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THE EUROPEAN UNION UNDER THE CONVENTIONAL ANALYSIS OF CONVERGENCE (*)

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1 — Introduction

As is well known convergence in the European Union (EU) is a major issue. The Economic and Monetary Union (EMU) construction has led to nominal convergence of the poorer southern countries towards the group of richer northern countries. But nominal convergence can only be seen, at the most, as a pre-condition for real convergence.

Has real convergence been a reality between the fifteen members of the EU from 1960 to 1990? If so, does this process lag behind? These are the central issues raised by this paper. The possibility of the existence of any tendency towards the approximation (equalisation) of the European citizens' levels of real per capita income will be studied exclusively within the framework of the Theory of Growth. The issue of real convergence in the EU is approached solely through the so-called conventional analysis of convergence based on the predictions of exogenous growth theories and cross section data.

The paper is organised as follows. After the Introduction, the second part is a summary of the main convergence predictions of the exogenous growth models (1). The third part presents the empirical analysis of β convergence. The cross section analysis of absolute β convergence is followed by the cross section analysis of conditional β convergence, without and with human capital (five types of human capital proxies are considered) (2). The fourth part contains our main conclusions. These are: acceptance of a conditional β convergence process but at a very slow pace (the speed of convergence is around 2 % a year, which implies a half-life of 35 years).

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(1) For further references and a more detailed study on this subject please see Simões (1999).

(2) The econometric tests of the convergence hypothesis were carried out using the software RATS 4.21.

2 — Convergence between economies: theoretical analysis

The neoclassical model of growth with one type of capital, known as the Solow-Swan model (3), considers a one-sector economy where output is used both for consumption and investment through savings ($S=I=s_kY$). The aggregate production function shows constant returns to scale, positive but diminishing marginal productivities to inputs and respects the four Inada conditions (4). One of the main conclusions of the model is that an economy like this has a steady state growth equilibrium. In the long run real per capita income grows at the exogenous and constant technological progress growth rate (as well as any of the other macroeconomic variables). Due to diminishing marginal productivities to the capital input, the only one that can be accumulated, the economy converges to the steady state growth equilibrium whatever position it starts from.

If the Solow-Swan model explains growth in the fifteen member states we can consider that each one of them faces an aggregate production function of Cobb-Douglas type given by equation (1):

$$Y_i(t) = [K_i(t)]^{\alpha}[A_i(t)L_i(t)]^{(1-\alpha)}, \text{ with } 0<\alpha<1 \qquad \textbf{(1)}$$

where Y is real output, K the stock of real physical capital, L the labour force, A the level of technology and α the capital share. The subscript i denotes the country and t is the time period.

The technology and labour force growth rates are constant and exogenous (m and n, respectively):

$$A_i(t) = A(0)e^{mt} \text{ and } L_i(t) = L(0)e^{nt}$$

Technological progress is a pure public good immediately available to all countries. Therefore m, the technological progress growth rate, is equal across economies. This means that the diffusion of technology is instantaneous which is not a very unrealistic hypothesis if we think about integrated economies with similar levels of education like the EU.

Equation (1) can be written in units of effective labour as shown in equation (2):

$$y_i = k_i^a \qquad \textbf{(2)}$$

where lower case letters denote quantities per unit of effective labour, that is, $y=Y/AL$ and $k=K/AL$.

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(3) Solow (1956) and Swan (1956).

(4) $\lim_{K\to 0} \frac{\partial Y}{\partial K} = \lim_{L\to 0} \frac{\partial Y}{\partial L} = +\infty$ and $\lim_{K\to\infty} \frac{\partial Y}{\partial K} = \lim_{L\to\infty} \frac{\partial Y}{\partial L} = 0$.

The accumulation of physical capital can be described by equation (3) (5):

$$\dot{k}_i = s_{ki}\, y_i - (n + m + \delta) k_i \qquad (3)$$

where s_k is the fraction of real output invested in physical capital and δ its depreciation rate, assumed common across countries. We can interpret equation (3) as follows: the stock of physical capital (per unit of effective labour) of the economy grows if investment ($s_{ki}\, y_i$) is more than enough to compensate for the effective depreciation of the stock of physical capital [$(n + m + \delta)k_i$]. In the steady state growth equilibrium the stock of physical capital in units of effective labour does not grow so $\dot{k}_i = 0$.

