EU GROWTH, CONVERGENCE AND THE KNOWLEDGE ECONOMY: AN EMPIRICAL INVESTIGATION

by

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DISCUSSION PAPER No. 175

July 2006

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This paper is under review (after revision) in *Regional Studies*

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ABSTRACT

This paper attempts to examine whether, and to what extent, knowledge-economy related variables have contributed to per capita income convergence among EU regions in the decade of the 1990s. First, we use a neoclassical growth framework to test for β-convergence in per capita GDP in 205 EU-regions, for the periods 1991 and 1999. Then the impact of the knowledge-economy variables, namely, the extent of low and medium education, expenditure in research and development, the no of patents, and employment in high tech and knowledge sectors, on β and σ convergence, is assessed on a cross-sectional basis. The empirical results reveal a limited degree of convergence in the 1991-99 period, while among the knowledge variables, only employment in high tech sectors is found to contribute to the convergence process, and only R&D and medium education are found to contribute to the reduction of income variability, i.e., to σ-convergence. From an economic geography perspective the results reveal the existence of a "centre-periphery" pattern in the EU, while an attempt to draw policy implications from both new growth and economic geography approaches points to the need for regional policies which would assist the diffusion of knowledge variables to poorer EU regions.

Key words: new growth models, β-convergence, σ-convergence, knowledge economy, new economic geography, EU regional disparities.

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1. Introduction: The problems of Convergence and Cohesion in the EU and recent theories on the convergence/divergence debate

In the course of the past 40 years or so, per capita income disparities between EU countries have diminished, as the lagging peripheral countries have improved their relative income position, initially between 1960 and 1973 and, in a second step, after 1986 (TONDL, 2001). Between 1986 and 1996, the lagging countries achieved higher growth rates than rich countries and a catching up process was set in. In particular, the average per capita income of the three cohesion (and poorer) Member States, i.e., Greece, Spain and Portugal, increased from approximately 68% of the E.U. average in 1988 to about 79% in 2000, on the average (COMMISSION OF THE EC, 2002). Real convergence has therefore been achieved on the country level. However, Greece has experienced modest growth rates, so its convergence pattern has not been as strong as for the other two Cohesion countries, revealing this country's increased degree of peripherality, following European economic integration (MARTIN, 1999; DAll' ERBA, 2003).

On the regional scale there has been a slower overall reduction in disparities relatively to the national scale, so that regional disparities appear to be more serious than disparities among countries. The reason lies in the growing income disparities within some Member-States (TONDL, 2001; COMMISSION OF THE EC, 2002). Thus, while per capita income differences have, overall, narrowed between countries during the '80s and '90s, they have generally widened between regions within countries (DALL' ERBA, 2003; MARTIN, 1999, 2004; BARRIOS & STROBL, 2005). Some writers have, in particular, found that half of the income inequality existing between EU regions is accounted for by regional inequalities within individual countries (MARTIN, 1999; PUGA, 2002). This finding, in turn, suggests that any gains from economic integration have mainly benefited the richest regions of the poorer countries in the EU, so that, in fact, a trade-off between growth (in terms of p.c. GDP) and equity (measured by the degree of regional income inequalities) has been taking place (QUAH, 1996, 1997; CANOVA, 2001; GIANETTI, 2002; DALL' ERBA, 2003; PETRAKOS et al., 2003; MARTIN, 1999, 2004; BARRIOS & STROBL, 2005). In other words, countries with a per capita GDP level above the EU average also experience above average regional disparities and vice versa. For example, the three poorest (EU-15) countries, Greece, Spain and Portugal, have the lowest level of regional disparities, but these disparities increased substantially in Spain and Portugal, which achieved a relatively higher growth rate and converged with the rest of the EU (MARTIN, 1999; DALL' ERBA, 2003; PETRAKOS et al., 2003).

The existence of income disparities between EU Member States has been considered as an important constraint for the deepening of the European integration process and has resulted in the adoption of the so-called regional and cohesion policies, mainly from the Single European Act (1986) onwards. Since then, regional policy became part of the Community's constitutional framework (Single European Act, Article 130a-e), in combination with the objective of economic and social cohesion.

On the theoretical level, the diverging income levels among EU regions, which was not in line with the traditional neoclassical growth model, led to the emergence of two, new, strands of thought in regional economics, both reflecting a revival of earlier regional growth and development theories: the *new growth models* in the mid-1980s and the *new economic geography*, in the early 1990s[1].

The new growth models, initiated with the works of ROMER (1986, 1990), LUCAS (1988), REBELLO (1991) and BARRO and SALA-I-MARTIN (1991, 1992) are also known as *endogenous*, due to their underlying assumption, that technological change (caused by investment in physical or human capital, both being characterized by increasing returns) is an endogenous process. The new growth theory suggests that human resources (innovation activities, education and professional skills) are highly related to regional income differences: the accumulation of human capital means accumulation of knowledge, which eventually leads to *knowledge-spillovers* within a region; thus, wealthy regions tend to strengthen their relative position, the more they invest in research and development (R&D) activities, and the end result will be divergence in growth rates among regions.

