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The Impact of Human Capital on Economic Growth

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ABSTRACT:

The aim of this paper is to theoretically study the impact of human capital on economic growth according to the neo-classical and the new growth theories. This is of interest because many empirical results have shown that human capital is of importance for the growth performance of a country. The object of this study is, however, not to cover the entire field of relevant growth models, but to study the subject with a couple of suitable models. In the appendix, the standard neo-classical growth model will also be augmented by an endogenous human capital parameter. The main finding is that according to most of the models studied, human capital definitely has a positive influence on economic growth. It turns out, however, that different models give quite a different role for human capital in explaining economic growth.

KEY WORDS: Human Capital, Economic Growth, Production Function

Contents

1. Introduction

1.1. General Discussion

The level of human development, i.e. the level of education and health etc., differs across countries. Economic theory has given a name for the level of human development: human capital.

Robert J. Barro and Xavier Sala-i-Martin have in a recent study tried to explain per capita growth rates in 87 countries for the period of 1965-75 and in 97 countries during 1975-85. Among the determinants were, for instance, the stock of physical capital and the stock of human capital in the form of educational attainment and health, the ratio of government consumption to GDP, the ratio of domestic investment to GDP, the black-market premium on foreign exchange as a proxy for market distortions, movements in terms of trade, the fertility rate, measures of political instability and the rule of law, the amount of political freedom and civil liberties and tariff rates.[1]

Barro and Sala-I-Martin also used an interaction term between initial per capita GDP and initial human capital per person in their regression, because they believed that a higher level of human capital raises the responsiveness of the growth rate to reductions in the initial level of per capita GDP. They found that the interaction between the initial level of per capita GDP and human capital easily leads to differencies in growth rates. The interaction effect between GDP and human capital means that fast growers have low values of initial per capita GDP in relation to their levels of schooling and life expectancy, i.e. human capital. They also found that *public spending on education*

[1] See Barro (1995), p.421.

has a clear positive effect on growth whereas government consumption, political instability, and market distortions have clear negative effects. In addition, higher and secondary school enrollment rates for males and life expectancy at birth for males and females had significant positive effects on growth. For this paper the most important conclusion of Barro and Sala-I-Martin’s study is that high levels of human capital have obvious positive effects on economic growth.[2]

Another study made by Baumol, Batey and Wolff (1989) tried to find answers to why the initially poorer countries (the sample was extended to all developing countries) are not catching up with richer countries. They added an educational variable into their regression analysis and found that countries with similar educational levels were converging among themselves but did not catch up with the countries where educational levels were higher.[3] Bart Verspagen (1991) has found that countries that are characterized by a large technological gap to leader countries’ technology and a low "social capability" have a great risk of getting caught in a low-growth trap. His model proxies social capability by educational level.[4] Another study made by Bruno Amable (where technological change is endogenous, 1993) found out that most countries will eventually converge towards a level below the most advanced countries, but some will be caught in a low-growth trap forever. Particularly vulnerable to this trap are countries that have a low level of education and a high share of goverment consumption (of GDP).[5] Ross Levine and David Renelt examined 119 countries over the time period 1960-1989. When analysing the basic variables most often included in growth

[2] Barro (1995) pp.449 & 455.
[3] Fagerberg (1994) p.1160.
[4] Fagerberg (1994) p.1161.
[5] Fagerberg (1994) p.1162.

regressions, they found a positive and robust correlation between the initial secondary-school enrollment rate and economic growth.[6] Frankel and Bosworth discovered that adding human capital significantly improves explanatory power in growth regressions. Krueger found out in the 1960’ s that close to 60 percent of the difference between developed and less developed countries is attributable to human capital.[7]

Different variables are often used in different studies, because no consensus theoretical framework exists. Cross-country growth regressions offer a systematic way of explaining basic facts but their results should not be understood as pure causalities, but rather as approximations of the real relations.[8]

According to Fagerberg the main conclusion from the vast field of catch-up and growth studies is that catching up to leader countries is not an easy task, and only countries with appropriate economic, social, and institutional characteristics will succeed in it.[9] One could add that the level of human capital is of major importance and could be included in Fagerberg’s "social characteristics".

All in all, human capital seems to play a decisive role in the performance of an economy both, ’cross-sectionally’ and over time. These empirical results motivate a closer look at the growth theories in order to find out what their emphasis on the subject is.

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[6] Levine & Renelt (1992) p.946.

[7] Romer (1995) pp.322-323.

[8] As pointed out by Pack (1994): pp.68-69.

[9] Fagerberg (1994) pp.1160 & 1171.

1.2. Questions

My aim in this paper is to study the impact of human capital on economic growth. More precisely, I compare the growth literature's answers on three separate questions about human capital. These questions are numbered in the following way:

1. Is human capital (H) central to the theory?
2. What are the principle relations between H and other growth factors?
3. What is the impact of H on the growth of an economy according to the model?

The study will thus have a strict theoretical character. The importance of human capital has already been emphasized in many empirical studies. I will not try to cover the entire field of relevant growth models, but will, instead, study the subject with some suitable models. In spite of the hypothetical and functionally rigid nature of most growth models, I will freely discuss the importance of human capital (among other factors). The models studied can be said to have the scope, but also the shortcomings, of aggregate models.

The remainder of this paper is organized as follows. In the following chapter I will introduce the neo-classical growth theory. As the standard neoclassical model is defective in what comes to human capital measurement, I will, in the appendix, augment the standard model by allowing for a human capital parameter. The neo-classical model can be developed in this direction without losing its theoretical core.

Chapter four presents a variety of models of the New Growth theory. A few interesting models - i.e. Mankiw’s neoclassical backlash model and Barro and Sala-I-Martin’s two sector model - are presented separately in sections five and six. Chapter seven concludes the paper.