Using an asterisk to denote steady-state values we can thus write:

$$k_i^* = \left(\frac{s_{ki}}{n + m + \delta}\right)^{1/1-\alpha} \qquad (4)$$

Substituting equation (4) into equation (1) we arrive at the steady state growth equilibrium value for real output per unit of effective labour which depends on s_k, n, m, δ and α (the structural parameters of the economy):

$$y_i^* = \left(\frac{s_{ki}}{n + m + \delta}\right)^{\alpha/1-\alpha} \qquad (5)$$

The equilibrium solution is stable and unique which means that the economies will converge to it whatever their point of departure. It also means that the growth rate of real per capita output depends negatively on its initial level.

If we recall equation (3) and take logarithms:

$$\frac{d \log k_i}{dt} = s_{ki} e^{-(1-\alpha) \log ki} - (m + n + \delta) \qquad (6)$$

In the steady state equilibrium situation equation (6) becomes:

$$\frac{d \log k_i}{dt} = 0 \Leftrightarrow s_{ki} e^{-(1-\alpha) \log ki^*} = (m + n + \delta) \qquad (7)$$

If we apply an order one development of the Taylor series to equation (7), in the neighbourhood of the steady state equilibrium situation, we have:

$$\frac{d \log k_i}{dt} \approx \left.\frac{d \log k_i}{dt}\right|_{\log k_i^*} + \frac{d}{dt}\left.\left(\frac{d \log k_i}{dt}\right)\right|_{\log k_i^*} (\log k_i - \log k_i^*) \qquad (8)$$

(5) $\dot{X} = dx/dt$ denotes the instantaneous growth rate of x.

The first term on the right hand side of equation (8) equals zero so, after rearranging, we arrive at equation (9):

$$\frac{d \log k_i}{dt} = -\beta \log \frac{k_i}{k_i^*} \qquad \textbf{(9)}$$

where $\beta=(1-\alpha)(n+m+\delta)$ is the velocity at which k converges to its steady state equilibrium level, also known as the speed of convergence towards the steady state growth equilibrium.

Turning now to real output, and considering how it relates to k through equation (1), we can write:

$$\frac{d \log y_i}{dt} = -\beta \log \frac{y_i}{y_i^*} \qquad \textbf{(10)}$$

that is, β is also the speed of convergence of y towards its steady state equilibrium value. What equation (10) tells us is that the growth rate of real output per unit of effective labour depends negatively on the distance of real output from its steady state equilibrium value. The further away a country is from its equilibrium situation the higher its real output growth rate is.

Note that equation (10) is a differential equation in *logy*. By solving it we arrive at:

$$\log y_i(t) = e^{-\beta t} \log y_i(0) + (1- e^{-\beta t}) \log y_i^* \qquad \textbf{(11)}$$

Since real output per unit of effective labour cannot be measured we have to write equation (11) in per capita terms considering that:

$$\log y_i(t) = \log \frac{Y_i}{L_i}(t) - \log A(0) - mt \qquad \textbf{(12)}$$

Substituting (12) into (11) we arrive at the behaviour of the real per capita output growth rate:

$$\frac{1}{T}[\log y_i(T) - \log y_i(0)] = m + \frac{(1-e^{-\beta T})}{T}[\log y^{\wedge *} + \log A(0)] - \frac{(1-e^{-\beta T})}{T} \log y_i(0) \qquad \textbf{(13)}$$

Analysing equation (13), we can say that if we are thinking about convergence between a group of countries that have identical structural parameters (which implies $y_i^* = y^*, \forall_i$), then all the economies will converge to the same level of real per capita output. Poorer economies will grow faster than richer ones and we have what is called «absolute or unconditional convergence». If, however, the economies have different structural parameters ($y_i^* \neq y^*$), each one will converge to a different level of real per capita output but all will grow at the same rate, m, from this point onwards. Controlling for structural differences between economies, we say that they exhibit conditional convergence whenever poorer economies still tend to grow faster than richer ones.

