# Documents de travail

# « Human Capital and Economic Growth »

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# Human Capital and Economic Growth

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Abstract: The aim of this entry is (I) to undertake a critical reading of the seminal contribution of Lucas' work to construct a model which represents the complexity of the links between human capital and economic growth (II) to review the empirical assessments of its endogenous nature.

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**Introduction**

As in the 19th century, long-term fluctuations and growth in the productive potential of the advanced industrial nations and what they imply for social well-being remain central to current economic debate. The issue was controversial after Word War II, with the interest focused on the long-term stability of market economies. However, following Solow's economic-growth model (1956), neo-classical thinking gradually extended its power. Its reasoning is clear and it explains numerous factors of growth. These are well summarised in Kaldor's six 'stylised facts' (1963). Then this research lost its appeal. With hindsight, there were two explanations for this. The dominance of narrow inquiries into short-term fluctuations was intellectually shorted-sighted and no progress was being made to develop analytical tools capable of accounting for hitherto unmeasurable growth factors, internal or external. Post-war neo-classical models accounted for growth in terms of exogenous factors[2]. They implied that technical progress is achieved without cost, outside the economic system, while Solow's model provides no explanation for the divergence of international growth rates, as contemporary theories of long-run equilibrium assumed that all countries progressed at identical, exogenous rates of technical progress. Nor does the hypothesised negative correlation between income levels and economic growth derive from reliable empirical verification and there is no evidence to corroborate the convergence hypothesis, that there will be a flow of capital from the richest to the poorest countries (Barro, Sala-I-Martin, 1995).

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[2]The exception is Ramsey's model (1928) that was rediscovered very recently.

In the 1980s, the work of Lucas (1988) and Romer (1986, 1990) did attract attention, marking a *renaissance* of scholarly interest in neo-classical growth theories. Its prime objective has been to overcome the weaknesses of the earlier models, by answering new questions: What are the determinants of sustainable economic growth? Can technical progress alone increase social welfare or can capital accumulation also lead to a permanent increase in *per capita* income? What factors of production engender sustainable growth: physical capital, environmental capital, human capital, social capital or technological knowledge? What mechanisms guarantee long-term growth in a market economy? What is/are the market structure/s within which such growth can be achieved? To answer these questions, research into the determinants of economic growth processes is flourishing, with important implications for policy. The argument that endogenous factors account for long-term growth is becoming accepted and new conceptualisations support the idea that the introduction of new accumulation factors, such as education and knowledge, will stimulate self-maintained growth in extension to the founding work of North American human capital scholars such as Mincer (1958), Schultz (1961) and Becker (1964). However, in spite of numerous theoretical advances, attempts at empirical verification continue to run up against methodological difficulties. In the 21st century, we still do not know how the development of knowledge relates to economic growth or even if knowledge is a driving force behind it. Numerous new hypotheses are proposed, but their statistical verification is limited. Formalised analytical procedures remain weak, while an alternative body of possibly more accurate qualitative observations and intuitions is insufficiently precise to serve as a base for growth strategy decisions.

With reference to the above, the aim of this entry is (I) to undertake a critical reading of the seminal contribution of Lucas' work to construct a model which represents the complexity of the links between human capital and economic growth (II) to review the empirical assessments of its endogenous nature.

## I. The Lucas Model

The new growth theories developed since the end of the 1980s are seen by many as a decisive step forward compared to Solow's standard exogenous growth model. The poorly matching hypothesis of the exogenous nature of technical progress is abandoned in order to see growth as a truly endogenous process.

The new growth theories are constructed around the central idea that factor returns no longer decrease when it is accepted that components other than physical capital (such as human capital) exist and can display endogenous accumulation. This endogenous character of growth, linked with the existence of positive externalities, compensate the falling marginal productivity of physical capital. These externalities originate in activities such as research and development, the dissemination of knowledge or the construction of public infrastructure. In short, growth is a self-maintaining process taking place at a constant rate because the returns of the accumulation factors are constant.

Endogenous growth theories therefore have the common aim of understanding the long-term growth of *per capita* income and describing it as the product of the economic system. The differences in development between nations and the non-convergence observed would thus have a theoretical explanation in the dependence on initial conditions.