2. The Human Capital Concept

The stock of human capital in a country is most often viewed as a result of different kinds of educational investments, although different theoretical schools and models have different interpretations. According to Ryszard Wilczynski human capital is not only accumulated through formal education but also through self-education, health services, increased mobility and the stock of professional information of labour.[10]

It has also been emphasized that ’learning-by-doing’ and ’job-training’ are of great importance in human capital accumulation. Kim Huynh and Marie-Pierre Merlateau have wanted to separate general education from vocational training and consider therefore human capital as ”heterogenous”.[11] Mankiw (1995) defines human capital as different kinds of skills acquired by the work force, with the restriction that these skills have to have some connection to production. According to him, skills can be attained by education and on-the-job training.[12] Many authors have also considered ’learning by doing/using’ as a source for human capital accumulation.

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[10] See Wilczynski (1993), p.4.

[11] See Huynh (1994), pp.196-213.

[12] Mankiw (1995), p.293. Mankiw is a so called "backlasher theorist” in relation to the Solow model (See chapter 4) and his assumptions about human capital will be discussed in more detail in chapter 5.

3. Human Capital in the Neo-classical Growth Theory

3.1. Solow's Model[13]

In this section I will show the basic features of the most well known model of economic growth, the Solow growth model. The model is named after Robert M. Solow and was developed by him in the 1950’s and 1960’s.

Solow’s model is a so-called ”neo-classical” model and it – as most of the other models of modern growth theory – generalises the production of an economy with the production function. This idealized aggregate production function can be represented for instance by the following equation:

(1) $$Y = F(K, L*E)$$

Output depends on the capital stock, K, the labour, L, and the efficiency of labour E. E depends on education, knowledge, skills and health of the labour force and thus includes the elements of human capital.[14] The term L*E is the labour force measured in so called efficiency units. Advancement in E is called *labour-augmenting* technological progress, i.e. the production function (1) assumes that technological progress is labour augmenting.

This production function (1) is neo-classical because it satisfies the following three properties: First, it exhibits

[13] Subsection 3.1. largely follows Mankiw (1994).

[14] Though it is not uncontroversial in the theoretical literature to include

positive and diminishing marginal products with respect to each input. Second, it exhibits constant returns to scale. Third, the marginal product of physical capital (or labour) approaches infinity as physical capital (or labour) approaches 0 and approaches 0 as physical capital (or labour) approaches infinity.[15]

According to the neoclassical model, one source of economic growth[16] is the accumulation of physical capital. Accumulating physical capital more rapidly will raise the growth rate of the economy, but only for a while before a new steady state is reached. The steady state represents the long-run equilibrium of the economy. In the steady state investment in physical capital equals depreciation of physical capital.

Output *per worker* grows in the steady state with the rate of technological advancement. Such progress only can explain rising standards of living and sustainable growth. Development of technology therefore allows for improvements in the production function.[17] The problem is that the basic neoclassical model takes technological progress as exogenous and does not try to explain it. According to the model, the same level of technology is available everywhere in the world.[18]

Solow used the phrase "technical change" as an expression for any

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human capital elements in the E-factor.

[15] This last property is called *Inada condition,* see Barro (1995), p. 16.

[16] Per efficiency unit of labour, see Mankiw (1994).

[17] Mankiw (1994), pp.114-115. Sometimes a term ”TFP”, i.e. total factor productivity is used to describe technological change and the productivity of both inputs (K and L). Some authors have assumed that it can also reflect economies of scale in different production methods, not necessarily development of technology. See for instance Bergman (1992), pp.5 & 23.

[18] Paul M. Romer and many others have criticized - as adherents of the so called new growth theory, see chapter 4. - the assumption that technology can be taken as this kind of a public good (Romer (1995), p.314). Although there are models where technological progress is embodied in investments I

kind of shift in the production function. He noticed that it thus also includes "slowdowns, speedups, improvements in the education of the labour force".[19] But since the term E is just a residual and captures *anything* that changes the relation between measured L and output, the neoclassical model does not include any specific measure of human capital.[20]

Differencies in technology between countries would result in differencies in labour productivities and thereby in different growth rates of the economies. The problem is that the neo-classical theory does not take into account these kinds of differencies, but assumes that the level of technology is uniform and thus the same worldwide. Therefore, the neo-classical model cannot explain the determinants of a long-run per capita growth rate differencies.

New growth theory has introduced a new generation of models which attempt to describe technological progress. These models allow for different levels of technology in different countries. Some of the models have also considered human capital as an separate and endogenous factor of production. Models of the New growth theory will be discussed in chapters 4. and 6.

3.1.1. The Neo-classical Answers

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will not consider them here.

[19] See Solow (1957), p.312.

[20] There are, however, some neo-classical models that have tried to incorporate human capital as a separate input: In a 1992 paper Mankiw, David Romer and David N. Weil presented a neoclassical model which considers human capital H as a direct input that covariates with physical capital K across countries. There are, however, extensive quantitative problems with this model, see Romer (1995), p.316. Mankiw’s ”backlash model” is another one, and it will be discussed later, in chapter 5. See also appendix for my own augmentation of the Solow model.

The answer to question number one – i.e., ”is H central to the theory?” - is thus negative for the Solow model because it does not include any separate human capital measure at all. The answer to question number two, i.e. ”what are the principle relations between H and other growth factors?”: H is - possibly - only a part of the external variable E. Question number three, i.e. ”what is the impact of H on the growth of an economy according to the model? Cannot be answered because of the external and indistinctive role of human capital in the model.

