Cognitive Capital and Islands of Innovation: The Lucas Growth Model from a Regional Perspective

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INTRODUCTION

At any institutional level of regional policy, from the European Union to regional governments, policy-makers are aiming to reduce spatial disparities by focusing on factor endowments (EUROPEAN UNION, 1999).[1] In particular, skill levels and educational attainments are often considered to be of strategic importance. In a knowledge-intensive economy human capital is a major driver of regional performance; hence, small differences in human capital endowments may induce large long-run differences in economic performance in a spatial economy.

Despite the broadly recognized relevance of spatial imbalances, there is growing evidence of disparities across the European space in terms of human capital endowment. Not only labour flows from peripheral to core regions, but also regional human capital tends to concentrate in a few high-performance regions in the what is known as 'Pentagon' area in Europe. This process is linked to the emergence of 'islands of innovation' (HILPERT, 1992, 2009; COOKE *et al.*, 2000; KOURTIT *et al.*, 2011) or, in other words, spatial singularities where innovative activities tend to concentrate. In qualitative studies, such as that by BAGCHI-SEN and LAWTON-SMITH (2008), the reasons for this Marshallian concentration of innovative firms in spatial clusters are analysed from a perspective analogous to that of the present paper.

In order to illustrate possible time trends in the concentration of the skilled labour force in Europe, Figs 1a and 1b show, respectively, a time-series of the Krugman Specialization Index[2] and the Fractionalization Index (ATLAS NARODOV MIRA, 1964).[3] This paper measures regional human capital as the regional labour force (in European NUTS-1 regions[4]) with ISCED 5 and 6 education.[5]

Fig. 1a shows how, in recent years, the European regions have departed from the average European Union educational level. This implies that regions have been either specializing or de-specializing, implying a growing concentration of the educated labour force in selected islands of innovation. Fig. 1b, then, shows the probability that two randomly selected individuals meet people who have a different educational level, providing evidence that because of the widespread changes in the spatial distribution of the educated labour force, the chance of two educated people from different regions randomly meeting when travelling is decreasing over time.

With these two indices as background information, the aim is to analyse two relevant issues relating to European regional human capital:

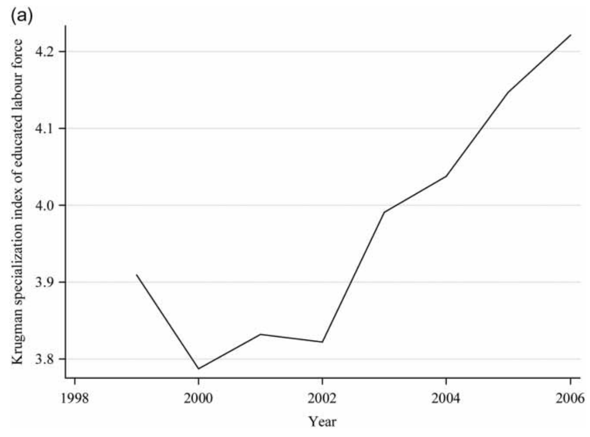

Fig. 1a. *Krugman Specialization Index for an educated labour force, NUTS-1 regions*
Source: Eurostat, 1999–2006 data, authors' own calculations

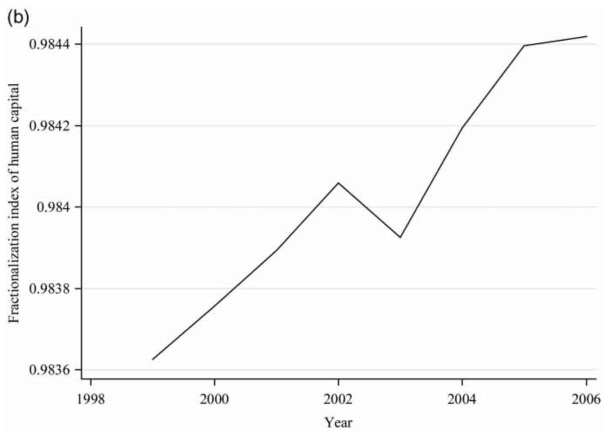

Fig. 1b. *Fractionalization index for an educated labour force, NUTS-1 regions*
Source: Eurostat, 1999–2006 data, authors' own calculations

- To identify the difference between the human capital endowment of each region *i* and all other regions by taking the absolute values of the difference between their shares of human capital-rich labour force, summed over all regions.
- To measure the probability that two randomly selected individuals from a population have different levels of education.

Both graphs (Figs 1a and 1b) show an upward trend: this implies generally both a growing regional concentration of an educated labour force in fewer *islands of innovation* (HILPERT, 1992) and a growing probability for individuals within each region to meet people with different levels of education. Therefore, time-series show an increase in both cross-regional as well as intra-regional differentials of human capital-rich labour force.

The concentration of an educated and innovative labour force calls for a solid conceptual and empirical analysis. The discrepancy between policy objectives and actual achievements is due to several complex reasons. This paper argues that a severe misspecification of the problem may be caused by ignoring the role of what is called cognitive capital in the specification of the correct production function underlying the economic analysis. It is argued that including informal cooperation patterns among workers and firms, as well as the economic value of cooperating in a production function, may add significantly to an understanding of the emergence of 'islands of innovation'. Moreover, by using modern spatial econometric techniques, the long-run impact of each of the variables considered is verified, therefore possible spillover effects of human capital and cooperation networks in regional innovative labour forces are identified.

This paper is organized as follows. The second section critically reviews the most influential studies on the theory of human capital. The third section introduces the concept of cognitive capital, and then offers the authors' own definition of this concept. The fourth section paves the way for empirical estimates by setting up a micro-founded regional growth model based on the work of LUCAS (1988). The fifth section contains a detailed description and a relevant analysis of the spatial distribution of the data employed in this empirical study. In the sixth section empirical tests are carried out on the basis of the main theoretical model. Finally, the seventh section concludes.

HUMAN CAPITAL AND ECONOMIC GROWTH

The traditional approach

Since the seminal work of BECKER (1964) and MINCER (1974), many publications have been devoted to disentangling the complex relationship between level of education and economic performance. In view of the endogenous elements in this dynamic relationship, it is not easy to identify unambiguously cause–effect patterns in a long-run analysis. The literature on the role of education in explaining long-run growth started from the striking fact that neoclassical predictions on the relatively fast convergence of countries towards their steady-state growth rates showed disappointing results in real life. The 1960s was a decade of exceptionally fast growth in most Western countries, and several least developed countries tried to achieve a rapid pace of development by means of accumulating physical factors. However, this did not suffice to achieve their goals, and economists found a likely reason for this failure in the relatively low endowment of education and skills in the least developed countries' labour forces.

BECKER (1964) and MINCER (1974) have summarized at length the rich literature on this topic produced in the 1960s and 1970s, with a clear exposition of some possible ways in which human capital in a broad sense may cause an increase in the long-run growth rates of countries (although being a-spatial in nature, most of the conclusions of these works can be applied to regions as well).

There are numerous studies that arrive at similar findings. A comprehensive review of more recent versions of such studies is given by KRUEGER and LINDAHL (2001). Their study offers a theoretical bridge between 'Mincerian' (that is, studies at the micro-level with the general aim of identifying monetary returns from an additional year of education) and human capital-based growth regressions, where a society's aggregate level of education is shown to be positively correlated with the country's growth rate. Among the most recent and comprehensive studies of the first type, ASHENFELTER *et al.* (1999) constructed a comprehensive meta-analysis of micro-returns and found that the ordinary least squares (OLS) returns to education averaged 0.066, whereas instrumental variables (IV) estimates yielded an average return of 0.093 per year, on a sample of ninety-six estimates and twenty-seven studies.[6] However, the most frequently cited study on the role of human capital in long-run growth is that by MANKIW *et al.* (1992), where a bridge between traditional neoclassical growth models à la Solow and Swan (SOLOW, 1956, 1957; SWAN, 1956) and endogenous growth models was built through the mechanism of human capital.

Correlations between education and economic performance are traditionally explained on the basis of the theory of human capital (BECKER, 1964; MINCER, 1974). This theory posits that as individuals commit more time to the accumulation of skills, they become more productive in the workplace. Mincer's famous wage equation reads as follows:

$$\ln W_i = \beta_0 + \beta_1 S_i + \beta_2 X_i + \beta_3 X_i^2 + \varepsilon_i \qquad (1)$$

where $\ln W_i$ is the natural base log of the wage of the i-th individual; S_i is a measure of level of education; X_i

Table 1. Theories on the role of human capital in regional development

Definition of distance	Physical	Relational	Institutional
Knowledge theory	Knowledge spillovers	Milieu *innovateur*	Learning region

is a measure of experience; X_i^2 is experience squared; and ε_i is a disturbance term. The idea behind this literature is that the labour force becomes more productive as the level of formal education increases. Although this model offers a consistent improvement in one's understanding of how labour markets work, this early literature was not capable of fully explaining what the classical SOLOW (1956) model left unexplained.

More recently, it has also been recognized that formal education may exhibit increasing returns when moving to the aggregate level: not only does more education make people more productive per se, but also there are increasing returns because of the mutually more productive interaction of higher educated people (BOOTH and COLES, 2007; TROSTEL, 2004).

While neoclassical economics dealt with human capital and growth mainly by means of micro-founded mathematical models, regional economists tended to study the role of education in regional competitiveness primarily on the basis of a more qualitative case study approach. Using internally coherent analytical frameworks, it was argued that a systematic investment in enhancing the educational and knowledge basis of regions would lead to an increase in the long-run performance of regional systems. Clearly, regions may be hampered by socio-cultural isolation and geographical distance frictions. Following CAPELLO (2007), the main analytical approaches on the role of education in regional development are classified here by their underlying treatment of distance (or proximity) (Table 1). This systematic survey table raises the issue of knowledge spillovers to adjacent regions.

