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Proximity, Networking and Knowledge Production in Europe

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Motivation

The capacity of a region to generate, transmit and acquire innovation depends on a multifaceted set of factors:

- investment in R&D,
- education and training,
- work force experience,
- collaboration networks,
- capacity to absorb external knowledge,
- technology transfer mechanisms,
- mobility of researchers
- ....

In general, innovation activity depends on internal factors (R&D, HK) as much as on external elements (knowledge spillovers, circulation of ideas). (Grossman, Helpman, 1990; Rallet, Torre, 1999; Jaffe, 1989; Coe, Helpman, 1995).

Aims

The main aim of our research is to analyze the interaction of internal and external factors in determining the technological performance of the European regions.

More specifically:

- we investigate to what extent the regional innovative capacity depends on intra-regional efforts like R&D expenditure and human capital and on the ability to exploit inter-regional knowledge spillovers;
- we analyze the channels, i.e. different kinds of proximity and networks, which facilitate the emergence of such spillovers and how they interact - are they complementary or substitute?

Literature background

- The literature on Endogenous Growth and on New Economic Geography provides theoretical backing to the idea that there are technological spillovers within and across regions and countries.

- Spillovers are related to the geographical dimension since close-by agents are believed to have a better innovative performance because of pecuniary and pure technological advantages.

- The French School of Proximity argues that geographical proximity is neither necessary nor sufficient: there is a separate role for a-spatial links among agents (Carrincazeaux - Coris, 2011).

- Knowledge exchange and technological interdependence across agents are influenced by four other proximity dimensions: institutional, technological, social, organizational (Boschma, 2005).

Types of Proximity, beyond geographical space

- **Institutional proximity (I):** the effective transmission of knowledge may be facilitated by a common institutional framework, such as laws and norms (Maskell-Malmberg, 1999; Gertler, 2003).

- **Technological (or cognitive) proximity (T):** knowledge transfer requires appropriate absorptive capacity (Cohen-Levinthal 1990) which entails an homogenous cognitive base with respect to the original knowledge in order to understand and process it effectively.

- **Social (or relational) proximity (S):** social closeness facilitates firms capacity to learn, absorb external knowledge and innovate since this breeds trust which, in turn, lowers transaction costs and facilitate collaboration (Granovetter, 1985).

- **Organisational proximity (O):** relations within the same group or organisation influence the individual capacity to acquire new knowledge coming from different agents (Kirat - Lung 1999).

Types of Proximity, beyond local knowledge spillovers

- Another relevant concept for the analysis of knowledge flows is the distinction between unintented and intented spillovers (Maggioni et al., 2007). Proximity may induce a process of knowledge diffusion that does not depend directly on economic agents' decisions.
- In the case of intended spillovers, knowledge flows across a-spatial networks where agents exchange ideas on a voluntary base thanks to formal or informal agreements (Cowan and Jonard, 2004).
- Exchanges may be market or non market mediated, that is either pecuniary or pure technological spillovers (Breschi and Lissoni, 2001 and 2009, and Antonelli, 2007)

Empirics on knowledge spillovers

- Seminal paper on geographical spillovers: Jaffe 1989.
  Extensions for US consider mainly geographical proximity (Acs et al 1992; Audretsch and Feldman, 1996; Anselin et al 1997; O´hUallachain - Leslie 2007).
- Contributions on EU regions introduce technological and institutional proximity (Bottazzi-Peri 2003, Greunz 2003, Moreno-Paci-Usai 2005).
- Role of social/relational networks (as a regional indicator) together with geographical proximity within a KPF: Maggioni et al. 2007, Lobo –Strumsky 2008 for US MSA’s, Crescenzi et al. 2007 for both US and EU, Miguelez-Moreno 2010 for EU NUTS2 regions.
- No contributions on the role of organizational proximity on regional innovation performance. The only partial exceptions are Sorensen et al 2009, Oerlemans-Meeus 2005 at the firms level.

Our contribution

- We extend the Knowledge Production Function (KPF) model by including human capital as an additional input (important factor to account for the absorptive capacity).
- Broad territorial coverage 276 regions in 29 countries (EU27 plus Norway, Switzerland).
- We assess the role of different types of proximity and networks in channeling technological spillovers across regions.
- Computation of direct, indirect and total impact of each factor.
- Spatial econometric techniques are applied to assess the role of different (two at a time) proximity dimensions simultaneously.
- Tentative and preliminary interpretation for policy suggestions.