The new economic geography, also known as *new location theory*, was initiated by the works of KRUGMAN (1991a, b) and KRUGMAN/VENABLES (1995). This approach is based on the assumptions of both internal and external economies of scale, which cause the concentration of economic activity in large-scale agglomerations, and the "home market effect", which causes economic activity to locate where market demand is highest. The inclusion of a third assumption, the existence of transport (or trade) costs, completes the “centripetal” forces, which induce economic activity to cluster in space, at intermediate levels of economic integration (i.e., at intermediate levels of trade costs). In this framework, knowledge spill-overs are important in forming localized external economies and industrial clusters, which can give a region a long lasting competitive advantage over other regions. Therefore, this approach also suggests that “learning by doing” processes can be important tools for strengthening a central region’s superiority, thus for maintaining regional income differences. Both approaches then suggest that the process of growth in itself can cause *external economies* or *positive spillover effects*, which create conditions of further growth and thus lead to increasing divergence among regions. However, economic geography models show that in more advanced stages of economic integration, when transport costs are sufficiently low or even zero, a number of “centrifugal” forces set in, causing the dispersion of economic activity in different regions. Thus, economic geography models suggest that both convergence and divergence are possible outcomes, but they correspond to different stages of the economic integration process (see for example, PUGA, 1999 & 2002). The possibility of this outcome is also considered by some growth theorists, who suggest that, under certain conditions, convergence can be a possible outcome, resulting from knowledge-spillovers between regions in the course of economic integration (see for example LUCAS, 1988 and WALTZ, 1998).

Another recent approach in research combines economic geography elements with elements of endogenous growth (BALDWIN, 1999, MARTIN & OTTAVIANO, 1999 and 2001): growth is driven by accumulation of knowledge capital, which is a prerequisite for innovation and product differentiation, and self-sustaining agglomeration occurs from localised knowledge spillovers once a critical level of reduction in trade barriers has been reached (MARTIN, 1999; PACI, R. & S. USAI (2000); TONDL, 2001).

The statistical evidence on the evolution of disparities in the EU, presented above, appears to confirm the neoclassical growth model of convergence at country-level and the endogenous growth model, with economic geography elements, at regional level - especially as far as regional disparities within individual countries are concerned (see also MARTIN, 1999 and PETRAKOS et al., 2003). While the use of new economic geography models for the empirical testing of convergence/divergence trends among U.S. or E.U. regions has been rather limited, the new growth models have been widely used for such testing. Based on the traditional neoclassical framework, a number of studies compare the relative growth rates of a country's regions with the corresponding rates in other countries and attempt to interpret their empirical findings from the point of view of the new/endogenous growth models, where possible (see for example BARRO and SALA-I-MARTIN, 1992, COULOMBE & LEE, 1995 and SALA-I-MARTIN, 1996). Using the concept of β-convergence, proposed by BAUMOL, 1986 and BARRO and SALA-I-MARTIN, 1991, 1992, convergence occurs when growth rates are negatively associated with initial levels of the variable under consideration, in this case regional per capita income. Convergence also occurs when the dispersion of the cross-sectional distribution of income decreases over time. This is the σ-convergence concept suggested by BARRO and SALA-I-MARTIN, 1995. According to another interpretation, convergence occurs when the income distribution converges to a unimodal distribution. The emphasis of this approach, advocated by QUAH, 1996, is on the distributional dynamics of income.

Concerning empirical findings at the European level, although BARRO and SALA-I-MARTIN, 1991, found evidence in favour of convergence, most analysts have found diverging income levels among European regions for most periods. For example, BUTTON and PENTECOST, 1995, have found that European Union regional incomes diverged during the 1980s, and PAGANO, 1993, concluded that the process of convergence in regional European productivities or incomes was halted by the first oil shock of 1973. NEVEN and GOUYETTE, 1994, concluded that dualism of the north-south type characterised the whole of the European Community in the '80s, while MAGRINI, 1999, found evidence of "polarisation" in European regional incomes in the 1979-1990 period, reflected in the existence of "growth leaders", "growth followers", and some very poor regions at the bottom of the income distribution. MAURO and PODRECA, 1994, suggested the presence of dualism in the case of Italian regions, while SIRIOPOULOS and ASTERIOU, 1998, using the tools of β-convergence and estimating conditional and unconditional β-regressions to check for regional income convergence in Greece concluded on the existence of economic dualism between northern and southern Greek regions.

Given the persistence of regional inequalities at EU level, confirmed in all the empirical studies mentioned above, theories that interpret divergence (rather than convergence) among regions assume tremendous importance. Moreover, given the significance of human capital and knowledge-related spillovers in interpreting diverging regional incomes, in both new growth and new economic geography approaches, these variables can be considered as important determinants of European regional income trends. The same variables could, in this framework, be used to interpret convergence, which would result from their diffusion among regions, in more advanced stages of economic integration. This paper attempts to contribute to the convergence literature: (a) by examining whether, and to what extent, knowledge-economy variables have contributed to per capita income convergence among European regions in the decade of the 1990s; (b) by introducing an economic geography element in the interpretation of empirical results. A combination of (a) and (b) has not, to our knowledge, been attempted in previous studies, so we consider them as this study's unique contribution to this literature.

