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Education and Economic Growth: Endogenous Growth Theory Test. The French Case

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Abstract: The debate concerning the various determinants of economic growth has attracted considerable attention, due to both the importance of its implication in terms of economic policy and the number of theoretical and empirical analyses engendered by it. Thus, the argument according to which endogenous growth models explain long–term economic growth is often put forward. Particularly, it is held that the production of knowledge by education induces self–sustained economic growth. However, in spite of numerous theoretical developments, attempts at empirical verification give contradictory conclusions. The aims of this article are therefore to undertake a critical reading of the theoretical contribution of new growth theories and to present an empirical testing for France in the 19th and 20th centuries to justify or invalidate the probable endogenous nature of economic growth induced by education. In short, it is an empirical test of Lucas' model (1988). The results are surprising and so in contradiction with the hypothesis of new growth theories: human capital returns are decreasing and thus knowledge produced by education cannot be the engine of self-maintained economic growth.

Introduction

The new theories of the growth attach to education and broadly to knowledge a central role and place as essential engine of the economic growth. The argumentation according to which endogenous growth models explain the long term

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economic growth is often put forward. The production of knowledge by an educational sector induces self-sustained economic growth because the marginal returns on this new factor – human capital – are not decreasing. In short, growth is a self-maintaining process taking place at a constant rate because the returns of human capital accumulation are constant. However, in spite of numerous theoretical developments, attempts at empirical verification seem to be incomplete and often contradictory. In this context, it seems interesting to call into question the assumption that education is the prime engine of self–sustained economic growth in the long term. Nothing allows to assert whether it is the case, because it is difficult, even today, to specify the real contribution of the production of knowledge to the growth process. Within the framework of endogenous growth models, the question raises about the nature of education production returns. The aim is, therefore, to verify the hypothesis of not decreasing returns using empirical data. Thus, the question of the real role that education plays in the process of growth can be answered and so the endogenous character of growth can be verified. Lucas (1988) supposes that education is a central component of the growth process because knowledge is considered according to an individual logic, it is human capital incorporated into individuals. The empirical test of the hypothesis is carried out for France in the 19th and 20th centuries. The originality of this work is to be situated in a perspective of long term and so to break with the tradition of cross sections. The interest of such a choice is double: analyses in reference cross sections are already numerous, and furthermore, endogenous growth theories being supposed to explain the growth of long term, it seems interesting to be situated in this temporal frame.

I. Lucas's (1988) model: theory and empirical assessment

1. Theory

The analysis by Lucas (1988) characterizes the field of education as a central component of the growth process by using a 'subjective' conception of knowledge[1]. Knowledge is a rival good and its use is exclusive[2]. It is incorporated in persons as human capital. Lucas 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

[1] The conception of knowledge is qualified as being subjective, i.e. incorporated in individuals, as opposed to an objectivised conception, where knowledge is materialised in equipment.

[2] Its use by one agent excludes use by another individual. Its owner can use technical or legal systems to prevent others from using it.

for growth. He defines it as the 'general skill level', this being the individual's set of physical, intellectual and technical capabilities. 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. 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*):

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

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 φ is assumed to be non-decreasing). 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, φ, the scale of its effect on production as an externality, γ, 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 γ 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 φ 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[3] 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 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. But 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 φ. In Lucas' model, human capital replaces the labour factor. It becomes an accumulation factor inducing self-maintained growth. The function φ 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 φ 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. Azariadis and Drazen (1990) propose an endogenous growth model with overlapping generations in which human capital is the engine of growth since its accumulation displays increasing social returns to scale. Inherited human capital exercises a positive external effect on the effectiveness of teaching, this introduces an intergenerational externality, source of growth. Thus they don't keep Lucas' hypothesis of linearity which seems no realistic like emphasise it Aghion et Howitt (1998, p.330) : "*The Lucas model is elegant and simple, but as always this comes at the expense of some realism. For example, equation (10.2)* (human capital accumulation) *means that individual's returns to education remains constant over his or her whole lifetime, an assumption that its at odd both the empirical evidence on education and with Becker (1964) indeed sug-*

[3] "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).

gest that the returns to education tend to decrease over the lifetime of an individual".

