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European regional growth, technology gap and R&D efforts

Lydia Greunz, Université Libre de Bruxelles, DULBEA, CERT CP-140

50, Av. F.D. Roosevelt, B-1050 Bruxelles

(lgreunz@ulb.ac.be)

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Abstract: This paper aims at testing the technology gap hypothesis in order to explain the growth patterns of European regions. After a review of the related literature, we construct a simultaneous equation model of cumulative growth where catching up is driven by "social capability". This model is applied on an extended sample of 153 European NUTS I and NUTS II regions. The FIML estimates are used to cluster the sample of European regions with respect to their growth paths. Globally, 30 % of European regions should converge to the level of development achieved by the tree best performing ones. About 57 % of European regions move to their own steady state level of GDP per capita but never catch up the frontier regions and for 13 % relative backwardness seems to be a recurrent issue of the growth mechanism.

1. INTRODUCTION

Since the early days of European economic integration, one of the central goals for the European Union has been greater equality of income and productivity among member states and regions. As shown by Barro (1991), Fagerberg and Verspagen (1996), and Fagerberg, Verspagen and Caniëls (1997), this goal has been achieved for a long time. Indeed, from the early 1950s onwards, differences in GDP per capita within European regions declined steadily. However, more recently, the process of European economic convergence has slowed down considerably and, according to a widening group of economists, has ceased at the regional level after 1980 (Fagerberg and Verspagen 1996; Tondl 1997; Beine and Philippe 2000).

The scholarly work on convergence is largely based on the traditional neo-classical theory of economic growth. In its initial formulation, all countries and regions should converge to the same level of economic development provided that economic agents are endowed with the same tastes and benefit from the same access to technology[1]. Within the various assumptions, the one, which probably raises most doubts about its degree of relevance in a regional context, seems to be the hypothesis of immediate diffusion of knowledge. The issues of space and distance and also the time it needs to bridge the distance are completely ignored within the traditional neo-classical model.

In contrast to the neo-classical theory, "endogenous growth" models have focused on the possibility of divergent growth paths between countries or regions (Grossman and Helpman 1991; Temple 1999). This approach considers that the national accumulation of knowledge and technology is basically endogenous so that countries and regions build their own technological know-how instead of having free access to an international stock of blueprints from which they extract techniques to be brought into operation at home.

Research on technology diffusion and technology gaps within countries and regions was deepened during the 1980s. In this setting, concepts of "catching up" and "falling behind" play an important role and attempt to explain the differences in growth rates between countries or regions (Chappelen, Fagerberg and Verspagen 1999; Fagerberg and Verspagen 1996; Amable 1993; Fingleton 2000). Within the technology gap literature a variety of ideas is brought forward with respect to the specific way convergence is perceived[2]. In particular, two fundamentally different schools of thought can be distinguished. For the first one, the main idea underlying the technology gap approach is that technological differences between countries or regions, opens up the possibility for countries at a lower level of economic and technological development to catch up by imitating the more productive technologies of the leading country (Fagerberg 1987). The basic foundation for such an "advantage in backwardness" is that imitating foreign best practices is supposed to be considerably less costly than to innovate. However, technology is not assumed to be a perfect public good in the sense that it is equally available to everybody free of charge. It is argued that successful adoption of new technology is generally costly and typically requires what Abramovitz (1986) calls "social capability" and "technological congruence". "Social capability" refers to factors that facilitate the imitation of a technology or the implementation of technology spillovers. "Technological congruence" concerns the extent to which the country is "technologically near" to the leading country and captures the ability of a country to apply the technical features from new knowledge. The second school

of thought considers that the accumulation of knowledge is basically endogenous. This consideration comes close to the preoccupation of Myrdal (1957) and Kaldor (1966) on cumulative causation and the possibilities of divergent growth. Within this alternative view, economies are largely considered as if they were mutually independent, each moving along its own balanced growth path. Technological gaps and, as a consequence, productivity gaps would have to arise since the (constant) productivity growth rates differ. Put differently, for Kaldor and some of the endogenous growth theorists, countries follow their own national growth paths, building their own technological capabilities, with, as a corollary, little tendency for convergence in income or productivity levels.

Amable (1993) tried to integrate the two different schools of thought in adopting a "broad" Kaldorian view where growth takes place in a context of cumulative causation. He tested whether catching up has taken place during the period 1960-85 in considering a cross section of 59 developed and developing countries and using a system of equations with variables expressed in terms of averages over the considered period. His results suggest a general pattern of equilibrium divergence rather than convergence in productivity levels. In a recent study, Fingleton (2000) takes up the idea investigated by Amable as well as his data set. With respect to Amable's study, the most important new hypothesis tested by Fingleton is that a country's level of technology influences the neighbouring country's R&D activity and thus its productivity and output growth. His system of equation's estimates support this hypothesis which, in a less restrictive manner, has already been put forward in the recent literature (Grossman and Helpman 1991, 1994; Coe and Helpman 1995; Verspagen 1997).

While Amable and Fingleton have investigated the catching up hypothesis for a cross section sample of 59 developed and developing countries, the aim of this paper is to concentrate the analysis onto an extended sample of European regions. It is worth mentioning that our sample is considerably larger than the ones used in related studies. Whereas the latter uses generally NUTS I samples (about 60 regions), our sample contains a total of 153 NUTS I and NUTS II regions. Another novelty of this paper with respect to the studies of Amable and Fingleton relies in the introduction of R&D expenditures into the catching-up framework.

The rest of the paper is organised as follows: The next section explains the system of equations of our catching up model and the role and interactions of the variables included. After investigating some theoretical aspects, the model is tested at the European regional level. In particular, the crucial role of "social capability" for the catching up process is discussed. The estimation output is used to cluster European regions with respect to their level of steady state GDP per capita. Some salient observations about this clustering precede our conclusions, policy implications and suggestions for further research.