The Knowledge Spillover (KS)[7] theory studies the role of physical proximity (as a proxy for a more complex underlying distance variables) in explaining knowledge transfer processes among agents and regions (DÖRING and SCHNELLENBACH, 2006). If knowledge were a truly public good, and space did not matter, a spatially even distribution of knowledge indicators should be observed. Real data, on the contrary, show that knowledge and innovation are highly concentrated economic facts, which, according to the KS theory, may be due to the tendency of economic agents to access physically close knowledge because of lower transaction and transport costs, shorter distance in terms of tacit and social knowledge, and local social or network capital. Operationally, KS has been analysed in three main ways:

- Tracking patent citations, following the seminal study by JAFFE *et al.* (1993).
- Following the career paths of 'star-scientists', based on the assumption that consistent knowledge is embedded in people, who bring it to new workplaces when they relocate (for example, TRIPPL and MAIER, 2010).
- Testing knowledge production functions in spatial econometrics models, where the coefficient of the lagged dependent variable, which usually is a measure of knowledge output, represents an assessment of the extent to which knowledge flows over space (for instance, FISCHER and VARGA, 2003).

The modern approach

Physical distance cannot account for all regional variations in human capital growth-enhancing effects. Moreover, in the long run, education levels tend to grow steadily over all advanced regions, although it ought to be recognized that innovation and economic performance still display wide differentials. These have been mainly accounted for by means of two, territorially oriented and spatially bounded, definitions of proximity: relational and institutional proximity. The first definition of distance mainly characterizes the 'innovative milieu' theory (for example, AYDALOT, 1986; AYDALOT and KEEBLE, 1988; BELLET *et al.*, 1993; CAMAGNI, 1991, 1995; CAMAGNI and MAILLAT, 2006; RATTI *et al.*, 1997); the second definition characterizes the learning region approach (also HASSINK, 2005).

According to both theories, regional knowledge is the basis for a region's socio-economic performance. The local relational aspect of the mechanism of the formation of increasing returns is the focal point of the *milieu innovateur* approach. This was developed by the GREMI group;[8] it focuses mainly on the construction of knowledge through cooperative learning processes, enabled and fostered by spatial proximity (which enters the theoretical foundations of the *milieu* literature as a form of 'atmosphere' effects), network relations (where long-distance relationships can be as effective as face-to-face contacts in a selected set of top-notch, knowledge-intensive relationships), socio-cultural interaction, and creativity. The role of the local *milieu* is to make things happen: abstract geographical space becomes real 'territory', that is, a relational space where functional and hierarchical, economic and social interactions take place and are embedded in active geographical space. The *milieu* works as a 'cognitive engine' fostering innovation by reducing uncertainty and information asymmetries, fostering interactions among agents and, finally, socially sanctioning free-riding, thereby reducing its likelihood of occurrence (CAMAGNI, 1991, 2004; BELLET *et al.*, 1993; RALLET and TORRE, 1995; CAPPELLIN, 2003).

A different approach has formed the basis of the learning region theory (LUNDVALL, 1992; LUNDVALL and JOHNSON, 1994; MORGAN, 1997). In this case, it is mainly the institutional distance that forms the basis of evolutionary economic growth analyses. The 'learning region' approach addresses local actors and their interactions which belong to a system of homogeneous socio-economic and institutional conditions. Although this has often been applied to regional development analyses, it is essentially an a-spatial approach: it has in fact been applied to different spatial aggregations related to nations or regions. Its main contribution is, therefore, the stress put on the role of knowledge for the socio-economic success of a spatial unit. The spatial component enters the analysis only through spatial networks. In a mainly qualitative approach, increasing returns are triggered by the interactions among economic agents in this ideal knowledge economy.[9] This process tends to stimulate the rise of 'islands of innovation'.

All these theories share some common elements, which form the root of the analysis presented here. All regional theories underline the role of synergies among actors, and in particular the characteristic of the formation of increasing returns to knowledge use in trust-oriented networks. Labour markets thus benefit from a capital of stable, business-oriented relationships, that may enhance the emergence of increasing transactions by reducing costs and completing contracts. Therefore, these theories may work as tools to interpret and explain both the formation and the evolution of European islands of innovation.

COGNITIVE CAPITAL: OLD WINE IN NEW BOTTLES?

The idea behind this paper is that formal education does not suffice per se to generate increasing returns in regional growth. While more educated workers are also on average more productive, the network of such workers may benefit from an increased wealth of cognitive characteristics, which is labelled here as 'cognitive capital'. In fact, such externalities in the form of synergies among individuals arise when cooperation becomes not only feasible, but also inexpensive; and this in turn happens when trust, a sense of belonging or the existence of long-lasting business relations characterize networks of actors.

This argument is strongly linked to the social capital literature. The idea of social capital has enjoyed vast academic and policy support in the last twenty years. Among the reasons for this achievement is the availability of theories explaining the reasons why, and the ways how, norms, values and institutions may affect economic outcomes,[10] as well as the collection of large sets which enable researchers to verify such theories empirically. In fact, between the 1980s and the 1990s, various influential studies (COLEMAN, 1988; BOURDIEU, 1983; PUTNAM, 2000; PUTNAM *et al.*, 1993; FUKUYAMA, 1995) attracted the interest of both academicians and policy-makers on the mechanisms through which norms, networks and institutions (that is, social capital) determine the way societies interact.

Subsequently, a burgeoning stream of research in the economic and sociological domain[11] has focused attention on why societies with similar endowments of physical capital performed so differently, even when accounting for a number of potentially relevant countrywide or firm-specific controls (that is, the level of education of individuals and the workforce, the endowment with natural resources, potential access to rich markets, etc.). The recent emergence of neuroscience as a discipline which merges evolutionary and learning-based research from medical science, psychology, anthropology and the natural sciences has prompted much interest in the complex mechanism that governs the way the human mind perceives the surrounding environment. That has induced new ideas on cognitive drivers in economic development.

UPHOFF (1999) proposed an insightful classification of the concept of social capital, based on two interrelated categories of phenomena, namely *structural* and *cognitive* social capital. The former is defined as the forms of social organization (in particular roles, rules, precedents and procedures) that contribute to cooperative behaviour, and ultimately determine mutually beneficial collective action (seen as the positive outcome of social capital). In the spirit of structural social capital, cognitive (social) capital is then defined as

> mental processes and resulting ideas, reinforced by culture and ideology, specifically norms, values, attitudes, and beliefs that contribute cooperative behavior and mutually beneficial collective action.
>
> (UPHOFF, 1999, p. 218)

Cognitive social capital lies, therefore, at the roots of the positive effects of social capital, and can be seen as the mindset that motivates economic agents who engage in mutually beneficial collective action. From an economic point of view, this happens through the higher predisposition of agents towards cooperation, trust (and trustworthy) behaviour, and an openness to new ideas. In this light, and following Uphoff's classification, the following definition is presented:

> *Cognitive capital is defined as the set of mental processes, reinforced by culture and ideology, in particular encompassing norms, values, attitudes, and beliefs that positively contribute to cooperative behaviour and mutually beneficial collective action.*

From a neuroscience perspective, the concept of cognitive capital rests on the notion of *cognitive functions*. These are

> concerned with those human faculties such as memory, attention, perception, problem solving and mental imagery that are central to cognitive capacity and adaptive capability in adult life.
>
> (BYNNER and WADSWORTH, 2007, p. 3)

The set of actors' perceptions of the surrounding environment comprises the actors' cognitive map. When the focus moves to more aggregate and complex systems such as regions, aggregate cognitive maps comprise so many objects that it becomes difficult to represent them synthetically. In fact,

> the basic problem is that the mappings we are trying to learn are usually multidimensional, possibly involving several dimensions in a complex, nonlinear relation. We only have a finite, often very small, data sample of real experiences from which to learn this mapping.
>
> (DENZAU and NORTH, 1994, p. 7)

This is the point of departure for a new, regional concept of cognitive capital. In order to understand better the economic side of the concept of cognitive capital, the object of the present analysis needs to be focused on a subset of individual perceptions, or elements, in the cognitive map.

If a world of imperfect information and incomplete contracts is assumed, repeated interaction where trust is missing may become cumbersome and inefficient. Completing contracts may require a lengthy and detailed list of rules to obey and subsequent punishment for infringing them. In the people's mind, a belief concerning the possible behaviour of the counterpart of any economic interaction determines the agents' actions at least as much as other, more objective economic facts (such as market conditions, current exchange rates, the availability of a high-quality labour force, etc.). If those beliefs concern possible infringements of formal contracts, more time and resources will be devoted to writing down complex formulae to avoid the free-riding behaviour of actors. However, this type of behaviour may not necessarily become a reality, since economic interactions may be fostered by a capital of trust among individuals. The higher the level of trust among actors, the higher the ease with which economic interactions can take place, the lower transaction costs among them, and the stronger the sense of belonging to the same social environment; in other words, the stronger the inclination to cooperate.

The next section outlines a model based on Lucas's endogenous growth theory, including knowledge factors. This model was inspired by the above-mentioned cognitive approaches. The fifth section below provides more details on the way cognitive capital is measured in an empirical analysis.

A MODEL FOR COGNITIVE CAPITAL AND SPATIAL KNOWLEDGE SPILLOVERS

In order to frame better the research question in the context of sound economic theory, this paper adapts the LUCAS (1988) growth model for the interpretation of regional growth patterns. Despite its long career as a theoretical tool, it has seldom been subject to empirical verification, whilst originally Lucas's work was also meant as an applied 'software' capable of explaining real growth patterns:

> I prefer to use the term' theory' in a very narrow sense, to refer to an explicit dynamic system, something that can be put on a computer and run.
>
> (LUCAS, 1988, p. 5)

The present paper uses this theoretical model to interpret regional growth patterns. This choice was motivated mainly by two arguments. First, the authors believe a good theoretical framework is needed in order to break down correctly the complex relations between regional growth-enhancing factors and regional performance: it is now a truism to state that regional levels of education drive regional performance, but at the same time the reverse is, at least in the long run, true. The use of a micro-founded theoretical model as a base for applied work allows the identification of correct causal mechanisms.

