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Total Factor Productivity, Intangible Assets and Spatial Dependence in the European Regions

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Total Factor Productivity, Intangible Assets and Spatial Dependence in the European Regions

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DETTORI B., MARROCU E. and PACI R. Total factor productivity, intangible assets and spatial dependence in the European regions, *Regional Studies*. The aim of this paper is to analyse the determinants of the efficiency levels across the European regions. Firstly, a regression-based measure of regional total factor productivity is derived by estimating a spatial Cobb–Douglas production function. Secondly, the role played by intangible factors (human capital, social capital and technological capital) on total factor productivity levels is investigated by applying the spatial two-stage least-squares (2SLS) method and the spatial heteroskedasticity and correlation consistent (SHAC) estimator to account for both heteroskedasticity and spatial autocorrelation. It turns out that a large part of total factor productivity differences across the European regions is explained by disparities in the endowments of these intangible assets.

Total factor productivity Human capital Social capital Technology Europe

DETTORI B., MARROCU E. and PACI R. 欧洲地区总要素生产力、无形资产以及空间依赖，区域研究。本文旨在分析欧洲区域决定其效率等级的不同要素。首先，通过估测空间生产职能本研究对区域总要素生产力进行了基于回归的测量。其次，通过应用空间两阶段最小二乘算法（2SLS）以及考虑了异方差以及空间自相关的SHAC估算，研究考察了无形要素（人力资本、社会资本以及技术资本）对于总要素生产力水平的影响。

总要素生产力 人力资本 社会资本 技术 欧洲

DETTORI B., MARROCU E. et PACI R. La productivité des facteurs de production globaux, les immobilisations incorporelles et la dépendance géographique dans les régions européennes, *Regional Studies*. Cet article cherche à analyser les déterminants des niveaux d'efficacité à travers les régions européennes. Primo, on établit une mesure de la productivité des facteurs de production globaux basée sur la régression en estimant une fonction de production géographique du type Cobb–Douglas. Secundo, on examine le rôle joué par les immobilisations incorporelles (à savoir, le capital humain, le capital social et le capital technologique) sur les niveaux de la productivité des facteurs de production globaux en appliquant la méthode géographique des moindres carrés à deux degrés (appelée 2SLS) et l'estimation SHAC pour tenir compte à la fois de l'hétéroscédasticité et de l'autocorrélation géographique. Il s'avère qu'une part non-négligeable des écarts de la productivité des facteurs de production globaux à travers les régions européennes s'explique par des disparités de la dotation de ces immobilisations incorporelles.

Productivité des facteurs de production globaux Capital humain Capital social Technologie Europe

DETTORI B., MARROCU E. und PACI R. Gesamtfaktorproduktivität, immaterielle Vermögenswerte und räumliche Abhängigkeit in den europäischen Regionen, *Regional Studies*. In diesem Beitrag werden die Determinanten des Effizienz-niveaus in verschiedenen europäischen Regionen analysiert. Zu Beginn wird ein regressionsbasierter Maßstab der regionalen Gesamtfaktorproduktivität durch Schätzung einer räumlichen Cobb–Douglas-Produktionsfunktion abgeleitet. Anschließend wird die Rolle von immateriellen Faktoren (Humankapital, Sozialkapital und technologisches Kapital) für das Niveau der Gesamtfaktorproduktivität untersucht, indem die Methoden der räumlichen zweistufigen Kleinstquadrat-Schätzung (2SLS) und des SHAC-Schätzers angewandt werden, um sowohl die Heteroskedastizität als auch die räumliche Autokorrelation zu berücksichtigen. Es stellt sich heraus, dass sich ein Großteil der Unterschiede bei der Gesamtfaktorproduktivität in den verschiedenen europäischen Regionen auf Disparitäten hinsichtlich der Ausstattung mit diesen immateriellen Vermögenswerten zurückführen lässt.

Gesamtfaktorproduktivität Humankapital Sozialkapital Technologie Europa

DETTORI B., MARROCU E. y PACI R. Productividad total de factores, activos intangibles y dependencia espacial en las regiones europeas, *Regional Studies*. El objetivo de este artículo es analizar los determinantes de los niveles de eficacia en las regiones europeas. En primer lugar, derivamos una medición basada en la regresión de la productividad total de los factores regionales al calcular una función espacial de producción Cobb–Douglas. En segundo lugar, analizamos el papel desempeñado por los factores

intangibles (capital humano, capital social y capital tecnológico) sobre los niveles de productividad total de los factores aplicando el método espacial de mínimos cuadrados en dos etapas (2SLS) y el estimador SHAC para tener en cuenta la heteroscedasticidad y la autocorrelación espacial. Parece ser que una gran parte de las diferencias en la productividad total de los factores en la regiones europeas se explica por las desigualdades en las dotaciones de estos activos intangibles.

Productividad total de los factores Capital humano Capital social Tecnología Europa

JEL classifications: C31, C33, O47, O52, R11

INTRODUCTION

Recent empirical literature on economic growth, at both country and regional levels, has shown that the differences in the income levels are mainly due to disparities in the total factor productivity (TFP) levels and to a lesser extent to the factors of production. EASTERLY and LEVINE (2001) reported that more than 90% of the differences in growth rates among nations are explained by TFP rather than by traditional factor accumulation. Moreover, a strongly stylized fact that emerges from the empirical literature is that regional disparities are larger and more persistent when compared with cross-countries' differences, at least within the industrialized economies (for a review, see MAGRINI, 2004).

Since the differences in productivity turn out to depend on the efficiency levels, the attention of economists has been increasingly devoted to searching for additional factors which may account for such disparities. Several explanations for the TFP gap have been put forward, but among them a key role appears to be played by the intangible factors human capital, social capital and technology. They create the base of the 'knowledge economy' which, in turn, constitutes the most favourable environment to foster the economic performance of countries and regions, as stated by the Lisbon declaration in 2000. As a matter of fact, in the industrialized economies the ability to compete in open markets is increasingly based on production factors like the quality of labour, the degree of cohesion, the level of trust in the society and the accumulation of technological capital. However, there is a lack of systematic studies on the effects of different kinds of intangible assets on the economic performance at the regional level. In a number of studies human capital is often included as a determinant of the efficiency level; other works emphasize the effects of the knowledge-creation process and, only recently, social capital has been considered as a relevant variable in the context of explaining TFP variation across regions.

The main purpose and the novelty of this paper is to assess the effect of three different types of intangible assets on the economic performance at the regional level in Europe. Ideally, such a purpose would be nicely pursued by augmenting the traditional production function model with proxy variables for the intangible factors. However, for the European regions data on human, technological or social capital are not

consistently available for all the regions over the entire sample period considered in this study. To deal with this severe lack of data, a two-step estimation strategy is adopted. In the first stage, a measure of the TFP for the European regions is derived by estimating a Cobb–Douglas production function that includes only the traditional inputs of physical capital and labour. This is done in a panel data context controlling for spatial dependence, time series non-stationarity and endogeneity. The estimated fixed-effects represent an accurate long-run measure of regional TFP which is directly derived from the production function estimation without imposing any (untested) restriction on the inputs' elasticity parameters. The second step provides some interesting new evidence on the role played by intangible assets in determining the regional level of efficiency by including them as regressors in a model for the TFP data obtained in the first stage. It is worth stressing that, to the best of the authors' knowledge, this is the first attempt to estimate 'simultaneously' the effects of three different types of intangible capitals on the regional level of productivity.