2. A CATCH UP MODEL FOR THE EUROPEAN REGIONS

2.1. The model and the role of variables

In our model growth takes place in a context of cumulative causation similar to the approach of Amable and Fingleton. Two factors influence the cumulative mechanisms. The first one is innovative activity measured by patent activity and the second one is the structure of the productive system approximated by the proportion of industrial and service employment. Interactions between these factors and the

technology gap constitute the growth dynamics. In addition to these endogenous components, "social capability" is captured by the following variables: an indicator of physical infrastructure, a measure of the level of qualification of the working age population and real R&D expenditures. The model can be formulated in the following way:

$$y \quad = \quad a_1 + b_1\,G + c_1\,IS + d_1\,K + e_1\,Q \tag{1}$$

$$IS \quad = \quad a_2 + b_2\,y + c_2\,P \tag{2}$$

$$P \quad = \quad a_3 + b_3\,G + c_3\,Q + d_3\,R\&D \tag{3}$$

where variables[3] are expressed in terms of averages over the period 1989-96 and where

y is the growth rate of real GDP expressed in terms of PPA deflated by the GDP deflator with respect to the price level of 1990;

G is the technology gap in 1989 measured as the regional level of real GDP per capita expressed in terms of PPA deflated by the GDP deflator with respect to the price level of 1990 relative to that of the three most performing regions (Bruxelles, Hamburg, Île-de-France)[4];

IS is the percentage of employment in industry and services with respect to total employment;

K is an indicator of physical infrastructure defined as $\sqrt{\dfrac{kmmot}{pop} * \dfrac{kmmot}{km^2}}$ where kmmot is the number of kilometres of motorways, pop is population and km^2 is the surface of the region;

Q is proportion of highly and moderately qualified working age population (25 to 59 years) relative to total working age population;

P is the number of patents for 1000 inhabitants;

$R\&D$ is R&D business expenditure per capita in PPS deflated by the GDP deflator with respect to the price level of 1990.

Intuitively one expects: $b_1 > 0$, $c_1 > 0$, $d_1 > 0$, $e_1 > 0$, $b_2 > 0$, $c_2 > 0$, $b_3 < 0$, $c_3 > 0$, $d_3 > 0$.

Equation (1) states that the regional growth rate depends on the initial technology gap (G), the employment concentration in industry and services (IS), physical infrastructure (K) and the qualification levels of the working age population (Q).

The technology gap variable (G) captures the idea that technological differences between regions allow the lagging ones to catch up with the leading ones by imitating their more productive technologies. It is in this sense that a technology gap reflects an "advantage in backwardness". Abramovitz (1986, 1989) argues that backwardness carries an opportunity for modernisation and faster growth. However, the actual catch up is largely dependent on a region's ability to pick up this opportunity. Put differently, the existence of a technology gap offers a potential for faster growth but the realisation of this potential depends on factors that are space (and time) dependent. As a measure of the technology gap, the level of real GDP per capita relative to that of the three best performing regions has been chosen[5].

The structure of the productive system of a region is one of the elements that allows to pick up the opportunity of backwardness. We approach it by the employment concentration in industry and services (IS). Neither Amable nor Fingleton do consider this variable. However, a high dependence on agriculture has been shown to be determinant of low regional growth (Fagerberg and Verspagen 1996), among other

things because of low technological opportunities, and slow growth of the market. Regarding the share of industry in total employment, traditionally, manufacturing industry has been considered as an "engine of growth" (Kaldor 1966). However, in recent years, technological progress largely occurs in the service sector (OCDE 1996, 1997). To cover both arguments our variable includes employment in industry and services[6]. Actually, the relation between the structure of the region's productive system and its growth performance is simultaneous[7]. This fact is captured by equation (2) which postulates that the rate of growth of demand addressed to a region (*y*) will boost employment essentially industry and services. Patent activity (*P*) has similar effects. Innovative activities in a region reflect not only its ability to develop new technologies but also its capacity to absorb technologies developed elsewhere. The outcome of this process is increased competitiveness that allows to maintain or to increase the employment level in industry and services.

Another important component of a region's "social capability" is considered to be the qualification level of the working age population (*Q*). The technical competence of the labour force and the availability of various skills are essential to absorb technologies developed elsewhere as well as developing one's own. Different tests have been performed in order to determine whether only high qualification or also moderate qualification is relevant. Both of them turned out to be parts of "social capability". Amable and Fingleton choose primary and secondary education to capture the human capital component of "social capability". With respect to the time period covered by our sample, these variables do not represent a region's ability to integrate new technologies and to benefit from spillover effects. If a relatively short time period is examined as in our framework, it is the qualification level of today's working age population that represents "social capability" and not the qualification level of tomorrow's.

Capital-embodied technology (*K*) plays an important role in the catching up process. Amable and Fingleton used the ratio of equipment investment over GDP to capture this component of the catching up mechanism. This variable is not available for the European regions. In this paper, we adopt the approach of Cappelen, Fagerberg and Verspagen (1999) in using as an approximation to the private investment variable an indicator of physical infrastructure (based on the density of motorways in a region). Physical infrastructure is a main component of a region's attractiveness. A region's attractiveness in its turn is a main determinant of private investment (Quinet 1992). Furthermore, physical infrastructure is supposed to have a positive impact on technology diffusion, since a more developed infrastructure increases the profitability, reduces the cost of introducing new technologies and speeds up the diffusion process[8].

Variables representing the level of innovative activity such as R&D expenditures should be viewed as prime candidates for explaining differences in catching up since an effort in innovation is often a precondition for successful imitation in so far as it feeds the "knowledge base" (Dosi 1988) upon which a country builds its technical competence. Having an innovative activity confers an expertise that facilitates the assimilation of knowledge developed elsewhere, and thus magnifies the R&D spillovers (OECD 1999). Equation (3) takes into account this important catching up component which has not been considered by Amable nor by Fingleton. As far as R&D expenditures are concerned, they should positively influence the patenting activity, a measure of R&D output. In our model, only business sector R&D expenditures are taken into account since for higher education R&D expenditures as well as

government R&D expenditures, the link with the patenting activity is more complex and takes time. In this context and since our model is based on average values over the period 1989-96, higher education R&D expenditures and government R&D expenditures turned out not to be significant.