Also, the adoption of this model is not neutral, but adapted to the regional setting through the use of the novel concept of cognitive capital, which is inherently space specific and cannot freely move across space. This generates a different set of incentives for local actors, which are imperfectly free to move and are induced to concentrate in 'islands of innovation', since local societies, endowed with high stocks of cognitive capital, generate inherently local externalities, which in turn increase the returns from individual decisions on education investment. Therefore, the choice to adopt this model, which is in itself a well-established toolbox, offers a new contribution to the existing literature by identifying region-specific characteristics that make underlying competition mechanisms imperfect, and alter the spatial distribution of incentives available to individual agents.

This section shows how an endogenous growth model with a cognitive capital externality can generate increasing returns to physical production factors. Here, it follows the approach advocated by LUCAS (1988). As REBELO (1991) pointed out, endogenous growth models obtain long-run growth with a factor that can perpetually accumulate, while never falling into decreasing returns. In the original LUCAS (1988) growth model, this mechanism is the average human capital in a society or area: people enjoy positive spillovers from fellow members of the same social group, thus becoming more productive themselves. In the present version of the model, the mechanism that produces increasing returns is the presence of higher cognitive capital.

At the individual level, the production function in the original Lucas growth model exhibits constant returns to scale, so that technological progress is assumed to be exogenous, as in SOLOW (1957). To avoid this trap in the growth analysis, it is assumed that people benefit from positive externalities from cognitive capital. In an environment that is endowed with fluent interpersonal relationships, where people trust each other, tolerance for diversity enhances creativity, and governance of cultural and natural institutions can properly manage public endowments, people are expected to gain more than proportionally in productivity. This is in line with the concept of islands of innovation.

Lucas's model incorporates the agents' choice on how much time to devote to education and to working. The economy is made up of $N(h)$ workers with skill level h; therefore:

$$N = \int_0^{\infty} N(h)\mathrm{d}h$$

Each worker faces the choice of how much of his/her non-leisure time to devote to work, $u(h)$, while the rest, $1 - u(h)$, is devoted to education (the activity which allows the worker to accumulate human capital). Aggregate human capital in the model is defined as:

$$h_a = \int_0^{\infty} hN(h)\mathrm{d}h / \int_0^{\infty} N(h)\mathrm{d}h$$

LUCAS (1988) assumed that some of the positive effects of human capital accumulation were not taken into consideration by individual agents when deciding how much time to allocate to education (hence, they faced a real, positive, externality). The stock of human capital is accumulated by obeying the following law of motion:

$$\dot{h}_1 = h_1 \delta(1 - u_1), \qquad u_1 > 0 \tag{2}$$

whilst preferences over consumption are described by a constant elasticity of substitution (CES) function of the usual form:

$$U_0 = \int_0^{\infty} \frac{c_t^{1-\sigma} - 1}{1-\sigma} e^{-(\rho-\lambda)}\mathrm{d}t \tag{3}$$

where $\sigma - 1$ measures the inter-temporal elasticity of substitution; and ρ is a discount rate. In the Lucas growth model, labour productivity is raised not only by individual human capital, but also as a result of the increase in the aggregate level of human capital. Mathematically, this boils down to solving the model from an individual (household) and a (benevolent) social planner perspective. Whilst individuals do not take into account the positive externalities arising for the society in which they live, and stemming from their individual choices of the level of h_i they accumulate, the social planner does do this, thus preventing the society as a whole from under-investing in the education of individuals.

Analogously, when considering their time allocations, agents do not take into account the possible positive spillovers from their collective behaviour. Aggregate cognitive mechanisms, in the form of improved mutual understanding (for example, district economies), thick and dense social networks (relational capital), the wise management of collective goods that prevents spoiling natural resources, and the efficient transfer of research and development results, all combine as a cognitive catalyst that optimizes the combination of physical factors and generates increasing returns (also BATHELT and GLUCKLER, 2003; STEINER and PLODER, 2008). Therefore, it is not just aggregate human capital that determines the generation of increasing returns to individual education, but also the regional endowment of cognitive capital. This last point represents a crucial assumption in this paper and will be fully explained in the subsequent section.

The share of time $(1 - u)$ devoted to education in the model is not simply the result of the sum of individual time devoted to individual learning; a common mutual understanding, social networks, mutual trust and sense of belonging all generate collective learning, which is higher than the sum of knowledge obtained by the sum of individual time devoted to learning. Knowledge externalities arise as a result of an additional investment in the accumulation of these soft forms of capital.

The model for the individuals in this economy is:[12]

$$y_{r,t} = Ak_{i,r,t}^{\alpha}\left(uh_{i,r,t}\right)^{1-\alpha} \tag{4}$$

while the aggregate economy is described by the following equation:

$$y_{r,t} = Ak_{r,t}^{\alpha}\left(uh_{r,t}\right)^{1-\alpha} cc_{r,t}^{\eta} \tag{5}$$

where $0 < \alpha < 1$; and A, k, u and h are defined, respectively, as the technology parameter, the stock of capital (which is estimated with the perpetual inventory method[13]), the share of time devoted to working, and the stock of human capital (that is, education) of an individual (or a region); here cc is a measure of cognitive capital. The crucial assumption of the empirical component of this paper is that individuals create collective (that is, regional) cognitive capital when investing in their own education. Formally, the definition of the Lucas growth model externality may be rewritten as follows:

$$cc_{r,t} = \int_0^{\infty} h_{i,t}N(h)\mathrm{d}h / \int_0^{\infty} N(h)\mathrm{d}h \tag{6}$$

Equation (6) states that the average aggregate level of human capital in the economy ultimately creates the level of cognitive capital. The model based on LUCAS (1988) will now be tested empirically. The fifth section describes the data used to estimate equations

(4) and (5) and it explains the empirics of the measure of cognitive capital externality.

DATA SET AND ANALYSIS

To test the above model calls for extensive data. A comprehensive data set on European regions was built by combining Eurostat data for the quantitative variables in the Lucas growth model and European Values Study (EVS)[14] data for the cognitive elements of regional knowledge systems. All data covered a cross-section of the year 2000: this choice was motivated by the availability of EVS data for that year.[15] Table 2 shows the main sources of the data set. The top section of Table 2 shows the main variables used to test the Lucas growth model in an individual setting (see equation 4); the central part of Table 2 shows data for the aggregate setting test (see equation 5); and finally the bottom part of Table 2 shows the cognitive capital measures.

The individual household test was carried out on 16 929 observations in the EVS data set, which are those in the EU-27 for which there are answers to all four questions related to the Lucas growth model (Table 3).

The *uh* component, which represents a crucial departure of the Lucas growth model from similar endogenous growth models, can be aggregated at the regional level (by calculating regional averages of the household levels). This should thus reflect a double mechanism: the *u* variable should capture both the work incentives (given by the local wage structure, public incentives-to-work activities, etc.), as well as the social propensity to work (which tends to be spatially and socially clustered due to cultural factors; for example, HOFSTEDE, 2001).[16]

Table 2. Data set

Data description	Source
Household real income	EVS
Household education level	EVS
Household stock of capital/savings	EVS
Share of time devoted to work activities	EVS
Regional gross domestic product in constant 2000 prices	Eurostat
Regional investments (yielding the capital stock with the perpetual inventory method)	Eurostat
Regional human capital: share of human resources in science and technology	Eurostat
Cognitive capital elements (norms, values, attitudes and beliefs)	EVS

Note: EVS, European Values Study.

Fig. 2 maps the regional average levels of the *uh* variable, which does indeed show consistent spatial patterns, with peripheral countries (Spain, Greece, Italy, Bulgaria and the Baltic countries) presenting the highest combination of time devoted to work activities times the skills accumulated with private education.

The innovative feature in the present study is its attempt to measure cognitive capital variables. As the set of soft regional production factors is extremely complex both to understand and to represent, one of the most cited and convincing studies on social capital (PUTNAM, 2000) is followed in order to identify the four major axes along which cognitive social capital can be measured: community organizational life; engagement in public affairs; community volunteerism; and informal sociability (PUTNAM, 2000, p. 291). As these measures capture radically different economic facts, a principal components analysis (PCA) will next be employed.

EVS data cover all 'soft elements' domains. Each EVS question used had a specific aim and scale: to test for the effect of high levels of soft forms of capital on economic performance, and to calculate the percentage of the main answers given to each question for each region. Table 4 summarizes the questions chosen and the respective scales.

The PCA technique allows one to decompose the variance in the data set into a subset of variables which captures as much of the original variance as possible, without imposing a predetermined structure on the statistic summarizing the data. In other words, PCA represents the internal structure of an (*n*-dimensional) data set with a lower-dimensional picture, projecting the original data on a hyperplane of smaller dimensions.

Table 3. European Values Study (EVS) questions chosen to test the Lucas growth model at the individual household level

Variable	EVS identification	Question
Household real income	Q110 (v320)	Here is a scale of incomes and we would like to know to what group your household belongs, counting all wages, salaries, pensions and other income that come in. Just give the letter of the group your household falls into, after taxes and other deductions. (1–10 scale)
Household education level	Q94 (v304)	What is the highest level you have reached in your education? (1–8 scale)
Household stock of capital/savings	Q110a (o49)	Socio-economic status of the respondent. (1–4 scale)[a]
Share of time devoted to work (u)	Authors' own calculation	Obtained as 1 – Q93 (v303[b])/80
Units of effective labour	Authors' own calculation	Obtained as u*Q94 (v304)

Notes: [a]This is essentially a proxy for the extent of household savings, based on the assumption that the socio-economic status of the respondent crucially depends on his/her wealth.