It should be noted here that the generic term *endogenous growth* covers a host of models. Indeed, these theories are characterised by the great variety of the sources of growth chosen: investment in physical capital, human capital, public capital, learning by doing, division of labour, research and technological innovation. These sources have long been identified by economists but endogenous growth theories formalise them for the first time and thus make it possible to gain a better view of their effects.

From this point of view, Lucas pioneering model analyses the individual decisions aimed at acquiring knowledge, their consequences for the productivity of individuals and for economic growth as a whole. He considers human capital as an alternative and a complement to technical progress in its function as a driving force for growth. He defines it as the 'general skill level', this being the individual's set of physical, intellectual and technical capabilities. Human capital is rival and exclusive because it is incorporated in individuals. A production sector and an education sector coexist in his model. The first produces goods from physical capital and part of human capital, which according to Lucas can be accumulated, with non-decreasing and at least constant marginal productivity. In the second sector, human capital forms and accumulates through itself, with the part of human capital not used in the production sector. The individual educates himself using his time and part of the skills that he has already acquired.

An individual thus devotes his non-leisure time to production or education activities. This allocation affects his productivity and his level of human capital *h.* Thus, if *N* workers considered as identical agents possess the same skill level *h* and devote a fraction *u* of their non-leisure time to current production, the remaining part *1-u* is allocated to accumulation of human capital. The effective workforce, that is to say the sum of human skills devoted to present production, is written as follows:

$$L^e = uhN$$

Production is a function of total physical capital *K* and of effective work: $Y = F(K, L^e)$. Lucas identified two effects of human capital. The first is internal and affects the productivity of the individual who has gained skills, whereas the second is considered as external insofar as human capital accumulation by an individual contributes to improving the productivity of others. This external effect is not taken into account in the time allocation decisions taken by economic agents. This externality in the production of the good represents the average and not the total human capital of individuals participating, noted $h_a$. It represents the idea that individuals will become more productive if they are in contact with trained, qualified persons and that this will result in enhanced collective skills thanks to the exchange of ideas and practices. At equilibrium, as all individuals are identical, the average skill level $h_a$ becomes simply *h.* In the production section, production good technology is written as follows:

$$Y(t) = N(t)c(t) + \dot{K}(t) = AK(t)^{\beta}[u(t)h(t)N(t)]^{1-\beta} h_a(t)^{\gamma}$$

*c*(*t*) is per capita consumption. Technology level *A* is assumed to be constant. Externality is not necessary to obtain endogenous growth, since an accumulation input—human capital—with non-decreasing returns is substituted for the labour factor in the production function, thus making positive growth possible. Lucas uses this demonstration to account for the dependence of the per-capita income path on the initial conditions and hence the persistence of international differences in development, and the non-convergence of economies and other phenomena such as population movements (which, however, are outside the scope of this discussion).

Human capital produces itself in the educational sphere. The effort devoted to the accumulation of human capital *1-u*(*t*) should be related to the rate of variation of its level *h*(*t*). Achieving exogenous growth, without taking into account the existence of a possible externality, requires that the returns of accumulation of human capital do not diminish. The expression of $\dot{h}(t)$ below does not induce decreasing returns of human capital stock $h(t)$:

$$\dot{h}(t) = h(t)\phi[1 - u(t)]$$

As knowledge accumulation is assumed to be linear (which is questionable because one might support the hypothesis that the stock of knowledge displays threshold effects), it displays non-decreasing marginal returns that enhance unlimited growth. Encouragement to invest in human capital is non-decreasing (function $\varphi$ is assumed to be non-decreasing). An increase in the stock of human capital requires an identical effort whatever the level previously attained. In substance, the accumulation of human capital intrinsically displays factor returns that are at least constant in comparison with the level previously attained. *In relative terms*, human capital increase is independent of existing human capital. In one hour of training, a child learning to read makes less progress in terms of absolute value than an engineer (whose stock of human capital is obviously considerable) learning new techniques. However, the child makes perhaps as much if not more progress in relative value, in such a way that the marginal productivity of human capital is always at least constant as one invests in education. This in an inherent feature of an intangible good, as stressed by Lucas. The human capital growth rate thus appears to be independent of the initial human capital level[3]:

$$\dot{h}(t) / h(t) = g_h = \phi(1 - u(t))$$

To prevent the stock of human capital of households from remaining constant, Lucas assumes that the $\dot{h}(t)$ equation applies to a representative household with an infinite lifetime. This hypothesis makes it possible to affirm that human capital accumulation does not display decreasing returns. Clearly, this formulation no longer applies when one considers an individual whose lifetime is limited and whose human capital disappears with him when he dies. The initial level of each new member becomes proportional (and not equal) to the level already attained by the older members of the family. The optimal growth path corresponds to choices of consumption flow and the time spent working (or studying) that maximise the inter-temporal use of agents while respecting the constraints of physical and human capital accumulation. Assuming a closed economy and a population rising at a fixed rate *n*, the preference of the representative household is expressed by

[3]"*A given percentage increase in h(t) requires the same effort, no matter what level of h(t) has already been attained.*" Lucas (1988, p. 19).

the isoelastic utility function below, in which the variable $\rho$ represents a preference rate for the present and $\sigma$ the constant inter-temporal elasticity of substitution:

$$\int_0^{\infty} e^{-(\rho-n)t}[\frac{c(t)^{1-1/\sigma}}{1-1/\sigma}]dt$$

Dynamic optimisation is used to solve the maximisation program and to determine the value of *g,* the common growth rate of consumption, capital and product:

$$g = g_k = (1-\beta+\gamma)g_h/(1-\beta) = \varphi(1-\beta+\gamma)(1-u)/(1-\beta)$$

The engine of economic growth is thus the effectiveness of accumulation of human capital, $\varphi$, the scale of its effect on production as an externality, $\gamma$, and the fraction of time available allocated to knowledge accumulation (*1-u*). The source of growth thus resides in unlimited accumulation of human capital *h* whose returns do not diminish. In other words, the linear growth of *h* during each period accounts for the potentially unlimited nature of economic expansion. The existence of the externality measured by parameter $\gamma$ is not essential for achieving positive growth, it just accelerates it. However, its presence leads to differentiating between balance and optimum and to taking into account the inadequacy of investment in education, justifying public education policies. Nevertheless, the hypothesis chosen for function $\varphi$ brings up a number of questions. Indeed, what arguments form the basis for Lucas' affirmation that human capital accumulation displays non-decreasing returns? Is not Uzawa's hypothesis (1965) that this function is a decreasing one just as realistic? Endogenous growth is therefore based on a very particular hypothesis that can easily be called into question. The level of growth and not its rate would depend on the effort made in education. In short, in contrast with Lucas' assumption, endogenous growth would seem to be based more on the existence of externalities resulting from human capital accumulation than on the non-decreasing returns of the latter.

The models proposed by Lucas and by Uzawa finally seem very similar, with the noteworthy exception pointed out by Mino[4] that Uzawa refuses to consider the hypothesis of externalities of the 'Marshall' type in human capital accumulation. In other words, he does not envisage the hypothesis

[4]"*Although modeling strategies of Uzawa (1965) and Lucas (1988) are based on similar ideas, there are important differences between their discussions. First of all, Lucas introduces Marshallian externalities of human capital, while Uzawa ignores externalities*." Mino (1996, p. 227).

of increasing returns to scale. However, Lucas mentions the possibility of unbalanced growth and, *a fortiori*, that of a situation that is not optimal with regard to the Pareto's criterion. Thus the major difference between these two models resides in the nature of the factors and in the hypothesis put forward with regard to the education function $\varphi$. In Lucas' model, human capital replaces the labour factor. It becomes an accumulation factor inducing self-maintained growth. The function $\varphi$ is assumed to be non-decreasing, enabling limitless accumulation of the human capital that is the source of endogenous growth. Meanwhile, Uzawa retains the 'classical' notion of the non-reproducible labour factor. $A(t)$ can be modified instantaneously and bears no trace of the past. The function $\varphi$ still has decreasing returns and because of this the growth rate of the economy still depends on exogenous features such as the rate of growth of the working population, the speed of technical progress or the improvement of labour efficiency.

