Galton's Fallacy and Economic Convergence: An Alternative Approach to Regional Convergence in Greece

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Most empirical studies on regional convergence are concentrated on testing the 'conventional' measures of σ and β-convergence. However, these measures are crucially flawed as measures of convergence, especially at the regional level of analysis. As a response to this, Lichtenberg (1994) introduces a measure that overcomes the limitations of the 'conventional' measures of convergence. More specifically, this measure combines the tendencies towards decline inequalities (σ-convergence) with the tendencies of poor regions to grow faster than rich regions do (β-convergence). Having the measure introduced by Lichtenberg (1994) as the main vehicle of analysis this paper offers an alternative view on the issue of regional convergence in Greece. According to empirical results the 51 NUTS-3 regions of Greece follow a pattern characterized by distinct phases of convergence and divergence.

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I. Introduction

During the last twenty years there has been a proliferation of studies on economic convergence (*e.g.* Baumol 1986; Barro and

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Sala-i-Martin 1992).[1] Empirically, the concept of convergence is frequently encapsulated by a negative relation between the growth rate during a given time period and initial level of *per-capita* GDP. A central question to the issue of convergence is, therefore, whether poor economies grow faster than rich economies.

More specifically, the convergence issue can also be tackled with respect to different areas within a country, that is to say, regions, where the term 'region' refers either to areas determined according to similarities in geographical characteristics or areas corresponding to administrative divisions, which may be arbitrary. In the empirical literature of regional convergence, the unit of analysis has been an individual region observed either as part of a cross-section (*e.g.* Coulombe 2000; Lee 1997) or in time series (*e.g.* Alexiadis and Tomkins 2004).

This paper reconsiders the question of regional convergence with respect to the regions of Greece. In the remainder of the paper we first provide an overview of the theoretical underpinnings of the concept of convergence and we discuss three alternative empirical measures. Next we present an explanatory analysis of the Greek regional dynamics over the period 1970-2000. We then assess the results of a confirmatory econometric analysis of the regional income convergence hypothesis using a measure developed by Lichtenberg (1994) that allows for a more thorough understanding of the convergence tendencies across a variety of observational units. The paper closes with a summary and some concluding comments.

II. Alternative Measures of Convergence

The primary purpose of this section is to articulate the theoretical framework upon which the empirical analysis will be conducted. The 'standard' neo-classical model provides a starting point in the debate for growth and convergence. Throughout this paper a greater emphasis is placed upon the particular model, for two reasons. First, this model offers both a theoretical explanation and testable predictions concerning the possibility of convergence in *per capita* incomes. Indeed, most of the conceptual definitions of

[1] For a more detailed review see de la Fuente (1997).

convergence used in empirical studies derive directly from the neo-classical model. Second, most empirical studies have, in fact, tested the neo-classical model rather than alternative models.

According to the neo-classical growth theory, market forces will lead to a general convergence of *per capita* income or output across economies over time. Using a general equilibrium framework the neo-classical theory predicts that disparities across economies are unlikely to occur or, at least, to be persistent. Barro (1997) offers a lucid explanation of the neo-classical property of convergence:

> 'The convergence property derives in the neo-classical model from diminishing returns to capital. Economies that have less capital per worker (relative to their long-run capital per worker) tend to have higher rates of return and higher growth rates.' (p. 2)

In the 'standard' neo-classical model the tendency for convergence across economies derives from the diminishing returns to capital. The higher the rate of return on capital in poor economies – or at least in economies which are further below their own steady-state positions – generated a faster rate of growth.

To make progress we will outline first the main elements of the standard neo-classical model, as outlined by Solow (1956) and independently by Swan (1956) and Abramovitz (1956).[2] For ease of presentation we will, in general, consider that in an economy total output (Y_i) is characterised by the following production function:

$$Y_i = \min A_i F[K_i, L_i] \tag{1}$$

Equation (1) in intensive form can be written as:

$$\hat{y}_i = f(\hat{k}_i) \text{ with } f'(\hat{k}_i) > 0,\ f''(\hat{k}_i) < 0 \tag{1.1}$$

where $K_{i,t}$ and $L_{i,t}$ are the physical capital and the labour employed in production and $\hat{y}_i = Y_i / A_i L_i$ while A_i represents an index of technology and $\hat{k}_i = K_i / A_i L_i$ is the capital stock per effective unit of labour.

