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Is networking a substitute or a complement to regional innovation capacity?
Evidence from the EU's 5th Framework Programme

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Acknowledgements

Executive Summary

A recent debate in the context of the future evolution of the European Research Area is concerned with the optimal spatial and thematic allocation of resources for research. This stems from a concern that EU research funds are spread too thinly across Europe without achieving the impact that is expected of them.

"Smart specialisation" or the spatial and thematic concentration of R&D resources on the basis of existing patterns of technological specialisation, is put forward as one possible policy direction. Agglomeration economies have been shown to be important for research: scientists and technologists tend to be more productive when located in proximity to populous communities of knowledge workers and knowledge-intensive business services. Network effects have also been shown to have a positive influence on regional knowledge production processes. A policy of sustaining or even increasing the degree of connectedness in EU research, or "networked specialisation" is therefore put forward as a possible alternative.

The present policy note draws from original empirical work attempting to shed some light on the joint importance of regional innovation capacity (proxied by a novel index of regional agglomeration of knowledge intensive employment) and scientific networking (proxied by an index of interregional collaboration in Framework Programme (FP) 5) on R&D productivity and draw comparisons.

We find that regional innovation capacity and scientific networking are neither complements nor substitutes but have different functions according to the type of research involved. Our findings indicate that there are distinct paths to obtaining "critical mass" for scientific and technological research. The regional agglomeration of innovation capacity is important for the productivity of technological research whereas this is not the case for scientific research; likewise, scientific research is more productive in regions that are well connected in interregional knowledge production networks, but the same networking has no discernible effect on technological research.

These findings suggest that differentiated responses will be needed, with increased networking for scientific research and a strengthening of regional innovation capacity for technological research. In that respect, the adoption of fine-tuned instruments for industry (Integrated Projects (IP), Specific Targeted Research Projects (STREP)) and science (Networks of Excellence (NoE)) from FP6 onwards appear to be a step in the right direction. Complementary interventions will be needed to support the innovation capacity of lagging regions.

1. Introduction

A recent debate is concerned with the optimal spatial and thematic allocation of resources for research[1]. This stems from a concern that EU research funds are spread too thinly across Europe without achieving the impact on growth and employment that is expected of them[2]. The recent Green Paper on the European Research Area expresses concern at the lack of critical mass and suggests that "[…] *some concentration and specialisation is necessary* […][3]". Precisely what policies may foster such changes is still an open question.

"*Smart specialisation*" or the spatial and thematic concentration of R&D resources on the basis of existing patterns of technological specialisation, is put forward as one possible policy direction[4]. This draws from a long strand of literature on economic geography (dating back to the pioneering work of Alfred Marshall) which highlights the positive effects of regional concentration of economic activity, or what is often referred to as *agglomeration economies*. Agglomeration economies have been shown to be important for research: scientists and technologists tend to be *more productive* when located in proximity to populous communities of knowledge workers and knowledge-intensive business services.

Modern Information and Communication Technologies (ICTs) offer the possibility for delocalised contact and collaboration. It has therefore been argued, that delocalised networking could complement agglomeration economies or (in their absence) even substitute them[5]. The Framework Programme for research (FP), the major EU research policy instrument, is implicitly built on this assumption. The FP unites research teams from across Europe, promotes an international and interregional division of labour and facilitates the sharing of knowledge and capacity building. Impacts stemming from networking, as distinct to those of other factors, are often referred to as *network effects*. Network effects have also been shown to have a positive influence on regional knowledge production processes. A policy of sustaining or even increasing the degree of connectedness in EU research, or "*networked specialisation*" is therefore put forward as a possible alternative[6].

However, until now, the forces of agglomeration and networks have not been studied jointly.

The present policy note draws from original empirical work attempting to shed some light on the joint importance of regional innovation capacity and scientific networking on *R&D productivity* and draw comparisons.

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[1] See the contributions of participants to the JRC-IPTS workshop "R&D Specialisation in the EU" (Barcelona, June 30, 2008) in Pontikakis, Kyriakou and van Bavel (forthcoming).