The paper is organized as follows. The second section presents the results for the Cobb–Douglas production function estimation and derives the TFP variable. The third section discusses the main features of the intangible factors and analyses the related literature. The econometric evidence on the role played by intangible assets in enhancing regional productivity is discussed in the fourth section. The fifth section offers some concluding remarks.

MEASURING TOTAL FACTOR PRODUCTIVITY

Data description and spatial patterns

The two-step strategy for the estimation of regional TFP starts with the specification of the traditional Cobb–Douglas production function, which includes the conventional inputs, physical capital and labour, for a panel of 199 European regions observed over the period 1985–2006; the regions belong to fifteen member countries of the EU-15 plus Switzerland and Norway. The Nomenclature des Unités Territoriales Statistiques (NUTS) classification provided by Eurostat is followed, and national and sub-national units, a combination of NUTS-0, -1 and -2 levels, characterized by

an adequate degree of administrative and economic control (see Appendix A for details) are selected. A detailed description of the variables used in this study, along with the indication of the sources, is presented in Appendix B.

For each region and year over the period 1985–2006, the stock of physical capital is calculated by applying the perpetual inventory method from the flow of gross investment in the previous period and assuming an annual depreciation rate equal to 10%. The capital stock value for the initial year 1984 has been assumed to be equal to the cumulative sum of investment flows over the ten-year period 1975–1984.

In Fig. 1 the geographical pattern of value added (a) and capital stock (b) is depicted by reporting the quintile distribution of the time average; the series are rescaled with respect to the population size in order to reduce the degree of heterogeneity across regions.

Fig. 1(a) shows evidence of significant cross-region dependence in the value-added distribution that follows a clear spatial scheme: among the worst performers are all the Greek and Portuguese regions, four Spanish regions and the South of Italy. The top region is Denmark, followed by Inner London, Zurich, Brussels and Oslo. All Swiss high-performing regions create a well-defined cluster, as well as the Norwegian ones and a group of German and Austrian regions; also the Southern area of the United Kingdom forms a cluster of high value-added regions. The spatial distribution of labour units is very similar and is not reported here to save space. Fig. 1(b) shows the distribution of the physical capital stock: Central and Northern Europe show a large high-performance cluster, which starts from Steiermark in Austria, passes through most of the Southern German regions, and ends with Denmark

and the Southern regions of Norway. Detached from this cluster one finds the capital regions of London (which shows the best performance) and Paris (Île-de-France). The regions displaying the worst performance are located at the European borders: in the West with Portugal and Spain, and in the South with the Southern regions of Italy and the Greek ones. As regards spatial variability, value added shows a stronger dispersion of values across regions, as indicated by a higher coefficient of variation (0.39) with respect to capital stock (0.31) and labour units (0.17).

The presence of spatial dependence, evident in the figures discussed above, is formally tested by means of the cross-section dependence (Cobb–Douglas) test proposed by PESARAN (2004) and the panel version of Moran's I test (KELEJIAN and PRUCHA, 2001). All tests turned out to be highly significant leading to the rejection of the null hypothesis of no cross-section dependence among the European regions.¹ The Cobb–Douglas test provides evidence that significant correlation is present between pairs of regions for all variables, while Moran's I test suggests that such a correlation is most likely due to spatial interdependence among regions.²

The estimation procedure presented in the next section will deal with this aspect of the data.

Some econometric issues

The traditional Cobb–Douglas production function includes the conventional inputs physical capital and labour and is formulated as:

$$Y_{it} = A_i K_{it}^{\beta_1} L_{it}^{\beta_2} e^u \quad (1)$$

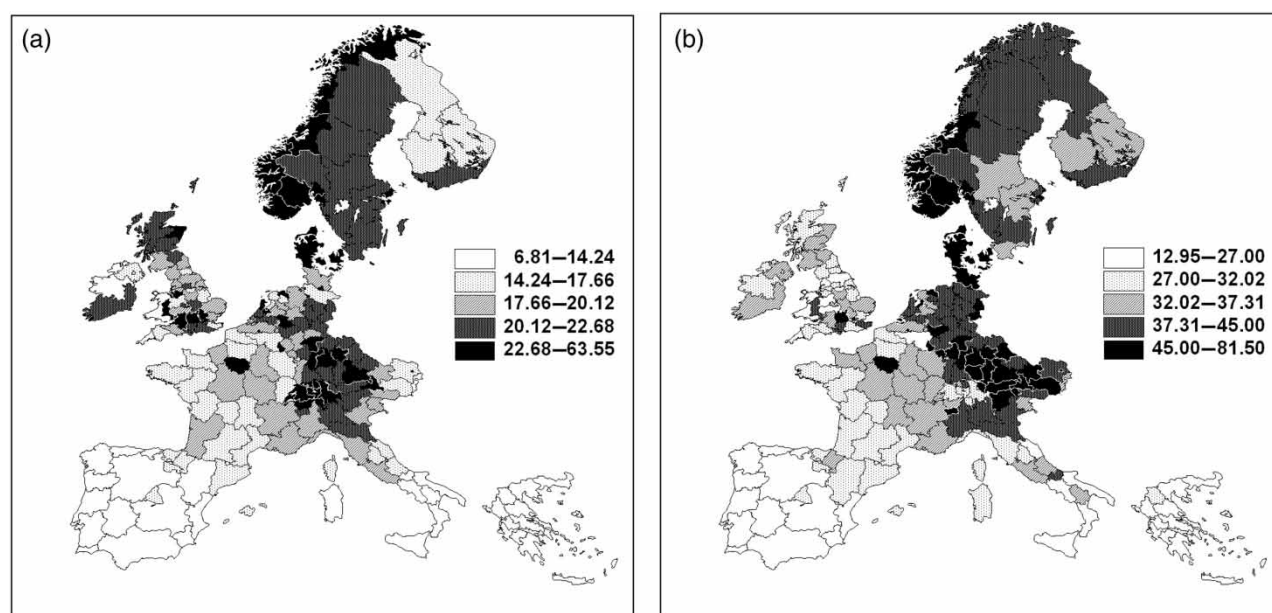


Fig. 1. Value added and capital stock, average 1986–2006: (a) value added (per capita, €, thousands year 2000); and (b) capital stock (per capita, €, thousands year 2000)

where Y is value added at 2000 base prices; K is the stock of capital; L is labour units; A is the efficiency level; u is an error term; $i = 1, 2, \dots, N = 199$ regions and $t = 1, 2, \dots, T = 22$ (for the period 1985–2006); all variables are normalized to population in order to control for the different sizes of the regions.

The production function is estimated in a log–linear form within a spatial lag framework. The empirical panel model is specified as follows:

$$y_{it} = \alpha_i + \beta_1 k_{it} + \beta_2 l_{it} + \rho \tilde{W} y_{it} + \theta_t + u_{it} \quad (2)$$

where lower case letters represent the log-transformed variables; α_i is the regional fixed effects, which, as will be discussed below, represent the measure for TFP; $\tilde{W} y_{it}$ ^[3] is the spatially lagged dependent variable; and \tilde{W} is the normalized weight matrix; time fixed-effects have also been included to account for common shocks affecting the pooled regions.

The choice of the spatial lag model specification was motivated by two fundamental reasons. The first is based on the importance to model explicitly (potential) economic spillovers arriving from neighbouring regions.⁴ The second motive is related to the issue of tackling the possible endogeneity of the capital and the labour inputs; as pointed out by FINGLETON and LE GALLO (2008, p. 230), consistent estimators are only the instrumental variable (IV) ones derived within a spatial lag specification. The elements of the (before normalization) weight matrix W are given by the inverse of the square distance expressed in kilometres across regions. This choice was driven by preliminary error diagnostics as the linear weights did not prove adequate to capture the spatial structure present in the data; the square values are supposed to be more informative and more powerful in discriminating between neighbouring and distant regions as they increase the relative weights of the closest ones.