This is the basis of the conventional analysis of convergence also known as β convergence [6] (absolute or conditional). As far as the well being of the European citizens is concerned, absolute β convergence implies an equalisation of real per capita incomes while conditional β convergence implies only an approximation. Important differences in the levels of per capita income might remain.

Qualitative predictions of the Solow-Swan model (absolute or conditional convergence) are usually supported by the data. The same does not happen to its quantitative predictions (β convergence): namely, the capital share implied by the estimated β is in general too high. This led to the construction of other exogenous growth models that tried to reconcile the quantitative convergence predictions with empirical evidence. The Solow-Swan model was then expanded to include another capital input, human capital, and to consider the open economy situation.

Mankiw, Romer and Weil (1992) suggested that the Solow model should include human capital, H, as an input to production so that its quantitative predictions should be in accordance with the data. The aggregate production function becomes something like equation (14):

$$Y_i(t) = [K_i(t)]^{\alpha}[H_i(t)]^{\eta}[A_i(t)L_i(t)]^{(1-\alpha-\eta)},\quad 0<\alpha,\eta<1,\ 1-\alpha-\eta<1 \tag{14}$$

with the same properties as before.

Once more the economy converges to steady state growth equilibrium where real output per capita grows at the technological progress growth rate. Now, real output per unit of effective labour depends also on the fraction of real output invested in human capital (s_h):

$$\hat{y}_i^* = \left[\frac{s_{ki}^{\alpha}\, s_{hi}^{\eta}}{(n+m+\delta)^{\alpha+\eta}}\right]^{\frac{1}{1-\alpha-\eta}} \tag{15}$$

All the other exogenous growth models that followed the Solow-Swan model support the existence of β convergence, absolute or conditional, that is, its qualitative convergence predictions and at the same time allow for better quantitative predictions (see table 1). Empirical studies with different groups of countries usually lead to a speed of convergence around 2 % a year between the countries considered. So, the Augmented Solow model of an open economy with constraints to capital circulation is the one that best fits the data.

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(6) Barro (1991), Barro and Sala-i-Martin (1992, 1995), Lopes (1996), Sala-i-Martin (1996), Simões (1999), Temple (1999).

TABLE 1

Speed of convergence in exogenous growth models
(n=0,01, m=0,02, δ=0,05, θ=2 (*s* variable), ρ=0,02, α=0,3 e η=0,5) (7)

Model \ Savings	*s* constant	s variable (8)
Physical capital (9)	$\beta = (1\text{-}\alpha)\ (m+n+\delta) = 0{,}056$	$\beta = \frac{1}{2}\left\{\xi^2 + 4\left(\frac{1-\alpha}{\theta}\right)(\delta+\rho+\theta m)\left[\frac{\delta+\rho+\theta m}{\alpha} - (\delta+m+n)\right]\right\}^{1/2} - \xi = 0{,}09$
Physical and human capital (10)	$\beta = (1\text{-}\alpha\text{-}\eta)\ (m+n+\delta) = 0{,}016$	$\beta = \frac{1}{2}\left\{\xi^2 + 4\left(\frac{1-\alpha-\eta}{\theta}\right)(\delta+\rho+\theta m)\left[\frac{\delta+\rho+\theta m}{\alpha+\eta} - (\delta+m+n)\right]\right\}^{1/2} - \xi = 0{,}014$
Open economy with constraints (11)	$\beta = (1\text{-}\varepsilon)\ (m+n+\delta) = 0{,}023$	$\beta = \frac{1}{2}\left\{\xi^2 + 4\left(\frac{1-\alpha}{\theta}\right)(\delta+\rho+\theta m)\left[\frac{\delta+\rho+\theta m}{\alpha} - (\delta+m+n)\right]\right\}^{1/2} - \xi = 0{,}022$
Open economy without constraints (12)	$\beta = \infty$	$\beta = \infty$

(7) θ represents the intertemporal elasticity of substitution and ρ the intertemporal discount rate.