There are two exogenous sources of growth in effective labour units namely, technical progress and population growth. Full

[2] Cass (1965) and Koopmans (1965), based on Ramsey (1928), extend the neo-classical model with refinements on optimal growth.

employment prevails and labour supply is always equal to labour demand and labour grows at a constant proportional rate:

$$L_t = L_0\, e^{\eta t} \tag{2}$$

Equation (2) states that labour force is growing from an initial level of L_0 at a constant proportionate rate η. More formally,

$$\frac{\dot{L}_t}{L_t} = \eta \text{ where } \eta \geq 0 \tag{2.1}$$[3]

Technological progress is considered to be exogenously given, *i.e.* is determined outside the economic system and grows at a constant rate g:

$$A_t = A_{t,0}\, e^{gt} \text{ or } \frac{\dot{A}_t}{A_t} = g \text{ where } \dot{A}_t = \frac{dA_t}{dt} \tag{2.2}$$

Assuming perfect capital markets, the mechanism for equating investment with savings in full employment is the interest rate. Aggregate savings S_t are assumed to be a constant proportion of output, that is,

$$S_t = sY_t \tag{3}$$

where $0 \leq s \leq 1$ is the propensity to save.

Available savings S_t will, therefore, finance gross investment, given that savings are automatically invested and there are no capital inflows (or outflows). Gross investment, in turn, is equal to the increase in gross capital stock less depreciation. Hence, the net increase in the stock of physical capital ($\dot{K}_t$) is determined as follows:

$$\dot{K}_t = I_t - \delta K_t \tag{4}$$

where I_t is gross investment and δ is the rate of depreciation with $\delta > 0$.

In a closed economy, investment is equal to saving, *i.e.* $Y_t - C_t$,

[3] A dot over a variable indicates the growth rate of this variable.

where C_t is consumption. Thus,

$$\dot{K}_t + \delta K_t = Y_t - C_t \tag{5}$$

Capital accumulation grows as follows:

$$\dot{\hat{k}}_t = f(\hat{k}_t) - \hat{c}_t - (\eta + g + \delta)\hat{k}_t \text{ where } \hat{c}_t = \frac{C_t}{A_t L_t} \tag{6}$$

The representative household maximises utility (U) as follows:

$$U = u(c) \text{ with } u'(c) > 0,\ u''(c) < 0 \tag{7}$$

Total social utility in each period is weighted by the size of population and the rate of time preference (ρ) in each period. Social utility is maximized by adding social utility over all future periods. Thus,

$$u = \int_0^{\infty} u(c)^{-(\rho - \eta)t} dt \tag{8}$$

The optimal growth path can be derived by maximising Equation (8), subject to Equation (6). The current value of the Hamiltonian function is defined as follows:[4]

$$H = u(c) + m[f(k_t) - c_t - (\eta + g + \delta)k_t] \tag{9}$$

The 'maximum principle' requires that

$$\frac{\partial H}{\partial c} = u'(c) - m = 0 \tag{9.1}$$

$$\frac{\partial H}{\partial m} = f(\hat{k}_t) - \hat{c}_t - (\eta + g + \delta)\hat{k}_t = \dot{\hat{k}}_t \tag{9.2}$$

$$\frac{\partial H}{\partial k_t} = m[f'(k_t) - (\eta + g + \delta)] - (\rho - n)m = -\dot{m} \tag{9.3}$$

[4] This technique is based on Optimal Control Theory (OCT). For a more detailed exposition of OCT see Ferguson and Lim (1998).

Differentiating Equation (9.1) with respect to time yields:

$$u''(c_i)\dot{c}_i = \dot{m} \tag{10}$$

Using Equations (8) and (9.2) to eliminate m and $\dot{m}$ in Equation (9.3) we may write:

$$\dot{c}_i = \frac{u'(c_i)}{u''(c_i)}[f'(k_i) - (\delta + g + \rho)] \tag{11}$$

Utility takes the following functional form:

$$u(c_i) = \frac{c_i^{1-\theta} - 1}{1-\theta} \quad \text{with } u'(c_i) = c_i^{-\theta},\ u''(c_i) = -\theta c_i \tag{12}$$