As knowledge-economy variables, we use the extent of low, medium and higher education, expenditure in research and development, the no of patents, and employment in high tech manufacturing and knowledge-intensive sectors. These were considered as the most characteristic variables of the knowledge economy. Expenses in low, medium and higher education correspond to "human capital", which is a prerequisite for the generation of other knowledge-sectors, for R&D and innovations. As patents protect the innovations of firms, in the context of imperfect competition and increased economic integration they constitute a strong incentive for firms to engage in product development. Moreover, patents usually contain "geographic information" about their inventors, so they reflect localised knowledge-spillovers, which, in turn, may be the result of a pre-existing pattern of geographic concentration of knowledge-related activities (see Jaffe et. al, 2002). The concentration of knowledge-related variables and activities in the already prosperous, higher-income, EU regions and the cumulative growth processes which they induce (through for example spillovers) probably reveal an association between regional (per capita) income disparities and increasing returns to education (see also Canova, 2001; Martin 1999 & 2004; Barrios & Srobl, 2005). These variables are, thus, assumed to be negatively related to the speed of the convergence process, i.e., to delay convergence among regions with different per capita income-levels, or to contribute to increased regional divergence, especially under conditions of increased economic integration. Under certain conditions, however, they can be assumed to lead to convergence. It should perhaps be mentioned that we are actually trying to relate the convergence process to some underlying forces, which, we believe, are connected to knowledge, as the new growth theory suggests. Thus, we do not adopt an "agnostic" or "mechanical" point of view that would amount to relate the convergence process to growth itself.

The second section of this paper presents the methodology adopted for estimating the impact of knowledge-economy variables on diverging or converging per capita income levels among EU regions. The third section presents the empirical findings and attempts to interpret them from the perspective of both theoretical approaches discussed above. Finally, the fourth section draws the conclusions and refers to some policy implications.

2. Methodology

β - and σ -convergence

Following BARRO and SALA-I-MARTIN, 1992, β-convergence is defined as the negative correlation between the growth rate and the initial level of income. To test for β-convergence the following regression may be used:

$$T^{-1}\ln(\frac{y_{rT}}{y_{r0}}) = c - T^{-1}(1-e^{-\beta T})\ln(y_{r0}) + u_{rt}$$

where y_{rT} denotes real income per capita in region r $(r = 1,...,N)$ and year T, $T > 0$. The left hand side of equation (1) is the growth rate of per capita income between periods 0 and T, c is a constant term, β is the rate of convergence, y_{r0} is the initial level of income, and u_{rt} is an error term with zero mean. If $\beta > 0$, this implies absolute β-convergence. It must be noted that estimation of the above equation is based on cross-section data, involving growth rates for period T and initial real income.

For further exposition of this technique, see BAUMOL, 1986, and BARRO and SALA-I-MARTIN, 1992. For applications in regional convergence, see BARRO and SALA-I-MARTIN, 1991, CASHIN, 1995 for Australian states, COULOMBE and

LEE, 1995 for Canadian provinces, MAURO and PODRECA, 1994, for Italian regions, and TSIONAS, 2000, for the United States. The dispersion of incomes over time is referred to as σ-convergence: if there is convergence of incomes, then the dispersion of income distribution must be decreasing over time. It can be measured by the cross-sectional standard deviation at time t, defined as

$$v_t = \sqrt{(N-1)^{-1}\sum_{r=1}^{N}(y_{rt} - \bar{y}_t)^2}\ ,\ t = 1,...,T$$

where N is the number of regions, T is the number of time periods, and the cross-sectional average is

$$\bar{y}_t = N^{-1}\sum_{r=1}^{N} y_{rt}\ .$$

A plot of v_t over time, which shows a tendency for the cross-sectional variance to decrease over time, would provide evidence in favour of σ-convergence. It is worth mentioning that β-convergence is a necessary, though not sufficient condition for σ-convergence: if poor economies grow faster than wealthier ones, a reduction in income disparities will take place; however, a negative β-value does not guarantee that income dispersion will be smaller at the end of the period under examination than at the beginning, or that regions will converge to a common steady state. It has been shown that for these conditions to occur, a value of β between 0 and -2 (i.e., $-2<\beta<0$), would be required. Similarly, conditional β-convergence, introduced by QUAH, does not necessarily indicate a reduced dispersion of incomes (TONDL, 2001).