The issue of normalization of the W matrix has recently received increasing interest given its economic – rather than pure statistical – content. In most applied studies W is row-standardized such that each row sums to unity; in this case the impact of all other regions on a particular region i is given by the weighted average of all regions' impacts and it is implicitly assumed that only *relative* rather than *absolute* distance matters.⁵ Alternatively, the W matrix can be normalized with respect to a single normalization factor, its largest row/column sum or its largest characteristic root. In a recent paper KELEJIAN and PRUCHA (2010) argued that such a normalization is sufficient, while row-normalization imposes strong restrictions on the spatial process since each row of the W matrix is normalized in a different way.

The present study applies the largest eigenvalue normalization, which, differently from the row-standardization, has also the nice feature that the symmetry of the weights is preserved;⁶ this is particularly important when W is an inverse distance matrix used

to describe a 'distance-decay' type of economic behaviour, as stated by ANSELIN (1988), 'scaling the rows so that the weights sum to one may result in a loss of that interpretation' (p. 24).⁷

As far as the endogeneity issue is concerned, model (2) above is characterized by an 'intrinsic' endogeneity problem arising from the inclusion of the spatial term, which induces a two-way causality in the neighbour relation in space. In this case consistent estimators are the ones derived from the maximum likelihood method or from the two-stage least squares (2SLS) one, based on the inclusion of instrumental variables. In the growing empirical literature on spatial models great care has been devoted so far in tackling the endogeneity due to the spatially lagged term, while the potential endogeneity of the explanatory variables has often been overlooked, particularly in the panel data context.⁸ This study also attempted to take into account the endogeneity between output and the production factors which can arise from system feedbacks or measurement errors.⁹ Since the usual Durbin–Wu–Hausman (DWH) test points out that the stock of capital and (marginally) the labour units can be considered endogenous with respect to value added,¹⁰ the 2SLS estimation method is adopted here in order to estimate the single structural equation of interest – the production function – without explicitly modelling the entire system relationships causing simultaneity (as in FINGLETON and LE GALLO, 2008). Following DAL'ERBA and LE GALLO (2008), in the present work the instruments for the productive factors are derived by applying the three-group method proposed by KENNEDY (2008). Spatial lags of the three-group instruments are considered for the spatially lagged dependent variable (KELEJIAN and PRUCHA, 1999).

Econometric results

The estimation results are reported in Table 1. The estimated results of a sort of a 'benchmark' model, which is a standard fixed-effects model with time dummies of the log-linearized version of the Cobb–Douglas function reported in equation (1), are first presented; different specifications of spatial panel models which explicitly take into account the geographical correlation among the European regions are then proposed.

The first column in Table 1 (1.1) reports the ordinary least-squares (OLS) estimation results for the basic model which, besides the individual intercepts and the dummy variables, includes only the traditional productive factors. The estimated coefficients are 0.27 for the capital stock and 0.30 for the labour input. The bottom of the column reports the Lagrange multiplier (LM) test for (remaining) spatial error correlation¹¹ and Moran's I test; both tests indicate that, as expected, the estimated residuals are affected by spatial dependence.¹²

Regression 1.2 results from the application of the spatial 2SLS estimator, which allows one jointly to take into account the two different sources of endogeneity

Table 1. Production function estimation

Dependent variable: value added	1.1	1.2	1.3	1.4
Estimation method	OLS	2SLS	2SLS	2SLS
Instruments	Three-group instruments and their spatial lags			
Capital stock	0.270 (21.3)	0.291 (8.0)	0.329 (8.8)	0.336 (23.3)
Units of labour	0.299 (21.4)	0.278 (11.3)		0.868 (36.8)
Dependent variable spatial lag		0.305 (3.6)	0.328 (4.3)	0.014 (1.9)
Hours worked per year			0.259 (4.6)	
Dummy Objective 1 regions				-0.285 (-33.2)
Regional fixed-effect	Yes	Yes	Yes	No
R ² (pseudo)	0.98	0.98	0.98	0.78
LM test for residual spatial correlation	45.251	0.174	0.245	4.290
p-value	0.000	0.677	0.621	0.038
Moran's I test on residuals ^a	6.279	0.362	0.465	2.070
p-value	0.000	0.718	0.642	0.038

Notes: ^aFor models estimated by two-stage least-squares (2SLS), Moran's *I*-test is calculated as the variant proposed by ANSELIN and KELEJIAN (1997) for instrumental variable (IV) residuals.

The sample period is 1985–2006; $N \times T = 4378$.

All variables are normalized to population and log-transformed.

The spatial weight matrix is the square of the inverse of distance (km).

Time-fixed effects are included in all regressions.

The asymptotic *t*-statistic is given in parenthesis.

All coefficients are significant at 1% probability.

R² (pseudo) is calculated as the ratio of the variance of the fitted values to the variance of the actual values.

LM, Lagrange multiplier; OLS, ordinary least-squares.

discussed above;¹³ the instruments included are the three-group method instruments for capital and labour and functions of their spatial lags, their adequacy is assessed by the Sargan's test, which yields a *p*-value of 0.14. The estimated coefficients are 0.291 for capital and 0.278 for labour; no evidence of spatial correlation is detected for the estimated residuals according to the Lagrange multiplier test and Moran's *I* test.¹⁴

Note that the coefficients associated with each production input cannot be *directly* interpreted as an elasticity due to the presence of spillover effects, which through the spatial multiplier lead to a different spatial steady-state equilibrium as a consequence of a unit (or percentage) change in one of the regressors. The spatial multiplier can be derived from the following compact reduced form expression for model (2):

$$y = [(I_T \otimes (I_N - \rho \tilde{W}))^{-1} X \beta + [(I_T \otimes (I_N - \rho \tilde{W}))^{-1} u \quad (3)$$

where the labour and capital input are included in the *X* matrix.

Assuming that the weight matrix is row-standardized, LESAGE and PACE (2009) explained that the direct effect of a unit (or percentage) change in the *r*th variable for region *i* is obtained as the own-partial derivative of y_i with respect to x_{ir} calculated from the function:

$$S(\tilde{W}) = [(I_T \otimes (I_N - \rho \tilde{W}))^{-1} I_{TN} \beta_r$$

while indirect effects are given by the cross-partial derivatives; the total effect is obtained as the sum of direct and indirect effects.

For regression 1.2 the average summary expressions for the three effects are calculated; for the capital input the direct effect is 0.291 and the total one is 0.294; while for the case of labour they are 0.278 and 0.281, respectively. These reported values have to be interpreted cautiously since the summary measures are computed under the assumption that the weight matrix is row-standardized, while, as discussed above, the preference was for the largest eigenvalue normalization.¹⁵ Notwithstanding this point, the estimated model provides valuable indications on the role played by productive inputs and spatial spillovers in determining the regional output level in Europe.

Regression 1.2 represents the base model for the calculation of the regional TFP variable, while the last two regressions reported in Table 1 allow one to evaluate some particular aspects of the production function relationship. Specifically, regression 1.3 allows one to check for the robustness of a different measure of the labour input. The variable 'hours worked per year' is included in place of 'units of labour' to control for differences in the weekly worked hours provided for by different national legislation. The estimated coefficients (0.26 for labour and 0.33 for capital) are in line with those obtained from the previous specification.