Given Equations (6) and (11) we may write:

$$\dot{c}_i = \frac{c_i}{\theta}[f'(k_i) - (\delta + g + \rho)] \tag{13}$$

Equations (6) and (11) determine the steady-state growth paths for k_i and c_i. In steady-state equilibrium y_i, k_i, and c_i grow at a constant rate g. Log-linearization of Equations (6) and (11) around steady-state equilibrium $(\bar{c}_i, \bar{k}_i)$, yields:

$$\begin{bmatrix} \dot{k}_i \\ \dot{c}_i \end{bmatrix} = \mathbb{A}\begin{bmatrix} k_i & -\bar{k}_i \\ c_i & -\bar{c}_i \end{bmatrix}, \text{ where } \mathbb{A} = \begin{bmatrix} \Psi & -1 \\ (c_i/\theta)f'(k_i) & 0 \end{bmatrix}$$
$$\text{and } \Psi = \rho - \eta - (1-\theta)g > 0 \tag{14}$$

Matrix $\mathbb{A}$ has a positive trace and a negative determinant, *i.e.* $Tr(\mathbb{A}) = \Psi > 0$ and $Det(\mathbb{A}) = (c_i/\theta)f'(k_i) < 0$ while the stable root, let β, is $\beta = -Tr(\mathbb{A}) + [Tr(\mathbb{A})^2 - 4Det(\mathbb{A})]^{1/2}$.
In steady-state equilibrium:

$$f'(k_i) = \delta + \rho + (1-\theta)g \tag{14.2}$$

Assuming a standard Cobb-Douglas production function, *i.e.* $f(\hat{k}_i) = A\hat{k}_i^{\alpha}$, β is calculated as follows:

$$\beta=\frac{1}{2}\left\{\Psi^2+4\left(\frac{1-\alpha}{\theta}\right)(\rho+\delta+\theta g)\left[\frac{\rho+\delta+\theta g}{\alpha}-(\eta+\delta+g)\right]\right\}^{1/2}-\frac{\Psi}{2} \qquad (15)$$

Moving away from these abstract considerations, so as to get closer to the complications of the real situation, account has to be taken about the empirical measurement of convergence. Next section outlines two frequently used empirical measures of convergence.

III. Empirical Measures of Convergence

It might be argued that of particular concern in the '*convergence debate*' is the efficiency of economic growth in improving the distribution of income. Sated in alternative terms, economic convergence assesses the tendencies in increasing or decreasing of *inequality* among economies, where 'inequality' is defined in terms of differences in the distribution of income (or levels of labour productivity, *i.e. per capita* output) among the agents in an economy (countries or regions). The recent explosion of interest in regional growth and convergence, however, has not followed a uniform path. Instead, several distinct types of convergence have been suggested in the literature, each being analysed by distinct groups of scholars employing different methods. Nevertheless, two measures of convergence, frequently used in empirical studies, are σ and β-convergence.

σ-Convergence

Following Barro and Sala-i-Martin (1992), σ-convergence occurs if the dispersion of *per capita* income (or any other variable) across economies display a tendency to *decline* through time. This notion of convergence is, typically, measured by calculating two statistical indices, namely the *coefficient of variation* and the *standard deviation*.[5]

The coefficient of variation (c) of a variable (y) across a group of $i=1,\cdots,n$ observational units at any time t is calculated as follows (Dalgaard and Vastrup 2001):

[5] These two measures have been used interchangeably, since they are, to a certain extent, equivalent.

$$c=\sqrt{\frac{1}{n}\sum_{i=1}^{n}\left(\frac{y_i-\bar{y}}{\bar{y}}\right)^2} \quad \text{where} \quad \bar{y}\equiv\frac{1}{n}\sum_{i=1}^{n}y_i \tag{16}$$

Dispersion may be measured by using a slightly different approach; that of standard deviation, computed as follows

$$\sigma=\sqrt{\frac{1}{n}\sum_{i=1}^{n}\left[\log\left(\frac{y_i}{y^*}\right)\right]^2} \quad \text{where} \quad \log y^*\equiv\frac{1}{n}\sum_{i=1}^{n}\log y_i \tag{17}$$

σ-convergence requires that (Sala-i-Martin 1996, p. 1020):

$$\sigma_{yt+T}<\sigma_{yt} \tag{17.1}$$

β-Convergence

β-convergence is encapsulated in a negative relationship between growth rate and initial level of *per-capita* income. In empirical terms β-convergence is expressed as follows:

$$y_{i,T}-y_{i,0}=a+by_{i,0}+u_{i,T} \tag{18}$$

where $y_{i,T}$ and $y_{i,0}$ are the natural logarithms of output per worker during the terminal and initial time, respectively. a and $u_{i,T}$ stand for the constant and the error term of the regression, respectively, while i indexes the economies included in the regression.