Empirical model/1

General form for the KPF model as a log-linearized CD function:

$$inn_i = \beta_1 rd_i + \beta_2 hk_i + \phi\ controls_i + \gamma\ \ proximity\ \ factors + \varepsilon_i$$

lower case letters indicate log-transformed variables, *i*=1,...276 regions

Dependent variable

inn: yearly average of patents per capita, 2005-2007

Internal determinants of innovation

- *rd*: R&D expenditures over GDP, 2002-2004
- *hk*: human capital, graduates over total population, 2002-2004

Controls

- population density
- regional share of manufacturing activities

Proximity factors

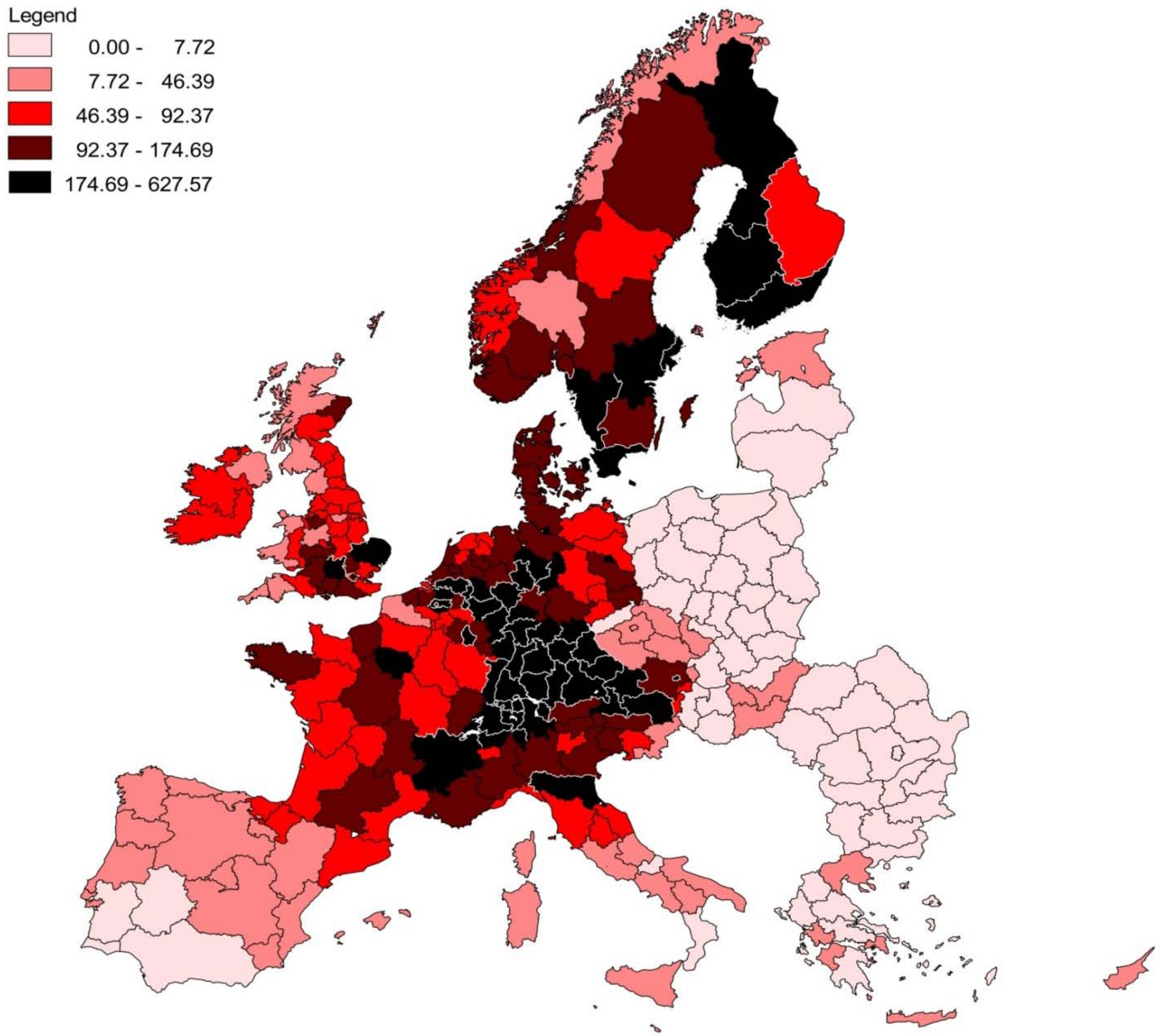
