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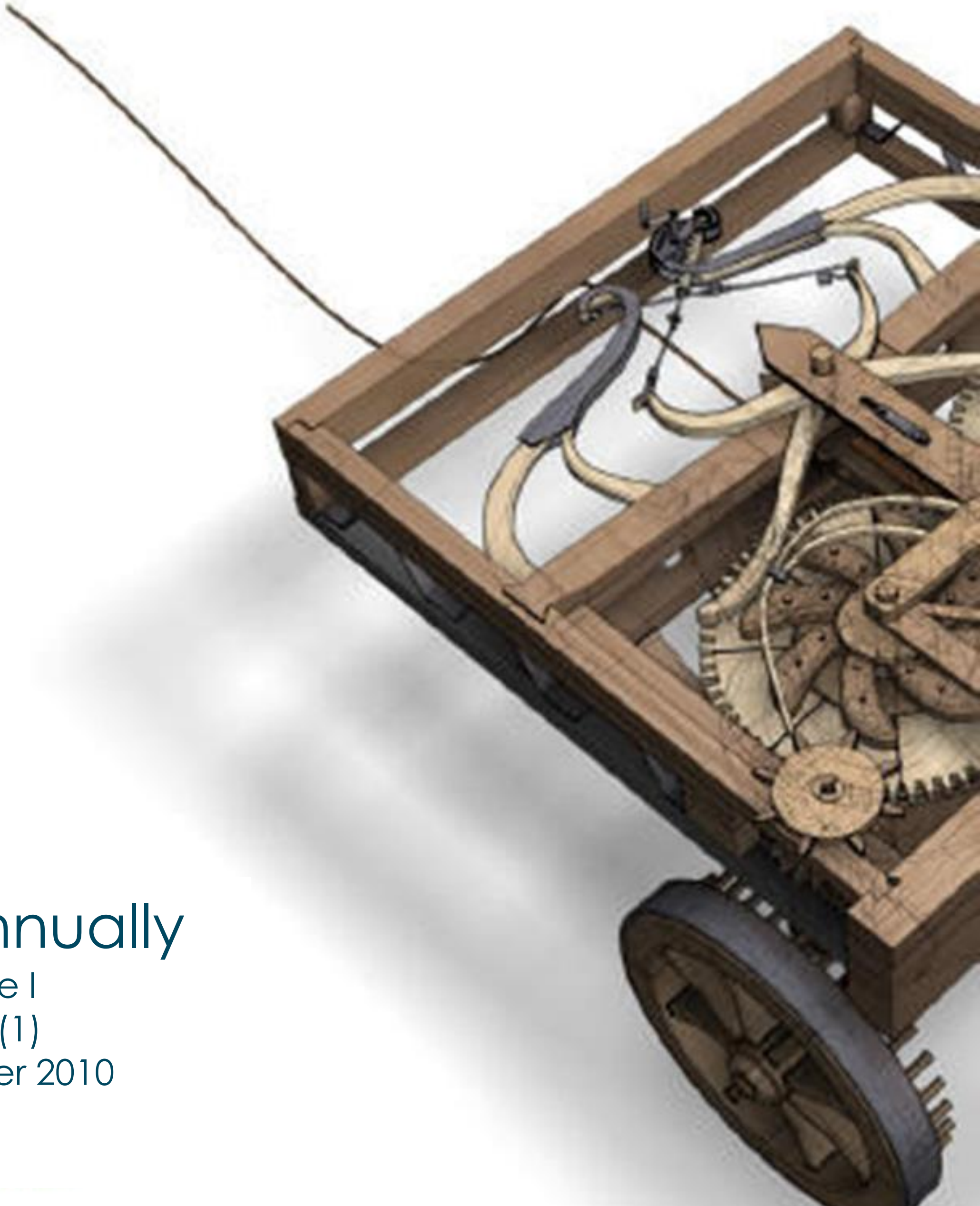

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THE NEXUS BETWEEN REGIONAL GROWTH AND TECHNOLOGY ADOPTION: A CASE FOR CLUB-CONVERGENCE?