If economies with higher initial levels of *per capita* output grow slowly, then this implies a negative value of b and *vice versa*. A value of b equal to -1 corresponds to perfect convergence: Higher initial income on average lowers subsequent growth one-for-one, and so output per person in the terminal year is uncorrelated with its value in the initial year (Romer 1996). If $b=0$, then growth is uncorrelated with initial income and economies included in the data set exhibit divergence, indicating that the gap between rich and poor economies has increase over the examined period.

Barro and Sala-i-Martin (1992) argue that b can be expressed as follows:

$$b=-(1-e^{-\beta}) \tag{19}$$

where β indicates the speed at which economies approach their steady-state value of output per worker.[6] Equation (19) implies that b is bounded to the sign of β. Since $b<0$ implies convergence then β should be positive. In other words, if $\beta>0$ then this indicates convergence and *vice versa*.

σ and β-Convergence: Two Identical Concepts?

σ-convergence assesses if the distribution of income across economies tends towards equalisation, or not, during a given time period while β-convergence captures movements of economies towards a new distribution of income. In this respect, it might be argued that β-convergence appears to be a more dynamic concept, compare to that of σ-convergence.

However, as Barro and Sala-i-Martin (1995) argue, even if absolute β-convergence holds, the dispersion of *per capita* income does not necessarily tend to decline over time. It follows, then, that β-convergence can occur simultaneously with absence of σ-convergence. In this respect σ-convergence is a stricter criterion than β-convergence. This can be demonstrated as follows.

Equation (18) can be written as follows:

$$y_{i,t}=a+(1+b)y_{i,t-1}+u_{i,t} \tag{20}$$

It is assumed that $u_{i,t}$ is a random variable with zero mean, with constant variance over time[7] and the covariance between $u_{i,t}$ and $y_{i,t-1}$ is zero, implying absence of any autocorrelation and heteroscedasticity. More formally, the variance of the disturbance term (σ^2_{ut}) is given as follows:

$$\sigma^2_{y,t}=(1+b)^2\,\sigma^2_{y,t-1}+\sigma^2_{u,t} \tag{20.1}$$

σ-convergence requires that the sample variance of *per capita* output decreases through time, which means that the standard

[6] Barro and Sala-i-Martin (1992) argue that Equation (19) implies that $\kappa_{\hat{y}}\cong -\beta[\log(\hat{y}_t/\hat{y}^*)]$ where $\kappa_{\hat{y}}$ is the growth rate and $\hat{y}^*$ is the steady-state level of *per capita* income. This is a differential equation with solution: $\log(\hat{y}_{i,t})=(1-e^{-\beta t})\log(\hat{y}^*)+e^{-\beta t}\log(\hat{y}_{i,0})$. The time for which y_t is halfway between the value during the initial year and the steady state, satisfies the condition: $e^{-\beta t}=1/2$.

[7] This condition implies that $\sigma^2_u=\sigma^2_{u,t},\ \forall t$.

deviation (σ_y) declines as well. It follows, therefore, that σ-convergence also implies that $b<0$, *i.e.* β-convergence. In this light, a necessary but not sufficient condition for σ-convergence is β-convergence.[8] Sala-i-Martin (1996) has succinctly put the argument as follows:

> 'Moreover, it is natural to think that when an initially poor economy grows faster than a rich one, then the levels of GDP *per capita* of the two economies will become more similar over time. In other words, *the existence of β-convergence will tend to generate σ-convergence.*' (p. 1021) [Emphasis in the original]

Nevertheless, at this point it is worth mentioning that, $-1<b$ excludes the possibility of the *leapfrogging* or *overshooting* effect. This term is used to describe a situation by which poor economies not only catch up rich ones, but also *exceed* or surpass the growth rate of rich economies. Such a situation is excluded a priori in the neo-classical model, from which the concept of β-convergence is determined.[9] More formally, excluding the leapfrogging effect in terms of the Equation (20) requires that, for any pair of regions i and j for which $y_{i,0}\geq y_{j,0}$, the mathematical expectations must satisfy the following condition:

$$E(y_{i,t})\geq E(y_{j,t})\,\forall\, t>0 \tag{20.2}$$

Barro and Sala-i-Martin (1995) argue that while the existence of β-convergence is a necessary condition for the existence of σ-convergence, nevertheless β-convergence is not a sufficient condition for the presence of σ-convergence. Their argument runs as follows. It is possible to rewrite Equation (20.2) as follows:

$$\sigma^2_{y,t}=e^{-2\beta}\sigma^2_{y,t-1}+\sigma^2_{u,t} \qquad (20.3)^{10}$$

Equation (20.3) is a first order differential equation and since the variance of the disturbance is time invariant, solving Equation