- G, I, T, S, O proximity matrices

Dataset

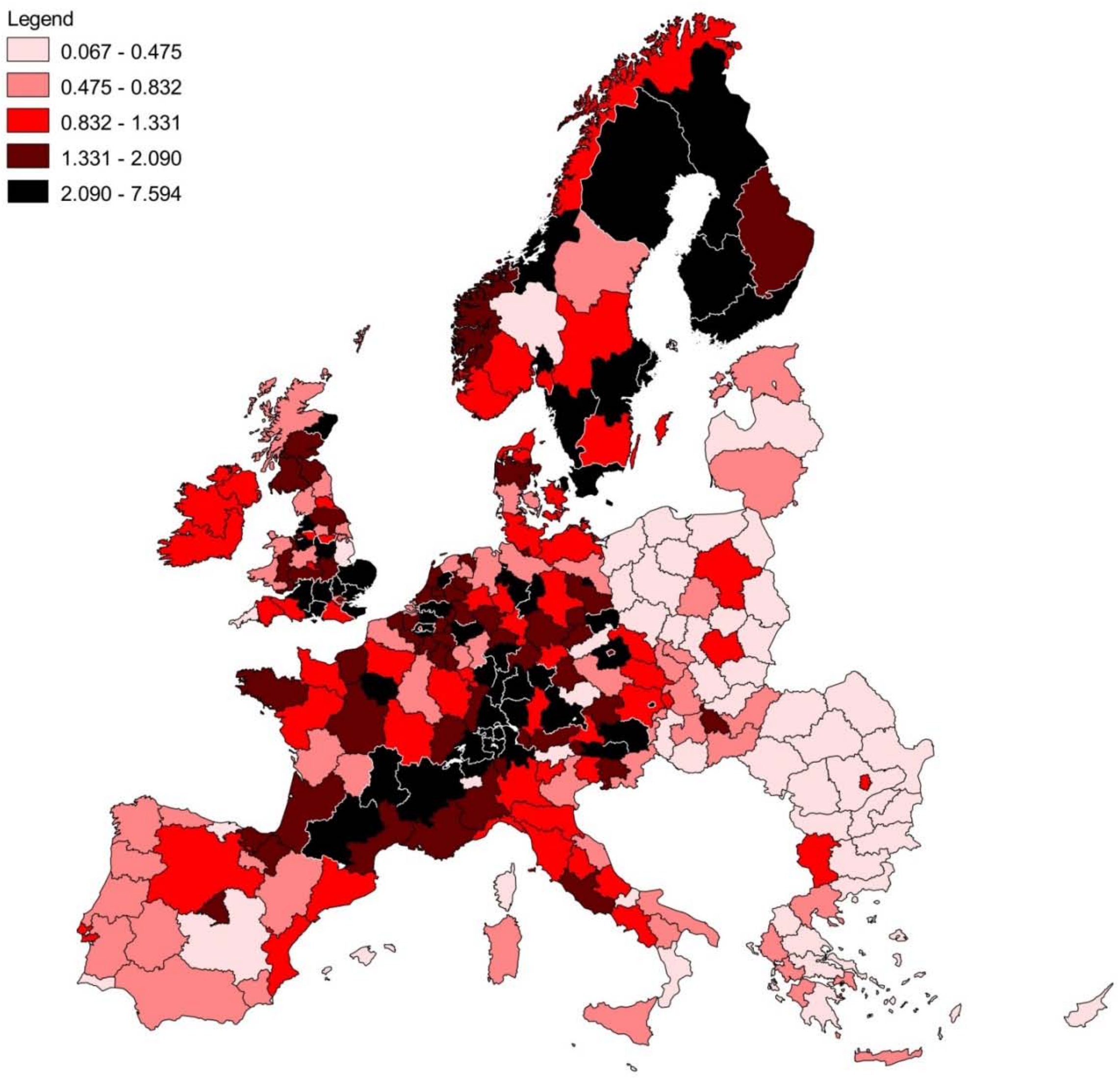
Variable		Primary Source	Years	Definition
Patent	INN	OCSE Pat-Reg	average 2005-2007	total patents published at EPO, per million population
Research & Development	RD	Eurostat	average 2002-2004	total intramural R&D expenditure, over GDP
Human Capital	HK	Eurostat	average 2002-2004	population aged 15 and over with tertiary education (ISCED 5-6), over total population
Population density	DEN	Eurostat	average 2002-2004	Population per km^2, thousands
Manufacture specialisation	MAN	Eurostat	average 2002-2004	manufacturing employment over total employment