It is worth mentioning that the "social capability" has often been treated as exogenous, but there are strong reasons to consider that the elements that we have chosen to represent it are, at least partly, endogenous to the growth process. In fact, the cumulative aspect of the growth mechanism is reinforced if one admits that innovative activity measured by patenting activity or employment concentration in industry and services are positively associated with the level of development. A high initial technology gap is generally associated with low values of these variables, which in turn prevent high economic growth. Among the components of "social capability", innovative activity is the most likely to be dependent on the technological level of a region. Regions that suffer from a substantial technology gap are expected to have a weak innovative performance. A weak innovative performance in turn is generally associated with a low capability to integrate knowledge developed elsewhere. For regions with a low initial level of technological capability, the distance to the countries at the technological frontier is too important to benefit from the spillover effects induced by the latter. For this reason, patenting activity, taken as an indicator of innovation, should be a negative function of the technology gap. The contrary should be observed for innovation efforts in terms of R&D expenditures as well as for the qualification level of the labour force.

2.2. Theoretical implications of the model

Coming back to the model described in the previous section it is useful to work out its reduced form and to derive the steady state levels of GDP per capita. In a reduced form, the rate of growth is:

$$y = \frac{a_1 + c_1 a_2 + c_1 a_2 a_3}{1 - c_1 b_2} + G\left(\frac{b_1 + c_1 c_2 b_3}{1 - c_1 b_2}\right) + Q\left(\frac{e_1 + c_1 c_2 c_3}{1 - c_1 b_2}\right) + R\&D\left(\frac{c_1 c_2 d_3}{1 - c_1 b_2}\right) + K\left(\frac{d_1}{1 - c_1 b_2}\right) \quad (4)$$

Given that the technology gap is defined as: $G = 1 - \frac{Y}{Y^*} = 1 - R$ \hspace{2cm} (5)

where Y and Y^* are respectively the GDP per capita of the lagging region and of the three leading ones and since for the leading regions G must be zero, their rate of growth y^* can be expressed in the following way:

$$y^* = \frac{a_1 + c_1 a_2 + c_1 a_2 a_3}{1 - c_1 b_2} + Q^*\left(\frac{e_1 + c_1 c_2 c_3}{1 - c_1 b_2}\right) + R\&D^*\left(\frac{c_1 c_2 d_3}{1 - c_1 b_2}\right) + K^*\left(\frac{d_1}{1 - c_1 b_2}\right) \quad (6)$$

where Q^*, $R\&D^*$ and K^* are the values of highly and moderately qualified working age population, business R&D expenditures and endowment of physical infrastructure applying to the leading countries. Subtracting equation (6) from equation (4) yields:

$$y - y^* = G\left(\frac{b_1 + c_1 c_2 b_3}{1 - c_1 b_2}\right) + (Q - Q^*)\left(\frac{e_1 + c_1 c_2 c_3}{1 - c_1 b_2}\right) + (R\&D - R\&D^*)\left(\frac{c_1 c_2 d_3}{1 - c_1 b_2}\right) + (K - K^*)\left(\frac{d_1}{1 - c_1 b_2}\right) \quad (7)$$

From the definition of R, the rate of growth of the relative GDP per capita ratio is:

$$\frac{\dot{R}}{R} = y - y * \qquad (8)$$

In replacing *G* by its alternative expression (*1-R*) in equation (7) and in taking account of the expression (8), it is possible to infer from equation (7) the dynamics of *R*:

$$\dot{R} = \alpha R - \beta R^2 \qquad (9)$$

where

$$\alpha = \left(\frac{b_1 + c_1 c_2 b_3}{1 - c_1 b_2} \right) + (Q - Q^*) \left(\frac{e_1 + c_1 c_2 c_3}{1 - c_1 b_2} \right) + (R\&D - R\&D^*) \left(\frac{c_1 c_2 d_3}{1 - c_1 b_2} \right) + (K - K^*) \left(\frac{d_1}{1 - c_1 b_2} \right) \quad (10)$$

and $\beta = \left(\dfrac{b_1 + c_1 c_2 b_3}{1 - c_1 b_2} \right) \qquad (11)$

In steady state $\dot{R} = 0$ so that the equilibrium ratio of GDP per capita of lagging regions over GDP per capita of frontier regions, that we denote R^{SS}, can be expressed in the following way: $R^{SS} = \dfrac{\alpha}{\beta} \qquad (12)$

The above formulation indicates that the steady state ratio of GDP per capita of a region over GDP per capita of the frontier regions is a function of the region's current deficit/excess in terms of qualification, R&D activities as well as endowment of physical infrastructure.

2.3.   Testing the model

The model is tested on the European regional landscape over the period 1989-96. A total of 153 European regions are covered by the sample which is composed of 120 NUTS II regions, 31 NUTS I regions and 2 NUTS 0 regions. For the latter - The Netherlands and Ireland - no regional data on R&D is available. This is also the case for Açores and Madeira. Belgian regions could only be covered at the NUTS I level. As far as Danish regions are concerned, aggregations of NUTS III regions have been performed since R&D data are only available in this aggregated form. Germany's new Länder as well as Luxembourg were excluded as R&D data does not exist for these regions.

Table 1 summarises the main empirical findings. One can observe that all the coefficients have the expected signs and all of them except one are significant at the 5 % level. Goodness of fit is acceptable. Together, these two elements confirm (or at least do not contradict) our reflections about the functioning of the catching up mechanism, the role of variables and their interactions. The FIML method has been used to estimate the system of equations[9]. Each equation in the system has been separately tested for omitted variables, misspecification and normality of error terms using the Ramsey's regression specification error test. For each of them, the hypothesis of omitted variables, misspecification and non normality of error terms was rejected at the 5 % level.