[8] Lichtenberg (1994) also argues on similar lines.

[9] While leapfrogging is excluded by definition in the standard neo-classical model, some authors, notably Brezis *et al.* (1993), argue that it is possible for countries where the benefits from backwardness are strong enough.

[10] Recall that since $b=-(1-e^{-\beta})$ then $(1+b)^2=e^{-2\beta}$.

(20.3) yields:

$$\sigma^2_{i,t} = \frac{\sigma^2_u}{1-e^{-2\beta}} + \left(\sigma^2_{i,0} - \frac{\sigma^2_u}{1-e^{-2\beta}} \right) e^{-2\beta t} \tag{20.4}$$

where $\sigma^2_{i,0}$ stands for the variance of the initial level of *per capita* output of region *i*. Equation (20.4) implies that $\sigma^2_{i,t}$ approaches its steady state value $\sigma^2 = \sigma^2_u/(1-e^{-2\beta})$ monotonically, which increases with the variance of the disturbance term but decreases with β. If the initial value of the variance of the initial *per capita* output is less (greater) than the steady state value, then $\sigma^2_{i,t}$ increases (decreases). Hence, a positive convergence coefficient β does not imply a decline in $\sigma^2_{i,t}$. Put it differently, as a consequence β-convergence does not inevitably imply σ-convergence.

'Galton's Fallacy' and Regression towards the Mean

Barro and Sala-i-Martin (1992) argue that even if absolute β-convergence holds, the dispersion of *per-capita* income does not necessarily tend to decline over time and β-convergence can occur simultaneously with absence of σ-convergence. In this respect σ-convergence is a stricter criterion than β-convergence. Nevertheless, Friedman (1992) argues that β-convergence is a weak criterion due to a problem known as *'regression towards the mean'* or 'Galton's Fallacy', after Francis Galton a statistician who examined the heights of fathers and sons, and found that the sons of tall fathers tended to be shorter than their fathers while the fathers of tall sons tended to be shorter than their sons.[11]

Having this observation as a basis for his contribution in the convergence debate, Friedman (1992) argues that non-persistent fluctuations in the initial level of *per capita* income would lead to a negative regression coefficient even if the population variance of *per capita* income were to show no downward trend. β-convergence means that economies that start out with below average *per capita* incomes tend to grow faster than do economies that start with above average *per capita* incomes. In this respect, β-convergence is compatible with constant or even rising standard deviation or coefficients of variation, *i.e.* σ-divergence. Thus, according to Fried-

[11] See also Bliss (1999, 2000), Cannon and Duck (2000).

man (1992), empirical studies on convergence are all biased with Galton's fallacy. Consequently, an unbiased index for convergence would be the shrinking over time of the variance of *per capita* income among the economies under examination.

Lichtenberg (1994) offers a solution to this problem by using the following ratio:

$$S_{i,T}=\sqrt{N}\frac{\hat{\sigma}^2_{i,1}/\hat{\sigma}^2_{i,T}-1}{2\sqrt{1-(1-\hat{\beta}_i)^2}} \tag{21}$$

where N is the number of observations and convergence is accepted if $S_{i,T}$ is statistically different from zero while a value of 1 indicates perfect convergence.

Equation (21) allows a researcher to obtain a more detailed view on convergence since it provides an 'interaction' of the effects from reductions in inequalities and those from differences in the growth rates. Especially, in an explicit spatial context, such 'interaction' is stronger across regional economies. Empirical applications of this statistic, however, have concentrated exclusively at the international level and in particular across the OECD countries (Carree and Klomp 1997; Carree *et al.* 2000). Nevertheless, despite the fact that such an approach has important implications for regional convergence no empirical studies have been conducted. This paper, therefore, contributes to the empirical literature by testing for regional convergence in Greece using this alternative notion of convergence. The empirical results are reported in the next section.