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Abstract

Although the importance of technology adoption has been acknowledged, nevertheless, at a more general level, a critical question arises: what is the implication of a 'low' or a 'high' adoptive ability for regional convergence? A model is developed in which the pattern of convergence is attributed to the rate of technological adoption across regions. According this model convergence towards leading regions is feasible only for regions with a sufficient ability to adopt technology. A scheme of measurement is developed to calibrate this argument and data for the EU27 NUTS-2 regions for period 1995-2006 are used to develop an empirical analysis of the processes and conditions that have been hypothesised as generating differential regional economic change. The results suggest that adoption of technology has a significant effect on regional growth patterns in Europe, and hence the analysis has important implications for the direction of regional policy in Europe.

Key words: convergence-club, technology adoption, European regions

JEL classifications: O18, R11

1. Introduction

The debate on regional convergence has bred, and continues to do so, dozens of empirical studies (e.g. Button, and Pentecost 1995; Neven, and Gouyette 1995; Martin 2001). In this fast growing literature technological progress has been acknowledged to be of critical importance in promoting regional convergence. Nevertheless, the impact of the adoption of technology has received less attention. Indeed, Bernard and Jones (1996) claim that empirical studies on convergence have over-emphasised the role of capital accumulation in generating convergence at the expense of the diffusion of technology. It is the intention of this paper to develop and apply a model that incorporates technology adoption in an extensive regional context, namely that of the NUTS-2 regions of the EU. Divided into five sections, the theoretical framework upon which the empirical analysis will be conducted is articulated in Section 2. Data related issues are overviewed in Section 3, and the models are submitted to the usual econometric test yielding the main findings in Section 4. In the concluding section we offer a possible explanation for the results we obtain and suggest that might afford an interesting policy conclusion.

2. Regional Convergence and Technology Adoption

In the neoclassical model, a factor that promotes, and accelerates, regional convergence is the process of technology diffusion; a process that occurs instantly across regions. However, several criticisms have been raised against the conclusions, which this model yields, because of various simplifying assumptions underlying the results. To be more concrete, when the neoclassical model is applied to a system of regional economies, (exogenous) technology is assumed to be a public good characterised by two features, namely non-rivalry in consumption and non-excludability. Under the assumption of perfect competition it may be argued that technology has such characteristics and is, as Borts and Stein (1964) argue 'available to all' (p.8). A process of technology adoption, however, is not a simple and automatic process. Instead, it requires[1] that lagging economies should have the appropriate infrastructure or conditions to absorb technological innovations. If infrastructure conditions are not 'sufficiently developed' then it cannot be presumed that there is an 'advantage of backwardness' associated with a high technological gap[2].

Based on this argument a model, alternative to the neoclassical, is developed in this paper. The model considers a system of a large number n of *interrelated* regions, indexed by $i = 1, \ldots, n$. In such a framework, a distinction must be made between two sources of technological change. The first is a process of intentional

* The author is grateful to Mrs Judith Tomkins for her valuable comments, which substantially helped to sharpen the arguments and the focus of this paper.

[2] An argument commonly attributed to (Abramovitz 1986).

creation of technology; an autonomous process that takes place exclusively within the 'borders' of a region. As regions are, by definition, open economies technology is also affected by technological improvements that take place in other regions. This process is usually termed as *technology adoption* and constitutes the second source of technological change. Alternatively, this source refers to the part of technology that is generated from *interaction* between spatial units. An essential assumption for the purpose of this paper is that technology adoption is related to the size of the 'technological gap'[3]. This can be defined as the difference between an exogenously determined best-practice frontier (x), and the prevailing level of technology in a region (a_i), i.e. $b_i = a_i - x_i$; a measure which can be conceived as an approximation of 'technological proximity'. Thus, the growth of technology in a region ($\dot{a}_i$) can be described as follows:

$$\dot{a}_i = \tilde{\theta}_i + \xi b_i \quad (1)$$

In Equation (1) $\tilde{\theta}_i$ denotes the autonomous part of technology growth, i.e. technology created within a region. The ability of a region to implement technological innovations is represented by the parameter ξ, which reflects the opportunities for technological catch-up. Given that $b_i = a_i - x_i$, then the technological distances between a leading and a follower region, are given by: $b_l = a_l - x$ and $b_f = a_f - x$, respectively or $\dot{a}_l = \tilde{\theta}_l + \xi b_l$ and $\dot{a}_f = \tilde{\theta}_f + \xi b_f$. The growth rate for the technology gap between the two regions ($\dot{b}_{lf}$) is therefore:

$$\dot{b}_{lf} = \dot{a}_l - \dot{a}_f = \left(\tilde{\theta}_l - \tilde{\theta}_f\right) + \xi\left(b_l - b_f\right) \quad (2)$$

Defining $b_{lf} = b_f - b_l$ and $\tilde{\theta}_{lf} = \left(\tilde{\theta}_l - \tilde{\theta}_f\right)$, Equation (2) can be written as follows:

$$\dot{b}_{lf} = \tilde{\theta}_{lf} - \xi b_{lf} \quad (3)$$

Assuming that ξ is a decreasing function of the *initial* technological gap in a region, i.e. $\xi_i = f\left(b_{lf_{i,0}}\right)$ with $f' < 0$, then a relatively high initial level of technological gap implies that the prevailing conditions are not favourable for technology adoption and, consequently, the distance from the technological leader increases through time. Conversely, a relatively low level of the initial technological gap can be taken as an indication that conditions allow adoption of technological innovations, reflected in a relatively high value of ξ. Obviously, regional disparities in the absorptive parameters generate a strong tendency for regional per-capita output to diverge.

It becomes of crucial importance, therefore, to determine the dynamic path of convergence that this model implies. This can be shown using an example in which the economy is divided into three regions, one 'leader' (l), which is at the technological frontier $(b_l = a_l - x = 0)$, and two followers, i.e. $i = 1, 2$. Assume that $\tilde{\theta}_{lf_1} - \tilde{\theta}_{lf_2} = 0$ and $b_{lf_{1,0}} - b_{lf_{2,0}} > 0$, which implies that $\xi_1 - \xi_2 < 0$. If this difference remains unchanged over a given period of time, then a catch-up, in terms of technology, between region 1 and 2 is not feasible. Stated in alternative terms, if $\left(\Delta\xi_{1,2}\right)_t \to \infty$, then $\left(\Delta b_{lf_{1,2}}\right)_t \to \infty$, as $t \to \infty$ and the two regions move towards different directions (Figure 1). Only regions with low technology gaps are likely to converge towards a steady-state equilibrium growth path, as represented by the growth rate of the leading region. Regions with relatively large technology gaps may fall progressively behind. It seems thus legitimate to ask, if there is a way for the 'technologically poor' regions to catch-up with the 'technologically rich' regions? In this example a catch-up is feasible only if region 1, viz. the 'technologically poor' region, improves its adoptive ability, i.e. if the value of ξ increases through time, from ξ_1 to ξ_1', as shown in Figure 2. Provided that $\left(\Delta\xi_{1,2}\right)_t \to 0$, then gradually $\left(\Delta b_{lf_{1,2}}\right)_t \to 0$, allowing region 1 to catch-up with the 'technologically rich' region 2. The conclusion to drawn is that a pattern of club-convergence is the most probable outcome, if the adoptive parameters differ across regions. Movements towards overall convergence occur only as regions become similar in terms of their adoptive abilities.

[3] It is possible to extend this model by assuming that the process of technology creation is also a function of the 'technological' gap. *See* Alexiadis (2010) for an elaboration of this argument.