Table 1: Estimates of the system of equations of the catching up model

y	=	-0.22	+ 0.05 G	+ 0.18 IS	+ 0.34 K	+ 0.04 Q	(1)
		(-2.82)	(2.39)	(1.89)*	(3.41)	(1.99)	R²=0.59, SE=0.02
IS	=	0.85	+ 1.40 y	+ 0.54 P			(2)

		(71.42)	(2.98)	(4.75)			R^2=0.45, SE=0.07
P	=	0.06	- 0.16 G	+ 0.09 Q	+ 0.27 R&D	(3)	
		(1.84)	(-4.86)	(2.68)	(7.73)		R^2=0.75, SE=0.04

Estimation method: FIML, Log likelihood: 1190.44;
t-statistics between brackets;
number of observations: 150 + 3 leading regions;
* significant at the 6% level.

A comparison with the results obtained by Amable and Fingleton seems relatively difficult. Neither the covered periods nor the included variables are identical. The only comparable variable in terms of units is the technology gap. The coefficients obtained by Amable and Fingleton are respectively 0.04 and 0.02 while it turns out to be 0.05 in our setting. Despite differences in the sample sizes (59 in the Amable and Fingleton models and 153 in ours), the respective periods (1960-85 in the Amable and Fingleton models and 1989-96 in ours), as well as the model specifications, our coefficient is not statistically different from the one obtained by Amable.

Table 2: Testing the role of "social capability"

Dependent variable: y		First equation of the		
Estimation method:		"Basic model" FIML	"Basic model" OLS	"Extended model" OLS
constant	(a_1)	*-0.22* (-2.82)	*-0.21* (-7.25)	*-0.25* (-8.02)
G	(b_1)	*0.05* (2.39)	*0.06* (3.63)	*0.14* (3.59)
IS	(c_1)	*0.18* (1.89)*	*0.15* (5.11)	*0.16* (5.81)
K	(d_1)	*0.34* (3.41)	*0.30* (2.76)	*0.32* (2.90)
Q	(e_1)	*0.04* (1.96)	*0.05* (6.50)	*0.11* (4.27)
G.Q	(f_1)			*-0.13* (-2.04)
R^2		0.59	0.60	0.61

Number of observations: 150 + 3 leading regions;
Heteroskedasticity consitent t-statistics between brackets;
* significant at the 6 % level.

While the results reported at Table 1 globally supports the theoretical foundation put forward in the technology gap literature, it does not allow one to verify explicitly the main hypothesis driving the catching up process. This hypothesis can be formulated as follows: catching up in the context of technological backwardness can only be realised if "social capability" is sufficiently developed to imitate best practices developed elsewhere. In order to test this assumption more directly, let us consider qualification as the representative component of "social capability" and let us concentrate on the first equation of the system which has been augmented by a new variable, the product of the technology gap and "social capability". Table 2 shows the alternative result obtained with this additional variable.

In order to facilitate the interpretation of the estimation output and, in particular, the negative sign associated with the new variable *G.Q*, it is useful to reformulate the first equation of the "extended model" in the following way:

$$y = -0.25 + G (0.14 - 0.13 Q) + 0.16 IS + 0.32 K + 0.12 Q \qquad (13)$$
$$(a_1) \qquad (b_1) \quad (f_1) \qquad (c_1) \qquad (d_1) \qquad (e_1)$$

This formulation allows one to distinguish easily the different effects related to an increase in "social capacity". Firstly, as stated previously and captured by the coefficient (e_1), an increase of "social capability" positively influences the growth performance. Secondly, and according to the technology gap literature, a relatively high technology gap offers the opportunity for faster growth. This effect is captured by the coefficient (b_1). Now, if "social capability" is rising, economic growth is strengthened and, as a consequence, the technology gap should reduce. In other words, an increase in "social capability" weakens the influence of the technology gap on economic growth (f_1) as well as the technology gap itself. In fact, a higher degree of "social capability" increases the region's ability to imitate best practices developed elsewhere, which, as a consequence, boosts economic growth and thus reduces the technology gap.

In a less intuitive manner, the partial derivatives of the augmented equation with respect to the two variables of interest, G and Q, are shown below. Following GREEN, 2000, these partial derivatives have been evaluated at their respective average over the total sample[10].

- $$\frac{\partial y}{\partial G} > 0$$
- $$\frac{\partial y}{\partial Q} > 0$$
- $$\frac{\partial G}{\partial Q} < 0$$

It is worth mentioning that business R&D expenditures as well as endowment of physical infrastructure have also been tested as alternative representative variables of "social capability". In these alternative settings, the coefficients associated with $G.R\&D$ and $G.K$ exhibited the expected signs but did not reach the significance level of 10%.

3. EVALUATING THE GROWTH PATHS OF THE EUROPEAN REGIONS

3.1. A regional clustering

The preceding estimation results can be used to get deeper insight into the respective growth dynamics followed by each individual region. In order to determine whether a region is currently engaged in a catching-up process, or on the contrary, in a process leading to relative underdevelopment, it is useful to evaluate for each region the steady state level of GDP per capita. This is possible by applying the theoretical considerations developed previously. The estimated coefficients of the system of equations reported in Table 1 and equation (11), although valid on average over the period 1989–96, allow one to compute the value of β which turns out to be 0.05. From equation (10) it is clear that the value of α varies for each region. Using the difference between the regional values and the values computed for the three best performing European regions of the exogenous variables, namely the rate of employment of highly and moderately qualified working population ($Q-Q^*$), the amount of R&D expenditure per capita ($R\&D-R\&D^*$) and the endowment of physical infrastructure ($K-K^*$), one can compute the value of α. From equation (12), the equilibrium ratio of GDP per capita, R^{SS}, for each individual region is straightforward. Since β turns out to be positive, three cases can be distinguished:

- case 1:
$\alpha > 0, \beta > 0, R^{SS} > 1$
- case 2:
$\alpha > 0, \beta > 0, R^{SS} \leq 1$
- case 3:
$\alpha < 0, \beta > 0, R^{SS} \leq 0$[11]

In case 1, whatever the initial position, the lagging region will eventually converge to the three leading ones. This means, that taking into account the extent of the initial technology gap, the "social capability"

of the region is strong enough to reach a steady state development level similar to the one of technological leaders. In what follows, only this kind of regions are called "converging" ones. In the second case, there is an equilibrium level of the technology gap ($1-R^{SS}$), so that the lagging region never catches up completely the three best performing European regions even if its level of development is initially close to that of the leading ones. This situation is analogous to the findings of Verspagen (1991). Within this case, catching up as well as falling back to a lower level of steady state GDP per capita can occur. In case 3, the lagging region never catches up to the leading ones. "Social capability" is too low to enable a positive growth dynamics. Without an adequate set of policy measures, an inversion of their relative impoverishment process turns out to be highly unlikely.