2. Empirical assessment

With the early work of Solow (1956 and 1957) and Denison (1962 and 1967), it is clear that economic growth can't be only explained by the multiplication of capital and labor. Their aim is to measure 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. 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 of 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, 1991) 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 extend 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 the level of education has 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, the human capital level plays a substantial role as determinant 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. This result is in contradiction with endogenous growth theories. On the

other hand, Lee and Lee (1995) consolidate the success of the new growth theories, just as the conclusions of Charlot (1997): the returns on the education are increasing and they influence positively growth rate. The results of Barro (2000) confirm it.

In short, the different evaluations lead to diverging conclusions, while none of them directly tests the endogenous growth hypothesis. The testing of an assumption is only acceptable if the latter is both a hypothesis and a result of the model as is stressed by Solow (1998): the wished result is always supposed. Is knowledge really the main engine of growth? This question always remains without evident answer. Thus a test concerning the returns of educational function is proposed, this implies to know the time of training, (*1-u),* and the stock of human capital *h.* The applied method is a simple linear regression; this choice which imposes the linearity is justified by the fact that Lucas supposes (and so imposes too) a linear relation between average duration of training and growth rate of the stock of human resources.

II. Lucas' model testing

Following early works more general like Monteils (2000, 2001) or Diebolt and Monteils (2000a and b, 2001 a and b) which describe some tests of the endogenous growth model where knowledge is the product of education, research or learning by doing, a test of Lucas' model is proposed.

1. Used approximations

The test of the returns to education production function needs to know the average duration of training and the stock of human capital. The method applied is linear regression; this choice is contestable but Lucas supposes a linear relation between the average duration of training and the growth rate of human capital stock.

The first stage consists in calculating the average duration of training of the working population, *(1-u)*. The data of Villa (1997) are directly used, calculations are also made by putting several assumptions: school attendance by level forms the starting point of this work, this analysis uses the data acquired by INSEE. The most interesting work concerns the evaluation of human capital stock. The average duration of education or the school attendance rate are generally used as indicator for the level of human capital. Therefore, it would be tautological in Lucas' model to say that the average duration of education or even the school attendance rate are functions of training duration. Several approximations are proposed: illiteracy rates, schooling levels or diplomas at the exist of educational system and annual average wages. First the human capital stock is defined as the opposite of the illiteracy rates. Two series, published by

INSEE (1988), are used: illiterate men and women (1854-1931) and illiterate conscripts (1832-1934). The building of the human capital stock supposes that individuals enter in the stock at the date of their marriage, or their conscription, and go out at the date of their pension.

A second attempt of estimate consists in measuring human capital by the validation of the training. Spence (1973) considered that education improves individual productivity, the latter remaining an unknown quantity for the employers who are forced to refer to various signs and indexes such as the level of the qualifications in order to make an assessment. The starting point of the method used here is the same: a qualification is a sign of the level of human capital on individuals. The data of INSEE (1987, 1988, 1993, 1996) and DEP (1998) used for the analysis, contain informations about the flow of net exits of the educational system by level and diploma between 1970 and 1996. The flow is weighted by a cost coefficient (in this case expenditure on education) as the year of schooling and diplomas are not equivalent. The human capital stock is then estimated: individuals enter in the stock at the exit of the educational system and go out 37,5 years later (legal duration of active life necessary for the obtaining of a pension at full rate).

To verify obtained results, a supplementary estimate is finally proposed supposing that the annual average wages directly represent human capital.