[2] Foray and Van Ark (2007). For a similar assessment of the performance of European universities (though not specific to EU funds) see Soete, L. (2005).

[3] CEC (2007), p. 14

[4] Foray and Van Ark (2007)

[5] Johansson and Quigley (2004)

[6] Georghiou et al. (2008)

2. Why R&D productivity matters

Not all regions get the same amount of knowledge outputs for a given level of inputs. Improvements in R&D productivity are one of the principal expectations attached to policy arguments in favour of specialisation.

Faced with a budget constraint, a rational decision maker will want to maximise the amount of output that can be had for a given level of inputs. From a public finance perspective, governments would like to ensure that their R&D expenditures have a meaningful impact. Private companies too make decisions on the location of their R&D investments on the basis of expectations about future returns. In the long-run and for a given level of commitment to R&D[7], interregional convergence of research capacities is conditional on improvements in R&D productivity.

3. The determinants of regional R&D productivity

Literature insights

Localised interactions play a central role in innovation[8]. The importance of scale effects on the productivity of regional innovation systems has also been acknowledged: prior work[9] has identified a threshold level of regional agglomeration, above which increases in the marginal productivity of R&D inputs can be expected. This suggests that regional research efforts can have a much more meaningful impact where a critical mass of agglomeration (in terms of business services and high-technology employment) is present.

Other studies emphasise the role of networks and evolving structural features and highlight the systemic nature of regional knowledge production processes[10]. Importantly, different types of research impose different requirements on scale and place a different emphasis on tacit knowledge and by extension, proximity[11].

A sharp contrast can be expected between the worlds of scientific and technological research. Scientific research relies to a great extent on knowledge codified in scientific publications. This is possible because in the world of academic research openness and sharing of methodological steps and findings tend to be the norm. To contrast with, research seeking technological improvements is, more often than not, motivated by expectations of monetary returns which may be undermined by full disclosure. Much of the knowledge that is relevant for cutting-edge research of this type is therefore often not codified and even when it is, secrecy and intellectual property rights are used to limit its

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[7] The difficulties faced so far in reaching the Lisbon's Strategy's elusive 3% target, serve to underscore the limits of what can be achieved by resource mobilisation. And although the impact of the current financial crisis on R&D expenditures remains to be seen (in the US at least the American Recovery and Reinvestment Act foresees generous endowments for scientific research), an adverse macroeconomic outlook has traditionally been associated with the rationing of R&D resources. Both contingencies bring the issue of R&D productivity to the fore.

[8] Jaffe et al. (1993) and Anselin et al. (1997)

[9] Varga (2000)

[10] Maggioni, et al. (2007); Ponds et al. (2009)

[11] Malmberg and Maskell (1997)

widespread diffusion. As a result, research conducted with economically useful applications in mind places a premium on tacit knowledge – that is knowledge possessed by individuals that can by definition be only in one place at any one time.

An econometric analysis of regional knowledge production supported by FP5

Our empirical work is based on aggregate statistics at the level of regions (see the Annex for a description of data and sources). We proxy agglomeration economies with a novel index of *regional innovation capacity* (δ_i) and network effects with an index of *interregional collaboration in FP5* (NET_i). Our analysis estimates an enhanced Romer-Jones knowledge production function (KPF) at the EU regional level, within a framework that also takes into account possible spatial dependence effects (see extensive description in the Annex).

In its simplest form (see Figure 1), knowledge outputs (in our case counts of patents and publications in 2002) are assumed to be a function of R&D expenditures (our variable GRD2001, i.e. regional GERD for 2001), past knowledge (our variable PSTCK2001, i.e. accumulated stock of EPO patents by 2001, depreciated) and other variables (including various forms of spatial dependence). This framework allows us to estimate jointly the effects of regional innovation capacity and scientific networking on R&D productivity and draw comparisons.

