing countries	Growth regressions; general economic equilibrium model	Educational attainment; school enrollment rates	Growth determines human capital formation but not the other way round.
Topel (1998)	Summers & Heston (1995) and Barro & Lee (1993); 111 countries	Growth regressions	Educational attainment	An increase of one year in the educational attainment of the labour force leads to a raise in the income per worker from 5 to 15 %.
Pritchett (1999)	Barro & Lee (1993) and Nehru, Swanson and Dubey (1994); 96 developed and developing countries	Neoclassical approach	Human capital measures based on Mincer specification	Neither the increases in the enrolment rates nor the increase in educational attainment have a statistically significant impact on growth.
Hall & Jones (1999)	Summers & Heston (1995); 79 countries	Growth regressions	Educational attainment; percentage of the population speaking English and European languages European as foreign languages.	Education explains only partially the differences in the income per capital. There is a positive impact of speaking English and
Krueger & Lindahl (1999)	Summers & Heston (1991) and Barro & Lee (1994); developed and developing countries, OECD members	Statistical analysis of the reliability of the human capital measures	Educational attainment	Statistically insignificant relation between human capital and growth is due to measurement errors in human capital indicators.
Hanushek & Kimko (2000)	Barro & Lee (1997) and the results from the international comparative studies of cognitive skills among students; 39 countries	Growth regressions	Indicators of the quality of the labour force calculated on the basis of the results from the international tests on students' cognitive skills	The quality of the labour force has a positive impact on growth.
de la Fuente & Domenech (2000)	Barro & Lee (1996) and OECD statistics on education; 21 OECD members	Growth regressions	Educational attainment	They improve the data sets on education. Their revised human capital measures have stron statistical influence on income and growth.

Table 2 (continuous)

1	2	3	4	5
Temple (2001)	Benhabib & Spiegel (1994); OECD members	Growth regressions	Educational attainment	Strong positive relation between the educational attainment and growth.
Krueger & Lindahl (2001)	Barro & Lee (1993), Benhabib & Spiegel (1994) and Kyriacou (1991); in total 600 panel observations of developed and developing countries	Neoclassical approach; Statistical analysis of the reliability of the human capital measures	Educational attainment	In most of the cases an increase in the educational attainment has a greater impact on growth in cross-country analysis than the analogical impact within each country.
Barro (2001)	Summers & Heston (1991) and Barro & Lee (2000); 81 developed and developing countries	Growth regressions	Educational attainment; results from international tests on students' cognitive skills	The positive impact of education on growth is observed only in the developing countries and is valid only for the education of men. This relation is small or statistically insignificant in the countries with higher incomes.
Sala-i-Martin, Doppelhofer & Miller (2003)	Heston, Summers & Aten (2002); Maddison (1991) and Barro & Lee (2000); 88 developed and developing countries	Growth regressions, based on BACE	Educational attainment; school enrollment rates	Primary school enrollment rates have positive impact on growth. There is a slight relation between growth and percentage of the population speaking foreign language. Public expenditures on education and higher education do not influence growth.
Barro & Sala-i- Martin (2004)	Summers & Heston (1991), Heston, Summers & Aten (2002) and Barro & Lee (1993); 86 developed and developing countries	Growth regressions; panel data analysis	Educational attainment; results from international tests on students' cognitive skills	The positive impact on growth is observed only in the secondary and higher education of men. There is greater growth influence of the quality of education than its quantity. There is no impact of public expenditures on education.