At this stage, it is worth remembering several facts that underlay our classification. Firstly, given the technology gap is calculated with respect to the three best performing regions, the second case does not imply that convergence to the European level is an inaccessible objective. Secondly, the steady state values of the technology gap suppose that the positions of frontier regions remain unchanged over time meaning that their GDP per capita does not improve. This is a relatively restrictive assumption, which constitutes an important limit to the analysis. Thirdly, the above classification and especially the levels of the steady state GDP per capita are only valid if no exogenous shock such as a new policy measure occurs.

Table 3 indicates to which case each region belongs. In order to achieve a higher degree of homogeneity, the second case has been split up into three groups according to the steady state level of the GDP per capita ratio R. Therefore, in what follows, we distinguish five different regional groups. Furthermore, since within a given group the growth dynamics are not necessarily identical, a regional clustering with respect to the most striking common characteristics has been performed.

Globally, 30 % of European regions should converge to the level of development achieved by the three best performing European ones (case 1). In what follows, only regions belonging to this group are qualified as "converging". About 57 % of European regions move to their own steady state level of GDP per capita but never catch up the frontier regions (case 2). However, "catching up regions" are expected to reach a steady state ratio of GDP per capita relatively close to the one of "converging regions", whereas the contrary prevails for the group of "falling behind regions". Finally, for 13% of the European regions, relative backwardness seems to be a recurrent issue of the growth mechanism.

As indicated in Table 3, the group of **regions converging to the performance level of the technological leaders** (Bruxelles, Île-de-France and Hamburg) has been split up into three categories according to their growth dynamics. "Best performing regions" exhibit low technology gaps and levels of "social capability" close to the ones of technological leaders. Beside the German regions Bremen, Oberbayern, Stuttgart, Mittelfranken, Darmstadt, Karlsruhe and Düsseldorf, the capital regions Stockholm, Wien, Kobenhaven and Uusimaa belong to this category.

Table 3: Classification of regions on the basis of the estimation output

Case 1	Case 2	Case 3

Table: Regional convergence classification

Regions converging to the performance level of the technological leaders $R^{ss} = 1$	α	R^i
Best performing regions		
DE5-Bremen	79	86
DE21-Oberbayern	69	87
SE01-Stockholm	69	82
AT13-Wien	64	91
DE11-Stuttgart	64	85
DE25-Mittelfranken	64	72
DE71-Darmstadt	63	94
DK-1-Kobenhaven	61	72
DE12-Karlsruhe	55	74
DEA1-Düsseldorf	52	71
FI11-Uusimaa	50	82
Potentially fast converging regions		
DEB3-Rheinhessen-Pfalz	61	65
DE91-Braunschweig	60	61
DEC-Saarland	59	62
DE3-Berlin	57	67
DE72-Gießen	57	57
DEB2-Trier	56	51
DEA2-Köln	56	67
DE14-Tübingen	56	69
DE26-Unterfranken	52	59
DK-3-Fyns amt	52	54
DK-5-Arhus amt	52	58
AT34-Vorarlberg	52	64
DE24-Oberfranken	52	60
AT21-Kärnten	52	50
DEA4-Detmold	51	63
DE13-Freiburg	50	66
AT32-Salzburg	50	69
DE23-Oberpfalz	50	55
DK-6-Nordjylland	50	54
DK-2	50	50
DEA3-Münster	50	56
DE73-Kassel	49	62
DE27-Schwaben	48	63
DEB1-Koblenz	48	55
DE92-Hannover	48	67
SE05-Västsverige	48	67
DEA5-Arnsberg	47	62
Converging regions		
SE02-Östra Mellansverige	46	62
AT33-Tirol	46	61
SE04-Sydsverige	46	64
DE22-Niederbayern	46	54
DEF-Schleswig-Holstein	44	57
DE94-Weser-Ems	44	56
DE93-Lüneburg	45	48
AT22-Steiermark	44	48

Catching up regions $R^{ss} \in [0,9 ; 0,7]$	α	R^i
Potentially fast catching up regions		
DK-4	43	60
AT31-Oberöst.	42	59
AT12-Nieder-öst.	39	51
FR42-Alsace	38	66
FR43-Franche-Comté	35	58
FR71-Rhône-Alpes	34	64
BE2-Vlaams Gewest	34	63
FR62-Midi-Pyrénées	34	55
BE3-Reg. Wallonne	33	50
FR61-Aquitaine	33	59
FR72-Auvergne	32	52
FR26-Bourgogne	31	58
AT11-Burgenland	40	37
NL-Netherlands	30	59
Slow catching up regions - Steady regions		
IT12-Valle d`Aosta	42	82
IT13-Liguria	31	72
SE03-Smland med Öarna	31	66
FR82-Provence Alpes-Côte d`Azur	31	61
FR23-Haute-Normandie	30	67