Finally, as the estimation of the regional production function is relevant in its own right – beside serving as the base for measuring TFP – it was also investigated whether Objective 1 regions exhibit a significantly different performance with respect to the average of the regions; the results point out that, for the same level of capital and labour endowments, the Objective 1 regions show a considerable lower level of production; it is worth noting that in regression 1.4 no fixed effects are included and this results in higher estimated coefficients for both productive inputs while the spatially lagged term is associated with a very low coefficient; this results in a misspecified model with spatially autocorrelated errors as diagnosed by the Lagrange multiplier test and Moran's *I* test.

For the estimated models reported in Table 1, one guards against possible heteroskedasticity and remaining spatial correlation by extending to the panel data framework the spatial heteroskedasticity and correlation consistent (SHAC) estimator for the variance-covariance matrix proposed by KELEJIAN and PRUCHA (2007). More specifically, in order to estimate

each element of the variance–covariance matrix the Parzen kernel function was chosen, as defined by ANDREWS (1991), whose argument is given by the ratio of the distance between each pair of regions to a selected bandwidth; for the latter the following values are considered: 100, 300, 600 and 1200 km; the first is a very short distance, the others approximately correspond to the lower decile, the lower quintile and the median of all the regional distances considered.

Table 2 reports the results for the t -ratios based on the SHAC estimates; in order to save space, those for the main explanatory variables of model 1.2 of Table 1 are presented.¹⁶

Overall the results obtained confirm the significance of all the regressors included in the model specifications considered; as expected t -ratios (standard errors) tend to decrease (increase) as a function of the bandwidth selected.

Total factor productivity (TFP)

TFP at a regional level, which, as known, measures the efficiency in transforming physical capital and labour into output, is derived from the fixed effects obtained from the estimation of regression 1.2. This approach was advanced, among others, by ISLAM (1999, and references therein) and it allows one to measure TFP as long-run equilibrium (average) values.¹⁷

The average values of TFP, computed as the index relative to the European average, for the period 1986–2006 are reported in Fig. 2(a). Denmark is the leading region, with values nearly triple the European average and way ahead of the other regions in the ranking. Zurich, the capital regions of Luxembourg, Belgium (Bruxelles) and Norway (Oslo) follow at some distance. Note that the efficiency index displays greater variability in the high end of the ranking compared with the tail.

As for the geographical distribution of the index, in the centre of Europe the concentration of high values can be observed around Switzerland and Western Germany regions. Moreover, the TFP map shows the highest levels for all Norwegian regions, North-eastern and Eastern Scotland, a cluster of regions in the Southern United Kingdom, three Dutch regions (Groningen, Utrecht and Noord-Holland), Lombardia (Italy) and the capital regions of France (Île-de-France), Sweden (Stockholm) and Austria (Vienna/Wien). Good results are also displayed by the Swedish regions, the French

regions of Rhône-Alpes, Provence-Alpes-Côte d'Azur and Alsace, the western regions of Aquitaine and Midi-Pyrenees, and the Centre-north of Italy (Trentino, Lazio, Val d'Aosta and Emilia-Romagna). Most of the regions of Portugal, Spain (except for the capital Madrid), Southern Italy and Greece (except for Sterea Ellada) stay in the lower part of the ranking. A very low value is unexpectedly found for the region of Outer London. This might be due to the presence of a high flow of labour commuting to Inner London.

Fig. 2(a) clearly depicts a spatial correlation pattern for the regional values of TFP values across Europe; this is confirmed by the significant value (17.02) found for Moran's I test. The following sections investigate the determinants of TFP levels within a spatial lag model framework.

INTANGIBLE ASSETS

An original aspect of this paper is that it analyses the concurrent effects of three types of intangible capitals: social capital, human capital and technological capital. In general, these intangible inputs are supposed to enhance the level of regional efficiency by creating a more favourable economic environment for the localized firms; for this reason in the Lisbon agenda they are considered strategic in economic growth policies. A complementary perspective, based on micro-data, considers the intangible assets as part of business investment, like software, research and development expenditure, patents, economic competencies, and employee training (ORGANISATION FOR ECONOMIC CO-OPERATION AND DEVELOPMENT (OECD), 1998). It is worth noting that MARROCU *et al.* (2009) for a large panel of European companies estimated that the share of the intangible assets over the tangible one is rapidly increasing and in 2006 it has reached, on average, the value of 42%, thus confirming the importance of including intangibles assets as determinants of productivity.

As mentioned in the Introduction, one novelty of the contribution is to consider how regional productivity levels in Europe are influenced by social capital, which is an aspect often neglected in economic analyses, as pointed out, among others, by COLEMAN (1990) and TEMPLE and JOHNSON (1998). In his well-known contribution on regional development in Italy, PUTNAM (1993) stated that social capital is a complex

Table 2. Production function model spatial heteroskedasticity and correlation consistent (SHAC) estimates

Variable	Coefficients	t -ratios				
		Classical	SHAC			
			$d_n = 100$	$d_n = 300$	$d_n = 600$	$d_n = 1200$
<i>Regression 1.2 table 1</i>						
Capital stock	0.291	8.019	6.372	5.661	5.036	4.655
Units of labour	0.278	11.296	9.279	8.122	7.339	7.105

Note: d_n is the Parzen kernel bandwidth (km).