4. Human Capital in the New Growth Theory

4.1. Introduction

The new growth theory differs from the traditional neo-classical growth theory because it takes growth as an endogenous outcome of the economic system itself and not as a result of forces from outside the system. This means that the technology level is not considered - as in the neo-classical theory - to be exogenous and worldwide, but endogenous and individual for each economy. According to some studies, levels of total factor productivity are often lower in less developed countries than in developed countries. This has motivated researchers to give up the assumption of a worldwide technology available for every country. Thus, many writers view different countries as separate technological systems. In addition, the new growth theory does not necessarily assume that capital has diminishing rates of return. There can be, for instance, externalities to capital and/or human capital that give capital constant (or increasing) rates of return.[21]

4.2. Linear models

The essence of endogenous growth theories can be described by the following simple equation

(2) $$Y = AK,$$

where A (A > 0) is constant reflecting the level of technology and K is a broad capital parameter including human and physical capital. Linear growth models do not assume any decreasing (or increasing) returns to factor inputs. The incorporation of human capital into the capital parameter K in eq. (2) can be considered a factor eliminating diminishing returns to capital.[22] Technology A is now applied to the production of both human and physical capital.

4.2.1. Answers

If K incorporates human capital, we get an affirmative answer to question number one, i.e. H is central to the theory. This opens up the possibilities for long term per capita growth even in the absence of exogenous/endogenous improvements in technology.

Question number two; ”what are the principle relations between H and other growth factors?”: There is an intimate relationship between physical capital and human capital in this model.

[21] Mankiw (1995), p.297, other solutions exist as well.

[22] See Barro (1995), pp.39-41,172.

Different kinds of capital are not separated. Their influence on growth is assumed to be completely similar and therefore there is only one parameter, K, representing capital viewed in this broad sense.

Question three; ”What is the impact of H on the growth of an economy?”: The growth rate of Y *per capita* depends on the willingness to save ”s”, the constant marginal productivity of the broad concept of capital, the rate of depreciation ”δ” and population growth ”n”. Equation (3) below shows how ’broad’ capital per capita changes with time:

(3) $\Delta k = sf(k)-(n+\delta)k$

If this equation is divided by k, then we get the growth rate of k:

(4) $\gamma k = sf(k)/k - (n+\delta)$

If $sf(k)/k > (n+\delta)$, then γ_k has a constant and positive value which is independent of the amount of k already achieved in the economy. The value stays constant, because the incorporation of human capital took away tendencies for diminishing returns to capital. Thus, the addition of human capital to the model allows for a constant growth of the economy even without technological progress. If the willingness to save or technological progress increase, then there will be even higher rates of permanent growth. This is not possible in the neo-classical model where growth is only temporarily raised by investments. The incorporation of H into the model can be thought to affect the productivity of capital positively by taking away the diminishing returns. Therefore this model does not predict - like the neo-classical ones do - any convergence of growth rates of different countries. Another thing allowing for this outcome is the fact that the technology parameter is expected to vary across countries. Changes in the parameters have permanent effects on the growth rate of a country.

4.3. Spillover models

Some theorists have assumed that investments in physical capital, for instance introduction of new techniques, lead to technological progress because of "learning by using" effects. This is a source of knowledge spillovers to the aggregate level of the economy. The spillovers are thus external to a single company. They can even generate increasing returns to scale at the aggregate level, while constant returns prevail at the company level. This means that the marginal productivity of capital does not decline with increasing levels of capital. Consequently rich countries with a lots of capital stay rich and poor ones stay poor.[23]

Lucas (1988) has presented a specific model within the new growth theory. His model takes only human capital as the source of positive spillover effects to the aggregate level of the economy. By human capital Lucas means simply the general skill level of an individual, so that the worker with human capital h(t) is as productive as two workers with human capital 1/2 h(t) each, or a half time worker with 2h(t).[24] He emphasized that there is both the usual internal and an external effect from investments in education. According to him, no-one who makes decisions on H

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[23] As pointed out by Fagerberg (1994), pp.1154 & 1163.

[24] See Lucas (1988), p.17.

takes the external effect into account, because it is not appreciable.[25] Lucas' production function of one particular economy is presented in its original form in equation (5) below:

$$(5) \qquad Y(t) = AK(t)^{\beta}\left[u(t)h(t)N(t)\right]^{1-\beta} * h_{a(t)}^{\gamma}$$

The term $h_{a(t)}^{\gamma}$ is the average level of skill in the economy, i.e. the external effect of human capital and contributes to the productivity of all factors of production. N is the total amount of workers. A is the level of technology, and Lucas assumes it to be constant. The term h(t) is the effect of each individual's human capital on his own productivity acquired by education in this model. u(t) is the non-leisure time devoted to production. Hence, Y(t) is a function of physical capital, human capital, and labour.

4.3.1. Answers

The answer to question number one, i.e. "is H central to the theory?", is yes in the case of Lucas' model. There are two kinds of capital in this spillover model which are of great importance: physical and human capital. Human capital creates two kinds of effects which affect the growth of the economy: an external ($h_{a(t)}^{\gamma}$) and an internal effect (h(t)).

Question number two was: "what are the principle relations between human capital and other growth factors?" In the Lucas' model, human capital accumulation affects both physical capital and labour by increasing their productivity. This interaction can

[25] See Lucas (1988), p.18.

be viewed as a engine of growth complementary to the traditional technological advancement. It is provided endogenously as a side effect of private investment decisions.[26]

Question number three was: ”what is the impact of H on the growth of an economy according to the model?” H increases the productivity of both physical capital and labour in the model. H thus affects the productivity of the entire economy positively and endogenously generates aggregate increasing returns to the model. Hence, the model differs from the neo-classical approach; it does not predict any convergence of growth rates of different economies because of these endogenously created spillovers. If there is no change in the values of the pivotal variables, initially wealthier countries remain wealthier permanently. In that case, the gap grows successively as there is increasing returns in the production function.