Suppose that y_{rt} is the *per capita* income in region r and year t, and $G_r = T^{-1}\sum_{t=1}^{T}\log(y_{rt} / y_{r,t-1})$ is the average growth rate over the entire time period. Our purpose is to investigate the extent to which the speed of convergence depends on certain predetermined variables, which are symbolized by x_r, and represent the variables associated with the knowledge-based economy. We modify the basic β-convergence model to allow for region-specific adjustment speed as follows:

$$G_r = \alpha + \beta_r y_{r0} + v_r\ ,\ \ r = 1,...,N\ , \tag{1}$$

where v_r is an error term, and α and β_r are parameters. The speed of the convergence parameter is made a function of the covariates that were mentioned above, which are**:** the extent of low, medium and higher education, research and development, patents, employment in high tech and knowledge sectors.

The reason is that knowledge variables tend to be geographically concentrated in the prosperous, "central" EU regions, which leads to a self-generating, circular, process of further concentration and economic growth. This observation has led a number of authors to the suggestion that the coefficient *β does* not in fact measure convergence among regions, but towards the long-run "steady state" of each region or clubs of regions – as regions tend to cluster within different clubs, each having a different steady-state - without much reduction taking place in the inequalities existing between clubs (Canova, 2001; Petrakos et al, 2003). In other words, the "steady-state" is itself a function of region-specific characteristics. The unequal geographical distribution described above then exerts a decreasing impact on the absolute value of *β*, or the speed of the convergence process.

The covariates mentioned are represented by z_r for the rth region and it is assumed that

$$\beta_r = z_r'\theta + \xi_r, \tag{2}$$

where θ is a parameter vector and ξ_r is an error term satisfying all classical assumptions. Combining (1) and (2) we obtain

$$G_r = \alpha + x_r'\theta + u_r, \tag{3}$$

where $x_r = y_{r0}z_r$ and $u_r = v_r + \xi_r y_{r0}$. Our approach is to estimate model (3) for a given specification of the covariates z_r by using OLS which allow for standard errors that are robust to heteroscedasticity of unknown form. This is meaningful since the random-coefficients assumption in (2) implies that the error term of (3) could depend on y_{r0}. Estimation of the growth rate regressions in (3) can be used to draw inferences about how the covariates affect other features of the distribution of growth rates, for example the second and higher moments. Specification (2) allows for a direct effect of the covariates on the speed of adjustment (or the conditional mean of growth rates) but does not allow for the possibility that the variance, the skewness, or the kurtosis of the conditional distribution vary with the covariates. To allow for this possibility, we denote by $\hat{u}_r$ the OLS residuals from regression (3). We consider the models

$$\hat{u}_r^m = x_r'\gamma_m + e_{m,r}, \quad m = 2,3,4, \tag{4}$$

where γ_m is a parameter vector and $e_{m,r}$ is an error term with zero mean. Specification (4) implies that the conditional variance, and the conditional third and fourth moments depend on the covariates[2], which allows for higher-order effects of the covariates on the conditional distribution of growth rates. The models in (4) can be estimated using OLS[3]. Before proceeding it is important to realize the implications of this formulation. First, the θ coefficients allow us to examine directly the effect of knowledge covariates on the convergence process so, also, on growth effects. Second, the γ_m coefficients allow us to examine the higher-order impact of knowledge variables upon the distribution of growth rates. It is possible, for example, that certain knowledge variables do not have a direct impact on the mean of the distribution but imply instead lower variance, more symmetry or less heavy-tailed growth distributions. To capture these higher order effects, equation (4) provides a convenient framework of analysis.

It must be noted that estimation of models (3) and (4) using OLS, results in consistent parameter estimators. It should further be mentioned that model (3) is *not* equivalent to conditional β-regression since the latter depends on the covariates as well as on initial per capita income separately and not in interaction form as the model we propose here suggests.

Clearly, particular attention must be given to the case $m = 2$, *i.e.* to results obtained when the conditional second moment is the dependent variable in regressions (4). This specification will allow us to study the impact of the knowledge-based economy variables on the dispersion of incomes and, therefore, the impact of such variables on σ-convergence. The case $m = 3$ will allow us to study the impact of the knowledge-based economy variables on the asymmetry of the conditional distribution of incomes. The case $m = 4$ refers to effects on the kurtosis of the distribution. This allows us to study in a systematic way the impact of knowledge-economy covariates on the fundamental features of the conditional distribution. Of course, the "ideal" knowledge variable would contribute to the convergence process (i.e. it would have a positive θ coefficient, but a negative coefficient in the variance, asymmetry and kurtosis equations (to be consistent with the fact that it) which would make the income distribution less dispersing around a higher mean, less asymmetric around the mean and with lighter tails. Another "ideal" case is a knowledge variable with the same first and second-order effects, which, at the same time would increase *positive* skewness as well as the *right* tail of the distribution. To figure out these cases along with parameter estimates we would additionally need to examine skewness and kurtosis before and after a possible increase in the knowledge variable in question.