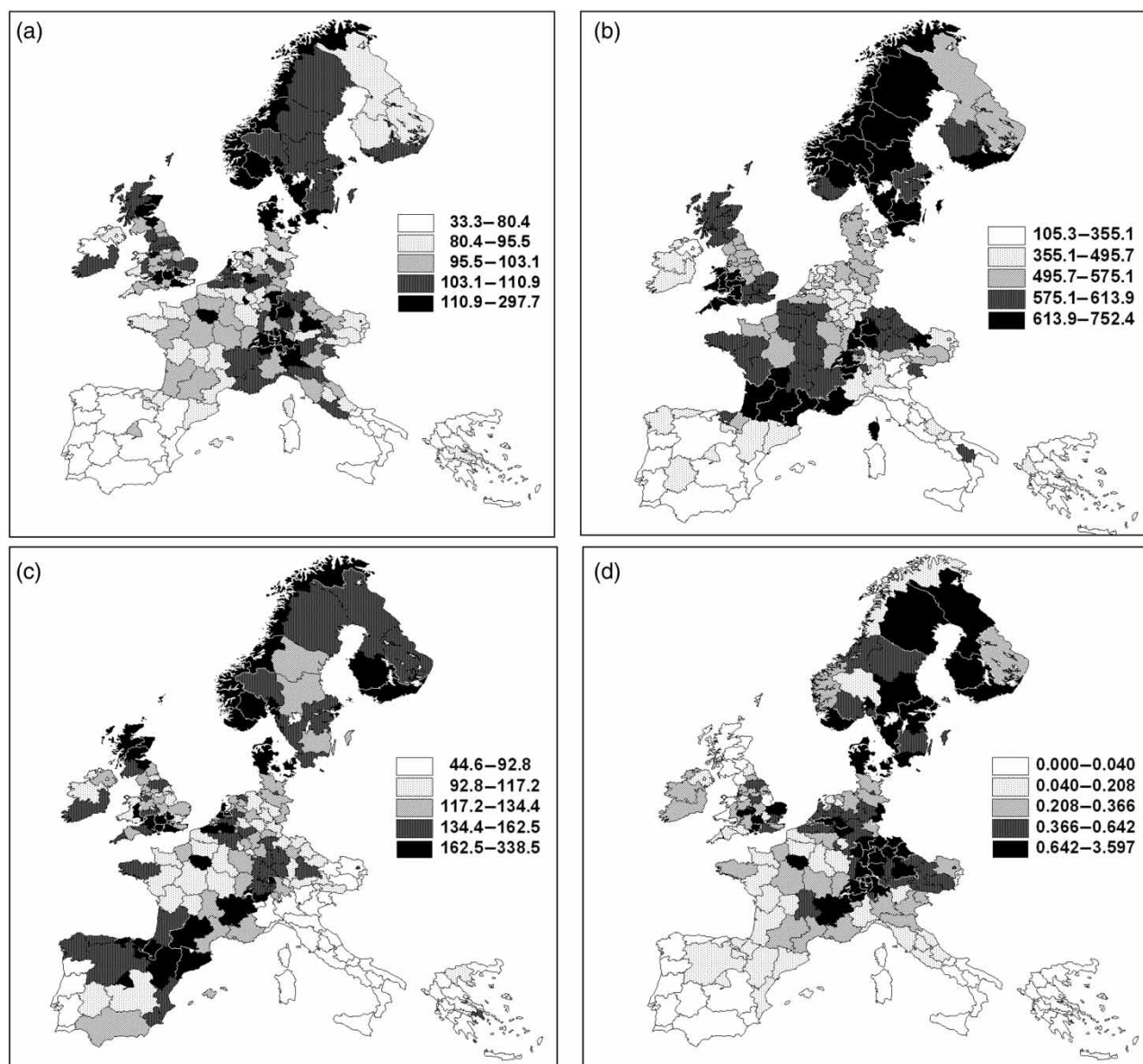


Fig. 2. Total factor productivity and intangible assets: (a) total factor productivity, 2004 index Europe = 100; (b) social capital, 2002 participation to social activities per 1000 population; (c) human capital, 2002 inhabitants with a degree per 1000 population; and (d) technological capital, 2002 patents PCT, five-year stock, per 1000 population

feature of social organization – represented by networks, norms and trust – which improves the efficiency of the local society by facilitating the coordination among actors. Since then a growing number of papers have tried to assess its role remarking how a high level of social capital in a certain area is associated with a reduction of transaction costs for both firms and consumers (DIANI, 2004), a wider diffusion of knowledge and innovation among firms (HAUSER *et al.*, 2007), and widespread trust which, in turn, facilitates cooperation among the members of a community; all these effects are proved to enhance the economic performance (KNACK and KEEFER, 1997).

It is not an easy task to measure a complex, and often informal, phenomenon as social capital (GLAESER *et al.*, 2002), and in this empirical work several indicators were

used. Some relevant contributions are listed in order to give an idea of the huge variability that characterizes the selection of *sound* and *satisfactory* indicators for social capital: newspaper reading and referenda turnout (HELLIWELL and PUTNAM, 1995), blood donation (GUISSO *et al.*, 2004), social infrastructure (HALL and JONES, 1999), the level of trust (LA PORTA *et al.*, 1997), the density of voluntary organization (PALDAM and SVENDSEN, 2000), and associational activity (BEUGELSDIJK and VAN SCHAİK, 2005). In the present paper, as a proxy for regional social capital, the notion of ‘active social participation’ is used: it is measured by the share of the population that have taken part at least once in the last twelve months in social activities such as voluntary service, unions and cultural associations’ meetings over the total population. This proxy, as emphasized

by PUTNAM's (1993) seminal paper, considers the structural features of social capital which are assumed to facilitate the creation of 'bridging networks', social ties and coordination among local agents. A dense network of association and participation encourages cooperation skills and collective efforts, therefore enhancing the efficiency of the local economy. The data on social participation come from the European Social Survey and have the advantage of giving a homogeneous measure of social capital at the regional level for the European countries considered.

The distribution of social capital across the European regions for the year 2002 is presented in Fig. 2(b).¹⁸ With reference to the geographical distribution of social capital in Europe, note that high values are located next to areas characterized by much lower values. The regions boasting the highest value of the indicator are located in the Scandinavian peninsula, in the four regions of Germany's Baden-Württemberg, in France's Mediterranean and Pyrenees areas, and in the UK's South-west.

The literature has also emphasized the positive role of human capital on productivity level and growth (MANKIW *et al.*, 1992; BENHABIB and SPIEGEL, 1994). At the regional level a higher availability of well-educated labour forces represents an advantage for the localization of innovative firms, thus promoting local productivity (RAUCH, 1993). As a proxy of 'high' human capital the share of population that has attained at least a university degree (International Standard Classification of Education (ISCED) 5–6) is used. This proxy has also been used for the European regions by BOTTAZZI and PERI (2003) and STERLACCHINI (2008).

The distribution of human capital across the European regions for the year 2002 is represented in Fig. 2(c). Italy stands out for having all regions in the lowest class, while all other countries, although displaying values below the European average, show greater variability and have at least one region higher in the rankings. This is the case with Portugal (with the Lisboa region) and Greece (with Attiki e Kentriki Makedonia). Note the excellent performance of Norway, Scotland, Finland's southernmost regions (Etela-Suomi and Lansu-Suomi) and Eastern Spain (Cataluña, Aragona, Navarra, Pais Basco and Cantabria).

The inclusion in the production function of a direct measure of technological stock has been originally suggested by GRILICHES (1979), and afterwards the knowledge-capital model has been used in several contributions at firm level and also extended to macroeconomic models both at regional and country level. The idea is that technology is partly a public good and firms benefit from a higher degree of knowledge capital available in their areas since it leads to an increase in productivity. There is a huge number of contributions, based on different theoretical approaches, that have studied the effect of technology on the economic performance and also how this effect spills over the regional boundaries to influence contiguous

areas (for a comprehensive survey, see AUDRETSCH and FELDMAN, 2004). Some recent studies, in the same vein of the contribution, have examined the effects of technological capital on the economic performance of the European regions. FISCHER *et al.* (2009b) found a positive influence of patent stock on TFP together with a significant interregional knowledge spillovers effect. The analyses proposed by STERLACCHINI (2008) and RODRIGUEZ-POSE and CRESCENZI (2008) are more general and offer support to the positive role exerted by research and development expenditure on gross domestic product growth rate also controlling for other regional determinants like human capital and infrastructures.

There is a long-standing debate on how to measure technological activity and all the proposed measures have pros and cons. Among them patent counts have the clear advantage of providing a long time span along with large regional and sectoral coverage; moreover, it has been proved that they are closely correlated with other measures of innovation, like research and development expenditures and new products (GRILICHES, 1990; ACS *et al.* 2002). Therefore, as an indicator for technological capital, this paper uses the number of patent applications adhering to the Patent Cooperation Treaty; this choice ensures that only patents with a good economic value are likely to be considered since this international protection of innovation is costly. In order to control for the high variability of the regional annual series, the indicator is computed as patent stock in the previous five years over the total population. The data have been regionalized on the basis of the inventors' residence; in the case of patents with multiple inventors, proportional quotas have been attributed to each region.