We measure the impact of local factors at the beginning of the decade, 2002-2004 on innovative performance measured at the second half of the decade, 2005-2007

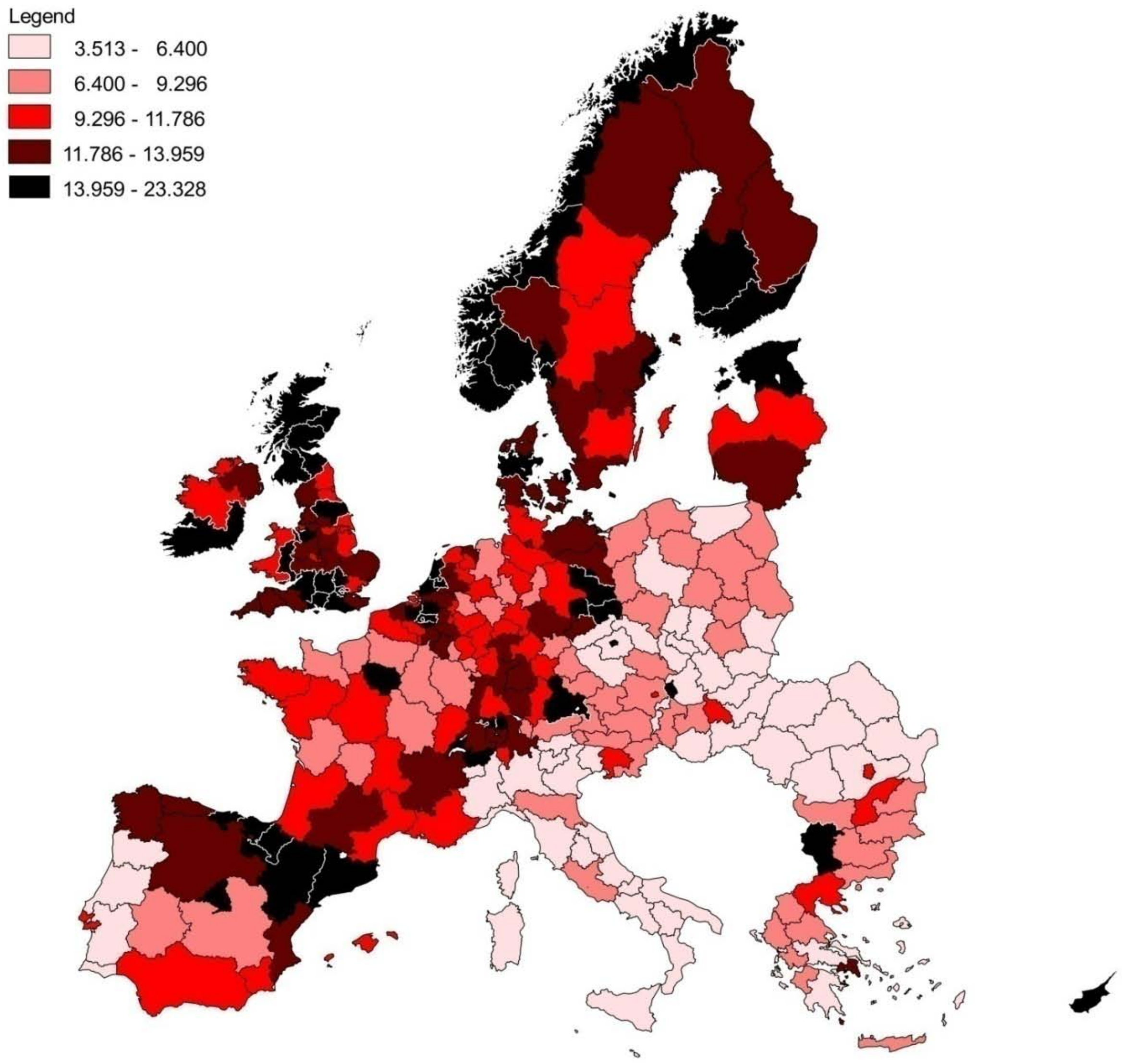
Dependent variable: Innovations, Patents (*per million inhabitants*)