3. The empirical results

To estimate the dependent variable, growth, we used data for GDP per capita in 205 EU-regions, for the periods 1991 and 1999. These are NUTS II regions, covering the entire EU-15 territory. As knowledge variables, we use the extent of low & medium education (MEDED), as well as of higher education (HIED), research and development (RD), patents (PAT), and employment in high tech manufacturing (HITEC) and in knowledge sectors (KNOW). MEDED and HIED are measured by the percentage of the population with primary/secondary education and higher education degrees, respectively. While both are considered measures of "human capital", the former is the step leading to higher education, and the latter, the source for highly skilled workforce – a prerequisite for R&D, the basic component of the knowledge economy. RD is measured by expenditures in R & D as a proportion of GDP. The number of patents (PAT) is included, as it is a good proxy for R&D success. "High tech manufacturing" (HITEC) refers to manufacturing sectors based on new technology (i.e., applied research sectors), such as IT sectors or pharmaceuticals; "employment in knowledge sectors" (KNOW) refers to "new economy" sectors, mainly R & D, which belong to services[4]. An additional variable, activity rate (ACTIV) is also included. The data used came from the following sources: STATISTICS IN FOCUS, REGIONS, EUROPEAN LABOUR FORCE SURVEY, 1996; EUROSTAT 1997, EDUCATION ACROSS THE EUROPEAN UNION, STATISTICS AND INDICATORS; EUROSTAT, 2002, STATISTICAL YEARBOOK FOR THE REGIONS.

First, we have estimated a simple β-convergence equation for the 205 EU regions and for the two periods mentioned above. The estimates yielded the following results.

TABLE 1
Dependent variable: GROWTH
Number of observations: 205

Mean of dep. var.	-.443604	LM het. test	6.02042 [.014]
Std. dev. of dep. var.	1.29636	Jarque-Bera test	59.7026 [.000]
Std. error of regression	1.22833	Ramsey's RESET2	.291182 [.590]
R-squared	.106600	F (zero slopes)	24.2218 [.000]
Adjusted R-squared	.102199	Log likelihood	-332.037
Variable	Coefficient	Standard Error	t-statistic
C	8.94291	1.25779	7.11004
Y0	-.988567	.138267	-7.14968

Standard Errors are heteroskedastic-consistent

The coefficient of initial income is negative and statistically significant, yet not very high, suggesting that some convergence (amounting to only about 1% annually) has taken place. This is as expected, given the persistence of regional income disparities among EU regions, which result in a clearly defined income-periphery pattern, widely known as the "North-South" divide. The problem is that the LM test for heteroscedasticity favours the hypothesis that heteroscedasticity in the error terms is a problem. Next, we consider augmenting this equation with the knowledge variables in interaction with the initial income level as in equation (3). Due to missing data, the number of observations now reduces to 120, which, however, are representative of all EU regions.

TABLE 2
Dependent variable: GROWTH
Number of observations: 120

Mean of dep. var.	.204888	LM het. test	.432743 [.511]
Std. dev. of dep. var.	.210741	Jarque-Bera test	54.1204 [.000]
Std. error of regression	.099210	Ramsey's RESET2	.065244 [.799]
R-squared	.793274	F (zero slopes)	53.2430 [.000]
Adjusted R-squared	.778375	Log likelihood	111.667
Variable	Coefficient	Standard Error	t-statistic
C	3.71361	.222931	16.6581
Y0	-.424553	.025029	-16.9623
XHIED	-.605788E-04	.180995E-03	-.334698
XMEDED	.268672E-03	.873116E-04	3.07716
XRD	-.240291E-03	938687E-03	-.255986
XPAT	.494926E-04	.113560E-04	4.35828
XHITEC	-.700464E-03	.263617E-03	-2.65713
XKNOW	.782387E-03	.188211E-03	4.15696
XACTIV	.379130E-03	.315021E-03	1.20351

Standard Errors are heteroskedastic-consistent

The beta coefficient now drops to -0.424, which is still highly statistically significant and there are no misspecification problems as indicated by the LM heteroscedasticity test or the Ramsey RESET test. Regarding the knowledge variables, MEDED, PAT, HITEC and KNOW are found to be statistically significant. Yet, only HITEC has a negative coefficient, implying a negative effect on growth and a positive effect on convergence. On the other hand, this might not be particularly disturbing, given that the effect of HITEC is ceteris paribus on holding constant a large number of other knowledge variables. R&D is found to be negative, but non-statistically significant for beta-convergence.

Next, we examine the effect of the knowledge variables upon higher moments of the income distribution. The results are given below.