5. Mankiw's Backlash

N. Gregory Mankiw has taken up the issue of human capital in the neo-classical approach (Mankiw, 1995). He tries to incorporate human capital into the neo-classical model. By this he attemps to save the neo-classical model from the critique by the new growth theorists. Conclusions of the neo-classical approach have been critizised by many authors, especially, because empirical support for the theory has been hard to find. The approach that he takes has the traditional assumption of exogenous and worldwide level of technology, typical for neo-classical models.

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[26] Bergman (1992), pp.9 & 11, has discussed a possibility that there is interplay between A and h so that a high level of A raises the level of h, because technology raises the motivation to self development. Better

Mankiw discusses the critique of the neo-classical model. According to him the problems with the neo-classical approach are: its prediction of less variation in income across countries than is empirically observed. Secondly, the model predicts a faster rate of convergence to the steady state of a country than is observed. Thirdly, the model predicts greater variation in rates of return to capital than is observed.[27]

Mankiw comes to the conclusion that these problems would disappear if capital share in the production function was higher than is traditionally assumed. He thinks that there might exist positive externalities to capital accumulation that could *raise the capital share*.[28] New ideas in connection to capital accumulation could create such externalities. But whether these externalities are great enough to solve the model's empirical problems discussed above is not clear according to him. These kind of externalities must also be geographically limited, i.e. stop at the border, if they are to help explain differences across countries. The realism of this assumption is also doubted by him.[29]

Mankiw presents another possibility to raise the capital share: to include human capital in it. With human capital he means different skills acquired by education and on-the-job training. The problem is how to measure human capital to get the right share into the production function.

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carrier possibilities exist in an environment of high technology.

[27] Mankiw (1995), pp.282-289.

[28] Notise the similarity of this Mankiw's view of capital with the endogenous spillover models. The difference is that Mankiw still thinks that the production function has constant returns to scale and only wants to raise the capital share in the function.

Mankiw presents two empirical ways to measure the capital share. The first one is to measure how much of labour income comes from human capital. The minimum wage is the return to labour with minimal amount of human capital, i.e. unskilled labour. In the United States it is one third of the average wage. This means according to Mankiw that the return to human capital is two thirds of labour income.[30] When the labour share of the national income (in the USA) is about two thirds, this means that the share of human capital of the national income would be about one-half. When he adds the share of human capital to the share of physical capital - which is one-third of the national income - he finds that the income from all capital is about 80 percent of national income.

The other method to estimate the share of human capital is to examine the returns to schooling. Each year of schooling raises a worker's wage by at least 8 percent according to labour economics. If the average time of schooling would be 13 years, it would mean that this human capital acquirement tripled the average worker's wage. This gives the same result as the first method: the return to human capital is about two thirds of labour income and human capital earns about one-half of the national income.

The Solow growth model, in a Cobb-Douglas form for instance[31], should thus be 'calibrated' in this way so that the capital share

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[29] Mankiw (1995), pp.291-293.

[30] Mankiw (1995), p.294.

[31] There is a one simple production function named the Cobb-Douglas production function which is often used as a (good enough) description of actual economies in the neo-classical approach: $Y = AK^{\alpha} L^{1-\alpha}$. In this model A(>0) is the level of technology and α is a constant with $0 < \alpha < 1$. This model gives the exact shares of both inputs in production determined by the parameter α (Mankiw 1994, pp.73-74).

would rise from one-third to about 0.8. This implies that α should then be 0.8, not 0.33, in the following production function: $Y = AK^{\alpha}L^{1-\alpha}$.

5.1. Answers

The first question was: ”is H central to the theory?”. After the addition of human capital into the capital measure, the problems with the neoclassical model would be smaller according to Mankiw. This makes human capital central for the theory. The model could then possibly better explain growth rate differencies observed in the real world. If the broad concept of capital has this large share, then it is the differencies in the endowment of this factor which most probably make the vast differencies in growth paths over time.

The second question was: ”What are the principle relations between H and other growth factors?” The only special relation is the assumption of human capital being a similar growth factor as physical capital. In my own augmentation of the neo-classical model, human capital is considered to be a part of the labour efficiency parameter, see appendix.

The third question: ”what is the impact of H on the growth of an economy according to the model?” Theoretically the incorporation of human capital into the model does raise the power of the model to explain income variations observed across countries. By raising the traditional neo-classical capital share it alters the shape of the production function. It does not, however, change the neo-classical nature of this model. Human capital cannot explain growth rate differencies in steady states. Output per capita still grows at the exogenously determined rate of the technological progress. But the transition period to a new steady state after a change in the saving rate now takes more time because of the higher capital share. The return to capital now declines less rapidly according to Mankiw.

The addition of H to the capital measure as an input thus allows for the possibility that there could be more countries in a transition phase showing (hence) different growth rates. If different countries are allowed to have different saving rates, then the amount of countries in a transition phase could be even higher. This model is not as illustrative for an analysis of the dynamic effects of different amounts of human capital on the growth rates of two economies as my own model in the appendix is, but it is a good augmentation of the standard Solow model, which clearly demonstrates the importance of human capital as a factor of production. My own augmentation also allows for different steady state growth rates *per capita* in different countries. This is not possible in Mankiw's model because the level of technology is the same for all countries.