Lucas' model has served as reference for numerous analyses studying the impact of investment in education on economic growth. Chamley's view (1993), for example, is the same as Lucas'. The conception of externalities, however, does differ. Lucas is of the opinion that they affect stocks of human capital (production goods). Chamley holds that they affect flows of human capital (production of human capital in the case of researchers working together).
This changes human capital accumulation:

$$\dot{h} = h_t \phi(u_t, \overline{h}_t)$$

in which $\overline{h}$ represents the average level of human capital. Chamley's conclusions concerning the importance of substantial investment in human capital as the main source of growth are nevertheless identical to those of Lucas.

Caballé and Santos (1993) do not consider the existence of externalities. They assume that physical capital can be an input in the production of human capital. Human capital accumulation is then written as follows:

$$\dot{h}(t) = \phi[\frac{(1 - v(t))K(t)}{N_0}, (1 - u(t))h(t)] - (\nu + \theta)h(t)$$

The education function $\varphi$ thus becomes a growing function of the two types of capital, in which $v(t)$ represents the fraction of physical capital devoted to the production of consumer goods, $u(t)$ is the proportion of human capital allocated to the production sector, $\nu$ is the growth rate of human capital, $\theta$ is the constant depreciation rate of human capital and $N_0$ is the initial state of the population variable.

Human capital remains the key factor in endogenous growth. Indeed, from a given equilibrium onwards, the injection of human capital leads the economy to another state of equilibrium with higher levels of physical capital and consumption. Likewise, an increase in physical capital engenders a process of human capital accumulation that enhances growth.

The fact that the increase in the average level of human capital is linear in these various models raises a number of questions. Indeed, might it not be possible that the accumulation of human capital by a representative individual may depend on the level already attained by his/her parents, the average level in the economy or the individual's initial level? Moreover, is not the hypothesis of an individual with an infinite lifetime too 'risky' and an over-simplification? In any case, by eliminating it, Azariadis and Drazen (1990) demonstrate that the accumulation of human capital displays threshold effects justifying the possibility of multiple equilibria and strong differences between the per capita growth rates of national economies.

In a model proposed in 1990, Romer provides a framework for analysis making it possible to apprehend this other dimension of knowledge and hence to gain another view of endogenous growth. Romer extends and goes beyond the approach to technical progress that is part of the 'capital generations' models of Johansen (1959) and Solow (1957) to show how technology can induce self-maintained growth. Technology is considered as targeted knowledge, a set of instructions (making it possible to manufacture capital goods) which, in contrast to Lucas' vision, is not part of the individual. Its growth is not linked to the life of the individual and can hence be unlimited. Better trained individuals can develop a larger number of innovations, an endogenous source of technical progress. Thus, the greater the stock of human capital, the stronger growth will be[5].

This conclusion is based on three postulates forming the basis for discussion: (I) technical progress is central to growth; (II) it is the result of voluntary decisions taken by individuals who respond to market incitements and seek to maximise profit and utility, making it endogenous; (III) the procedure for the implementation of technological innovations is intrinsically different from the modes of use of other economic goods. Technology is neither a conventional good nor a public good but a non-rival good for partially exclusive use. Once the cost of a new set of instructions has been borne, the latter can be used without limit at no additional cost. Technology induces only fixed costs. It is difficult to reconcile these three postulates with competitive equilibrium, since competition tends to become monopolistic. The production function can then be written with the expression below, in

[5]"*The main conclusions are that the stock of human capital determines the rate of growth, that too little human capital is devoted to research in equilibrium, ...*" Romer (1990, p. S71).

which *A* represents a non-rival input and *x* is a rival input: *F*(*A, x*). Homogeneity of degree one is not plausible as it is not necessary to duplicate non-rival goods to double production. As *A* is productive, the production function becomes non-concave in such a way that remuneration for marginal productivity is no longer possible. The general principle of the model consists of defining technology as a variable depending directly on the level of formation of human capital. Thus, the impact of human capital—and therefore of knowledge—on growth is analysed through its indirect effect on the production of innovations.