TABLE 3

Dependent variable: U2
Number of observations: 120

Mean of dep. var.	.910450E-02	LM het. test	1.85981 [.173]
Std. dev. of dep. var.	.019763	Jarque-Bera test	22257.0 [.000]
Std. error of regression	.019575	Ramsey's RESET2	1.33754 [.250]
R-squared	.076680	F (zero slopes)	1.32877 [.243]
Adjusted R-squared	.018973	Log likelihood	305.887
Variable	Coefficient	Standard Error	t-statistic
C	.010035	.015775	.636128
HIED	.290064E-04	.220718E-03	.131418
MEDED	-.348826E-03	.133971E-03	-2.60375
RD	-.314593E-02	.160554E-02	-1.95942
PATENT	.192486E-04	.163564E-04	1.17682
HITECH	-.250249E-03	.317415E-03	-.788395
KNOW	.355659E-03	.211799E-03	1.67923
ACTIV	.113965E-03	.330583E-03	.344740

Standard Errors are heteroskedastic-consistent

TABLE 4
Dependent variable: U3
Number of observations: 120

Mean of dep. var.	.833264E-03	LM het. test	1.40397 [.236]
Std. dev. of dep. var.	.811915E-02	Jarque-Bera test	46477.2 [.000]
Std. error of regression	.829808E-02	Ramsey's RESET2	.360815 [.549]
R-squared	.016883	F (zero slopes)	.274772 [.963]
Adjusted R-squared	-.044562	Log likelihood	408.875
Variable	Coefficient	Standard Error	t-statistic
C	.457840E-02	.528762E-02	.865871
HIED	.777586E-04	.618285E-04	1.25765
MEDED	-.482407E-04	.519409E-04	-.928761
RD	-.491509E-03	.683231E-03	-.719389
PATENT	.697839E-05	.647958E-05	1.07698
HITECH	.448081E-05	.772435E-04	.058009
KNOW	-.284802E-05	.533343E-04	-.053399
ACTIV	-.613924E-04	.100493E-03	-.610912

Standard Errors are heteroskedastic-consistent

TABLE 5
Dependent variable: U4
Number of observations: 120

Mean of dep. var.	.470232E-03	LM het. test	2.39463 [.122]
Std. dev. of dep. var.	.345285E-02	Jarque-Bera test	60670.1 [.000]
Std. error of regression	.351988E-02	Ramsey's RESET2	1.01747 [.315]
R-squared	.021923	F (zero slopes)	.358636 [.924]
Adjusted R-squared	-.039206	Log likelihood	511.786
Variable	Coefficient	Standard Error	t-statistic
C	.138279E-02	.161336E-02	.857089
HIED	.192462E-04	.189155E-04	1.01748
MEDED	-.287807E-04	.208636E-04	-1.37947
RD	-.336873E-03	.288123E-03	-1.16920
PATENT	.274914E-05	.263842E-05	1.04197
HITECH	.296342E-05	.289932E-04	.102211
KNOW	.857378E-05	.124446E-04	.688953
ACTIV	-.450668E-05	.191785E-04	-.234986

Standard Errors are heteroskedastic-consistent

From these results we cannot document an effect of the knowledge variables on the third or fourth moment of the income distribution. Even though, a number of them, and in particular, MEDED, RD and KNOW, are found to be statistically significant at the 10% level for the variance of incomes, only the first two have a negative effect. This means that higher MEDED and RD contribute to less income variability, or to σ-convergence, whereas higher KNOW contribute to higher volatility. The estimated equations pass standard misspecification tests for heteroscedasticity (see LM test) and erroneous functional form (see RESET test).

The results of all the estimates then, suggest that four variables are found to be statistically significant for (beta) convergence, namely MEDED, PAT, HITEC and KNOW, and three variables are found to be statistically significant for income variability, i.e., for σ-convergence, namely MEDED, RD and KNOW.

Among the former though, only HITEC has a negative impact, which implies that only this variable appears to contribute to regional income convergence in the EU. The positive impact of MEDED, KNOW and PAT on average growth (which is self-explanatory), i.e., their negative contribution to the convergence process (assuming that the growth process concerns the already advanced EU regions), is an indication of polarization or divergence among EU regions, resulting from the polarization of investment in knowledge-intensive sectors or human capital. The unequal geographic distribution of the knowledge variables in the EU, is shown in Table 1, in which EU regions are divided between "central" and "peripheral" regions. The former are the higher income, more advanced, regions, which also happen, to be, in most cases, geographically located in the central and western part of Europe, corresponding to the traditional European "centre"[5]. The latter are the lower income, often handicapped regions, mostly located in the periphery of Europe. The sample of regions in the table is based on the assumption that the specific regions are the most representative in terms of level of income and population density in each category.

Table 1 reveals a heavy concentration of knowledge variables in "central" EU regions, clearly defining a centre-periphery pattern from an economic geography perspective. Innovative activity, in particular, measured by PAT, appears to be mostly concentrated in German regions, as has also been pointed out in other studies (see for example, Paci & Usai, 2000). We assume that this concentration leads to local knowledge or technological spillovers, due to increasing returns from knowledge[6], which, in turn, result in higher growth and incomes in the areas where they are realized (Paci & Usai 2000; Martin, 1999 & 2004). This tendency is likely to be strengthened with the deepening of economic integration, as the most productive factors will flow towards these regions, leaving the disadvantaged areas behind (Canova, 2001). On the other hand, the fact that employment in high-tech sectors appears to affect the convergence process significantly can be due to the increasing share of a number of “peripheral” regions in such sectors (mainly in IT technology sectors), also shown in Table 1. This is so, despite the fact that original research, expressed by variables such as R&D and PAT, continues to take place in “central” regions. To interpret this development, we can assume that R&D spillovers move to some extent across borders, in the course of economic integration. This assumption underlines a number of analyses in the literature, which emphasize that there are countervailing forces to local increasing returns that “facilitate spatial diffusion of knowledge, experience and technologies…and may hinter the appearance of spatial patterns of innovative specialization (Paci & Usai 2000, p. 98)[7].