Edmund S. Phelps (1995) has criticised Mankiw's view of human capital as entirely analogous to tangible capital as a factor of production. He points out that during the communist rule in Eastern Europe, the high level of human capital did not make the countries grow fast. He means that the assumption of the similarity of the productivity of K and H is not directly applicable to all countries with different economic environments.[32]

Many other authors have criticised Mankiw's backlash as well; especially its assumption of the same technology level/total

[32] Phelps (1995) pp.311-313.

factor productivity in all countries.[33] In my own augmentation (see appendix) of the Solow model I assume that a part of the productivity of labour is endogenously determined by the amount of human capital in the country and changes in its amount affect the growth rate of the economy. Mankiw’s model underlines the importancy of human capital for production, but if all economies have once reached their steady states, then it is only differencies in saving rates that can explain different growth paths in his model.

6. Barro and Sala-i-Martin's K/H model

6.1. With Reversible Broad Capital

Robert J. Barro and Xavier Sala-I-Martin have analysed many endogenous growth models in their book ”Economic Growth” (1995). A few of these models also include human capital. In this section I will discuss a special K/H model, first with the assumption of one-sector production technology and then a version with two sectors of production.[34] The model assumes a Cobb-Douglas production function with constant returns to scale in H and K ($0 \leq \alpha \leq 1$):

(6) $$Y = AK^{\alpha}H^{1-\alpha}$$

H reflects the number of workers multiplied by the human capital of the typical worker. But the total labour force is assumed to be fixed, and H grows only because of improvements in the average

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[33] See Romer (1995), pp.318-323 for an overlook of this critique.
[34] See Barro (1995), pp.171-211.

quality of workers.

When analysing this model (under the assumption that households are the producers of goods and they maximize their overall utility[35]) Barro shows that there is a constant and unique value of K/H, which is:

(7) $K/H = \alpha/(1-\alpha)$

The net rate of return on physical and human capital is then given by

(8) $r^* = A\alpha^{\alpha}*(1-\alpha)^{(1-\alpha)} - \delta$

where "δ" is the rate of depreciation of both physical and human capital. The net rate of return is constant because K/H is constant. Diminishing returns do not apply to the production function (6) when the ratio K/H stays constant, K, H, and Y grow at the same rate.

If the economy begins with the two capital stocks deviating from the value K/H, then the model predicts immediate adjustments in the two stocks so that the value K + H does not change, i.e. an increase in one stock and a corresponding decrease in the other stock. This solution expects investments to be reversible, so that old units of one type of capital can be converted into the other type.

6.1.1. Answers

[35] See Barro (1995), pp.172-174 for the algebra.

H is an input directly affecting output of an economy. Thus, H is central to the Barro’s and Sala-I-Martin’s theory above and the answer to question number one is affirmative.

Question number two was: ”what are the relations between H and other growth factors?” There is a close relationship between physical capital and human capital in the model: the constant and unique value of K/H (= $\alpha/(1-\alpha)$, see above).

Question three was: ”What is the impact of H on the growth of an economy?” When K/H is fixed, H grows at the same rate as K and Y. Thus, the model allows for endogenous permanent growth even without endogenous or exogenous technological progress. Investments in H cannot alone, however, generate permanent growth rate differencies of countries because diminishing returns would then exist. If investments are made in both inputs at the same time and rate, then the economy also grows at this rate and possibilities for permanent growth differencies between countries exist.

If the willingness to save and technological progress increase, then there will be even higher rate of permanent growth. This was not possible in the neo-classical model where the growth was only temporary in the case of higher investments and sustained - but the same for every country - in the case of technological progress. Therefore this model does not predict any converge of growth rates of different countries.

6.2. Non-negative Gross Investment

If constraints of non-negative gross investment for both types of capital are applied to the model there are possibilities for imbalance effects between H and K that affect the growth rate. This means that the three questions have to be re-analysed.

If $K/H \neq \alpha/(1-\alpha)$; the growth rate will be the higher, the larger the gap between this ratio of physical to human capital and the steady state value of this ratio.[36] If there is too much H in relation to K then investments in H must stop. H is let to depreciate at the exogenously given rate δ. In this model the investments are not reversible. Old units of one type of capital cannot be converted into the other type. Only investment in K occurs at a decreasing rate and K/H increases untill a new steady state, where $K/H = \alpha/(1-\alpha)$ again, is reached.[37] The net marginal product of K falls, but it is all the time above the net marginal product of H. Gross investment in H is at its minimal value 0, until a new steady state is reached.

The further away the economy is from the steady state, i.e. the more above or below the K/H is from its steady state value, the greater the productivity and growth rate of the economy. In the new steady state, the economy grows again with the previous (= before the imbalance effect) endogenously determined rate.[38] These ’neoclassical’ dynamics apply only during the transition phase. There are no diminishing returns to broad capital, i.e. human and physical capital together, in the steady state when both inputs grow at the same rate.

The results are the same if the economy has more K than there

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[36] See Barro (1995), pp.171-172.

[37] See Barro (1995), p. 84, for an analysis of the convergence speed in the neo-classical growth model with Cobb-Douglas technology and with different capital shares. The main result of the analysis is that the growth rates of K and Y are the higher the further away the economy is from the steady state and decline as the steady state approaches. These dynamics can be applied to this model since investments are now only made in K.

[38] Barro (1995), p.176.

should be according to the K/H steady state. The only difference is that now investments are made in H, and K depreciates at the exogenous rate δ. K/H decreases and the net marginal product of H falls the more is invested. Again, the greater the imbalance effect the higher the growth rate.