Intermediate regions $R^{ss} \in [0,6 ; 0,4]$	α	R^i
Catching up regions		
ES23-La Rioja	30	53
UK8-North West	28	54
FR63-Limousin	28	49
FR81-Languedoc-Roussillon	26	49
GR3-Attiki	24	44
Steady regions		
SE06-Norra MellansVerige	30	64
FI12-Etelä-Suomi	30	60
FI15-Pohjois-Suomi	28	58
FR41-Lorraine	28	55
FR21-Champagne-Ardenne	27	61
FR24-Centre	26	61
ES21-Pais Vasco	26	56
FR53-Poitou-Charentes	26	53
FR22-Picardie	25	54
FR51-Pays de la Loire	25	57
IT71-Abruzzo	24	57
UK6-South West	24	57
ES22-Comunidad Foral de Navarra	24	60
FI14-Väli-Suomi	24	56
FR3-Nord-Pas-de-Calais	24	53
IT72-Molise	23	48
UK3-East Midlands	23	58
UK7-West Midlands	22	55
FI13-Itä-Suomi	22	51
UKB-Northern Ireland	21	45
Declining regions		
UK4-East Anglia	22	60
ES3-Comunidad de Madrid	22	58
FR25-Basse-Normandie	19	52
UK2-Yorkshire Humberside	19	54
IT52-Umbria	18	61
UKA-Ecosse	18	56
UK1-North	18	53
ES13-Cantabria	17	47
Strongly declining regions		
SE07-Mellersta Norrland	29	70
UK5-South East	27	72
SE08-Övre Norrland	25	68
IT11-Piemonte	22	74
IT31-Trentino-Alto Adige	21	74
IT33-Friuli-Venezia Giulia	20	74
IT4-Emilia-Romagna	17	79
IT6-Lazio	20	70
IT53-Marche	16	65

Falling behind regions $R^{ss} \in [0,3 ; 0,1]$	α	R^i
IT2-Lombardia	14	83
IT32-Veneto	14	72
FI2-Aland	7	85
UK9-Pays de Galles	13	51
IT93-Calabria	12	38
GR25-Peloponnisos	12	40
IT51-Toscana	10	68
FR52-Bretagne	10	53
GR12-Kentriki Makedonia	10	41
IT8-Campania	9	44
ES7-Canarias	9	46
ES24-Aragón	9	52
ES62-Murcia	9	43
ES12-Principado Asturias	9	44
ES53-Baleares	8	59
ES51-Cataluña	8	57
IT92-Basilicata	7	40
IE-Ireland	7	39
ES52-Comunidad Valenciana	6	47
ITA-Sicilia	5	42
ES41-Castilla y León	4	42
PT15-Algarve	4	35
IT91-Puglia	4	45
PT13-Lisboa e Vale do Tejo	3	54
GR24-Sterea Ellada	2	50

Losing regions $R^{ss} = 0$	α	R^i
FR83-Corse	0	51
GR11-Anatoliki Makedonia, Thraki	1	38
ES42-Castilla-la Mancha	0	39
ES11-Galicia	0	36
GR23-Dytiki Ellada	0	35
ES61-Andalucia	0	35
ES43-Extremadura	0	30
PT12-Centro	0	29
PT11-Norte	0	36
GR43-Kriti	0	45
GR13-Dytiki Makedonia	0	44
GR41-Voreio Aigaio	0	28
PT14-Alentejo	0	26
GR14-Thessalia	0	40
GR21-Ipeiros	0	29
GR42-Notio Aigaio	0	48
GR22-Ionia Nisia	0	38
ITB-Sardegna	0	46

Abbreviations: α indicates the region's "social capability" and is defined by equation (10), R^i represents the initial GDP per capita ratio defined by equation (5) and R^{ss} is the steady state GDP per capita ratio given by equation (12). The Danish DK-2 region is an aggregation of Vestsjllands amt, Storstrøms amt and Bornholms amt and DK-4 is made up by Sønderjyllands amt, Ribe amt, Vejle amt, Ringkøbing amt and Viborg amt.

In "potentially fast converging regions" "social capability" in terms of qualification and physical infrastructure is as important as in best performing regions. However, R&D activities are relatively less developed and the average technology gap is about twice as large. According to the technology gap literature and consistent with our estimations, these regions are prime candidates for convergence since their substantial endowment of "social capability" makes successful adoption of new technology possible.

About two thirds of German and Danish regions, one third of Austrian regions as well as the Swedish region Västverige exhibit these characteristics. Their process of convergence can be accelerated in concentrating regional development policies on R&D activities. For "converging regions", the diagnostic is basically the same as the one for "potentially fast converging regions" but is accentuated in terms of R&D deficiencies with respect to leading regions. Global "social capability" endowment is just sufficient to permit convergence to the current development level of leading regions.

Within the group of regions moving towards their own steady state level of GDP per capita, three major categories are distinguished in Table 3: **catching up regions** climbing to a steady state level of GDP which is higher than their current one, **falling behind regions** for which the contrary prevails and **intermediate regions** moving, on average, to a steady state level of GDP per capita half of the one of converging regions. "Potentially fast catching up regions" are "best performers" within the **catching up** group. If, on average, their current technology gap is similar to the one of converging regions, a lower endowment of "social capability" in the field of qualification as well as R&D activities prevents them from converging entirely to the development level of technology leaders. While Île-de-France clearly constitutes a technological leader, no French region is converging to the development level of the latter. Best performing French regions such as Alsace, Franche-Comté, Rhône-Alpes, Midi-Phyrénées, Aquitaine, Auvergne and Bourgogne are only "potential fast catchers up" moving to a steady state level of GDP per capita about 25 % below the one of Île-de-France, Bruxelles and Hamburg. For Belgian regions, The Netherlands and the remainder of non-converging Danish and Austrian regions a similar observation prevails. In comparison to potential fast catching up regions, GDP per capita of "Steady regions" is expected to evolve little. Social capability is just enough to maintain the current situation. In order to make catching up possible, Provence Alpes-Côte d'Azur and Haute-Normandie should foster qualification improvement. While Smland med Öarna ought to concentrate on the development of R&D activities, Valle d'Aosta and Liguria need to improve both, qualification and R&D capabilities.