Concerning the variables affecting σ-convergence, the negative impact of RD and MEDED on income volatility, that is, their positive contribution to σ-convergence could be attributed to the assumption that secondary education graduates have more or less similar knowledge and capacities, so they are equally productive in all sectors and regions. The positive contribution of KNOW to income volatility can be explained by the unequal spatial distribution of this variable in the EU, and the positive localized external economies & multiplier effects on growth and incomes, which it is brings about. In that sense, we would expect to have a positive impact of KNOW on the mean income as well as on its dispersion. We should finally add that HIED is found statistically insignificant for both β- and σ-convergence. This could be interpreted by the fact that a high percentage of University graduates in the population do not necessarily imply investment and employment in knowledge-economy sectors[8], which, in this model, are assumed to be the cause of both effects.

4. Conclusions and policy implications

The empirical findings of this study point to the existence of a limited degree of convergence among EU regions in the period 1991-1999. Per capita incomes of poorer regions show, in this period, a tendency to grow faster than wealthier regions, but the speed of the convergence process is found to be rather small, amounting to about 1% per year. These findings seem to confirm those of other studies, as well as of official EU publications, which indicate that economic disparities between regions of EU-15 have been diminishing in the last 15 to 20 years at a smaller pace than those between countries, where real convergence has already been achieved. They also point to the fact that polarization forces, suggested by both new growth and new economic geography approaches, are still quite strong in the EU, at the current level of economic integration.

The empirical assessment of the impact of human capital, measured by a number of knowledge variables, on β-convergence, has shown that only employment in high-tech sectors contributes to per capita income convergence among EU regions. Investment in medium education (MEDED), in knowledge-sectors (KNOW) and the number of patents (PAT) seem to contribute to income divergence among EU regions, i.e. to reveal a tendency towards polarization between "central" and "peripheral" regions – both being defined by income and geographical criteria. These results reflect the fact that high-tech sectors appear to be relatively equally spread between the two groups of regions, whereas the other knowledge-intensive sectors show an unequal geographic distribution, with a heavy concentration in central EU regions. Assuming that this concentration brings about localized knowledge and technological spillovers, which are subject to increasing returns, leading to cumulative growth and income processes, the above distribution clearly defines a center-periphery pattern from both an economic geography and an endogenous growth theory perspective. Of course, the apparently more equal regional distribution of high-tech sectors also reveals a certain degree of knowledge or R&D spillovers in peripheral areas, under conditions of increased economic integration.

On the other hand, estimates of σ-convergence reveal that among the knowledge-variables, only expenses on research and development (RD) and medium education (MEDED) contribute to the reduction of income variation. Employment in knowledge sectors (KNOW) contributes to greater income variability, which can be explained by the unequal regional distribution of this variable in the EU. In that sense, the findings are as expected, i.e., they reveal a positive impact of KNOW on both the mean income and its dispersion.

While the links of both new growth theory and new economic geography with policy design have been rather weak, both approaches, by offering theoretical explanations for regional growth differences, have provided rich arguments for policy intervention to eliminate such inequalities. In particular, both approaches stress the importance of "knowledge-creation" or "knowledge-spillovers" for the generation, thus, also, for the elimination of regional growth disparities. The new or endogenous growth models clearly offer support for the argument that investment in R&D and education can induce technological change and "endogenous growth" in a region. These models are considered to have contributed to the shift in policy focus towards "development from within", which has characterized regional policy from the mid-1980s onward. The diffusion of knowledge-sectors (technological diffusion) among regions with different innovating capacity in the course of economic integration (which fosters trade in goods incorporating new technology and capital movements) and the creation of conditions which would mobilize endogenous resources through the proper regional policies could then form important mechanisms for regional income convergence.

On the other hand, new economic geography models imply that the geographical distribution of economic activities is endogenous to most policy interventions, i.e. that most policy measures have "regional-side" effects. Thus, competition policy, by reducing the market power of firms, would lead to a more balanced distribution of firms. The models moreover imply that regional policies would become more efficient with economic integration, which increases the number of "footloose" or mobile firms (OTTAVIANO, 2003).

Within this theoretical framework we assume that technological diffusion can take place between regions with different R&D ratios or intensities (e.g. EU core and peripheral regions), as in the course of economic integration the wealthier regions have an incentive to expand their research activities, which become more profitable in the enlarged market. Then, even chronically non-innovating regions (like a number of peripheral regions in Greece and Portugal) can benefit from the generation of knowledge in technologically advanced regions (TONDL, 2001).