## II. Empirical Debates

The considerable progress made in the theoretical modelling of knowledge has not really induced comparable progress at an empirical level[6]. The main reason is certainly the very nature of the concept of knowledge. Indeed, knowledge is not a good like the others; it must be measured in a different way and its relation to the price system modified in comparison to that of other goods. Nevertheless, the importance of knowledge and particularly education for economic growth has been evaluated in numerous empirical studies. Early work was carried out on the subject by Solow (1956 and 1957) and Denison (1962 and 1967). Their aim is measuring the contributions of the factors of production—generally capital and labour—and the increase of technical progress to the growth rate as a whole. Their work consists of residual analysis of the contribution of the total productivity of the factors. In this context, Denison (1962) demonstrates that the growth of the average level of education—evaluated by income differentials that can be ascribed to each level of education and measured using the average number of years of formal education—accounts for more than 20% of US growth from 1929 to 1957[7].

[6]"*Although there has been some progress in modeling knowledge at theoretical level, less progress has been made at the empirical level.*" Aghion and Howitt (1998, p. 435). There are different databases available (Diebolt and Hippe, 2018, 2019). These are in part international databases, including European databases mostly at the national level or sometimes referring to large regions constituting those countries. Some of the most well-known are provided by Banks (1971), Flora (1983), Benavot and Riddle (1988), Barro and Lee (2001), Mitchell (2003), De La Fuente and Doménech (2006), Cohen and Soto (2007) and Morrisson and Murtin (2009).

[7]Checking theoretical hypotheses on economic growth requires always new statistical sets. The methods of national growth accounting, launching by Simon Kuznets, are essential for reaching this aim. It consists of assembling historical facts in homogenous, comparable time units in order to measure changes in intervals of time (generally annually). The advantage of these methods is that the moment of operation of the observer's choice is shifted. Instead of acting while observing the reality to be described, he operates during the construction of the reference system serving in the recording of facts rendered conceptually homogeneous. This methodology should allow for an empirical verification or the rejection of initial hypotheses hinged on the pattern of theoretical interpretation. For a helpful overview, see the website of the French Cliometric Association: http://www.cliometrie.org/en/

Subsequent empirical evaluation was focused on verifying the idea of at least conditional convergence of economies. Barro (1991) demonstrated in an article that in the period 1960-1985 the growth rate in a sample of 98 countries depended positively on the initial level of human capital measured by schooling rates and negatively on the initial level of per capita GNP. Convergence can thus be confirmed, since most poor countries tend to grow more rapidly than rich countries, but only for a given quantity of human capital.

Mankiw, Romer and Weil (1991), with an identical database (Summers and Heston, 1988) to that used by Barro (1991), confirm the conclusions of Solow's model (1956) on condition that the importance of human capital is recognised. They thus broaden Solow's model by introducing the accumulation of human capital measured by the rate of schooling. They conclude that differences in saving, education and population growth account for the differences in per capita income. Their model, which includes exogenous technical progress and decreasing returns on capital, better explains the international variations in output per person than the models of endogenous growth.

Barro and Lee (1993) have studied the rate of scholastic success in the adult population at various levels (uneducated, primary education, secondary education, higher education) from 1960 to 1985 in 129 countries and conclude that levels of education have considerable explanatory capacity. Education has direct positive effects on the growth rate of the GNP.

In contrast, Benhabib and Spiegel (1994) maintain that the growth rate of human capital measured by the number of years of education of the working population does not significantly explain the growth rates of per capita output. However, human capital levels play a substantial role as determinants of increase in per capita income. It is therefore no longer possible to consider human capital as a factor of production, as this hypothesis implies that its growth rate and not its level accounts for the rate of increase of per capita income.

Like that of Jones (1995), this conclusion leads to doubting theories of endogenous growth. Indeed, Jones (1995) criticises endogenous growth models based on research and development activities: input (measured by the number of scientists and engineers engaged in R&D activity) has increased significantly without any visible effects on the growth of per capita output and on growth of productivity. He concludes that long-term economic growth is not affected by structural parameters, except for those generally considered as being exogenous. He thus returns to Solow's conclusions.

In short, the different evaluations lead to diverging conclusions, while none of them directly tests the endogenous growth hypothesis. Maybe the testing of a hypothesis is only acceptable if the latter is both a hypothesis and the result of a model, as is stressed by Romer (1990, p. S84).