[b]Question Q93 (v303) is: 'At what age did you (or will you) complete your full-time education, either at school or at an institution of higher education? Please exclude apprenticeships; eighty years is the assumed life expectancy at birth for all European Union citizens.

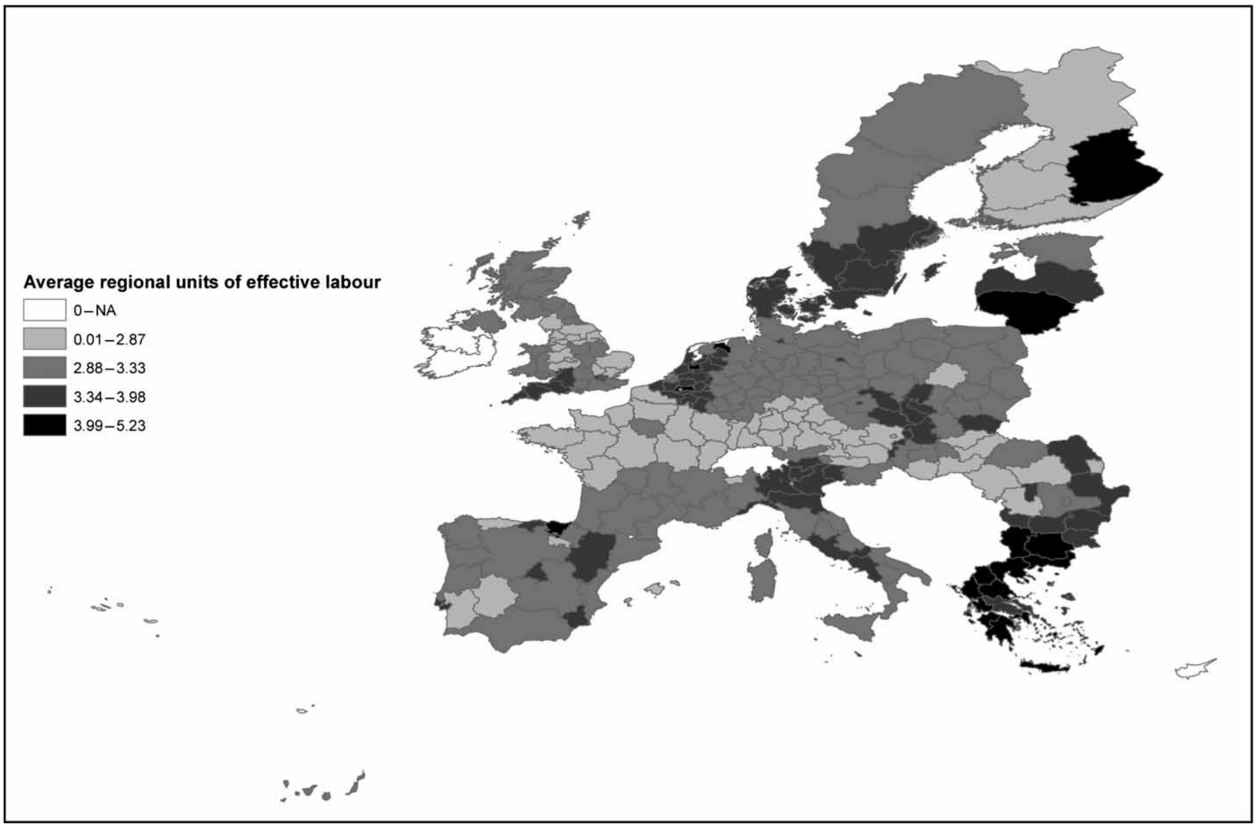

Fig. 2. Average regional units of effective labour in 2000

Table 4. Selected questions in the European Values Study (EVS) data set

Domain	Question	Scale
Community organizational life	How often is your time spent in clubs and voluntary associations?	1 Every week 2 Once or twice a month 3 A few times a year 4 Not at all
Engagement in public affairs	Participation in any social activity	0–1
Community volunteerism	Voluntary work in any community activity	0–1
Informal sociability	Agree that 'Most people can be trusted'	1 Trust them completely 2 Trust them a little 3 Neither trust nor distrust them 4 Do not trust them very much 5 Do not trust them at all

The indicator of cognitive capital is obtained by running a PCA for the above questions, following the line proposed by UPHOFF (1999) along with the Eurostat data which were described in Table 2. The first component explains 37% of the total variance; this is a satisfactory result, given the markedly different aspects that the indicators capture within the territorial capital theoretical framework. The vector scores highly in all cognitive characteristics underlying the sample (frequency of club meetings, engagement in public affairs, trust and a measure of cognitive receptivity, that is, the spatial lags of patent applications to the European Patent Office (EPO)). Therefore, this vector will be called 'cognitive capital'.[17] Cognitive capital as it is measured is characterized by a synergetic interaction with human capital in the production of regional gross domestic product (GDP). This provides an indirect proof of the relationship formally described in equation (6). Graphically, this is also evident by plotting on a three-dimensional diagram (Fig. 3) the measure of cognitive capital (x-axis), the measure of units of effective labour (y-axis) and the dependent variable in equation (5), that is, labour productivity (z-axis). Productivity depends positively on both cognitive and human capital, and the interaction mechanism between the two identifies a relation of complementarity;[18]

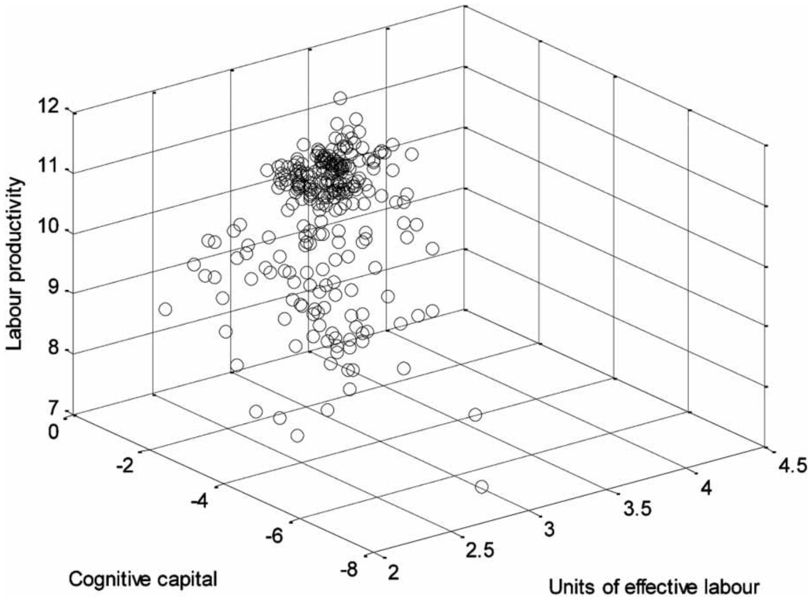

Fig. 3. Synergies between human and cognitive capital

analytically, this implies the existence of a concave function mapping from the human and cognitive capital plane on the productivity vector. In terms of the main topic of this paper, this interaction may be viewed as the synergy arising from more educated individuals in the regional labour force when cooperating. As individuals increase their own education level, labour markets as a whole benefit from more productive interactions. This is exactly the mechanism underlying the emergence of islands of innovation.

EMPIRICAL MODEL RESULTS

The aim of this section is to assess the relative contribution of highly skilled labour to the formation of regional wealth. The LUCAS (1988) growth model provides an important instrument to understand the mechanism through which individual and aggregate productivity increases as regional societies enjoy higher levels of education. However, so far its use has been to show theoretically the relative importance of human capital in long-run growth, rather than to serve as an empirical instrument. It is argued here that the model is actually capable of a good explanatory power for European growth patterns. This section comprises three basic sets of empirical tests. It shows the results of testing the micro-level version of the Lucas growth model – an individual production function based on the level of education of the individual worker. It then extends the analysis to a linear growth model where individual levels of education are aggregated, and identifies the notion of cognitive capital. Spatial patterns in the data are then evaluated, with the use of the Le Sage and Pace spatial Durbin model (SDM) and the spatial error model (SEM) (LE SAGE and PACE, 2009, ch. 4).

MICRO-REGRESSIONS

In the operational experimentation, testing the cognitive capital-augmented Lucas growth model calls for the use of log-linearized equations (4) and (5). In the first case one obtains:

$$\ln(y_{i,r,t}) = \ln(A_{r,t}) + \alpha \ln(k_{i,r,t}) + (1-\alpha)\ln(uh_{i,r,t}) \qquad (7)$$

Equation (7) can be tested with ordinary least squares (OLS), provided that classical assumptions are respected. It states that individuals become more productive as their capital labour ratio increases, but also as their optimal choice of education leads to a higher individual productivity (the *uh* term is in fact the product of the time devoted to working times the individual level of education).

Table 5 shows the results of this empirical test. In this first case, only OLS estimates have been carried out (spatial estimates are not feasible, due to the

Table 5. Estimation results for the cognitive capital-augmented Lucas growth model (equation 7)

Dependent variable: log of household income	OLS
Stock of capital/savings	0.47***
	(0.011)
Units of effective labour	0.24***
	(0.009)
Constant term	0.42***
	(0.016)
R^2	0.19
Adjusted R^2	0.19
Number of observations	16929

Note: *Statistically significant at the 90% level; **statistically significant at the 95% level; and ***statistically significant at the 99% level. *p*-values are given in parentheses.

simultaneous presence of more than one individual in each single point in space). A wide sample of microdata was used, that is, the 16 929 observations on those individuals who answered the EVS questions needed to build the data set and who live in one of the 261 NUTS-2 regions in the European sample. The individual capital stock is proxied by the individual level of savings as calculated in the EVS survey.