2. Results

Without omitting the unmistakable fact according to which an empirical invalidation is not tantamount to the refutation of a theory, the obtained results are convergent: they indicate a negative relation between the rate of growth of human capital and the average duration of training. The growth rate of human capital stock is decreasing, it can not explain or engender a self-sustained economic growth. Results are presented in the table below:

Picture 1 : Relation between growth rate of human capital stock and average duration of training

EXPLAINED VARIABLE, *y* : Human capital stock, *h,* (illiteracy of men and women)
1855 – 1931 ; 77 observations

VARIABLE	COEFFICIENT	ERROR	T-STUDENT
Duration of training	-0,019318	0,005929	-3,257984

Correlation coefficient : 0,768371
DW : 0,283584

EXPLAINED VARIABLE, *y* : Human capital stock, *h,* (conscripts illiteracy)
1834 – 1936 ; 103 observations

VARIABLE	COEFFICIENT	ERROR	T-STUDENT
Duration of Training	-0,014978	0,001285	-11,65474

Correlation coefficient : 0,793916
DW : 0,565896

EXPLAINED VARIABLE, *y* : Human capital stock, *h,* (diplomas)
1977 – 1996 ; 20 observations

VARIABLE	COEFFICIENT	ERROR	T-STUDENT
Duration of training	-0,022915	0,003218	-7,121095

Correlation coefficient : 0,738029
DW : 0,366012

EXPLAINED VARIABLE, *y* : Human capital stock, *h,* (level of schooling)
1980 – 1992 ; 13 observations

VARIABLE	COEFFICIENT	ERROR	T-STUDENT
Duration of Training	-0,043425	0,004072	-10,66510

Correlation coefficient : 0,911820
DW : 0,686668

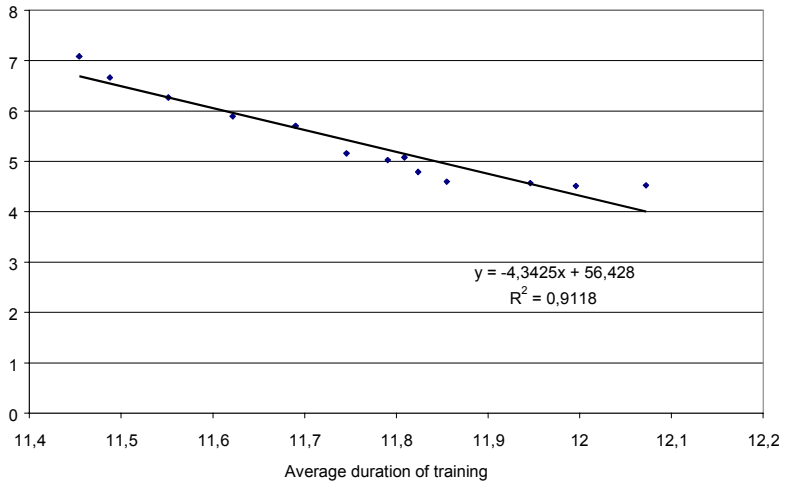
EXPLAINED VARIABLE, *y* : Human capital stock, *h,* (wages)
1954 – 1996 ; 43 observations

VARIABLE	COEFFICIENT	ERROR	T-STUDENT
Duration of Training	-0,015505	0,006388	-2,977248

Correlation coefficient : 0,125642
DW : 0,414001

The T of Student assessment shows that the explanatory variable fits the model very good. The link between average duration of training and growth of human capital stock is always negative. The graph below illustrates this finding (only the approximation with the level of schooling is showen, the other estimations are similar).

Figure 1: Relation between average duration of training and growth rate of human capital stock (estimated by level of schooling)



The human capital stock grows but at a decreasing rate, the endogenous character of the growth, such as Lucas supposes it, is not verified. The result seems to place Lucas' model in a normative field rather than a positive one as it is often supposed. The robustness of results is verified: it seems in general that the explanatory variable is the average duration of schooling, and not its growth rate notably, as well as the stock of human resources of the previous years. A test identifying the average duration of training and the stock of human capital inherited from the individuals (defines by Azariadis and Drazen (1990) as the average human capital) supplies the following results:

Picture 2 : Growth rate of human capital stock according to duration of training and stock of inherited human capital.