(8) All the exogenous growth models we mentioned can be modified in order to consider an endogenous propensity to save, which is the result of the optimisation behaviour of families. This hypothesis does not change the qualitative predictions of convergence.

(9) Barro and Sala-i-Martin (1992, 1995), Sala-i-Martin (1996).

(10) Mankiw, Romer and Weil (1992).

(11) Barro, Mankiw and Sala-i-Martin (1995), Barro and Sala-i-Martin (1995).

(12) Barro, Mankiw and Sala-i-Martin (1995), Barro and Sala-i-Martin (1995).

3 — Convergence between economies: empirical analysis

We can now move on to the empirical analysis of real convergence in the EU based on the convergence equation that can be derived from the models above. This equation is then estimated using econometric procedures that will allow us to validate or invalidate the convergence hypothesis for the EU.

3.1 — Absolute or unconditional convergence

Let us begin with the analysis of absolute or unconditional convergence. This means that we are considering that the whole fifteen countries have the same structural parameters, s_k, n and δ.

The convergence equation derived from any of the above mentioned models shows: (*a*) a negative relation between the average growth rate of real per capita output and its initial level and, (*b*) a positive relation to the steady state growth equilibrium value of real output per unit of effective labour. For our fifteen countries from 1960 to 1990 we can then apply the Ordinary Least Squares (OLS) estimation procedure to equation (16) (13), bearing in mind that all countries have the same structural parameters (14):

$$\frac{1}{T}\left[\log\frac{Y_i}{L_i}(T)-\log\frac{Y_i}{L_i}(0)\right]=a-b\,\log\frac{Y_i}{L_i}(0)+ui \qquad \textbf{(16)}$$

$$a=m+\frac{(1-e^{-\beta T})}{T}\,[\log\hat{y}^{*}+\log A(0)] \qquad b=\frac{(1-e^{-\beta T})}{T}$$

i = AUT, BEL, DNK, FIN, FRA, DEU, GRC, IRL, ITA, LUX, NLD, PRT, ESP, SWE, UK (15) time 0 = 1960; time T = 1990.

The coefficients a and b are constant across economies since we are considering identical structural parameters and we also suppose that the initial level of technology, $A(0)$, is the same across countries. We include an error term, $u_i \sim N(0,\sigma^2_u)$ and i.i.d., that reflects, for instance, unexpected changes in production conditions or preferences, making this a stochastic relation.

If the estimated coefficient on initial income is negative we can dismiss the null hypothesis of no convergence between the economies and say that there

(13) Derived from equation (13).

(14) Data taken from the PWT Mark 5.6, unless we say otherwise. Y/L is Real GDP per capita in 1985 international dollars.

(15) Country codes of the World Bank. DEU is the former Federal Republic of Germany.

was, in average, absolute convergence in the EU from 1960 to 1990. Our estimations led to the results shown in table 2 ([16]).

TABLE 2

Absolute or unconditional convergence

	OLS
Constant	0.155 (14.504)
log $(Y/L)_0$	– 0.0147 (– 11.681)
β	0.01939
Half life ([17])	35.7
R^2 aj	0.906

Note: t-student statistic values between brackets.

Looking at the results, it is possible to say that there was absolute convergence in the EU since we have a negative estimated coefficient on initial income and significant at the 5% confidence level. Each country converges to its steady state value at an average annual rate of 1.94 % that leads to a half-life of 35.7 years. Quite a long time therefore until we have an equal degree of welfare all over the EU!

But, since we can be in the presence of conditional convergence we must also test this hypothesis in order to establish a comparison.

3.2 — Conditional convergence

Consider now that the fifteen member states do not have the same structural parameters. There can still be convergence in the EU but this time conditional convergence, that is, there will be an approximation but not an equalisation of real per capita incomes. Testing the conditional convergence hypothesis forces us to distinguish between models without and with human capital.