Table 5 shows that the Lucas growth model is not only an interesting normative tool, suggesting that human capital is conducive to growth, but also it offers a simple, yet powerful and elegant, tool for regional analysis. In the sample of individual European Union citizens, savings are positively associated with household income, and so are the units of effective labour. Thus, not only do longer working hours lead to a higher income, but also their interaction with the level of education of European citizens is conducive to higher income levels. All coefficients yield meaningful and highly significant estimates. A first building block is laid down to explain the first step in the reasoning: from an individual perspective, more education increases the individual productivity level.

Regarding the assumption that regional economies in the data set are supposed to be in equilibrium, this implies an individual maximization problem that identifies the best possible combination of time devoted to education. Solving this maximization problem, individuals do not take into account crucial (and positive) externalities generated as their education increases. In fact, societies benefit more than proportionally from the aggregate wealth of education generated from agents. Assuming that individuals generate cognitive capital when increasing their own level of education (see equation 6), one can now test the framework at the aggregate level by estimating a modified version of the Lucas growth model.

REGIONAL GROWTH REGRESSIONS

The Lucas growth model is now solved from a (benevolent) social planner perspective in a spatial economy. In this case, Lucas assumes that a rational planner takes into account the positive externalities arising from individuals being more educated, and thus more productive. By doing so, he/she solves the problem of underinvestment in education caused by individuals not taking into account the positive spillovers from their own private education. Then, by log-linearizing equation (5), one obtains:

$$\ln(y_{r,t}) = \ln(A_{r,t}) + \alpha \ln(k_{r,t}) + (1-\alpha)\ln(uh_{r,t}) + \eta \ln(cc_{r,t}) \quad (8)$$

This double solution can also be interpreted from a regional perspective. Not only do societies become more productive as average education levels increase, but also it is plausible that social interactions become more fruitful in more indirect, albeit not less powerful, ways. Cognitive proximity is fostered by the accumulation of human capital. People with higher education levels are also facilitated in their mutual understanding, in shaping a more fruitful set of interpersonal relationships, which in turn become more productive. Education levels are positively and strongly correlated with non-material forms of capital, such as social and relational capital. A higher level of education for a society as a whole reduces the costs associated with investing in human relations and networks; this refers essentially to the 'weak ties' in Granovetter's definition.[19] Higher levels of education are also associated with higher levels of trust among citizens, which in turn fosters personal relations and enhances the capability of persons to interact in an economically fruitful way. To see how trust and human capital measures are highly correlated, it suffices to represent some measure of these two variables on a map or a plot.[20]

Cognitive capital is not always automatically conducive to growth. Too much cognitive capital can also result in social losses, such as reduced access to external information.[21] However, it seems consistent to state that cognitive capital is expected, on average, to foster the effectiveness of hard and structural soft production factors in growth processes.

This statement is now tested within the LUCAS (1988) growth model framework in order to assess whether cognitive capital may represent an additional source of increasing returns in a neoclassical, microfounded model, thus bridging regional development and neoclassical growth approaches to economic dynamics. To do so one again estimates the model on a cross-section of 261 NUTS-2 regions, where, along with traditional (measurable) production factors, the role of cognitive capital is evaluated. Instead of aggregating EVS data for the former variables, Eurostat data are used. In this way, the capability of EVS data to measure the underlying dynamic processes at the individual level can be demonstrated. In this second set of estimates, it is assumed that the regional economies lie on their balanced growth path, or, in other words, they lie on or around their steady-state growth path; this may be a plausible assumption, given the long time span before the year on which the assumptions are tested. This implies that u, that is, the share of time individuals in each region devote to work, is constant over space.[22] As such, the u term is ignored in the estimates, as it then enters the definition of the constant term. Data, therefore, comprise the log of per capita GDP in year 2000 euros, the log of the capital stock, the log of the share of human resources in science and technology, and, finally, the measure of cognitive capital. Table 6 shows the OLS estimates for the aggregate (society)-level model.

Table 6. Estimation results for the regional Lucas growth model (equation 8)

Dependent variable	Log of per capita GDP	Log of per capita GDP in purchasing power standards (PPS)
Stock of capital	0.40***	0.23***
	(0.03)	(0.02)
Units of effective labour	0.30**	0.13*
	(0.13)	(0.08)
Cognitive capital	0.16***	0.09***
	(0.02)	(0.02)
Constant term	3.95***	6.62***
	(0.04)	(0.32)
R^2	0.64	0.58
Adjusted R^2	0.63	0.57
Number of observations	249	248

Notes: *Statistically significant at the 90% level; **statistically significant at the 95% level; and ***statistically significant at the 99% level. *p*-values are given in parentheses.
GDP, gross domestic product

The results are shown in two columns, differentiated by the use of two alternative dependent variables (the log of year 2000 euros per capita GDP, and the log of year 2000 euros per capita GDP in purchasing power parity (PPP)).[23] The use of one of these dependent variables is not *ex-ante* to be preferred. PPPs correct the data to take account of the different purchasing power of citizens of different countries or regions. This is done by correcting the raw data by the regions' price levels. However, regional growth models implicitly assume spatial equilibrium (GLAESER, 2008). Spatial equilibrium is assured when prices levels make it rationally equivalent to locate in a poor or a rich region, because higher prices and rent discourage people from migrating to richer regions, thus further fostering agglomeration processes. The use of PPP data in regional analyses may therefore offer a somewhat blurred picture of true underlying parameters.

In Table 6, all coefficients turn out to be positively and significantly associated with regional GDP levels. While the magnitude of the coefficients is similar to the estimates obtained by estimating the simple household-level model, cognitive capital adds consistent increasing returns. Its estimated elasticity equals 0.16 in the first estimate, and 0.09 in the second, which implies that, *ceteris paribus*, investing an extra €1 in accumulating cognitive capital increases the level of per capita GDP by €0.09–0.16 in the European regions. From the empirical estimates it can be concluded that the role of human capital in economic performance is enhanced when a high level of cognitive capital is available in society. Individual endowment would then not suffice to contribute to economic growth in the absence of structural characteristics that lubricate the economy's mechanisms and a society's interactions.

A set of robustness checks was next carried out to test whether the results depended on the choice of the indicators, or were instead influenced by the omission of relevant variables. The results are shown in Table 7.

First of all, the results are analogous, in terms of signs and significance for the estimated parameters, to those obtained by regressing the regional averages of the individual EVS questions. The corresponding estimates are shown in column 1 in Table 7. Regressions were also run on the same functional form with robust standard errors, which again led to qualitatively similar results (column 2), with the cognitive capital parameter being estimated at 0.16 and yielding an $R^2 = 0.64$.

A third robustness check was obtained by including country fixed-effects in the regression (column 3). In this case, the picture became slightly blurred, since the correlation of some of the space-specific indicators used in the regression with the dependent variable was wiped out by including country effects. While, however, the parameters associated with the stock of capital and the stock of cognitive capital were both positive and significant – with a sign smaller in magnitude than that found in baseline estimates – the significance of the units of effective labour parameter was lost. That result may indicate that the quality of the labour force crucially depends on country-varying characteristics, which are captured by the inclusion of country fixed-effects. The significance of the cognitive capital parameter with the inclusion of country fixed-effects is, nevertheless, a remarkable result, which testifies to the robustness of the main message.

A final robustness check was run with the use of constrained OLS regression (column 4 in Table 7). This allows the empirical verification of one of the assumptions underlying the Lucas growth model, namely that of a constant returns-to-scale technology. Results of this exercise are in line with previous findings, although one major interesting outcome is the identification of regional labour as the main growth engine for the 'islands of innovation'; besides, the assumption of constant returns to scale in the model is not rejected, thereby providing further evidence on the effectiveness of this theoretical model beyond being purely normative.[24]

The estimates for R^2 were also much higher for regional rather than for micro-regressions, thus providing evidence of a much better fit of the model with the inclusion of the cognitive capital variable. These findings once more emphasized the relevance of islands of innovation. Furthermore, in these spatial singularities, endowed with educated and creative labour forces, the endowment of cognitive capital caused economic interactions to be more productive.

SPATIAL ECONOMETRIC GROWTH REGRESSIONS

As several variables may be strongly correlated across space, in particular the output measure, one has to test

Table 7. *Robustness checks on the results for equation (8)*

Dependent variable: log of per capita GDP

	(1)	(2)	(3)	(4)
Stock of capital	0.06***	0.40***	0.11***	0.40***
	(0.021)	(0.04)	(0.02)	(0.03)
Units of effective labour	0.31***	0.30**	0.01	0.46***
	(0.032)	(0.15)	(0.09)	(0.03)
Cognitive capital	0.019*	0.16***	0.04**	0.14***
	(0.01)	(0.03)	(0.02)	(0.02)
Constant term	–0.225*	3.96***	8.72***	3.44***
	(0.129)	(0.56)	(0.38)	(0.26)
Robust standard errors	No	Yes	No	
Country fixed-effects	No	No	Yes	
Constrained OLS	No	No	No	Yes
R^2	0.90	0.64	0.93	–
Adjusted R^2	0.90	0.65	0.92	–
Number of observations	200	249	249	249

Notes: *Statistically significant at the 90% level; **statistically significant at the 95% level; and ***statistically significant at the 99% level. *p*-values are given in parentheses.

OLS, ordinary least squares.

for spatial autocorrelation patterns. The local Moran's I statistic for the log of regional per capita GDP equals 0.4441, significant at the 0.001 level. Next, running a Wald test for spatial autocorrelation in the residuals of the linear regression model,[25] a Chi-square statistic equal to 262.5 is obtained, which should be compared with the threshold level of 6.635 for a 99% significance level (ANSELIN, 1988, pp. 103–104). Therefore, the null hypothesis of no spatial autocorrelation of the residuals of the linear model is rejected at any conventional level.