R&D expenditure (*over GDP*)



Human capital (per capita)



Proximity: proxies and measures

- Institutional proximity: country dummies.
  Alternative: matrix with value 1 if two regions belong to the same country and zero otherwise.

- Technological proximity: matrix of similarity index for the distribution of patenting activity among 44 sectors for each pair of regions ($t_{ij} \geq 0.50$).
  Alternative: sectoral distribution of employment shares.

- Social proximity: matrix of co-inventorship relations among multiple inventors of the same patent when they reside in different regions. The intensity of the links among inventors located in different regions catches the existence of a social network.
  Alternative: migration flows, FP5 networks, similarity in ESS answers.

- Organizational proximity: matrix of the affiliation of the applicant and the inventors of a patent to the same organization when they reside in different regions (inter-regional connections within the same organization or group).

Estimation strategy

1. Extensive preliminary analysis to select the most adequate spatial specification using several alternatives (SEM, SAR, SDM, SLX, SDEM) based on the geographical proximity **G** (inverse of distance in Km, $d_{ij} \leq 600$).

2. We choose to specify the estimation model as a Spatial Autoregressive (SAR) model, which takes the following form

$$inn_i = \beta_1 rd_i + \beta_2 hk_i + \phi\, controls_i + \gamma Winn_i + \varepsilon_i$$

W is a weight matrix which describes the interconnectivity among regions.

3. Assessment of other proximity measures (alternative W's): **I**, **T**, **S**, **O.**

4. Assessment of direct and indirect effects.

5. Assessment of complementarity among different proximity measures, **G**, **I**, **T**, **S**, **O,** based on a two-spatial-weight matrix SAR model (Lacombe, 2004).

Spatial KPF with alternative proximities

Dependent variable: Patents, 2005-2007 average per capita values
Estimation method: SAR

Proximity matrix	G	T	S	O
Effects estimates				
R&D				
direct	0.260 **	0.258 ***	0.188 *	0.206 **
indirect	0.067 *	0.110 ***	0.023	0.015
total	0.327 **	0.368 ***	0.212 *	0.221 **
Human capital				
direct	1.559 ***	1.344 ***	1.540 ***	1.499 ***
indirect	0.401 **	0.567 **	0.202 **	0.117 **
total	1.959 ***	1.911 ***	1.742 ***	1.616 ***
Spatial lag coefficient	0.202 ***	0.293 ***	0.115 ***	0.072 **
Diagnostics				
LM error test for SAR model residua	0.011	0.029	0.293	0.009
p-value	0.918	0.864	0.589	0.923

Institutional proximity included in all models by means of country dummies included
Controls: population density and manufacture specialization

Extension: complementary effects of proximity dimensions

- The best way to proceed would be to insert all four proximities in the same estimation model. Unfortunately, the available estimation codes for spatial econometrics do not allow this first best and we look for a second best.