([16]) We also estimated the convergence equation using the Non Linear Least Squares (NLLS) method in order to estimate directly the speed of convergence and the half life length. We do not present these results due to their similarity to the results using OLS.

([17]) Half-life=(log2)/β. Number of years an economy will take in average to eliminate half its distance from the departure situation to the equilibrium situation.

3.2.1 — ***Conditional convergence without human capital***

If the economies have different structural parameters then its steady state output per unit of effective labour will also differ. The convergence equation must now consider the influence on the average growth rate of these steady state differences, since an economy's growth rate is positively related to its steady state output. One of the consequences of this is that a can no longer be assumed constant across economies. As we cannot determine the steady state equilibrium value of real output per unit of effective labour we must include in our equation the determinants of the equilibrium value that we identified in section 2, equation (5). They are the propensity to save, the population growth rate, the technological progress growth rate and the rate of depreciation. The equation to estimate is then,

$$\frac{1}{T}\left[\log\frac{Y_i}{L_i}(T)-\log\frac{Y_i}{L_i}(0)\right]=a_0+a_1\ \log s_{ki}+a_2\ \log(m+n_i+\delta)-b\log\frac{Y_i}{L_i}(0)+u_i$$

$$a_0=m+\frac{(1-e^{-\beta T})}{T}\log A(0)\quad a_1=\frac{(1-e^{-\beta T})}{T}\frac{\alpha}{1-\alpha}\quad a_2=-\frac{(1-e^{-\beta T})}{T}\frac{\alpha}{1-\alpha}$$

Now, the constant term, a_0, represents the influence of the technological progress growth rate and of the initial level of technology on the average growth rate, common to all countries. If the estimated coefficient on initial income is negative we can reject the no conditional convergence hypothesis between economies. As proxies for the control variables we are going to use, for n the average population growth rate between 1960 and 1990, and for s_K the average investment in physical capital-output ratio, both taken from PWT Mark 5.6. We also consider $m+n\approx0,05$, as did Mankiw, Romer and Weil (1992).

We should keep in mind that the fitness of our model to the data depends also on the validity of the quantitative predictions implied by the speed of convergence and the coefficients of the determinants of the steady state output. The Solow model concludes that the coefficients on the propensity to save ($\log s_K$) and on the effective depreciation rate [$\log(m+n+\delta)$] are symmetrical and that $\beta=(1-\alpha)(m+n+\delta)$, which allows us to estimate the capital share, α. The results are shown in table 3.

TABLE 3

Conditional convergence without human capital

	OLS	NLLS	OLS: $a_1 = -a_2$
Constant	0,0025 (0,033)	0,095 (5,011)	0,095 (5,011)
$\log s_k$	0,011 (3,656)		0,01 (3,479)
$\log(m+n+\delta)$	– 0,042 (1,658)		
$\log(Y/L)_0$	– 0,0154 (– 16,646)		– 0,015 (– 16,255)
β	0,021	0,02 (11,797)	0,0199
α		0,406 (5,919)	0,4
Half life R^2aj	33 0,952	34,7 0,949	34,8 0,949
Wald's F test			1,575

If we compare these results with the ones in table 2 we see that we still get a negative coefficient on initial income and statistically more significant than previously. The adjusted R^2 is now higher. The coefficients on the other variables have the expected sign although the coefficient on the effective depreciation rate is only significant at the 10% confidence level. The speed of convergence is now of exactly 2 % a year meaning a half-life of 34.7 years, which is still a lot. The constraint imposed on the coefficients by the Solow model is accepted and the estimated value for the capital share is 40 %. This last value is however a little higher than the usual 30 % given by the National Accounts.

It seems then that convergence in EU is of the conditional type, not absolute. What does this imply for the European citizens? There will never be an equalisation of per capita output levels and the approximation is occurring at a very slow pace, which is not good news.

We will conclude our empirical analysis of the conditional convergence hypothesis by testing the equation with human capital in order top establish if the estimated capital share fits better the National Accounts predictions.