III. Empirical Application

In this paper we test for convergence in *per-capita* incomes across Greece over 1970-2000. The regional groupings used are those delineated by the Greek Statistical Agency and correspond to the 51 NUTS-3 regions of Greece. The National Statistical Agency of Greece, however, does not report any regional estimates of *per-capita* income. In this paper *per-capita* income is approximated by *gross value added per-worker* (hereafter GVA), which is a measure of regional productivity and competitiveness. Data were deflated to 1970 prices using deflators provided by the National

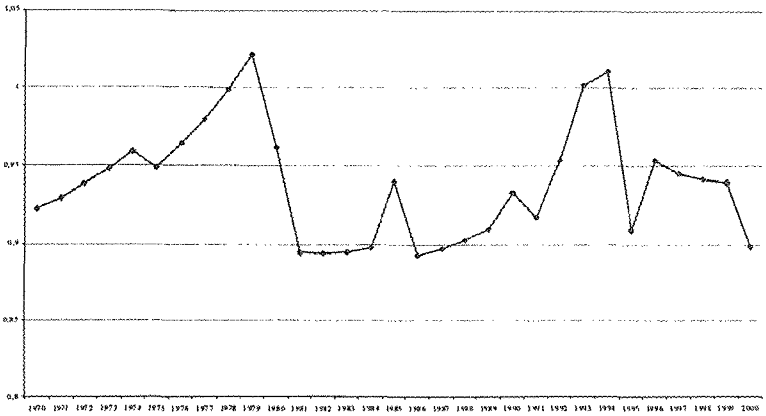

FIGURE 1
STANDARD DEVIATION, 1970-2000

Statistical Agency of Greece.[12]

Figure 1 portrays the path of standard deviation over 1970-2000.

Several impressions may be taken away from Figure 1. Figure 1 clearly shows that, during the entire period, standard deviation generally follows a decreasing tendency. This can be considered as evidence in favour of accepting the hypothesis of σ-convergence in Greece. Tendencies towards decreasing inequalities across the regions of Greece are more evident from the year 1975 and onwards. The period after 1980 is characterised by continuing decreasing tendencies in standard deviation. Overall, nonetheless, the long-run trend appears to have been towards convergence with a few exemptions, most notably over the period 1970-1979 and the slight increase over the period 1990-1995. Convergence was more rapid in 1980-1990 and 1995-2000.

Table 1 shows the estimates of β_i and $S_{i,T}$ for the overall period (1970-2000), for three individual decades and for 5-years sub-

[12] Ideally, the data should be deflated using regional deflators. However, such deflators are not available from any official source and we simply use national deflators.

TABLE 1
β_t AND $S_{t,T}$ ESTIMATES

Time Period	β_t	(t-ratio)	$\sigma_{t,1}$	$\sigma_{t,T}$	$S_{t,T}$	(t-ratio)
1970-2000	0.002924**	3.2149	0.922	0.898	0.4648**	6.7504
1970-1980	0.002723	0.6938	0.922	0.961	-1.1688	-1.4091
1980-1990	0.007768	1.2925	0.961	0.932	0.5579**	2.7057
1990-2000	0.010951**	2.0158	0.932	0.898	0.5790**	4.3076
1970-1975	-0.02263	-1.0366	0.922	0.948	N.A.	
1975-1980	-0.01569	-0.8074	0.948	0.961	N.A.	
1980-1985	0.03165	1.7410	0.961	0.939	0.6781**	3.5389
1985-1990	0.01028	0.7047	0.939	0.932	0.3762	1.4168
1990-1995	0.03454*	1.8951	0.932	0.909	0.7022**	3.8580
1995-2000	0.01396	1.6990	0.909	0.898	0.5284**	3.4221

Note: An * indicates significance at 90% level while ** at 95%, N.A. means 'not available'.

periods.

The results for the period 1970-2000 are in many ways the most interesting, since they summarise the experience over the whole of the period under investigation. Over this period, the 51 NUTS-3 regions of Greece were converging at a rate of 0.29%. Although this is a very slow rate of convergence, nevertheless, is accompanied with a tendency towards reduction in regional inequalities. This conclusion is enhanced further by $S_{t,T}$ statistic, which is considerably greater than zero (0.46) and statistically significant at the usual levels. Significant convergence is identified for individual two decades, *i.e.* 1980-1990 and 1990-2000, most notable in the first 5 years of the 1990s. Statistical significant convergence is also identified for three individual sub-periods (1980-1985, 1990-1995, and 1995-2000).