On average, **intermediate regions** move towards a steady state level of GDP per capita which represent half of the one of technological leaders. However within the group, catching up, steadiness as well as declining can be observed. "Catching up regions" exhibit an important technology gap which is much higher than the average one of intermediate regions, whereas the contrary can be observed for "social capability". According to the technology gap literature and consistent with our estimations, the juxtaposition of these factors makes catching up possible. On average, La Rioja, North West, Limousin, Languedoc-Roussillon and Attiki are expected to move from a current average level of relative GDP per capita of about 0.49 to a steady state value of 0.60. However, catching up is rather an exception within the group of intermediate regions. For the majority of the latter, GDP per capita is expected to evolve little. "Steady regions" are characterised by a medium technology gap and a medium level of "social capability". While for French, Italian, United Kingdom's and Spanish steady regions catching up presupposes important qualifications improvements as well as the development of R&D capacities, in Nordic regions, policy efforts should be concentrated on the endowment of physical capital. Whatever the current technology gap, low "social capability" is the common determinant of "declining regions" characterised by a steady state GDP per capita below their current one. Without important policy efforts aiming at strengthening "social capability", about half of United Kingdom's regions and one third of

Italian regions are expected to decline despite their low current technology gap. However, this diagnostic should be tempered especially for Italian regions. The "industrial district structure" of their productive systems is largely based on informal networks, co-operations on mutual trust (Pyke and Sengenberger 1992). These region specific endogenous factors considerably speed up technology diffusion, innovation adoption and knowledge creation. In such a context, official R&D business expenditure data may incorrectly reflect the effective social capability of these regions.

Belonging to the group of **falling behind regions**, the above reflections should also moderate the relatively problematical position expected for Lombardia, Veneto and Toscana. If on average the current GDP per capita of "falling behind regions" is about half the one of technological leaders, it is anticipated to move towards a steady state value of about 0.18. Extremely weak R&D capacities and important deficiencies in terms of qualification explain the falling behind region's negative growth dynamics. Finally, for **losing regions** the diagnostic is basically the same as the one for "falling behind regions" but is accentuated in terms of physical infrastructure deficiencies. Without an increased effort to raise "social capability", extreme and permanent backwardness seem to be the only perspective for the great majority of Greek, Spanish, Portuguese and South Italian regions.

3.2.   Some salient observations and reflections

In considering the grouping of regions illustrated in Table 3, it is worth noting some specific observations. There is an obvious dichotomy between federalised countries and countries which exhibit a more centralised structure. Regions belonging to federalised countries such as Germany, Austria and Belgium are performing clearly better than those belonging to countries with a relatively centralised structure. This is for instance the case of French regions, which are principally concentrated within groups of "intermediate regions" while Île-de-France is one of European leading regions. The message seems clear, an increased regional autonomy favours the local development of "social capability". This is not surprising since local authorities are, generally, more aware of local needs and are potentially better adapted to satisfy them, than the central authority (Braczyk, Cooke and Heidenreich 1998). However, it should be noted that federalism in this context must not be exclusively understood in terms of the legal organisation translated in the constitution of a country[12]. In our context, federalism refers to "real federalism" implying local responses and solutions to local challenges. "Real federalism" is based on the existence, at local level, of a high degree of consensus and efficient "private-private", "private-public" co-operations characterised by "partnerships" involving local authorities, national government, regional authorities, private business and the voluntary sector. With respect to this definition, "legal federalism" is not a guarantee for "real federalism" and "real federalism" can occur in "non federal" countries. "Real federalism" certainly characterises Germany and Austria but also Denmark and Belgium. In France, which is a "decentralised" state, as well as in Spain and Italy, which are "regionalised" countries, "real federalism" does not seem to prevail[13].

Even if it is less straightforward, in considering the clustering of Table 3, another dichotomy can be detected between regions belonging to the core of Europe and those situated on the European periphery. Ireland, Greek, Portuguese and Spanish regions are essentially classified in the groups of falling behind and losing regions. Being more or less far away from the European decision centres, it seems to be

relatively difficult for them to attain a level of "social capability" that permits them to catch up. One of the reasons that impedes catching up is shown to be the relative shortage of physical infrastructure, particularly in the field of transport (Biehl 1986; Keeble et al. 1982, 1988; Baldwin and Forslid 2000)[14]. Transport networks are still less developed in peripheral countries than in the core of Europe despite important external financial support (European Commission 1999). This situation leads to disadvantages in terms of transaction costs and economic attractivity, factors that hamper industrial and market service development. Where industrial activity is relatively low especially in technology advanced areas, related capital investments and know-how embodied in human and physical capital are scarce. In such circumstances, the emergence of a "learning economy" (in the sense of Lundvall 1988, 1992) evolving towards a "knowledge-based economy" able to compete in the context of globalisation is difficult to promote in practice. However, physical infrastructure deficiency even if important, is not the only disadvantage of peripheral regions. Distanced form the European decision centres, they encounter difficulties to integrate into formal and informal decision-making networks, which are crucial to making efficient working business trans-regional strategic alliances and co-operation programs. The peripheral situation also represents an important obstacle to benefit from knowledge spillovers and other kinds of positive externalities generated within the European core.

4. CONCLUSION

Over the last two decades, many studies have been investigating the catching-up hypothesis within the European regional landscape. These studies confirm the breakdown of the convergence process after 1980. If most empirical research in this field is based on single absolute or conditional equation methods "à la Barro", our approach drew on the technology gap literature where "social capability" is considered as a prerequisite for convergence. "Social capability" has been approximated by three variables namely, the qualification level of the working age population, the physical infrastructure endowment and R&D business expenditures. Compared to the traditional convergence approaches, the advantage of our framework relies on the explicit causal structure and the incorporation of "social capability" which provides interesting insights not available through the estimation of reduced forms. This approach enabled us to shed some light on the need of additional efforts to increase "social capability" in order to reduce the technology gap and thus to speed up economic convergence.

Estimated on the basis of 153 European NUTS I and NUTS II regions over the period 1989-1996 (that is a sample of regions more than twice as large as the ones used in related studies), the simultaneous equation model of cumulative causation developed in this paper lead to the following comments. The rate of aggregate output growth was shown to depend positively on the initial technology gap of a region with respect to the technology leaders, the employment concentration in industry and services, the endowment of physical infrastructure and the qualification level of the working age population. Actually, the relation between the economic structure of a region and its growth performance is simultaneous in the sense that the growing demand addressed to a region boosts industry and service employment. The effects of patenting on the economic structure are similar since the existence within a region of innovative activities reflects is ability to absorb technologies developed elsewhere and possibly its capacity to develop its own ones - a necessary condition to increase competitiveness and thus industrial and service employment.