3.2.2 — ***Conditional convergence with human capital***

To test for convergence with human capital the convergence equation must consider also as a determinant of the steady state output the fraction of real output invested in human capital, s_H in equation(15), so OLS is applied to:

$$\frac{1}{T}\left[\log \frac{Y_i}{Li}(T) - \log \frac{Y_i}{Li}(0)\right] = a_0 + a_1 \log s_{Ki} + a_2 + \log s_{Hi} + a_3 \log(m + n_i + \delta) -$$

$$- b \log \frac{Y_i}{L_i}(0) + u_i$$

$$a_1 = \frac{(1-e^{-\beta T})}{T}\frac{\alpha}{1-\alpha-\eta} \quad a_2 = \frac{(1-e^{-\beta T})}{T}\frac{\eta}{1-\alpha-\eta} \quad a_3 = \frac{(1-e^{-\beta T})}{T}\frac{\alpha+\eta}{1-\alpha-\eta}$$

If we consider the influence of the human capital equilibrium value on the equilibrium output given by:

$$y_i^* = \left(\frac{s_K}{m+n+\delta}\right)^{\frac{\alpha}{1-\alpha}} (h_i^*)^{\frac{\eta}{1-\alpha}}$$

we can estimate a slightly different equation:

$$\frac{1}{T}\left[\log \frac{Y_i}{Li}(T) - \log \frac{Y_i}{Li}(0)\right] = a_0 + a_4 \log s_{Ki} + a_5 \log h_i^* + a_6 \log(m_i + n_i + \delta_i)$$

$$- b \log \frac{Y_i}{L_i}(0) + u_i$$

$$a_4 = \frac{(1-e^{-\beta T})}{T}\frac{\alpha}{1-\alpha} \quad a_5 = \frac{(1-e^{-\beta T})}{T}\frac{\eta}{1-\alpha} \quad a_6 = \frac{(1-e^{-\beta T})}{T}\frac{\alpha}{1-\alpha}$$

As proxies for the propensity to save out of human capital and the human capital equilibrium value we are going to use mostly data on education but also on health. Since it is quite difficult to find a suitable measure for any of the variables under analysis we consider several definitions (table 4). The estimation results of both equations are presented in tables 5 and 6.

TABLE 4

Human capital proxies

Authors	S_H	h^*
A — Mankiw, Romer and Weil (1992).	Number of students enrolled in secondary education with ages between 12 and 17 years old divided by the work force wih ages between 15 and 19 years old.	
B — Levine and Reneit (1992)	Number of students enrolled in secondary education divided by total population over 25 years old.	
C — A. de la Fuente (1998)	Number of students enrolled in secondary and higher education divided by the work force.	
D — Islam (1995)		Average schooling years of total population.
E — Sachs and Warner (1997)		Average life expectancy.

TABLE 5

Conditional convergence with human capital (S_H)

	Without constraint						With constraint: $a1 + a2 = a3$		
	OLS-A	NLLS-A	OLS-B	NLLS-B	OLS-C	NLLS-C	OLS-A	OLS-B	OLS-C
Constant	0,013 (0,165)	0,098 (5,122)	-0,052 (-0,691)	0,088 (4,719)	0,018 (0,023)	0,093 (3,744)	0,103 (4,968)	0,093 (4,873)	0,09 (4,315)
$\log s_k$	0,011 (3,614)		0,01 (3,943)		0,011 (3,495)		0,01 (3,454)	0,01 (3,404)	0,011 (3,406)
$\log s_h$	-0,004 (0,915)		-0,002 (1,834)		-0,002 (-1,14)		-0,002 (-0,95)	-0,001 (-1,039)	-0,0022 (-1,169)
$\log (m+n+\delta)$	-0,039 (-1,53)		-0,056 (-2,327)		-0,039 (-1,467)		-0,009 (-2,453)	-0,009 (-2,645)	-0,009 (-2,384)
$\log (Y/L)_0$	-0,0152 (-16,1)		-0,0142 (-13,203)		-0,014 (-8,249)		-0,0151 (-15,782)	-0,0144 (-12,081)	-0,014 (-8,034)
β	0,02 (11,614)	0,02	0,019 (8,989)	0,0188	0,018 (6,215)	0,017	0,02	0,019	0,018
α		0,41 (5,949)		0,414 (5,896)		0,45 (5,689)	0,44	0,4	0,41
η		-0,001 (-1,033)		-0,0009 (-1,137)		-0,0014 (-1,327)	-0,19	-0,15	-0,07
Half life	34,7	34,7	36,5	36,9	38,5	40,8	34,7	36,5	38,5
R^2 aj	0,951	0,95	0,96	0,95	0,949		0,949	0,95	0,947
Wald's *F* test							1,45	3,911	1,338