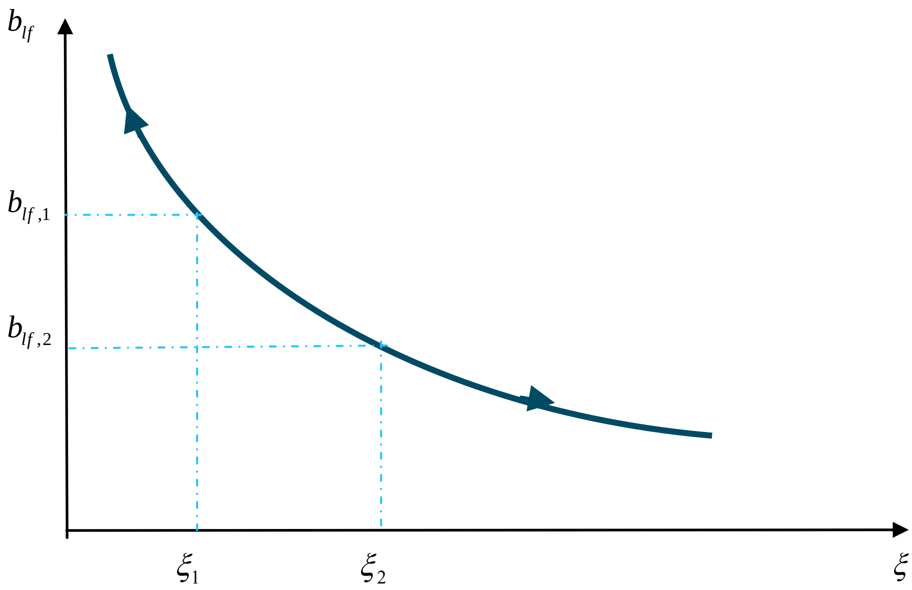

Figure 1. A pattern of regional divergence

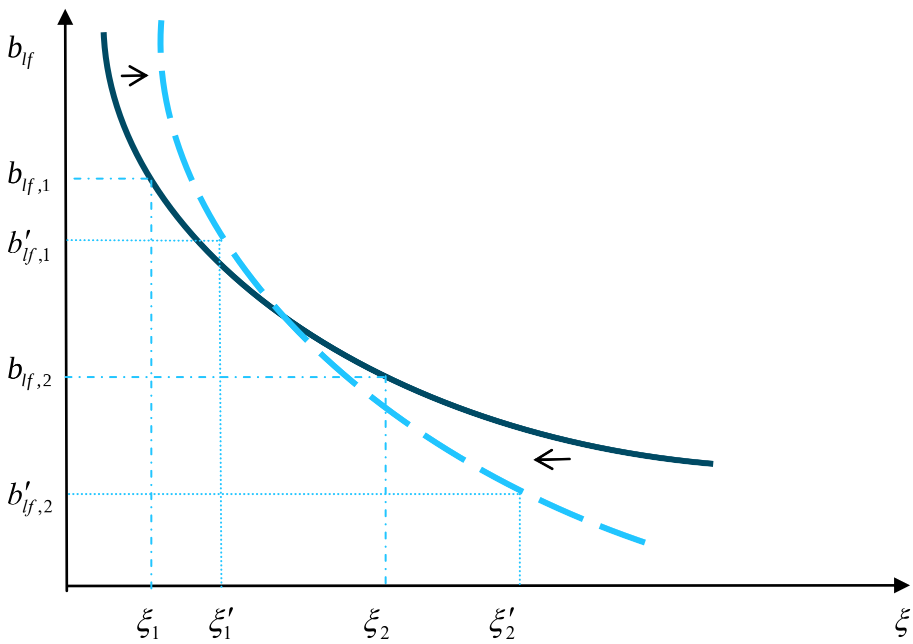

Figure 2. Club-convergence

Overall, this model suggests that convergence towards the leading region(s) is feasible only for regions with sufficient absorptive capacity. There is the distinct possibility that only regions with low technology gaps are able to converge towards a steady-state equilibrium growth path, relative to the growth rate of the leading region. Regions with large technology gaps may fall progressively behind.