- We use a SAR model estimated by including two different proximity-lagged terms at a time in order to account for complementarities between pairs of knowledge spillovers channels (Lacombe, 2004). The two-weight matrix SAR model is specified as:

$$inn_i = \beta_1 rd_i + \beta_2 hk_i + \phi\, controls_i + \rho_1 W_1 inn + \rho_2 W_2 inn + \varepsilon_i$$

A step towards assessing complementarity

Two-weight-matrix SAR models:

Proximity matrices included	**G, T**	**G, S**	**G, O**	**T, S**	**T, O**	**S, O**
Effects estimates						
R&D						
direct	0.264 ***	0.215 **	0.223 **	0.194 **	0.206 **	0.193 **
indirect	0.317	0.076	0.072 *	0.161	0.145	0.025
total	0.581 **	0.292 **	0.295 **	0.355 *	0.351 **	0.218 **
Human capital						
direct	1.381 ***	1.554 ***	1.533 ***	1.332 ***	1.295 ***	1.515 ***
indirect	1.651 *	0.549 **	0.498 **	1.089 **	0.921 **	0.196 *
total	3.032 ***	2.103 ***	2.030 ***	2.421 ***	2.216 ***	1.711 ***
Spatial lag - 1st proximity matrix	0.213 ***	0.172 ***	0.183 ***	0.312 ***	0.320 ***	0.095
Spatial lag - 2nd proximity matrix	0.307 ***	0.083 *	0.057 *	0.127 ***	0.085 ***	0.017

Institutional proximity included in all models by means of country dummies included
Controls: population density and manufacture specialization

A further step: model combining…

A combined model is obtained on the basis of probabilities calculated from biased-adjusted AIC values (Burnham and Anderson, 2002)

Estimated lag coefficients

First proximity matrix		*Second proximity matrix* G	T	S	O	**Weighted average**
	G	0.202	0.213	0.172	0.183	0.162
	T	0.307	0.293	0.312	0.320	0.298
	S	0.083	0.127	0.115	0.095	0.018
	O	0.057	0.085	0.017	0.072	0.008

Diagonal entries are the estimated lag coefficients of one-weight matrix SAR models

Off-diagonal entries are the estimated lag coefficients of two-weight matrix SAR models

… and overall effects

Weighted Effects	
R&D	
direct	0.248
indirect	0.164
total	0.413
Human capital	
direct	1.366
indirect	0.903
total	2.269

A numerical “what if” exercise

R&D

if the ratio R&D/GDP increase by 10%, from an average actual value of 1.4% to 1.56% it produces a total increase (+4.1) on patents (per million inhabitants) from the observed average value of 105 to the new estimated value of 109.1. The increase is due to the direct effect for 2.5 and to spillovers for 1.6.

Human capital

an increase of 10% in the share of graduates, from the average value of 10.5% to 11.6%, yields a total increase in patents (per million inhabitants) of +23, 13.7 attributable to direct effects and 9.3 due to spillovers.

Main conclusions

- R&D and human capital are essential components for technological progress but with quite different impacts.
- All dimensions of proximities are significantly related to innovative performance and they represent complementary channels of knowledge transmission.
- Cognitive or technological proximity is individually the most effective and its role is enhanced by geographical closeness.
- Social and organizational dimensions are important too, although the size of their spatial lag is more modest. Besides, these two dimensions turn out to be not always complements since the two proxies suffers from some overlapping.
- Once the combined effect of all proximity measures is considered, it results that the effect of human capital on the production of knowledge is sizeable due to the spillover of external knowledge favoured by the absorptive capacity of well educated population within the region.

Policy implications/1

- Importance of policies aiming at increasing the endowments of well educated labor forces, given their strong and pervasive role in determining both the internal creation and the external diffusion and absorption of knowledge. Education in general and universities in particular have to be central in any innovation policy.
- The existence of several channels of interregional spillovers calls for a coordinated strategy able to achieve different targets with diverse instruments.
- More policies should aim directly to knowledge diffusion and absorption taking into account the diverse institutional and industrial contexts :no "one size fits all" policies (Todling and Trippl, 2005 and Asheim et al, 2011)
- Practically, policies should support and encourage the formation of dense networks among regional innovation systems which go beyond geographical clusters.

Policy implication/2

- Technological proximity matter much more than the geographical one in influencing innovation spillovers. This suggests the implementation of specific industrial policies to support the formation and the functioning throughout Europe of a-spatial industrial clusters characterized by proximate technology.

- Finally, the presence of externalities which exploit social interregional relations requires policies designed specifically to provide a balanced set of incentives to motivate economic agents towards more cooperative behaviours and actions with economic entities in other regions.