The best spatial regime is then tested for to obtain unbiased coefficient estimates. A general to a specific strategy is adopted: one starts by testing the most general spatial Durbin model, which takes on the unrestricted form:

$$y = \rho W y + x\beta + W x \gamma + \varepsilon$$

and encompasses the spatial lag and spatial error models as special cases (the spatial lag model obeying the restriction $\gamma = 0$, and the spatial error model the COMFAC restriction $\rho\beta + \gamma = 0$) (ROBERTS, 2006). The estimation results are shown in Table 8. Columns (1) and (2) show the results of estimating the main spatial model, respectively, with and without the constant term (the second case to account for some possible patterns of non-linearity in the data-generating process). Table 8 shows that while the significance and signs of the main regression coefficients are retained, their magnitudes vary with respect to the original linear model (Table 6). In particular, all main coefficients in the model have a lower estimated parameter value. However, this must be confronted with the direct and indirect effects of each variable. This is done with the use of maximum likelihood estimation routines, as suggested by LE SAGE and PACE (2009). Along with the estimation of the usual spatial model parameters, in fact this routine evaluates partial derivates of the spatial model in order to infer direct, indirect and overall impacts of each variable in the model. Thus, each variable impact can be decomposed into a direct (that is, simultaneous) impact on the dependent variable, a medium range impact, due to the spatial interaction between the direct impact and the stimulus given to neighbouring regions, and, finally, a total effect, as the sum of the two impacts above, which may be read as a long-run 'equilibrium' impact.

The results in Table 8 can now be interpreted in the light of these causal patterns. Whilst the accumulation of physical capital is associated with an overall positive long-run effect on the production of regional wealth, the effects of accumulating human capital and its interaction with the labour force parameter is more difficult to understand. Whilst its linear impact is positive and significant, its indirect effect seems to be strongly negative, and the magnitude of such a coefficient implies an overall negative impact in the model. This result is compatible with the notion of regional competitiveness: competition on non-material resources may cause the educated labour force to emigrate in the long run and cause a possible loss of productivity in the host country.

The sign of the cognitive capital parameter is positive over all decomposed classes of the total effect. This implies that not only does accumulating cognitive capital in the home regions increase the productivity levels of the local labour force, but also that regions benefit from being located near to regions with similarly high levels of cognitive capital. This first set of spatial estimates, therefore, shows that regional labour markets enjoy positive spillovers from the local and

Table 8. Estimation results for equation (7) using a spatial Durbin model

Dependent variable: log of per capita gross domestic product

	Spatial Durbin estimates	
	(1)	(2)
Stock of capital	0.20***	0.40***
	(0.000)	(0.000)
Units of effective labour	0.26***	1.10***
	(0.005)	(0.000)
Cognitive capital	0.06*	–0.09**
	(0.060)	(0.02)
Constant term	6.24***	–
	(0.000)	
Spatial autocorrelation coefficients		
ρ	0.53***	0.48***
	(0.000)	(0.000)
*W**Stock of capital	–0.086*	–0.07
	(0.07)	(0.29)
*W**Units of effective labour	–1.01***	–0.74***
	(0.000)	(0.000)
*W**Cognitive capital	0.44***	0.18***
	(0.000)	(0.000)
Direct effects		
Stock of capital	0.20***	0.42***
	(0.000)	(0.000)
Units of effective labour	0.15	1.07***
	(0.11)	(0.000)
Cognitive capital	0.12***	–0.08
	(0.000)	(0.03)
Indirect effects		
Stock of capital	0.04	0.23***
	(0.59)	(0.005)
Units of effective labour	–1.77***	–0.39
	(0.000)	(0.16)
Cognitive capital	0.94***	0.25***
	(0.000)	(0.003)
Total effects		
Stock of capital	0.24***	0.65***
	(0.000)	(0.000)
Units of effective labour	–1.61***	0.69**
	(0.000)	(0.02)
Cognitive capital	1.05***	0.17**
	(0.000)	(0.04)
R^2	0.70	0.57
Adjusted R^2	0.69	0.56
Log-likelihood	–13.74	–95.78
Number of observations	261	261

Note: *Statistically significant at the 90% level; **statistically significant at the 95% level; and ***statistically significant at the 99% level. *p*-values are given in parentheses.

general perception of the importance of cooperation networks.

The results were also tested on several consistency checks. Whilst the results in general do not suffer from consistent biases, evidence is found of heteroskedasticity in the model. In particular, the residuals of the spatial Durbin model seem to be clustered by country (Fig. 4). In Fig. 4, 'SDM' indicates the spatial Durbin model; the continuous line represents actual observations on regional labour productivity in the sample, while the dashed line plots the value predicted with the SDM specification; regions are shown on the *x*-axis, in alphabetical order according to the NUTS classification.

This result may be due either to real differences in the levels of the variables measured (that is, statistically different levels of human capital, GDP, etc.) or to different procedures that national statistical institutes follow to collect basic data. Although Eurostat instructs national statistical institutes to meet standardized requirements, national statistical offices may actually partially deviate from such guidelines.[26] The second explanation seems quite plausible. Therefore, in order to correct from this possible source of misspecification, the spatial Durbin specification is again tested with the inclusion of twenty-six country dummies (assuming Austria to be the base country). Results are shown in Table 9.

According to Table 9, twelve country dummies turn out to be significant, at least at the 5% significance level. Countries whose fixed-effect is significant include Bulgaria, the Czech Republic, Estonia, Hungary, Ireland, Lithuania, Luxembourg, Latvia, Poland, Romania, Slovenia and the Slovak Republic. The only Western European countries which are present here are Ireland (which experienced extraordinary growth rates at the time when the data set was assembled) and Luxembourg. Interestingly enough, ten out of twelve new member states display significant departures from the predicted level of wealth within a spatial Lucas growth model. Moreover, countries whose fixed-effect is significant are also those which display the highest residuals shown in Fig. 4.

A final refinement of the estimates implies the test of the best spatial regime in the model, given the analysed data sample. A likelihood ratio test carried out on the SDM model rejects the null of the spatial lag restriction at all standard levels, while it strongly suggests the validity of the SEM (that is, the COMFAC restriction cannot be rejected). Therefore, it was decided to use an error specification for the estimates.

The choice of the spatial error model also has an interesting econometric interpretation, compatible with the notion of contagion (for example, ANSELIN, 2002). Within a human and cognitive capital framework, this implies that education and cognitive capital stocks in a region's labour force influence the neighbouring regions' levels as well, and that the opposite also applies. This contributes to the debate on the death of distance:[27] the analysis shows that in both geographical and cultural terms distance is far from dead, and that initial physical, but also cognitive and cultural, aspects of a location still matter and influence the final outcome of regional growth patterns. The results of estimating the SEM are shown in Table 10.

It thus turns out that the main findings of this empirical section confirm the conceptual framework.

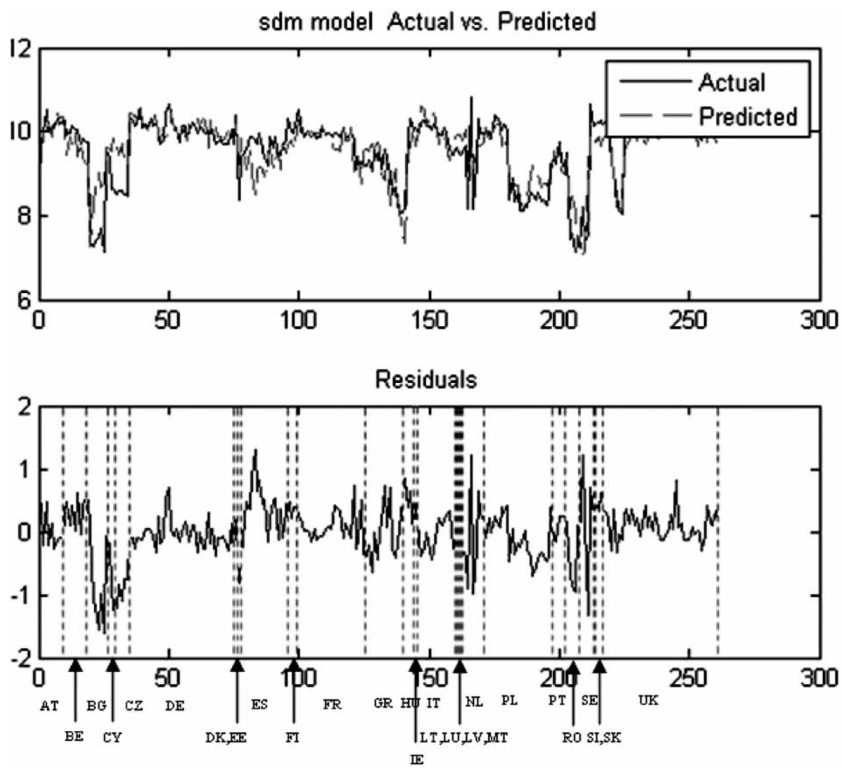

Fig. 4. Residuals of the spatial Durbin estimation of the Lucas growth model

Both an educated labour force and cognitive capital contribute to the formation of regional GDP. A high and significant degree of spatial autocorrelation of the residuals characterizes the data set, which is accounted for by the lambda parameter in Table 10. About 80% of total regional GDP variance is explained in this cross-section, with just three growth determinants.

CONCLUSIONS

This paper has combined two alternative approaches to the relation between education and economic performance, namely regional development and the neoclassical growth approach. Empirical estimates of the LUCAS (1988) growth model in this study are based on the EVS data set; it is shown that the level of education exhibits increasing returns from a social perspective. The externality driving the formation of increasing returns is not the aggregate level of education but the region's endowment with cognitive capital. Thus, societies benefit not only from a more educated labour force, but also from their level of cognitive capital, which represents the set of norms, values, attitudes and beliefs of a society which can enhance mutually beneficial collective action.