3. Econometric Specification

The empirical literature on regional convergence (e.g. Barro and Sala-i-Martin, 1992) makes extensive use of two alternative tests for convergence, namely absolute and conditional convergence:

$$g_i = a + b_1 y_{i,0} + \varepsilon_i \tag{4}$$

$$g_i = a + b_1 y_{i,0} + b_{\mathbf{X}_i} \mathbf{X}_i + \varepsilon_i \tag{5}$$

where y_i typically represents per-capita output, or output per worker, of the i[th] region (in logarithm form), $g_i = (y_{i,T} - y_{i,0})$ is the growth rate over the time interval $(0,T)$, and ε_i is the error-term, which follows a normal distribution.

Absolute (unconditional) convergence is signalised by $b_1 < 0$. On the other hand, conditional convergence is based upon the argument that different regional characteristics will lead to different steady-states. Conditional convergence requires that $b_1 < 0$ and $b_{X_i} \neq 0$. Consider two groups of regions, let $i = k, l$, that differ not only in terms of initial labour productivity, i.e. $\Delta \mathbf{y}_{kl,0} \equiv y_{k,0} - y_{l,0} \neq 0$, but also in terms of their structural characteristics, i.e. $\Delta \mathbf{X}_{kl} \equiv \mathbf{X}_k - \mathbf{X}_l \neq 0$. Assume that $\Delta \mathbf{y}_{kl,0} > 0$ and $\Delta \mathbf{X}_{kl} > 0$. An implication of this assumption is that a superior (inferior) regional infrastructure, approximated in terms of a high (low) $\mathbf{X}_i$, is associated with a high (low) level of initial level of labour productivity. Absolute convergence amongst these groups is possible if $g_{k,T} - g_{l,T} < 0$. However, given that $\Delta \mathbf{X}_{kl} > 0$, a relatively slow process of convergence is expected. It follows, therefore, that a test for conditional convergence is more suitable for the empirical application of the model developed in Section 2, with variable(s) representing technology the principal focus, which is what the remaining paragraphs of this section will be dealing with.

Technical change, leading to regional productivity growth, originates either from within the region, namely indigenous innovation (PI_i), or from other regions, i.e. technological spillovers from adopting innovations created elsewhere (ADP_i). In the former case, technical change may be approximated by the 'propensity to innovate' ($PI_{i,t}$), as proposed by Pigliaru (2003), and can be measured in terms of the number of patents per-capita in each region.

The second source of technical growth, namely the ability of a region to adopt technological innovations, is approximated as the percentage of total employment in technologically dynamic sectors:

$$ADP_{i,t} = \frac{\sum_{\rho=1}^{k} \eta_{i,t}^{\rho}}{\sum_{j=1}^{m} L_{i,t}^{j}} \tag{6}$$

where $\eta_{i,t}^{\rho}$ refers to personnel employed in high-tech manufacturing and knowledge-intensive high-technology services ($\rho = 1, \ldots, k$), while $L_{i,t}^{j}$ is the employment in all the sectors ($j = 1, \ldots, m$).

Equation (6), represents the level of technological development, but also, indicates a capacity for technology adoption, since these are taken to apply high technology. Therefore, it is possible to express a model of 'technologically-conditioned' convergence as follows:

$$g_i = a + b_1 y_{i,0} + b_2 PI_{i,0} + b_3 ADP_{i,0} + \varepsilon_i \tag{7}$$

In Equation (7) the variables related to technology are expressed in initial values. There are two primary reasons for such an approach. The first is related to the fact that creation and adoption of innovations, normally, have future or long-run effects on regional growth (Funke and Niebuhr 2005). In other words, future growth is affected by current efforts to enhance technology. Therefore, including the two technological elements at the initial time captures these long-run effects of technology on regional growth over a specific time period. A second reason for using initial values is that it tests the hypothesis that initial conditions 'lock' regions into a high or low position, for example, how high or low levels of technology affect the pattern of regional growth and convergence.

Equation (7), thus, incorporates the potential impact of both internally generated technological change and technology adoption upon a region's growth. Broadly speaking, it is anticipated that $b_2 > 0$, since high levels of innovation are normally associated with high levels of growth and vice versa. However, it is not automatically the case that this condition promotes convergence. In other words, if low productivity regions have a high initial level of intentional technology creation, then this will have positive impacts on convergence, by enhancing their growth rates. On the other hand, if such regions have a low propensity to innovate, then no significant impacts on growth are anticipated and, hence, it may be difficult to converge with technologically advanced regions. The latter case is the more likely.