There is, however, little empirical evidence about the growth effects from a sudden decline in human capital. According to Barro (1995, p.178), it is therefore not certain that the increase of K/H has a positive effect on growth; it could even have a negative effect(!). In practise there might even exist some adjustment costs especially for human capital investments. This means that if there is first a relative abundance of K, the theory predicts increasing investments in H that would generate a high growth rate of output. But because an attempt to accelerate the educational process is likely to meet rapidly diminishing rates of returns - i.e. more rapidly than in a similar case of K investments - the investment increase in H is not as high as expected and, hence, the growth rate of output is not as high as expected, either.[39] Thus, a relative loss of human capital is more difficult to ’cure’ and it would take more time to recover from that than from a loss of physical capital.

6.2.1. Answers

The first question was: ”is H central to the theory?” H is a central input affecting growth as in the previous version.

The answer to question number two, i.e. ”what are the principle relations between H and other growth factors?”: There is the

[39] See Barro (1995), pp.119 & 178.

special relation between H and K which is given by the steady state ratio of the two capital stocks; $K/H = \alpha/(1-\alpha)$, and the consequences of the possible deviations in this ratio.

The question number three was: ”what is the impact of H on the growth of an economy according to the model?” The further away the economy is from the steady state, i.e. the more above or below the K/H is from its steady state value, the greater the growth rate of the economy. In the new steady state, the economy grows again with the previous (= before the imbalance effect) endogenously determined rate. If much of physical capital is suddenly destroyed - for instance in a war - then the model predicts higher growth than usually for the economy for a while. The growth effect is however only temporary and decreasing along the transition back to the steady state level of the K/H ratio. There are certainly some countries which are in this transition phase, but the stock of H does not alone have a *permanent* impact on growth rate. In the steady state human capital, physical capital and the economy grow together at the same rate and possibilities for permanent growth differences between contries exist.

6.3. With Two Sectors of Production[40]

The model presented in equations (6)-(8) is now developed further by assuming that the production technology in the educational sector differs from that in the goods sector. According to Barro, it is empirically relevant to expect that the education sector is

[40] Barro (1995), pp.179-210 for a more thorough discussion.

more intensive in human capital than the goods sector which is more intensive in physical capital.[41]

This means that the share of physical capital in the goods sector ”α” is bigger than its share in the educational sector ”η”. This can be seen in the following model, where ”Y” is the output of *goods* and ”E” is the result of education, i.e. the output of *human capital*:

(9.1.) $$Y = A(vK)^{\alpha} * (uH)^{1-\alpha}$$

(9.2.) $$E = B[(1-v)K]^{\eta} * [(1-u)H]^{1-\eta}$$

”A” and ”B” are technological parameters and ”v” and ”u” are fractions of the capital inputs used in the two production sectors. Both equations show constant returns to scale in the two factor inputs. Thus, this extented version of Barro’s and Sala-I-Martins model has potential for endogenous steady state growth in a similar way as the earlier versions discussed above.[42]

The output can also be shown in a broader concept ”Q” which combines the two equations above:

(10) $$Q = Y + \rho B[(1-v)K]^{\eta} * [(1-u)H]^{1-\eta}$$

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[41] Barro (1995), p.180. In my and Mankiws (1995, p.281) opinion the production function should however not be viewed as a specific production technology, but as a way to measure the relation between inputs and output of an economy.

[42] Barro (1995), pp.180-181, 200. If one relaxes the assumption that the sums of the exponents in both sectors must each be at unity then the model becomes more flexible and it can be shown that diminishing returns to scale in one sector can be offset by increasing returns to scale in the other sector.

In this form ”ρ” is the shadow price of human capital in units of goods.[43]

In a steady state the system has constant value of ”K/H”.[44] The growth rates of K, H, Y and Q are equal in a steady state. Barro shows that if α is bigger than η, which is empirically relevant, then the shadow price of human capital in units of goods will converge monotonically to its steady state level.

6.3.1. Answers

The question number one was: ”is H central to the theory?” H is a central growth factor in the model and is needed in the goods sector and in the educational sector. Imbalances between K and H generate immediate effects on the growth rate of the economy.

The answer to question number two; i.e. ”what are the principle relations between H and other growth factors?”: Barro analyses the transitional dynamics of the model in a special framework where consumers are the producers of the output of both sectors and optimize their overall utility. The constraints of non-negative gross investments in both types of capital are not binding and there is no physical capital used in the educational sector, i.e. η=0.[45] He comes to the conclusion that K/H has a constant value in the steady state: $\varpi^* = K/H$. If $\varpi > \varpi^*$ then the

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[43] The shadow price of human capital in units of goods “ρ” is derived from the consumer optimization problem, see Barro (1995), pp.180-181. Barro assumes throughout the K/H model that households are the producers of goods and they maximise their overall utility.

[44] See sections 6.1.-6.2. for the dynamics of K/H ratio in the one sector model.

[45] If η=0 the dynamics of the model are easier to analyse. The conclusions of the dynamics of this special case are also valid for the general case,

model predicts that ϖ will fall over time until the steady state value has been reached. The value of this ratio is related in a special way to many of the parameters in the model, i.e. to the transitional dynamics of the growth rates of these parameters and the economy as a whole. For instance, a high value of ϖ means a high growth rate for H, Y and u, and a low growth rate for K and Q. A low value of ϖ means a high growth rate for K, Y and Q, and a low rate of growth for H and u. Notice that the growth rate of Y is high in both cases; it reaches its minimum at ϖ^*.

The question number three was: ”what is the impact of H on the growth of an economy according to the model?” The growth rate of the "broad output” Q has the following equation (where ”γ” = growth rate, u = the fraction of H used in the production of goods):

$$(11) \qquad \gamma_Q = \gamma_Y - \gamma_u(1 - \alpha)/(1 - \alpha + \alpha u)$$

The growth rate of the first term on the right hand side of eq. (11), i.e. the growth rate of the output of goods, has a similar type of relation to ϖ as the broad output of the one-sector model with constraints for nonnegative gross investments had. γ_Y has its minimum value in the steady state of ϖ (or in the vicinity[46] of it) and inbalances of this ratio raise the growth rate of Y (Y=output of the goods sector). Therefore, it is the second term on the right hand side of equation (11) which is of interest; it alters the conclusions of the imbalance effects of this two sector model compared to the one sector model.