This implies that regional policies which accelerate agglomeration of economic activity - including knowledge-economy sectors - in one or a few regions, can induce an increase in the rate of innovation and, thus, in the long-run growth rates. In this way, they can boost the overall rate of innovation in the integrated economy, which may also benefit less-developed regions, resulting in a reduction of regional income inequalities. On the other hand, traditional regional policies which aim at facilitating the transfer of economic activities in handicapped regions[9] and at directly combating regional income inequalities might have the opposite effect, by lowering the rate of innovation in the economy (see also Martin, 1999 & 2004). However, policies aimed at reducing the cost of innovation (or regulatory barriers to innovation), through, for example, the granting of R&D subsidies or financing education (training) infrastructure, can achieve simultaneously higher overall growth rates (for a given level of agglomeration) and reduced regional inequalities - by facilitating innovation and knowledge diffusion (Martin, 1999; Puga, 2002).

Our results can be interpreted as pointing to this type of regional policies, i.e., policies, which strengthen high-tech manufacting sectors in peripheral areas, with relative low intensity in R&D and other knowledge variables. This requires increased emphasis on the financing of telecommunications, but also in education infrastructures, so that a more balanced distribution, or a diffusion, of innovation activity, can be made possible.

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TABLE 6. Regional per capita GDP and knowledge-intensive variables in selected regions of EU-15

	Regional per capita GDP, as a % of EU-15 average, 1999	Employment in knowledge-intensive sectors, 1998 (%)	No. of patents per 1000 inhabitants, 1998	Percentage of population with medium education, 1997	Percentage of population with higher education, 1997	Employment in hightech manufacturing sectors, 1998, %	Expenditure in RD as a % of GDP, 1997
CENTRAL REGIONS							
BRUSSELS	221	45.91	157.31	28	33	4.29	1.92
STUTTGARD	140	28.40	555.01	54	23	20.44	0.49
OBERBAYERN	161	33.36	622.83	52	27	12.71	1.50
DUSSELDOLF	128	29.19	291.35	58	17	10.18	0.67
ILE DE FRANCE	163	43.45	263.60	38	28	6.72	1.64
SOUTHERN NETHERLANDS	116	41.49	137.84	41	21	8.55	0.61
SOUTH EAST (LONDON)	260	48.40	82.35	24	29	4.05	0.51
DENMARK	144	40.63	139.71	50	29	6.83	0.86
BERLIN	106	40.35	148.38	53	32	6.25	0.66
PERIPHERAL REGIONS							
PROVENCE- ALPES- COTE D' AZUR	96	36.56	89.53	44	16	4.01	1.92
LATIO	106	24.29	100.82	37	12	4.34	1.92
VENETO	101	32.82	43.40	29	7	9.66	0.49
SCOTLAND	109	40.12	91.00	33	22	6.93	1.50
ATTICA (GREECE)	59	29.59	14.16	40	21	4.20	0.67
MADRID	91	33.52	31.18	18	26	6.90	1.64
ANDALUCIA	49	23.70	5.72	12	15	2.35	0.61
SICILY	58	29.07	12.28	26	8	2.44	0.51
LISBOA E VALE DI TEJO	69	14.69	2.57	16	16	4.34	0.86
CENTRO	39	24.70	3.77	9	7	2.99	0.66

SOURCES:

STATISTICS IN FOCUS, REGIONS, EUROPEAN LABOUR FORCE SURVEY, 1996.

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ENDNOTES

1. In particular, while the origins of the endogenous growth theory trace back to the demand-oriented regional growth theories of the 1970s (mainly KALDOR's model), both theoretical approaches drew on earlier development theories, in particular, MYRDAL's model of cumulative causation (1957), PERROUX's model on growth poles (1955) and HIRCHMAN's model on backward and forward linkages (1958).

2. Due to heteroscedasticity in (3) implied in the random-coefficient assumption in (2), we also tested the initial income level in specifications (4).

3. Since all equations in (4) contain the same explanatory variables, the seemingly unrelated regressions estimation reduces to estimation by OLS.

4. In fact, a lot of modern manufacturing (e.g. high tech manufacturing) has more the characteristics of services rather than those of traditional manufacturing sectors (Krugman, 1991).

5. Exceptions include Scottish regions, which show per capita income indicators, even though they are not "centrally" located.

6. As has been suggested by Paci & Usai (2000, p. 98), "…proximity is important since knowledge, which is the prime base of technological change, is often imperfectly mobile and locally non-rival and can thus be easily appropriated by firms in a specific area. As a result, parallel to agglomeration economies which contribute to the creation of industrial districts, there exist increasing returns from knowledge which favour the formation of technological enclaves."

7. Some authors, however, claim that knowledge-spillovers are subject to strong distance-decay effects. This means that, despite the abolition of barriers in the course of economic integration, the diffusion of knowledge and innovation in the EU still has strong country and region specific characteristics (Barrios & Strobl, 2005).

8. This for example is the case in Greece.

9. For example, by financing intra-regional transport infrastructure.

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