The distribution of technological capital across the European regions in the year 2002 is represented in the last panel of Fig. 2; its per-capita values show a large high-performance cluster, which starts from Rhône-Alpes (in France), passes through all Swiss regions and ends at the South-central part of Germany (Oberbayern, Freiburg, Stuttgart, Rheinhessen-Pfalz, Mittelfranken, Karlsruhe, Oberpfalz, Darmstadt, Tubingen, Unterfranken, Oberfranken). Close to this agglomeration are those of Düsseldorf and Köln. These top-performance regions are surrounded by other high-performance countries. Detached from this cluster are the capital region of Paris (Île-de-France). Sweden, Finland and Denmark show top-high innovation performance, suggesting the presence of a Scandinavian cluster. All Southern European regions are characterized by very low levels of technological capital.

ECONOMETRIC ESTIMATION AND RESULTS

The purpose of this section is to provide empirical evidence on the role of intangible assets in determining the level of TFP for the European regions. As stated in the Introduction, due to the lack of available long-time

series for variables such as social capital, the analysis is now carried out in a cross-section framework. The estimations are based on the model specification reported below:

$$a_i = c + \beta_1 sk_i + \beta_2 hk_i + \beta_3 tk_i + \rho \tilde{W}_N a_i + \varepsilon_i \quad (4)$$

where lower case letters indicate values in logs; i is the 199 regions; a is TFP; sk is social capital; hk is human capital; tk is technological capital; and $\tilde{W}_N a_i$ is the spatially lagged dependent variable computed with the same normalized weight matrix adopted in the third section. All variables are normalized to population in order to control for different size of the regions. TFP is derived from regression 1.2 in Table 1. For the explanatory variables, the values refer to the year 2002.

Due to potential system feedbacks, omitted variables and measurement errors, endogeneity problems can also be present in model (4); therefore, following ANSELIN and LOZANO-GRACIA (2008), the spatial 2SLS method is applied, which allows one to guard against endogeneity

bias coming from different sources. The instruments for the explanatory variables are constructed by following the three-group method, as discussed in the previous section, while the spatial-lag term is instrumented by the spatial lags of the other instrumental variables.¹⁹

The results for the TFP spatial lag model estimated by 2SLS are reported in Table 3. The first column presents the base model where all the intangible assets exhibit positive and significant coefficients: 0.14 for social capital, 0.17 for human capital and 0.06 for technological capital. With the caveats already reported in the previous session, the direct, indirect and total impacts for the three intangible assets were calculated. For social capital the direct impact is 0.142 and the total one is 0.151; for human capital they are 0.177 and 0.188, respectively; while for technological capital they amount to 0.063 and 0.068. Although these effects are to be interpreted cautiously, the estimation results provide convincing evidence on the crucial role played by intangible productive factors as determinants of regional TFP.

Table 3. Total factor productivity and intangible assets

	3.1		3.2		3.3		3.4		3.5	
<i>Dependent variable: total factor productivity</i>										
Social capital	0.136	*	0.164	**	0.317	***	0.161	**	0.188	***
	(1.722)		(2.238)		(5.168)		(2.154)		(2.867)	
Human capital	0.170	***			0.152	**	0.169	***	0.161	**
	(2.819)				(2.476)		(2.966)		(3.045)	
Technological capital	0.061	***	0.060	***			0.050	***	0.038	**
	(4.375)		(4.347)				(3.171)		(2.184)	
Long-life learning			0.053	***						
			(3.388)							
Knowledge capital					0.050	***				
					(3.426)					
Accessibility							0.070	**	0.040	
							(1.925)		(1.187)	
Dependent variable spatial lag	0.895	***	0.879	***	0.924	***	0.926	***		
	(4.531)		(4.559)		(4.784)		(4.920)			
Distances for spatial lag (km)	All		All		All		All			
Spatial lag – distance 0–300 km									0.853	***
									(2.322)	
Spatial lag – distance 300–600 km									0.476	**
									(1.836)	
Spatial lag – distance 600–900 km									0.138	
									(0.391)	
Spatial lag – distance 900–1200 km									–0.253	
									(–0.653)	
Squared correlation	0.42		0.66		0.43		0.68		0.71	
IV-Moran	–1.749		–1.909		–1.660		–1.872		–1.773	
p -value IV-Moran	0.080		0.056		0.097		0.061		0.076	

Notes: All regressions are estimated by applying the two-stage least-squares (2SLS) method; endogenous variables are instrumented with three-group method instruments; all models include a constant term.

$n = 199$; all variables are normalized to population and are log-transformed.

For human capital, social capital and technological capital, the values refer 2002; for accessibility, the values refer to 2001.

Spatial weight matrix = square of the inverse of distance (km).

The asymptotic t -statistic is given in parentheses.

Squared correlation is the squared correlation between the predicted and actual values.

IV-Moran is the Moran I test proposed by ANSELIN and KELEJIAN (1997) for 2SLS residuals.

*Statistically significant at the 10% level; **statistically significant at the 5% level; and ***statistically significant at the 1% level.

As already pointed out, this is the first time that the simultaneous effect of these intangible assets on productivity is examined. One cannot therefore compare the magnitude of the results with previous literature. Within a knowledge production function model, the positive effects of various form of 'soft' inputs (human capital, research and development, social capital) for a small sample of European regions has been shown by TAPPEINER *et al.* (2008). For the case of Italian regions, the positive role of some intangible inputs was documented by both MARROCU and PACI (2010) and DI GIACINTO and NUZZO (2006). Evidence on the influence of human capital for the case of the European regions has been found by BOTTAZZI and PERI (2003) within a knowledge production function model and by STERLACCHINI (2008) and FISCHER *et al.* (2009a) in a productivity growth model. The latter authors also find an unexpected spatial indirect negative effect coming from neighbouring regions. As far as the social capital variable is concerned, a positive effect of the active participation in associational activity on gross domestic product growth rate of fifty-four NUTS-1 regions belonging to seven European countries is found by BEUGELSDIJK and VAN SCHAIK (2005), who also showed that trust is never significant. A positive influence of technology, measured by patent stock, on TFP is shown, within a spatial model, by LESAGE and FISCHER (2009) and FISCHER *et al.* (2009b) for the European regions and by MADSEN (2008) for Organisation for Economic Co-operation and Development (OECD) countries.

In order to check for the correct specification of the spatial pattern, the instrumental variable-Moran's *I* test is calculated (ANSELIN and KELEJIAN, 1997). According to the test result, no evidence of remaining residual spatial autocorrelation was found. Note that the coefficient of the spatially lagged term is strongly significant and high in value (0.89), confirming the occurrence of external spillovers from other regions even after controlling for the effects of the intangible factors.

A robustness check for the base specification was conducted by including a different proxy for human capital (regression 3.2) and for technological capital (regression 3.3).²⁰ For the first case an indicator of permanent education (share of population involved in lifelong learning programmes) is included.²¹ The coefficient turns out to be positive and significant, although its magnitude (0.053) is much lower than the previous proxy.

The new proxy for technology – called knowledge capital – is calculated as the total funding by the European Commission under the Fifth Framework Program (the programme covers the five-year period from 1998 to 2002). Data on individual projects were regionalized by means of the address and postcodes of participants (MAGGIONI *et al.*, 2007). In the case of more than one participant, a proportional share of the funding was assigned to each of them. This new variable is expected to capture the effects of the creation of (new) knowledge on regional TFP; such effects are supposed to

be more widespread and less specific, at least with respect to economic efficiency levels, than those induced by the patent activity. The coefficient of the knowledge capital variable is of the same order of magnitude as that associated with technological capital; however, its inclusion in the specification makes the coefficient of social capital higher. This result may be due to possible complementarities between the two assets. A thorough investigation of such complementarities in enhancing efficiency levels is left for future research.