The $ADP_{i,0}$ variable reflects two distinct features, namely the *initial* level of 'technological adoption' as well as the degree to which existing conditions in a region allow further adoption of technology. A low initial level of $ADP_{i,0}$ combined with fast growth may indicate, ceteris paribus, that less advanced regions are able to adopt technology, which is transformed into high growth rates and, subsequently, convergence with the technologically advanced regions. It may be argued, therefore, that the condition $b_3 < 0$ promotes convergence. On the other hand, a low initial value for $ADP_{i,0}$ may indicate that although there is significant potential for technology adoption, initial infrastructure conditions are not appropriate to technology adoption and, therefore, there are no significant impacts on growth. If the latter effect dominates then $b_3 > 0$, and convergence between technologically lagging and technologically advanced regions is severely constrained.

4. Econometric Estimation and Discussion

In this paper we exploit data on Gross Value Added (GVA) per-worker since this measure is a major component of differences in the economic performance of regions and a direct outcome of the various factors that determine regional 'competitiveness' (Martin 2001). The regional groupings used in this paper are those delineated by EUROSTAT and refer to 267 NUTS-2 regions. The EU uses NUTS-2 regions as 'targets' for convergence and are defined as the 'geographical level at which the persistence or disappearance of unacceptable inequalities should be measured' (Boldrin, and Canova 2001, 212). Despite considerable objections for the use of NUTS-2 regions as the appropriate level at which convergence should be measured, the NUTS-2 regions are sufficient small to capture sub-national variations (Fischer, and Stirböck 2006). The time period for the analysis extends from 1995 to 2006, which might be considered as rather short. However, Durlauf and Quah (1999) point out that 'convergence-regressions' are valid for shorter time periods, since they are based on an approximation around the 'steady-state' and are supposed to capture the dynamics toward the 'steady-state'.

The potential or otherwise for β-convergence is indicated in Figure 3, which shows a scatterplot of the average annual growth rate against the initial level of GVA per-worker. Even a cursory analysis of the EU27 data suggests that the inverse relationship between growth rate and initial level of labour productivity is not so obvious. Figure 4 indicates that this relationship is more probable to occur among regions that exceed a certain level of initial labour productivity. The presence or absence of β-convergence, however, cannot be confirmed by visual inspection alone. Therefore, the cross-section test, based on estimation of Equation (4) for the 267 NUTS2 regions, is applied to the period 1995-2006. Furthermore, the conventional test of regional absolute convergence is modified to include the hypothesis of 'technologically-conditioned' convergence. The relevant results are set out in Table 1.