TABLE 6

Conditional convergence with human capital (h^*)

	Without constraint				With constraint $a4=-a6$	
	OLS-D	NLLS-D	OLS-E	NLLS-E	OLS-D	OLS-E
Constant	-0,013 (-0,198)	0,077 (4,171)	0,484 (3,044)	0,294 (4,703)	0,077 (4,171)	0,294 (4,703)
$\log s_k$	0,011 (4,452)		0,007 (2,939)		0,011 (4,178)	0,008 (3,444)
$\log h^*$	-0,003 (-2,68)		-0,071 (-3,252)		-0,003 (-2,561)	-0,05 (-3,303)
$\log(m+n+\delta)$	-0,042 (-1,972)		0,029 (1,006)		-0,011 (-4,178)	-0,008 (-3,444)
$\log(Y/L)_0$ ...	-0,013 (-10,977)		-0,0106 (-6,499)		-0,0128 (-10,306)	-0,0122 (-10,427)
β	0,0165	0,0162 (8,009)	0,0128	0,0152 (8,235)	0,0162	0,0152
α		0,46 (7,199)		0,41 (5,994)	0,46	0,4
η		-0,002 (-2,721)		-0,03 (-3,072)	-0,125	-2,5
Half life	42	42,8	54,2	45,6	42,8	45,6
R^2 *aj*	0,967	0,964	0,973	0,971	0,964	0,971
Wald's F test					2,145	1,678

The coefficient on initial income is always negative and significant at the 5 % or 10 % confidence level. Convergence is now even slower. The coefficient on the effective depreciation rate usually has the expected sign but is not significant. Investment in physical capital influences as expected the average growth rate. None of the equations we estimated produced a coefficient on human capital (a_2 in the first equation and a_5 in the second) with the expected sign (positive). These results are worse than the ones we obtained for the model without human capital and do not support the idea that human capital has an influence on the average growth rate of the economies.

These bad results point out the conclusion that convergence in EU is of conditional type but without the influence of human capital. However this conclusion may prove hasty. The weak results could be caused by measurement errors due to the difficulty in gauging human capital. This issue is discussed earlier on by Mankiw, Romer and Weil (1992):

> To implement the model, we restrict our focus to human-capital investment in the form of education – thus ignoring investment in health,

> among other things. Despite this narrowed focus, measurement of human capital presents great practical difficulties. Most important, a large part of investment in education takes the form of forgone labour earnings on the part of students. This problem is difficult to overcome because forgone earnings vary with the level of human-capital investment: a worker with little human-capital forgoes a low wage in order to accumulate more human-capital, whereas a worker with much human capital forgoes a higher wage. In addition, explicit spending on education takes place at all levels of government as well as by the family, which makes spending on education hard to measure. Finally, not all spending on education is intended to yield productive human capital: philosophy, religion, as well as literature, for example, although serving in part to train the mind, might also be a form of consumption. ([18])

The study they made for the OECD did not present good results ([19]) which is in accordance to our weak results for the EU. This problem was dealt with thoroughly in subsequent studies. For instance, Knowles and Owen (1995) think that the weak results are due to the fact that investment in human capital is seen solely as investment in education ignoring health investment. To correct this they consider an aggregate production function where they separate human «education» capital (*E*) from human «health» capital (*X*): $Y=K^{\alpha}E^{\eta}X^{\psi}(AL)^{1-\alpha-\eta-\psi}$. They subsequently estimate the corresponding convergence equation for a sample of 84 countries and conclude that *X* explains short run growth but not *E*. Nonneman and Vanhoudt (1996) also suggest that the Mankiw, Romer and Weil (1992) model is not correctly specified. It should include technological know how as an input that can be accumulated.