The results are robust with respect to the choice of the estimation technique and the measure of human capital. Spatial issues in the data set are also taken into account, and unbiased estimates of the returns to human capital are obtained. This paper, therefore, contradicts the commonly held view that the Lucas growth model gives a more profound insight into the mechanisms of economic growth, rather than serving as an effective policy instrument. Instead, it has been demonstrated that the model fits the European data well and also highlights the crucial relevance of knowledge in modern regional economies. This has important implications for islands of innovation and growth.

Long-run trends of concentration of the skilled labour force in spatial singularities have relevant policy implications. As collective learning takes place at the regional level (STORPER, 1995; FLORIDA, 1995; MALMBERG and MASKELL, 2006), only those regions that succeed in retaining the skilled labour force formed in their own educational institutions, as well as in attracting a skilled labour force from outside, will manage to sustain long-run development. Competition for the possession of a skilled labour force, while already being evident from the data, will increasingly characterize European regions. The possible negative effects of outward skilled migration on sending countries' productivity levels, though increasingly on the policy-maker's agenda, will have to be more carefully considered. The emergence of islands of innovation, while representing an opportunity to achieve higher growth rates for regions endowed with such islands, will also offer a challenge to regions that are incapable of attracting an innovative and creative labour force. If, therefore, the European Union is really aiming to reduce spatial

Table 9. Estimation results for equation (7) using a spatial Durbin model with country fixed-effects

Dependent variable: log of per capita gross domestic product

	Spatial Durbin estimates (1)
Stock of capital	0.10***
	(0.000)
Units of effective labour	0.08
	(0.25)
Cognitive capital	0.04**
	(0.03)
Constant term	8.29***
	(0.000)
Spatial autocorrelation coefficients	
ρ	–0.05
	(0.47)
*W**Stock of capital	0.05
	(0.23)
*W**Units of effective labour	0.16
	(0.34)
*W**Cognitive capital	0.07
	(0.18)
Direct effects	
Stock of capital	0.10***
	(0.000)
Units of effective labour	0.08
	(0.29)
Cognitive capital	0.04**
	(0.03)
Indirect effects	
Stock of capital	0.04
	(0.22)
Units of effective labour	0.15
	(0.37)
Cognitive capital	0.06
	(0.22)
Total effects	
Stock of capital	0.15***
	(0.001)
Units of effective labour	0.23
	(0.22)
Cognitive capital	0.11**
	(0.05)
Country dummies	Yes
R^2	0.95
Adjusted R^2	0.94
Log-likelihood	167.97
Number of observations	261

Note: *Statistically significant at the 90% level; **statistically significant at the 95% level; and ***statistically significant at the 99% level. *p*-values are given in parentheses.

disparities, this issue should definitely be taken into account.

Regional labour markets for skilled personnel should consequently be shaped in order to maximize the returns to private education, and ease the transfer of knowledge across workers and the speed with which ideas cross-fertilize individuals. The attraction of a skilled labour force, while increasing productivity levels per se, may also increase the regional labour markets stocks of cognitive capital, thus generating a self-fulfilling prophecy: labour markets with higher stocks of human and cognitive capital may be more attractive to skilled and cognitively rich labour, star-scientists and top productivity innovators, in turn fostering the persistence of this situation over time.[28]

Table 10. Estimation results of equation (7) using a spatial error model

Dependent variable: log of per capita gross domestic product

	Spatial error model estimates (1)
Stock of capital	0.21***
	(0.000)
Units of effective labour	0.17*
	(0.07)
Cognitive capital	0.13***
	(0.000)
Constant term	6.69***
	(0.000)
Spatial autocorrelation coefficient	
λ	0.60***
	(0.000)
R^2	0.79
Adjusted R^2	0.79
Log-likelihood	–26.94
Number of observations	261

Note: *Statistically significant at the 90% level; **statistically significant at the 95% level; and ***statistically significant at the 99% level. *p*-values are given in parentheses.

The importance of such competences is maximum. Econometric analysis suggests that human capital, in the form of formal education and training, enhances the productivity of individual workers, who are nevertheless incapable of fully reaping the positive effects of their own level of education, generating in the end a potential market failure. Aggregate (that is, labour market-wide) positive spillovers are found to be generated when a high stock of cognitive capital is present, that is, when people are also endowed with a rich set of norms, values, attitudes and beliefs leading towards mutually beneficial collective action.

This paper has also offered a contribution to the current regional growth debate by testing a micro-founded level, at both the individual and the regional levels. The empirical evidence suggests both the relevance of a skilled labour force for a region's development, but also the synergic mechanism arising from geographical proximity to regions with similarly high endowments of skilled labour force. This study modelled and tested the competition for human capital in a spatial Durbin framework, whereas the evidence on knowledge spillovers is mixed and depends on the chosen functional form.

Evidence is also found for the role of cognitive capital in catalysing the formation of increasing returns to the efficiency of the skilled labour force. The higher the endowment of cognitive capital both within and outside a region, the higher the level of per capita GDP produced. A high endowment of cognitive capital may reduce the dispersion of the positive effects of human capital, thus representing the best solution for regions lagging in their capability to attract a skilled labour force. However, non-material components imply long periods of accumulation; therefore, regional policy-makers should take this into account and devise long-run growth strategies, which may sometimes be at odds with short-run political cycles typically associated with short-run policy instruments.

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APPENDIX A: HUMAN CAPITAL AND TRUST

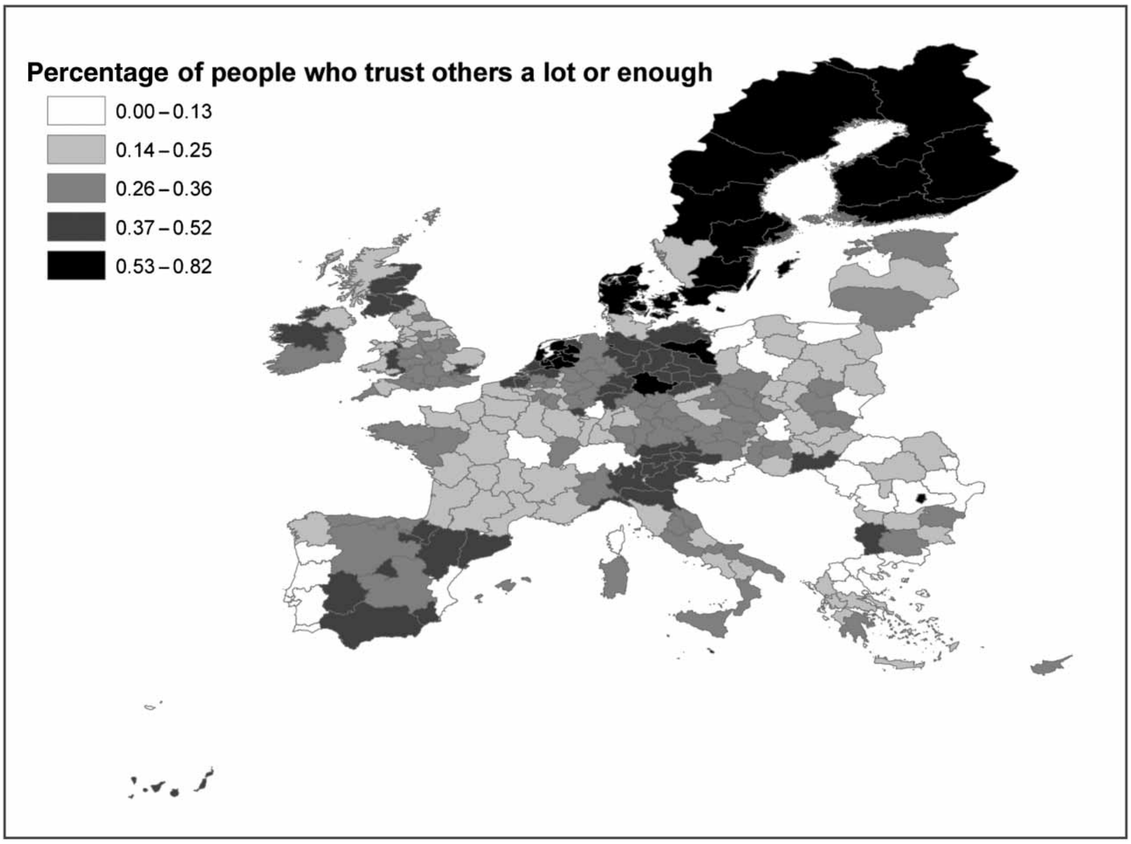

Fig. A1. *Trust in European Union regions*
Source: European Values Study (EVS) data, authors' own calculations