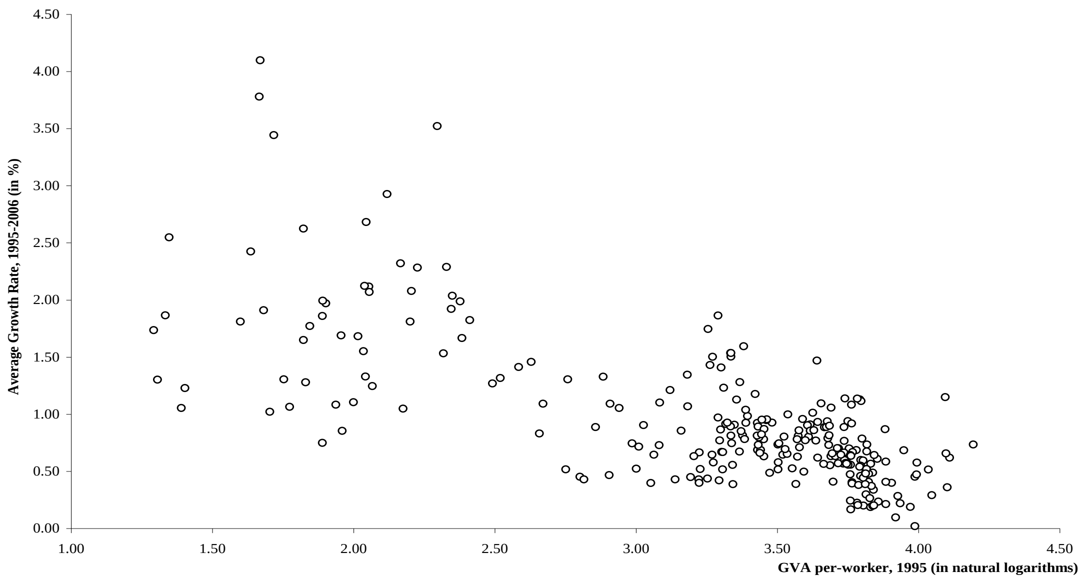

Figure 3. Absolute Convergence, GVA per-worker, EU NUTS-2 Regions, 1995-2006

Table 1. Regional Convergence, GVA per-worker, EU regions: 1995-2006

	Equation (4)	Equation (7)
Depended Variable: g_i , n = 267 NUTS-2 Regions, Ordinary Least squares		
a	0.5714**	0.4734**
b_1	-0.0747**	-0.0275*
b_2		-0.0406**
b_3		0.0650**
Implied β	0.0065**	0.0023**
LIK	147.552	164.440
AIC	-291.104	-320.879
SBC	-283.929	-306.530

Notes: ** indicates statistical significance at 95% level of confidence, * 90% level. AIC, SBC and LIK denote the *Akaike*, the *Schwartz-Bayesian* information criteria and Log-Likelihood, respectively.

As shown in Table 1, there is a statistically significant inverse relationship between growth over the time period, and the level of GVA per-worker at the start of the period. Nevertheless, the rate of convergence of labour productivity is a slow one, estimated to be 0.65% per annum. A negative and statistically significant coefficient is estimated for the variable describing technology creation. As argued in Section 3, a positive value of b_2 does not necessarily promote convergence as such, since regions with relatively high initial level of innovation exhibit relatively higher rates of growth. In this light, a negative coefficient implies that any attempts to improve technology creation, especially in lagging regions, lead to faster growth; a condition that indubitably promotes regional convergence. On the other hand, the $ADP_{i,0}$ variable is positive in sign. This suggests that, on average, regions with low values of $ADP_{i,0}$ at the start of the period, i.e. the technologically backward regions, grow slower than regions with high values, ceteris paribus. If technologically backward regions of the EU were successful in adopting technology, which subsequently is transformed into faster growth, then the estimated coefficient b_3 would be negative. Since $b_3 > 0$, and bearing in mind that a low value of $ADP_{i,0}$ implies a relatively high initial technological gap, this indicates that infrastructure conditions in regions with high technological gaps are inhibiting this process of technology adoption. A large initial technological gap may constitute an obstacle to convergence. This proposition is supported by the empirical analysis which suggests that, the rate of convergence implied by the 'technologically-conditional' model is considerably slower to that obtained from the absolute-convergence specification, 0.23% and 0.65%, respectively.

The superiority of the model described by Equation (7) is supported by both the criteria for model selection applied here, namely the *Akaike* (AIC) and the *Schwartz-Bayesian* (SBC) information criteria.[4] Further support is also provided by the value of the Log-likelihood (LIK), which increases, as anticipated, with the introduction of the technological variables. Overall, these results suggest a significant technological dimension in the process of European regional convergence. However, the relatively low rates of convergence imply that technological differences are considerable across the EU-27 regions. This brings the possibility of club-convergence into consideration.

It is possible to examine this hypothesis empirically by estimating Equation (4) and (7) for two different regional groupings. The first (leading) group includes regions with initial level of labour productivity more than 75% of the EU-27 average, while labour productivity in the members of the second (lagging) group is less than 75% of the EU-27 average. The relevant results are set out in Tables 2 and 3.

[4] As a rule of thumb, the best fitting model is the one that yields the minimum values for the AIC or the SBC criterion.