The results displayed in Table 1 are in accordance with the evolution of the standard deviation. In particular, the 1970s are characterized by divergence tendencies given that the $S_{t,T}$ statistic is negative. This conclusion is supported further from estimations obtained for the periods 1970-1975 and 1975-1980. To be more precise, the results indicate that over the periods 1970-1975 and 1975-1980 the Greek regions were diverging at a rate 2.2% and 1.5%, respectively, accompanied with considerable increases in standard deviation. Hence, it may be argued that over the 1970s, poor regions exhibit slow rates of growth and, as a result, regional inequalities are intensified. This argument is further supported from the fact that the $S_{i,T}$ statistic cannot be calculated for the two sub-periods, under consideration. Convergence tendencies start to appear in the first half of the 1980s. Indeed, as the β_i coefficient indicates, over the period 1980-1985 the regions of Greece were converging at 3% per annum on average. However, this estimation is statistically insignificant and, hence, any conclusions are only indicative. Nevertheless, the $S_{i,T}$ statistic for the period 1980-1985 is considerable higher than zero and statistical significant, indicating strong tendencies towards reduction of regional inequalities. After a period (1985-1990), characterized by a relatively slow rate of convergence (1% per annum, on average), in the period 1990-1995 the regions of Greece are experiencing the highest rate of convergence, namely 3.4% per annum, on average, although this rate is statistically significant only at 90% level of confidence. This catching up between the 'poor' and the 'rich' regions of Greece occurs simultaneously with an impressive reduction in regional inequalities, as this is clearly indicated by the value of the $S_{i,T}$ statistic. For this particular sub-period, the estimated value of the $S_{i,T}$ statistic is highly statistically significant at the usual levels of confidence and quite close to one (0.7), suggesting that levels of regional productivity, expressed in terms of GVA per worker, tend to be similar across the regions of Greece. Catching up also occurs for the subsequent sub-period (1995-2000) but to a lesser extent, as reflected in a relatively slow average rate of convergence, 1.3% per annum. Notwithstanding, this rate is not statistically significant while the estimated value of the $S_{i,T}$ statistic does not suggest any impressive tendencies towards reducing regional inequalities. To be more precise, its estimated value for this sub-period (0.5) indicates that regional inequalities tend towards a relatively stable position. From this perspective, it may be argued that Greek regions reaching a steady-state equilibrium with relatively stable levels of regional productivity.

From the analysis is this section, it follows that using the $S_{i,T}$ statistic, as an 'apparatus' for an empirical investigation of regional convergence, it is possible to obtain a more detailed view on this issue, by combining two different, although interrelated, aspects of convergence. To be more precise, while the 'conventional' measure of β-convergence measures the extend of catching-up between 'poor' and 'rich' regions remains silent on the question of reducing regional inequalities, which is measured by σ-convergence. Using the $S_{i,T}$ statistic, however, it is possible to assess the degree at which catching-up (β-convergence) contributes to a reduction of regional inequalities. In this way, therefore, an approximation of the process by which regions converge towards a steady-state equilibrium is feasible. As the empirical results indicate, in the case of the Greek regions, convergence towards a steady-sate equilibrium, approximated in terms of equalized levels of regional productivity, is in progress from 1990 and onwards. Of course, the levels of productivity across regions, are not equalized, nevertheless regional inequalities reach a stable position, which suggest that future improvements are possible.

IV. Concluding Comments

This paper reconsiders the question of regional convergence in Greece, using an alternative measure of convergence, which overcomes several defaults of 'conventional' measures of convergence by combining two distinct measures, σ-convergence (reduction of regional inequalities) and β-convergence (catching-up among 'poor' and 'rich' regions) in terms of a single ratio, namely the $S_{i,T}$ statistic. Existing empirical studies on Greek regions (*e.g.* Siriopoulos and Asteriou 1998; Paschaloudis and Alexiadis 2001; Tsionas 2002) use 'conventional' measures of convergence while the $S_{i,T}$ statistic has not received the attention it deserves. The results reported in this paper provide the first evidence of regional convergence using this alternative measure of convergence and suggest different phases of convergence and divergence across the regions of Greece.

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