EXPLAINED VARIABLE, y : Human capital (conscripts illiteracy) h
1883 – 1936 ; 103 observations

VARIABLE	COEFFICIENT	ERROR	T-STUDENT
Duration of Training	-0,008639	0,000512	-16,87741
Inherited Human Capital	$-3{,}83^{E}$-10	$2{,}49^{E}$-11	-15,41775

Correlation coefficient : 0,944930

DW : 0,909938

The results do not fundamentally change, relations among dependent variable and explanatory variable are negative. The correlation-coefficient, however, increases, the introduction of a new variable leads to a better fit of the model. The relation between the duration of training and the level of human capital is, therefore, positive. In growth models, only growth rates can be a factor of growth. Therefore, the growth rate of human capital is considered as a factor of growth instead of the level of human capital. Some data are integrated by order 1 (Dickey-Fuller' s test prove it); tests in first differences are realized and confirm again acquired results. So all the results call into question Lucas's hypothesis according to which the human capital grows linearly and without limit compensating decreasing returns on physical capital. According to the results human capital – comparable with the other variables – would not break the law of diminishing returns.

In addition the introduction of human capital stock in the function of final output do not seem to improve the efficiency of the labor factor.

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

$$\log Y = \alpha \log K + (1-\alpha)\log L + \gamma(1-\alpha)\log h = \alpha \log K + (1-\alpha)\log L + a \log h$$

Evaluation is proposed for 1970's to 1990 due to the *Accounts of the Nation* published by INSEE.

Picture 3: Function of output final

EXPLAINED VARIABLE, *y* : Output final
1970 – 1996 ; 27 observations

VARIABLE	COEFFICIENT	ERROR	T-STUDENT
Physical			
Capital1	0,358848	0,072374	4,958254
Labor	0,438116	0,081960	5,345477
Human			
Capital	0,215878	0,069007	3,128330

Correlation coefficient: 0,998491
DW: 1,234867

The elasticity of the production with regard to the human capital factor γ ($\gamma = \alpha / (1-\alpha)$) is lower than the unity; it is equal to 0,49; the introduction of a new factor does not improve the efficiency of the streams of work services. Consequently, everything proves that the human capital stock defines by Lucas is a factor as the others which does not break the law of diminishing returns and does not allow an endogenous economic growth. The aggregate form of production function is questionable but it is the one chosen by Lucas. In addition the Durbin-Watson values allow the detection of an auto-correlation of errors (order one) implying a bad specification of the model or a lack of an important explanatory variable. At the end, the linear form of the educational function can be criticizes. A more qualitative analysis can be implemented with a logistic regression. So the dependant variable takes value 1 when the growth rate of human capital stock is growing and 0 when is decreasing.

Picture 4: Logistic regression

EXPLAINED VARIABLE, *y* :
1883 – 1936 ; 103 observations

VARIABLE	COEFFICIENT	ERROR	T-STUDENT
Duration of Training	2,133195	1,714620	1,244121
Inherited Human Capital	-9,94^{E}-08	5,33^{E}-08	-1,863663

An increase of the training-duration leads to a greater probability to obtain a positive growth rate of human capital stock. An increase of the average human capital generates an opposed effect; this test calls into question Azariadis and Drazen' s model.

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 – here human capital - 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 zero. In the model category inspired by the work of Romer (1990), 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 increase in knowledge stock. 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 or by the existence of an positive externality due to learning by doing.

All the empirical evaluations lead to converging conclusions: the assumption of endogenous growth due to knowledge production is not verified. Knowledge is not a particular factor, the decreasing returns law is applied to it. This fundamental criticism opens up considerable research prospects. The first may 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. This idea is synonym of an economic growth not explained except if we refer to Solow (1998)'s reflections concerning growth theories. Indeed the latter considers that growth

theorists may have been mistaken in considering only the growth rates and not the levels. He considers that "*... we should consider everything that permanently raises the trajectory of the economy to be a factor of economic growth, even if it does not affect its growth rate*"[4]. Then the sense of the relation between knowledge and growth can be studied in details: it is possible that economic growth can engender a knowledge development and not the opposite; the both is probable too. Finally, models of endogenous growth can be extended for the integration of the entire complexity of knowledge.

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[4] Solow (1998, p.198)

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