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where there is physical capital in the educational sector.

[46] Barro’s numerical analysis shows that the minimum of γ_Y can occur at the steady state value of ϖ *or* in the vicinity of the value.

If K/H is below its steady state value, then the marginal product of physical capital is high in the goods sector, because u would be high in that situation; u > u*. γ_u would be low because high u and a low level of K implies that the marginal product of H in the goods sector is low and so is the wage rate. Growth is now expected to occur because of high investments in physical capital. As the economy starts moving back to the steady state, K/H increases, u gets smaller, and γ_u rises. This means that the term in the far right in eq. (11) slows down growth the more the closer the steady state (s.s.) of the economy gets. Hence, growth is the higher the more below K/H is its steady state ratio. Barro showed that the term γ_Y in eq. (11) does not affect this inverse relation between K/H and γ_Q, i.e. the term on the far right is strong enough to eliminate its effect. In the one-sector model of section 6.2., the growth rate of the economy was the higher the more below *or above* K/H was its steady-state level.

If K/H is above its steady state value, the marginal product of H is high in the goods sector. High growth rate of human capital would be expected to generate high growth for the economy. But a high value of K/H generates a high wage level. This motivates people to allocate their human capital from the educational sector to the goods sector. This is not possible in the one-sector framework. Therefore, the more above ϖ is compared to its steady state level, the higher is γ_U and the lower is γ_Q according to equation (11). γ_U is negatively related to γ_Q because the production of human capital (now a scarce factor) in the educational sector needs human capital as a factor of production. The higher u gets, the less H is allocated to the educational sector. As the economy starts moving back to the steady state, K/H and γ_U fall. According to (11), this implies that the growth rate of the economy, γ_Q, gets higher as steady state approaches. The conclusion is that the higher the value of K/H compared to its steady state value, the slower the growth rate. In the one sector model of section 6.2. a high value of K/H meant a high rate of growth for the economy!

All in all, the growth rate of broad output γ_Q is inversely related to the value of ϖ. All the variables grow at a constant rate in the steady state, which is also the growth rate of the economy. Hence, this model does not allow for H to affect growth rate differences in the steady state. But the greater the imbalance effect because of too abundant H, the higher the growth rate of the economy. Hence, the model predicts that the economy would recover faster from the destruction of physical capital than human capital.[47] The interplay between physical and human capital thus allows for the possibility that *too abundant human capital leads to temporary higher output growth.*

7. Conclusions

The aim of this paper was to find out what is the impact of H on economic growth according to the neo-classical and the new growth theories. Such analysis is of interest because many empirical results have shown that the so-called human capital is of great importance for the growth performance of a country.

The exploration and discussion of the theories was carried

[47] Barro (1995), pp.182-196, 201.

through in the form of finding answers to three progressive questions: 1. ”is human capital central to the theory?”, 2. ”what are the principle relations between human capital and other growth factors?”, 3. ”what is the impact of human capital on the growth of an economy?”. The main results are: The neoclassical model was initially defective and did not have any separate H variable. However, I have developed the model further to allow for an endogenous human capital parameter, see appendix. This modified model can explain growth differences in output per efficiency units along the transition to a new steady state caused by an endogenous alteration in the growth rate of H. The addition of endogenous H measure also allows for differences in *per capita* growth paths in steady states.

In many models of the new growth theory, H was given a special role from the beginning. The classic one of these models is the Lucas model, where H spillovers affect the productivity of the entire economy positively, thus clearly allowing for different growth paths for economies with different amounts of H.

Mankiw has tried to augment the traditional Solow growth model by raising the share of capital in the production function. This does not, however, change the neoclassical nature of the model. In the steady state growth rate differences could not be explained by the model. Models by Barro and Sala-i-Martin were also discussed: one model with a single “sector” of production, and an augmented version of this model with two sectors of production. Both of these models assumed that there is a constant steady state value of the K/H ratio, which determines the growth rates of the countries. The conclusion of the two sector model, i.e. that too abundant H leads to higher output growth, emphasized the importance of H as an explaining factor for growth rate differences.

There are thus many models that underline the special role of human capital as a growth factor. It is not obvious however, which is the best model. It has to be found out via empirical testing. It might be that one particular model could work well when applied to some economy but not when applied to another economy. This means that each country should be analysed separately. As the socialist experiment of eastern Europe showed, an abundant human capital cannot quarantee good economic performance. There are also many other important factors for growth performance of economies, of which ’social capital’, the quality of institutions, and good macroeconomic policy are certainly among the most important ones.

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Appendix

Labour-augmenting Human Capital

I will now show how differencies in the efficiency of labour can be caused by differencies in the growth of the stock of human capital. This could be one way to develop the Solow tradition further in order for it to become more graphical, since many studies now exist which underline the importance of human capital.

Human capital is also a part of the effiency term of labour according to Solow (see Solow (1957), p.312, and Mankiw (1994), pp.114-115) However, common sense dictates that there must be differencies in the level of H across countries. Therefore, in this section I will consider human capital as endogenous for an economy and not the same for every country in the world. The efficiency term of labour E is left to capture all the other efficiency increasing factors except H, which is exhibited separately. H is assumed to increase labour productivity. I will call human capital 'labour-augmenting' in the model, because it increases output in the same way as an increase in the efficiency of labour, E, does. To incorporate labour augmenting human capital into the model, I write the production function as follows:

(A) $$Y = F[K, LH*E]$$

L is the number of workers, H is their level of human capital, assumed to range from 1 to ∞, with value 1 of this parameter referring to unskilled 'raw labour'. H is equal to 1, also when there is no labour at all. E is an efficiency measure without human capital. E thus measures all other factors of labour efficiency like technological changes and the impact of ’social capital’ of an economy on labour. The term LH*E is the labour force measured in so-called efficiency units. The incorporation of H into the model does not change its neo-classical nature.