Finally patenting activity was shown to be positively influenced by R&D expenditures as well as by the qualification level of the working age population while the technology gap exerts an opposite effect.

The estimated coefficients were used to evaluate the different growth patterns currently taken up by the European regions. Considering Bruxelles, Hamburg and Île-de-France as references, we evaluated that about 30 % of European regions will converge to the level of development achieved by these three best performing European regions, 57 % move to their own steady state level of GDP per capita but never catch up these frontier regions and for 13% of the European regions, relative backwardness appears to be a recurrent issue of the growth mechanism. However, these findings rely on the assumptions that regional development policies are not changing over time and that GDP per capita of the three best performing regions remain unchanged. An obvious dichotomy between federalised countries and countries which exhibit a more centralised structure could also be observed. Regions belonging to countries where "real federalism" prevails clearly perform better. Even if less straightforward, another dichotomy could be detected between regions belonging to the central core of Europe and regions situated on the European periphery. According to our analysis, the latter converge to extremely low levels of steady state GDP per capita.

While our approach allows some interesting insights into the growth mechanism, the results should not be taken too literally but rather considered as indications. Probably, the growth performance of some regions has been underestimated while that of others may have been overestimated since the ingredients of "social capability" are certainly not limited to the variables taken into account in the model. The non-availability of more detailed data made it impossible to integrate other components that are however important for a complete evaluation of a region's "social capability" such as, for instance, an appropriated financial system, higher education centres and universities and their formal and informal links to networks integrating private and public socio-economic agents. The constitution of an European regional database in the above mentioned areas would not only enable a deeper insight into the growth forces at work but also the implementation of more efficient regional development policies.

These last comments naturally lead us to some considerations in terms of policy implications. Firstly, it was shown that qualification is an important part of social capability in the sense that improvements in this field enable the reduction of the technology gap. Secondly, lagging regions still suffer from a relative underdevelopment of physical infrastructure. Both elements seem to be partly responsible for the lack of innovative activities in lagging regions. Does this consideration mean that the latter are able to catch up in concentrating their policy efforts exclusively on qualification or alternatively on physical capital? A real improvement of "social capability" in lagging regions probably can not be achieved by adopting a dichotomous approach. Increased public incentives to enhance private R&D expenditures in a given sector without a simultaneous education and training programme specially adapted to the (latent or expressed) needs of the business enterprise sector will probably fail to hit the target. There is urgent need for a systemic policy approach not only at both, the national and regional levels but also, and above all, at the European level if socio-economic cohesion within Europe should become reality one day.

Our analysis was essentially based on aspects that refer to "social capability". An interesting area of investigation is certainly "technological congruence". We consider that the creation of a regional

"technological neighbourhood matrix", although a tricky operation, would represent an important contribution to the technological gap literature. Furthermore, an extremely interesting investigation consists in introducing into the basic framework, data, that, firstly, reflect the degree of "real federalism" within a region and, secondly, the region's distance with respect to the European decision centres. Together, these two elements seem to be influential determinants of a region's capacity to raise "social capability". Further research in this field will contribute to a better understanding of the growth mechanisms of leading as well as of lagging regions.

NOTES

[1] In fact, the convergence hypothesis has mostly been expressed with at least some qualifications (Baumol 1986; Delong 1988; Mankiw et al. 1992; and others).

[2] For an overview of empirical work on catch up and growth, including its theoretical underpinnings, see FAGERBERG (1994).

[3] Raw data come from Eurostat.

[4] For reasons of non availability of more desaggregated data, the selection of the three best performing regions was based on the regional desaggregation level NUTS II. However, at a more desaggregated level, other regions such as München, Frankfurt and London perform better than Bruxelles and Hamburg.

[5] In addition, several alternative measures of the technology gap were tested: technology gap based on the technological intensity (ratio of total real R&D expenditures over real GDP), technology gap based on the technological base (ratio of total real R&D expenditure over total population) and technology gap based on the propensity to patent (ratio of total number of patents over total R&D expenditure or alternatively over total population). However since, in general, the time span is relatively long between the moment where R&D expenditures are realised and the moment where these expenditures have an impact on economic growth, the alternative measures turned out not to be significant with respect to our relatively short period.

[6] For reasons of non availability of desegregated data, the variable also includes public services which is however supposed to have little influence on technological progress.

[7] Simultaneity is confirmed by the Hausman specification test.

[8] While other proxies such as the density of the telecommunication network would have been best candidates to capture the "capital-embodied technology effect", these variables are not available at the regional level.

[9] The system has also been tested by using 3SLS. Statistically, the differences with the FIML estimates are not significant.

[10] These average values are respectively 0.25 for the employment rate of highly and moderately working population and 0.43 for the technology gap.

[11] Only a non-negative value of R^{ss} makes sense from an economic viewpoint.

[12] There are only 3 federal states in the European Union: Germany, Austria and Belgium. Italy and Spain are "regionalised" countries and France is a "decentralised" country. It is beyond the scope of this work to deepen the different legislative implications of these organisational forms but for readers interested in this field, the following edition is strongly recommended: DEYON P., (1997), *Régionalismes et régions dans l'Europe des quinze*, Editions locales de France, Bruylant.

[13] The identification of "real federalised" countries is based on an investigation of the delivery system developed for the European Structural funds (EUROPEAN COMMISSION, 1999). In this system, the extent of inclusion of local representatives is flexible and at the discretion of Member States. It can be reasonably deduced that the extent of inclusion of local authorities complies with the traditional practice of authority delegation prevailing in a country.

[14] For an overview of empirical work, investigating the contribution of transportation networks to regional growth, see QUINET (1992).

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