Other authors tested the robustness of the model to the definition of human capital used. Dinopoulos and Thompson (1997) used two measures for the human capital equilibrium value: one they called input-based, the primary education enrollment rate, and another they called output-based, the results of students in maths and sciences tests. Neither of the results support the influence of human capital in growth.

Temple (1998) also tested the robustness of the Augmented Solow Model using the data from Mankiw, Romer and Weil (1992). This author defends that the model cannot explain growth in OECD if the data excludes outliers.

([18]) Mankiw, Romer and Weil (1992: pp. 418-9).
([19]) Mankiw, Romer and Weil (1992: pp.421).

This happens because the estimation results are quite sensitive to measurement errors [20].

4 — Concluding remarks

Our empirical conventional analysis of the convergence hypothesis for the EU from 1960 to 1990 led to the acceptance of the existence of a conditional convergence process. This reflects in our opinion the structural differences between member states, in particular the differences between southern and northern countries. Conditional convergence is not very good news for Europe since there will never be an equalisation of real per capita output among member states. The scenario becomes even worse because the estimated speed of convergence (around 2 % a year) implies a long half-life of 35 years. As for convergence without or with human capital no definite conclusion can be taken from our analysis. Although the results do not support the predicted relation between human capital and growth the problem lies in the lack of accuracy in the measurement of human capital.

What lessons can we take from this conventional analysis of the convergence process in the EU [21]? Can national governments or European institutions promote a faster real convergence process as they did with nominal convergence?

In the long run, the neoclassical growth model says that growth depends exclusively on the technological progress growth rate which, being exogenous, cannot be influenced by economic policies. However, in the short run these policies can promote growth and since it will take so long in the EU to get to the long run equilibrium this is in everyone's best interest. There is also room in the EU for policies that promote a higher investment in physical capital. And, although we could not infer that human capital has an influence on growth, in view of our criticisms to the human capital proxies, we are convinced that education and health policies that promote investment in human capital are crucial for growth. We hope that further empirical analysis based upon more accurate human capital measurements will prove it in a near future.

Appendix - The augmented Solow model [22]

Recalling that equation (14) is an aggregate production function with positive but diminishing marginal productivities to inputs, constant returns to sca-

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(20) We reproduced these studies with our sample but our results did not improve so we do not show them here.

(21) This question becomes even more important now that we are facing eastern enlargement.

(22) Mankiw, Romer and Weil (1992).

le and respecting the four Inada conditions we can write it in units of effective labour:

$$y_i(t) = k_i(t)^{\alpha} h_i(t)^{\eta} \qquad \textbf{(17)}$$

where η is the capital share.

The evolution of physical and human capital is given by:

$$\dot{k}_i = s_k k_i^{\alpha} h_i^{\eta} - (n + m + \delta) k_i$$

$$\dot{h}_i = s_h k_i^{\alpha} h_i^{\eta} - (n + m + \delta) h_i$$

In the situation of steady state equilibrium:

$$\dot{k}_i = \dot{h}_i = 0$$

The steady state values of physical and human capital are obtained by solving the former system of equations:

$$k_i^* = \left[\frac{s_{k_i}^{1-\eta} s_{h_i}^{\eta}}{n + m + \delta}\right]^{\frac{1}{1-\alpha-\eta}}$$

$$h_i^* = \left[\frac{s_{k_i}^{1-\alpha} s_{h_i}^{\alpha}}{n + m + \delta}\right]^{\frac{1}{1-\alpha-\eta}}$$

Substituting into equation (17) we arrive at the steady state value of real output per unit of effective labour:

$$y_i^* = \left[\frac{s_{k_i}^{\alpha} s_{h_i}^{\eta}}{(n + m + \delta)^{\alpha + \eta}}\right]^{\frac{1}{1-\alpha-\eta}}$$

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