Human capital can only *increase* labour efficiency. The fine structure of the neo-classical model now allows for an interesting analysis of the transitional dynamics of the model and the impact of H on the growth of an economy. The so called Inada conditions (following Inada (1963); see Barro (1995) p.16.) for labour with human capital are:

(B) $$\lim_{LH \to 0} \frac{dF}{dL} \left[K, LH \times E\right] = \infty, \quad (H \geq 1)$$

(C) $$\lim_{LH \to \infty} \frac{dF}{dL} \left[K, LH \times E\right] = 0, \quad (H \geq 1)$$

The new variabel has the following qualities:

(D) $$\lim_{H \to 1} \frac{dF}{dL} \left[K, LH \times E\right] = \frac{dF}{dL} \left[K, L \times E\right], \quad (H \geq 1)$$

(E) $$\lim_{H \to \infty} \frac{dF}{dL} \left[K, LH \times E\right] = 0, \quad (H \geq 1)$$

Conditions (C) and (E) mean that the production function exhibits diminishing rates of return to H and L investments. The assumption of diminishing returns on human capital investments is plausible, because quite a large empirical literature exists which shows that the return on shooling is higher in poor countries than in rich countries.

Education is assumed to influence the level of H. Improvement or deterioration in the educational level of an economy causes changes in the growth rate of human capital, “e”. Since labour force grows at the rate ”n”, human capital at the rate e and the ’rest efficiency term’, E, at the rate ”g”, the number of efficiency units of labour grows at the rate ”n+g+e”. Output per efficiency unit of labour y = Y/LH*E, depends on the amount of physical capital per efficiency units of labour k = K/LH*E:

(F) $y = f(k)$

The equation below shows how k changes with time:

(G) $\Delta k = sf(k) - (\delta + n + g + e)k$

Equations (F) and (G) state that the change in the capital stock per efficiency unit of labour k and accordingly the change in output per efficiency unit of labour y, equal the amount of investments (investments = I = sf(k) = share saved from national income, i.e. not consumed) minus depreciation ”δ”, population growth n, technological change g and the rate of change in the stock of human capital e.

Changes in the variables in equation (G) thus lead to changes in the economy’s level of output per efficiency unit. This results in a change in the growth rate of output per efficiency unit, but only in a short run, before the economy has reached a new steady state with a different amount of capital per efficiency unit than initially. The amount of capital per efficiency unit of labour is then constant again and so is output per efficiency unit of labour. In the steady state then: $\Delta k = \Delta y = 0$ and the amount k* satisfies the condition:

(H) $sf(k) = (\delta + n + g + e)k$

Output per worker Y/L, a good measure of standards of living, is however not constant in the steady state:

(I) $y = Y/(LH*E) \rightarrow Y/LH = y*E \rightarrow Y/L = y*E*H$

Output per worker (without human capital) grows in the steady state at the rate ”g + e”, i.e. at the same rate at which H and E evolve caused by investments in education in the country in question and the worldwide level of technological progress. Since Y = y*E*H*L, total output grows at the rate g + e + n.

The steady state growth rate is the same in this augmented Solow model as it was in the traditional model, minus the endogenously created difference in the value of the human capital parameter. Augmenting the standard neo-classical model in this way makes human capital central for the theory, especially if determination of the saving rate and the technological change are assumed to be exogenous to the model and the same for all countries.

We can use the dynamics of this model and assume that we have two economies which differ only in one respect: they have different growth rates in their stocks of human capital. In this situation the economies will end up having different amounts of capital per efficiency unit of labour in their steady states. During the transition to steady states, different growth rates of the economies can be observed, caused by different human capital growth rates, under the assumption that both economies had the same initial amount of physical and human capital per efficiency units. The resulting phenomenon is similar to the so-called conditional convergence, and human capital is the central factor causing it.

The further the economy is from a steady state the higher is the growth rate because of diminishing returns to physical capital investments. K per efficiency unit will end up being the higher the more e has fallen. Thus, a sudden fall in the human capital growth rate causes output per efficiency unit to grow at a higher rate, the bigger the fall in e (="$e_2\Downarrow$") is, until a new steady state has been reached (γ is the growth rate):

$$\text{(J)} \quad e_2\Downarrow \;\rightarrow\; e_1 > e_2 \;\rightarrow\; \gamma_{k^2} > \gamma_{k^1} \;\rightarrow\; \gamma_{y^2} > \gamma_{y^1}$$

If economy 2's human capital growth rate has fallen more from the initial level than economy 1's rate ($e_2 < e_1$), then this augmented neo-classical model predicts a higher growth rate of output per efficiency unit for economy 2, until the new steady state has been reached, ceteris paribus.

Hence, human capital significantly affects growth along the transition to a new steady state. H is a factor directly affecting the productivity of labour force in a similar manner as the exogenous technological change E, while it has a negative effect on the output per efficiency unit. The difference to E is that H is assumed to be endogenous to the economy, thus allowing for different steady states and conditional convergence across economies. This means that differencies in human capital growth rates have a clear effect on growth rate (per efficiency unit of labour) differencies across countries along the transition to a new steady state. Equation (I) also showed that differencies in the stock of human capital result in different growth rates of *per capita* output across countries.