Although the focus of this paper is on investigating the role of intangible assets in determining TFP, the authors are aware that such a complex economic phenomenon may depend on other factors. The empirical literature has identified in a good network of public infrastructure one of these factors.²² As a proxy for infrastructures, this paper uses a composite index of accessibility based on the potential accessibility by road, train and air and on the time necessary to reach the market (with a negative sign); it takes the value of 1 when the accessibility is very low and reaches the value of 5 for a very high accessibility level. In order to investigate the potential of physical infrastructure in determining TFP, the base model is augmented with the 'tangible' accessibility covariate. The results, reported in column 3.4 of Table 3, confirm the estimated coefficients for the intangible assets and offer empirical support to the hypothesis that a high degree of accessibility is TFP enhancing.

The literature has emphasized the localized nature of spatial knowledge spillovers which are facilitated by common institutions and culture and by face-to-face interactions. It is well-known that knowledge flows often spill beyond regional and national borders, although they tend to decline with distance (see the recent survey by DÖRING and SCHNELLENBACH, 2006). Therefore, it is an interesting issue to assess which is the 'crucial' distance to allow the benefits of one region to spill over into the neighbouring ones. Different non-overlapping weight matrices are calculated according to the distance selected; one starts from a distance of 0–300 km which guarantees that every single region has at least a connection to another region; three more distance ranges are then considered: 300–600, 600–900 and 900–1200 km. Note that the cut-offs distances – 300, 600 and 1200 km – roughly correspond to the lower decile, the lower quintile and the median of the regional distances among the European regions considered. Although the authors are aware that the wideness of the interval is arbitrary, on the basis of preliminary investigations it is believed that one can derive some interesting insights on the spatial pattern of the regional spillovers.

The results for regression 3.5, where the four spatially lagged terms included were disaggregated according to the range distances, reveal that only the first two are significant, thus signalling that the relevant links are those within a 600 km distance. Note that with the exception of the accessibility variable, all the explanatory variables remain significant and Moran's *I* test does not

Table 4. Total factor productivity model spatial heteroskedasticity and correlation consistent (SHAC) estimates

Variable	Coefficients	t-statistics				
		Classical	SHAC			
			$d_n = 100$	$d_n = 300$	$d_n = 600$	$d_n = 1200$
<i>Regression 3.1. table 3</i>						
Social capital	0.136	1.722	2.100	2.048	1.883	1.860
Human capital	0.170	2.819	2.933	2.511	2.146	2.058
Technological capital	0.061	4.375	4.119	3.359	2.676	2.320

Note: d_n is the Parzen kernel bandwidth (km).

signal residual spatial autocorrelation. To check the results, one then re-estimates regression 3.1 by including only one spatially lagged term in turn.²³ The evidence corroborates the previous finding, as only the 0–300 and the 300–600 lagged terms turned out to be significant. However, it is worth noting that when considering distances greater than 300 km the residuals are always spatially correlated, indicating that the 300 km distance range is capturing most of the spatial dependency present in the data.

These results are in line with previous findings which have noted the localized nature of geographical spillovers among the European regions, although direct comparisons are problematic given the heterogeneity of the methodological approaches and geographical units considered. More specifically, within a knowledge production function approach, BOTTAZZI and PERI (2003) found that technological spillovers are positive and significant only up to a radius of 300 km and MORENO *et al.* (2005) up to 250 km or second-order contiguity. In a regional growth model, PACI and PIGLIARU (2002) showed that spatial spillovers influence productivity up to the third-order contiguity and RODRIGUEZ-POSE and CRESCENZI (2008) up to three hours' drive (equivalent to approximately 200–300 km). It is worth noticing that in the data set the regions included in first-order contiguity have an average distance of 158 km, in the second-order 287 km and in the third-order 418 km. In conclusion, the empirical evidence indicates that spatial spillovers are important in determining the economic performance of the European regions and that their influence tends to decay rapidly once a distance of, roughly, 300 km is reached.

The present authors also calculates the SHAC estimates for the variance–covariance matrix; in Table 4 the *t*-ratios are reported for the main specification 3.1.

All the TFP determinants maintain their significance, thus confirming previous inference and the contribution of intangible assets in determining productivity.²⁴

CONCLUSIONS

The aim of this paper has been twofold. First, a regression was derived based on measure of regional total factor productivity (TFP) for Europe, which has the nice

advantage of not imposing a priori restrictions on the inputs elasticities; this is done by estimating a Cobb–Douglas production function relationship which includes the traditional inputs as well as a measure of spatial interdependence across regions.

Secondly, the determinants of the TFP levels were investigated by analysing the role played by intangible factors: social capital, human capital and technological capital. This was motivated by a wide recent literature providing evidence which suggests that the economic performance across regions differs not only in traditional factor endowments (labour and physical capital), but also mainly in technological, human and social capital.

The first part of this paper estimated a production function model over the period 1985–2006, which serves as the base to derive the regional TFP variable; this is obtained from an adequately specified model which properly accounts for the spatial pattern present in the data, without overlooking relevant econometric issues such as endogeneity and non-stationarity. The estimated TFP levels point out a concentration of high values around Switzerland, the Netherlands, Western Germany and Norway. Most of the Swedish regions, the French Southern and Western regions, and the Centre–North of Italy display values above average. Finally, most of the regions in Portugal, Spain and Greece are at the bottom of the ranking.

The second part of this paper investigated the determinants of TFP level among the European regions. To the best of the authors' knowledge, this paper represents the first attempt aimed at assessing the effects of three kinds of intangible assets on the regional efficiency levels in Europe. The estimated models have provided robust evidence on the role played by technological, human, and social capital in enhancing economic growth and social cohesion. This result indicates that a region with a higher level of social participation and cooperation enjoys a higher degree of trust among the members of the community, and this enhances the economic efficiency. At the same time the local economy benefits from the presence of a well-educated labour force which facilitates the localization of innovative firms and thus boosts the productivity of the entire economy. Finally, the presence in the region of high levels of technological capital turns out to be beneficial for the regional TFP since local firms can benefit from the public good

characteristic of technology. Some robustness exercises were also performed, including different proxy for human capital (lifelong learning participation) and for technological capital (participation to the Community 5FP), and the results remain unchanged. Moreover the characteristics of the regions are controlled in terms of accessibility and this 'tangible' asset turns out to influence positively the regional TFP level.

The issue of spatial dependence has been extensively examined by means of spatial lag models. The coefficients of the spatially lagged variable always appear to be positive and strongly significant, confirming the existence of external spillovers from other regions, which through the spatial multiplier reinforce the effects of each region's own intangible factors. More specifically, the spatial spillovers seem to generate their strongest impacts in the range 0–300 km, which roughly represents the lower decile of the distances among the European regions considered. This result confirms previous evidence about the fact that spatial spillovers are somehow bounded in space and that knowledge diffusion is more effective among closer regions.

In general the results have some interesting policy implications since they stress the importance of policy strategies aimed at accelerating the accumulation of the intangible assets which constitute highly effective production endowments. Such policies will allow the European economy to become, as put forward in the Lisbon agenda, the most advanced and productive society in the world.

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APPENDIX A

Table A1. *Regions and Nomenclature des Unités Territoriales Statistiques (NUTS) level*

Country	NUTS	Number of regions
Austria	2	9
Belgium	1	3
Denmark	1	1
Finland	2	5
France ^a	2	22
Germany ^b	2	30
Greece	2	13
Ireland	2	2
Italy ^c	2	20
Luxembourg	1	1
Netherlands	2	12
Norway	2	7
Portugal ^a	2	5
Spain ^a	2	17
Sweden	2	8
Switzerland	2	7
United Kingdom	2	37

Notes: ^aTerritories outside Europe are not considered.