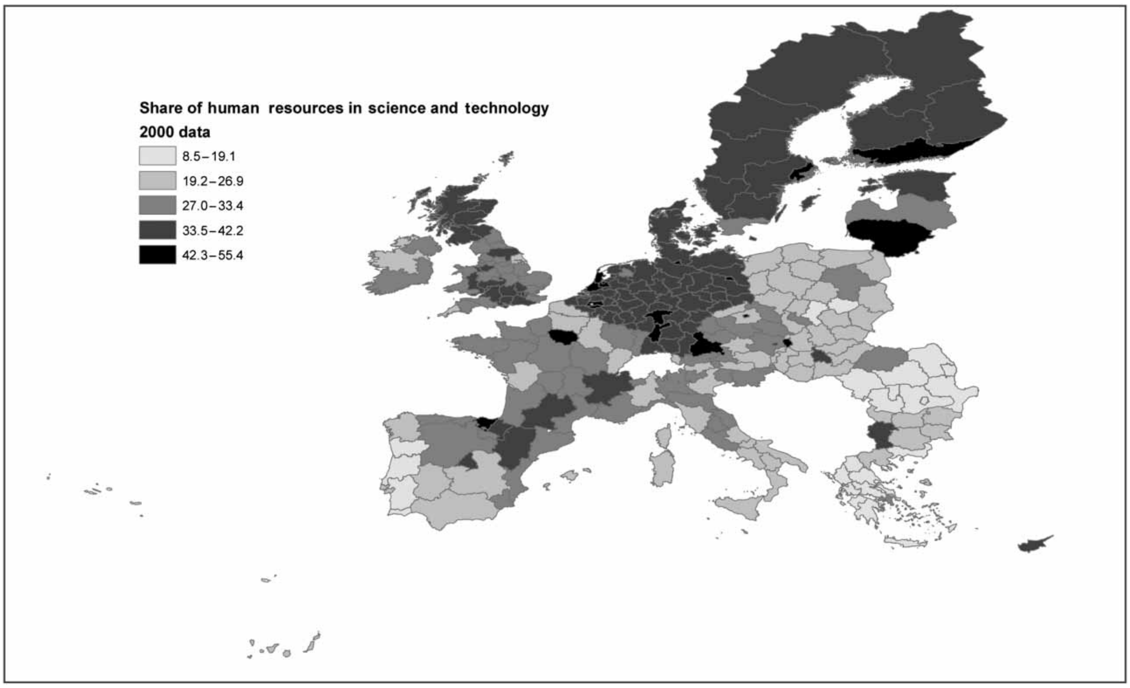

Fig. A2. *Human capital in European regions*
Source: Eurostat

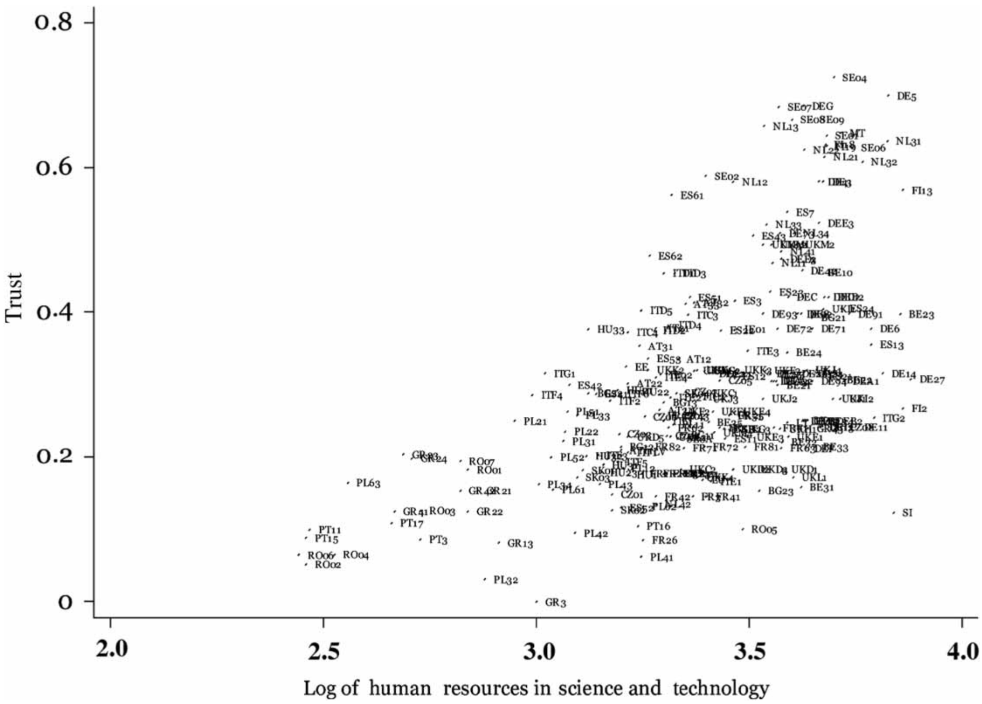

Fig. A3. *Human capital and trust*

NOTES

1. The EUROPEAN UNION (1999) states that:

> the three fundamental goals of European policy are achieved equally in all the regions of the EU [European Union]: Economic and social cohesion; the conservation and management of natural resources and the cultural heritage; a more balanced competitiveness of the European territory.

2. Here the Krugman Specialization Index is calculated as in MIDELFART-KNARVIK and OVERMAN (2002). The modified version does not capture sectoral issues; therefore, it does not satisfy all properties of the original index, which include assuming a maximum value of 2.
3. The index is calculated as the sum of the absolute differences in human capital intensity between each NUTS region and the average EU-27 level, the latter being 1 minus the Herfindahl Index of the educated labour force.
4. NUTS is the acronym for Nomenclature des Unités Territoriales Statistiques. The sample comprises all EU-27 NUTS-1 regions, except the Bulgarian regions, for which data on human capital attainments prior to 2006 are not available. The NUTS-1 level of aggregation is chosen, as Germany and the UK only release data at this level.
5.

> The International Standard Classification of Education (ISCED) was designed by UNESCO [United Nations Educational, Scientific and Cultural Organization] in the early 1970's to serve 'as an instrument suitable for assembling, compiling and presenting statistics of education both within individual countries and internationally'. It was approved by the International Conference on Education (Geneva, 1975), and was subsequently endorsed by UNESCO's General Conference when it adopted the Revised Recommendation concerning the International Standardization of Educational Statistics at its twentieth session (Paris, 1978).
>
> (UNESCO, 1997)

6. The choice of the proper estimation technique for individual Mincerian regressions is a highly debated issue. As personal ability is believed to influence the level of education of an individual, this generates endogeneity in these regressions. As personal ability is non-observable, IV are used to infer the individual's set of skills, frequently using his/her parents' level of education as a valid instrument. By their nature, nevertheless, IV regressions yield slightly higher estimation results than a simple OLS.
7. See, for example, ACS *et al.* (1994), who studied the capability of firms to exploit knowledge spillovers; AUDRETSCH and FELDMAN (1996) and FELDMAN and AUDRETSCH (1999), who critically reviewed the stylization of scientifically diversified and specialized spillovers; and ANSELIN *et al.* (1997), who identified the maximum distance threshold, equal to 50 miles, beyond which spillover effects from Metropolitan Statistical Areas (MSAs) fade away. Finally, see DE GROOT *et al.* (2001), who critically reviewed the literature on KS.
8. GREMI (Groupe de Recherche Européen sur les Milieux Innovateurs) was created by the late Philippe Aydalot in 1984; it focused its research on the determinants of the spatial concentration of small firms.
9. The literature on the 'innovative milieu' and the learning region is critically summarized in CAPELLO (2007).
10. In this case, the neoclassical paradigm has been insufficiently open and responsive to such new ideas. For a critical review of neoclassical and non-mainstream perspectives on economic geography, see BOSCHMA and FRENKEN (2006).
11. The literature offers many examples (LA PORTA *et al.*, 1997; ZAK and KNACK, 2001; BEUGELSDIJK *et al.*, 2004; KNACK and KEEFER, 1997). For a recent application with a regional perspective, see CAPELLO *et al.* (2011).
12. For the details of the model, see LUCAS (1988) and BARRO and SALA-I-MARTÍN (1995).
13. The assumptions include a depreciation rate equal to 2.5%, while the starting point of the capital stock time-series is 1998.
14. EVS consists of a set of individual questionnaires administered to European citizens. Data were collected in four waves: this paper uses the 1999–2000 wave, as it is the first to cover comprehensively the regional dimension of the analysis. For information on methods of data collection and on data stratification, see http://www.europeanvaluesstudy.eu/.
15. A fourth wave of the EVS has recently become available. Individual interviews were administered in the 2008–2009 period. Therefore, the use of such data would induce a simultaneity issue with the dependent variables being explained with the present model.
16. Geert Hofstede's model entails a classification of cultural differences along five dimensions, namely: Power distance; Individualism; Masculinity; Uncertainty avoidance; and Long-term orientation.
17. The PCA technique should ideally be performed on a complete data set (each gap in a single vector causing a missing value in the final scores). The missing value for each single vector on which the PCA was performed was filled in with the closest (in time or space) data. When data were missing, reasonable substitutes were chosen, according to spatial or time proximity. For example, the value of the patent applications to the EPO in Lincolnshire, UK (whose NUTS-2 code is UKF3) was substituted with that of the neighbouring counties of Leicestershire, Rutland and Northamptonshire (whose NUTS-2 code is UKF2). The authors preferred temporally to spatially close observations when both were available.
18. All variables are in logs in the graph.
19. GRANOVETTER (1973, 1985) deals with the role of 'weak' (that is, low-intensity, and relatively impersonal) relationships in generating economically fruitful interactions. From POLANYI's (1957) work the concept of 'embeddedness' is then further developed to explain how interpersonal relationships are rooted in social networks, which generate trust among economic agents in a framework which differs from that of the traditional neoclassical rational agent.
20. This is done in Figs A1–A3 in Appendix A.
21. For a theoretical perspective, see, for example, BOSCHMA (2005); similar arguments are summarized in PUTNAM (2000) from a social capital perspective.

22. For a thorough analysis of the mathematical properties of the LUCAS (1988) growth model, see PIRAS (1997). Piras kindly provided the authors with a printed version of his paper upon request.

23.

> PPPs are the rates of currency conversion that equalize the purchasing power of different currencies by eliminating the differences in price levels between countries.
>
> (OCED, n.d.)

The GDP in PPS measure is nevertheless still an imperfect solution to the absence of region-specific price indices. In fact, regional GDP in PPS is built using a common country-varying price level, which likely adds regional distortions in the measured spatial distribution of economic activities. The production of regional price indices would greatly benefit future applied work.

The authors thank an anonymous referee for suggesting that PPP GDP should be examined.

24. The authors thank an anonymous referee for the suggestion to experiment with the underlying utility function.
25. In running this test and in the rest of this section, unless explicitly stated, a row-standardized first-order contiguity matrix is used.
26. For similar findings, see ERTUR *et al.* (2008).
27. The classic reference on this issue is CAIRNCROSS (1997).
28. Indeed, this situation occurred in the academic world after the Second World War, when German scientific superiority in the fields of chemistry and physics was gone forever due to the migration of most of the best scientists to the United States because of the political situation in their homeland. Germany never had the scientific edge again.

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