Table 2. Regional Convergence in Europe, Leading group: > 75% of the EU27 Average

	Equation (4)	Equation (7)
Depended Variable: g_i, n = 183 NUTS-2 Regions, Ordinary Least squares		
a	1.2668**	1.0515**
b_1	-0.2635**	-0.1855**
b_2		-0.0382**
b_3		0.0626**
Implied β	0.0255**	0.0171**
LIK	132.4982	141.8320
AIC	-260.9951	-275.6630
SBC	-254.5760	-262.8250

Notes: ** indicates statistical significance at 95% level of confidence, * 90% level. AIC, SBC and LIK denote the *Akaike*, the *Schwartz-Bayesian* information criteria and Log-Likelihood, respectively.

Table 3. Regional Convergence in Europe, Lagging group: < 75% of the EU27 Average

	Equation (4)	Equation (7)
Depended Variable: g_i, n = 84 NUTS-2 Regions, Ordinary Least squares		
a	0.5689**	0.5026*
b_1	-0.0802**	-0.0515
b_2		-0.0358**
b_3		0.0682**
Implied β	0.0069**	0.0044
LIK	31.6536	37.2461
AIC	-59.3069	-66.4919
SBC	-54.4453	-56.7687

Notes: ** indicates statistical significance at 95% level of confidence, * 90% level. AIC, SBC and LIK denote the *Akaike*, the *Schwartz-Bayesian* information criteria and Log-Likelihood, respectively.

The results clearly indicate that the two groups converge at different rates. The estimated rate of absolute convergence for the leading group is 2.5% while the lagging regions move towards steady-state equilibrium at a considerably smaller rate (about 0.7% per-annum). Similarly, the rate of convergence, after conditioning for technological differences, in the group of lagging regions hardly exceed 0.4% per-annum, as opposed to rate more than four times higher rate in the leading group. It is important to note, however, that the two technological variables are statistically significant and positive for both groups. A necessary condition for lagging regions to converge is a negative value of the adoptive variable. It follows, therefore, that adoption of technology, although it might be the best 'vehicle' for lagging regions to converge with leading regions, is nevertheless a process which might be difficult for lagging regions, especially during the early stages of development when conditions are least supportive. In order, therefore, for the adoption of technology to set the lagging regions of the EU in a process of convergence with the leading regions requires an improvement in infrastructure conditions. The message, therefore, from the empirical application of the model developed in this paper is clear. The adoption of technology to set the lagging regions of the EU in a process of convergence with the leading regions requires an improvement in infrastructure conditions.

5. Conclusion

It is beyond argument that, although an increasing number of empirical studies have paid attention to issues of economic convergence in the EU, the impact of technology adoption in regional convergence has so far received more limited attention. We have attempted in this paper to address this question by developing a model of regional convergence that puts primary focus upon the infrastructure conditions in a region. This model is flexible enough to be applied to several regional contexts, especially to the new member-states of the European

Union. Estimating this model using data for the 267 NUTS-2 regions of the EU-27 over the period 1995-2006 yields some interesting results. To be more specific, it is established that the NUTS-2 regions of EU-27 exhibit a very slow tendency towards convergence in terms of labour productivity. An important conclusion to emerge from the empirical application is that the EU-27 regions exhibit even slower tendencies to converge *after* conditioning for technological differences across regions. This can attributed, possibly to inappropriate infrastructure conditions prevailing in lagging regions, which prevent or constrain convergence with the more technologically advanced regions. In this context, club-convergence seems to be a more probable outcome across the regions of an enlarged Europe. The evidence reported in this paper seems to confirm this hypothesis.

In terms of implications for regional policy, this paper raises a number of pertinent issues. A primary aim of regional economic policy in the context of an enlarged Europe should be the promotion of high-technology activities, and R&D, including universities, scientific and research institutions. Moreover, in order to enhance regional growth and convergence, policy should seek to reorient these activities. High-technological and knowledge-creating activities should be directed, if possible, at regions with unfavorable infrastructure conditions, the purpose being to stimulate the production structures of those regions to shift to activities that implement high technology.

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