^bBerlin and East German regions are not considered.

^cThe autonomous provinces of Trento and Bolzano are aggregated.

APPENDIX B

Table B1. *Data sources and variables description*

Variable	Source	Years	Measurement unit	Description
Value added	Cambridge Econometrics	1985–2006	€, millions, 2000	
Capital stock	Authors' own calculation	1985–2006	€, millions, 2000	
Units of labour	Cambridge Econometrics	1985–2006	Thousands	

(Continued)

Table B1. Continued

Variable	Source	Years	Measurement unit	Description
Hours worked	Cambridge Econometrics and authors' own calculation	1985–2006	Levels	Total hours worked by employees per year
Population	Cambridge Econometrics	1985–2006	Thousands	
Human capital	Eurostat	2002	Percentage	People with a degree, ISCED 5–6 (over the population aged 15 years and over)
Social capital	European Social Survey Round 1 2002 and Round 2 2004	2002	Percentage	People who have taken part at least once in the last twelve months in social activities such as voluntary service, unions and cultural associations meetings (over the total population)
Technological capital	OECD, REGPAT database	2002	Levels	Patent applications at Patent Cooperation Treaty (PCT), stock for the previous five years
Long-life learning	Eurostat	2002	Percentage	Participation of adults aged 25–64 years in education and training (over the population aged 25 years and over)
Knowledge capital	Authors' own calculation from the European Commission	1998–2002	€, current	Total funding by the European Commission under the 5th Framework Program (regionalized according to the research projects participants' address)
Accessibility	Eson, Project 2.4.2	2001		Regions are classified into five groups (from 1 = very low to 5 = very high) according to their potential accessibility by road, train, air and time to the market
Dummy Objective 1	Eurostat	2002		Regions of the Objectives 1 programme for the 2000–2006 Structural Funds, including the transition regions

Note: ISCED, International Standard Classification of Education; OECD, Organisation for Economic Co-operation and Development.

NOTES

- Results are not reported for reasons of space, but they are available from the authors upon request and reported in DETTORI *et al.* (2008) where an extended version of this paper can be found.
- To check the robustness of the results, Moran's I test is calculated allowing for different specifications of the spatial weight matrix. A more detailed discussion on the economic aspects of matrix normalization is postponed to the next section.
- When the panel data are stacked as T -subsequent cross-sections, one has:

$$\tilde{W} = (I_T \otimes \tilde{W}_N)$$

where I_T is a $(T \times T)$ identity matrix; and \tilde{W}_N is the normalized spatial weight matrix.

- ANSELIN (1988) emphasizes that the aim of spatial econometrics should be on measuring spatial spillovers. The alternative spatial error model specification is just a particular case of non-spherical errors which eliminates spillovers by construction.
- For a thorough discussion on normalization issues, see also ELHORST (2010).
- Note that, as emphasized by ANSELIN *et al.* (2008), row standardization also has the side-effect that the sum of all the elements in W equals N , the number of cross-sectional observations, and that the induced asymmetry

in the weights 'is an unusual complication with significant computational consequences' (p. 628).

- For a discussion on the relevance of absolute distance versus relative distance in economic phenomena, see BALTAGI *et al.* (2008).
- For cross-section analyses, exceptions are represented by KELEJIAN and PRUCHA (2004, 2007), ANSELIN and LOZANO-GRACIA (2008), FINGLETON and LE GALLO (2008), and DALL'ERBA and LE GALLO (2008); for a panel application, see ELHORST *et al.* (2007).
- TFP is estimated using measured inputs – a possible cause of the disparities among regions relies on measurement errors; moreover, there may be problems of misspecification of the production function (CASELLI, 2005).
- Similar results are found when testing for weak exogeneity of capital and labour within an error-correction model framework; only labour can be considered weakly exogenous (the p -value for the null hypothesis that the adjustment term is zero in the labour Error Correction Model (ECM) is equal to 0.293).
- The panel version of the test is reported in ANSELIN *et al.* (2008).
- Given that the sample refers to a period of twenty-two years, a panel co-integration analysis was also carried out in order to guard against the spurious regression problem. Evidence of a non-stationary kind of behaviour was detected for the individual variables by means of the cross-sectionally augmented Im Pesaran Shin (CIPS) unit root tests (PESARAN, 2007). The existence of a spurious relation between the variables of interest was ruled out

- by the results of the well-known co-integration tests developed by PEDRONI (1999, 2004), which allowed the null hypothesis of no co-integration to be rejected. All detailed results are reported by DETTORI *et al.* (2008).
13. Models that account for the two sources of endogeneity separately were also estimated. The model estimated by an instrumental variable without the spatial term, as expected, yields spatially autocorrelated residuals; this result points to the importance of modelling explicitly the spatial pattern. On the other hand, the spatial lag model for which the productive inputs are not instrumented (estimated by the maximum likelihood (ML) method) ensures that the residuals do not exhibit spatial autocorrelation, but the coefficients for the capital and labour regressors are quite similar to the ordinary least-squares (OLS) ones, signalling that the endogeneity bias is still present.
 14. For 2SLS estimated models, Moran's *I* test is calculated as suggested by ANSELIN and KELEJIAN (1997) for the case of instrumental variable residuals.
 15. For the same reason, the measures of dispersion for the impact estimates are not reported. Note also that for the normalized matrix adopted for each entry has a very small value.
 16. All the other results are available from the authors upon request.
 17. Note that possible changes in relationship 1.2 are accounted for by the temporal dummies. A subsample analysis was not carried out in order to check the robustness of the result, as splitting the sample would result in a loss of valuable information needed to estimate the fixed-effects accurately (it is well known that the fixed-effect estimator makes use of the within dimension of the sample information, which in the case is constituted by twenty-two time observations).
 18. For some regions in France, Germany and the UK, data are available at the NUTS-1 level so that that value is assumed for the included NUTS-2 regions.
 19. In the special case in which the omitted relevant variables follow a spatial autoregressive process and are also correlated with the included spatially correlated ones, LESAGE and PACE (2009) show that this leads to a spatial Durbin model specification. The 2SLS method is more general as it allows one to tackle different sources of endogeneity bias. Note also that in applying the latter method, instruments are represented by the explanatory variables spatial lags, so that it is not possible to include them as regressors, as would be required by the spatial Durbin model estimation. Moreover, as reported in the discussion of the empirical results, evidence of omitted relevant spatially correlated variables was not detected by the spatial diagnostics carried out on the residuals.
 20. In the base specification, research and development expenditure was also used (as an alternative to patent counts); however, research and development at the regional level is only available for different years in each country. Note that the correlation coefficient between patents and research and development is equal to 0.82.
 21. An indicator was also used for a 'low' level of human capital (that is, the share of the population that has attained at most a primary level, ISCED 0–2). As expected, it shows a negative and significant influence on TFP. Moreover, its inclusion reduces the significance of the social capital variable.
 22. Starting from the seminal contribution by ASCHAUER (1989), the literature has investigated the role of infrastructure, and more generally of public capital, on regional performances. See, among others, EBERTS (1990) for the United States and MARROCU and PACI (2010) for the Italian regions; for a useful survey, see GRAMLICH (1994).
 23. Detailed results are not reported here to save space, but are available in DETTORI *et al.* (2008).
 24. The same kind of results are obtained for all the specifications reported in Table 3. All detailed results are available from the authors upon request.

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