Measurement error may also account for some of the results (Krueger and Lindahl 2001). Thus, Sianesi and Van Reenen conclude in their literature survey in 2003 that "as a whole we feel confident that there are important effects of education on growth" (Sianesi and Van Reenen 2003, p. 197).

In addition, the more recent studies by De La Fuente and Doménech (2006), Cohen and Soto (2007), Goldin and Katz (2008) and Ciccone and Papaioannou (2009) show the crucial impact of human capital on growth.

The key contribution of cognitive skills is further highlighted by Hanushek and Woessmann (Hanushek and Woessmann, 2008, 2015). The authors argue that not the quantity of education matters, but its quality. These so-called approaches of the "quality of education" (see, for instance, Hanushek and Kimko (2000), Jamison, Jamison and Hanushek (2007) or Hanushek and Woessmann (2012) argue that the appropriate measurement of human capital is not the length of studies, but what is learnt at school or university. What matters are specific skills!

Many studies in the past were not able to measure skills because such data were not available. In consequence, instead of educational attainment measures it appears better to use measures of (international) achievement tests. There has been a growth in the number of these tests, often administered by the OECD or IEA; the most famous being PISA, PIAAC, TIMSS and PIRLS (Altinok, Diebolt and Demeulemeester, 2014).

Historical analysis as well, have opened up new paths of reflection on what types of human capital matter for economic growth, and hence how to measure it. The importance of apprenticeships, the presence of knowledge elites, the degree of centralization of education, the way it was financed, etc. are crucial factors that may have an impact on the level of human capital effectively accumulated at the aggregate level. These dimensions – and their impact on the way human capital affected the growth process - now give rise to close scrutiny in the historical literature (Le Chapelain, 2013).

## Conclusion

The literature on new growth theories is diverse in nature. However, the structure of the models is identical, with endogenous growth becoming possible after the introduction of a new accumulation factor whose results are at least constant. This factor makes it possible to compensate the decreasing returns of capital accumulation. Growth factors other than the traditional factors of capital and labour are modelled for the first time. However, it would seem that the results of the models depend very strongly on research hypotheses that have not yet been verified.

According to the thinking of Lucas, in particular, the source of economic growth lies in the unlimited accumulation of human capital. This boundless increase in human capital is based on major hypotheses of non-decreasing returns of technology and training and on the existence of externalities. In fact, in the long run and as in Uzawa's model, economic growth might just as easily be nil.

In the model category inspired by the work of Romer, economic growth is a function of research and development, the latter depending on the share of human capital allocated to the research sector. Accumulation of knowledge (innovations) forms the engine of growth and this accumulation can be unlimited because of the very nature of knowledge, which is a non-rival good with partially exclusive use. Nevertheless, self-maintained growth is based on the hypothesis of linear *A*. However, experience lends credibility to the thought that the opportunities in research do not diminish rather than affirming that the accumulation of human capital shows non-decreasing returns.

The other models achieve self-maintained growth in an identical way by means of hypotheses concerning the non-decreasing returns of the new factors of accumulation. This fundamental criticism opens up considerable research prospects, in particular with regard to empirical verifications. The latter may either confirm the endogenous growth hypotheses or, more simply, encourage a return to the Solowian tradition, since, *a priori*, there is nothing to prevent the inclusion of education, research and development, public expenditure, etc. in the model defined by Solow in 1956.

Today a promising research path addresses, in extension to Lucas (1988) and building on Galor and Weill (1996), the relation between economic growth and gender equality over the long-run of history (Diebolt and Perrin, 2013, 2019). The aim is to produce a cliometric projection of the social sciences on the past, structured by economic theory and mathematical modelling, using statistical and econometric models (Diebolt, 2016, Diebolt and Haupert, 2016). The anticipated step change for future research is twofold: building a bridge between theoretical growth models and economic history; and encouraging economists to examine more systematically these theories grounded upon history while nevertheless aiming at finding general laws. This middle road between pure empiricism and abstract theory might open the door to better economic theory, enabling the scientific community and the society in general to interpret current economic issues in the light of the past and to understand more deeply the historical working of socio-economic processes.

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