Figure 1: A conceptual diagram of new knowledge flows
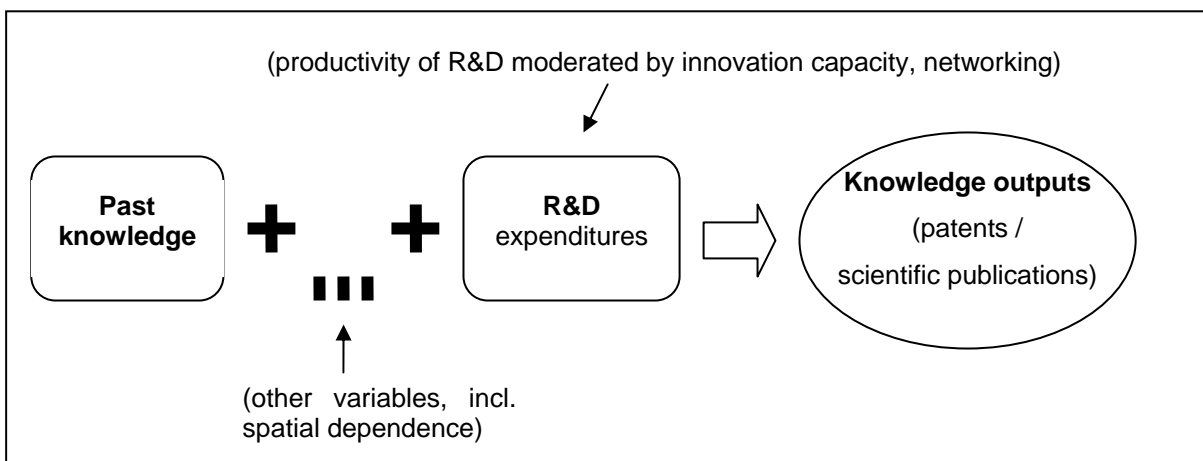
We estimate the KPF separately for patents and publications, testing for the statistical significance of regional innovation capacity and interregional collaboration in FP5. A detailed description of the econometric analysis and its results can be found in the Annex. The main findings can be summarised as follows.

With respect to the production of patents:

- Innovation flows throughout European regions are on average about proportionate to R&D inputs;

- Regional innovation capacity has a positive, statistically significant and quantitatively distinct effect on R&D productivity, confirming the significance of agglomeration effects;

- The average R&D expenditures of collaborating regions do not affect R&D productivity in the region, suggesting that FP5 networks did not have a statistically significant effect on regional patenting;

- Historically accumulated technological knowledge has a positive, statistically significant and quantitatively distinct effect on regional patenting;

- Overall, the inventive performance of adjacent regions does not seem to affect a region's innovation flows. However, the statistical importance of distance hints at some other important spatial limitation, possibly national boundaries.

With respect to the production of scientific publications:

- Gross regional R&D expenditures explain most of the variation, and, as with patents, the production of scientific publications is about proportional to R&D expenditures (near unit-elasticity);

- Strikingly, agglomeration effects appear to have no statistically significant influence on scientific R&D productivity;

- On the contrary, interregional scientific networking in FP5 exerts a statistically significant and quantitatively distinct influence on scientific R&D productivity. In other words, networked regions can perform research efficiently even in the absence of regional agglomeration;

- The fact that none of the spatial dependence measures is statistically significant, confirms the importance of codified (as opposed to tacit) knowledge for scientific research.

On the basis of the model coefficients, we can calculate *robust estimates* (i.e. controlling for factors such as R&D expenditures, prior knowledge stock and spatial dependence) of R&D productivity, given each region's innovation capacity endowment (δ_i) and manifested networking in FP5 (NET_i)[12].

As such, the following maps (Figures 2 and 3) relate the estimates of our models to the contemporary reality of the regional landscape in the EU, offering a more intuitive way of interpreting them. To facilitate comparisons, these are normalised in terms of standard deviations from the European average.

A quick glance at Figure 2 confirms that regions that are known for their high regional innovation capacity (industrial centres of Western Europe, Sweden, Finland and capital cities elsewhere) were amongst the most productive in terms of patenting. Likewise, Figure 3 highlights regions which scored highly in terms of interregional networking in FP5 and, by extension, in terms of scientific productivity.

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[12] The calculation method is detailed in the Annex (p. 17).

Figure 2: Regional R&D productivity in patenting
(expressed in standard deviations from the European average)
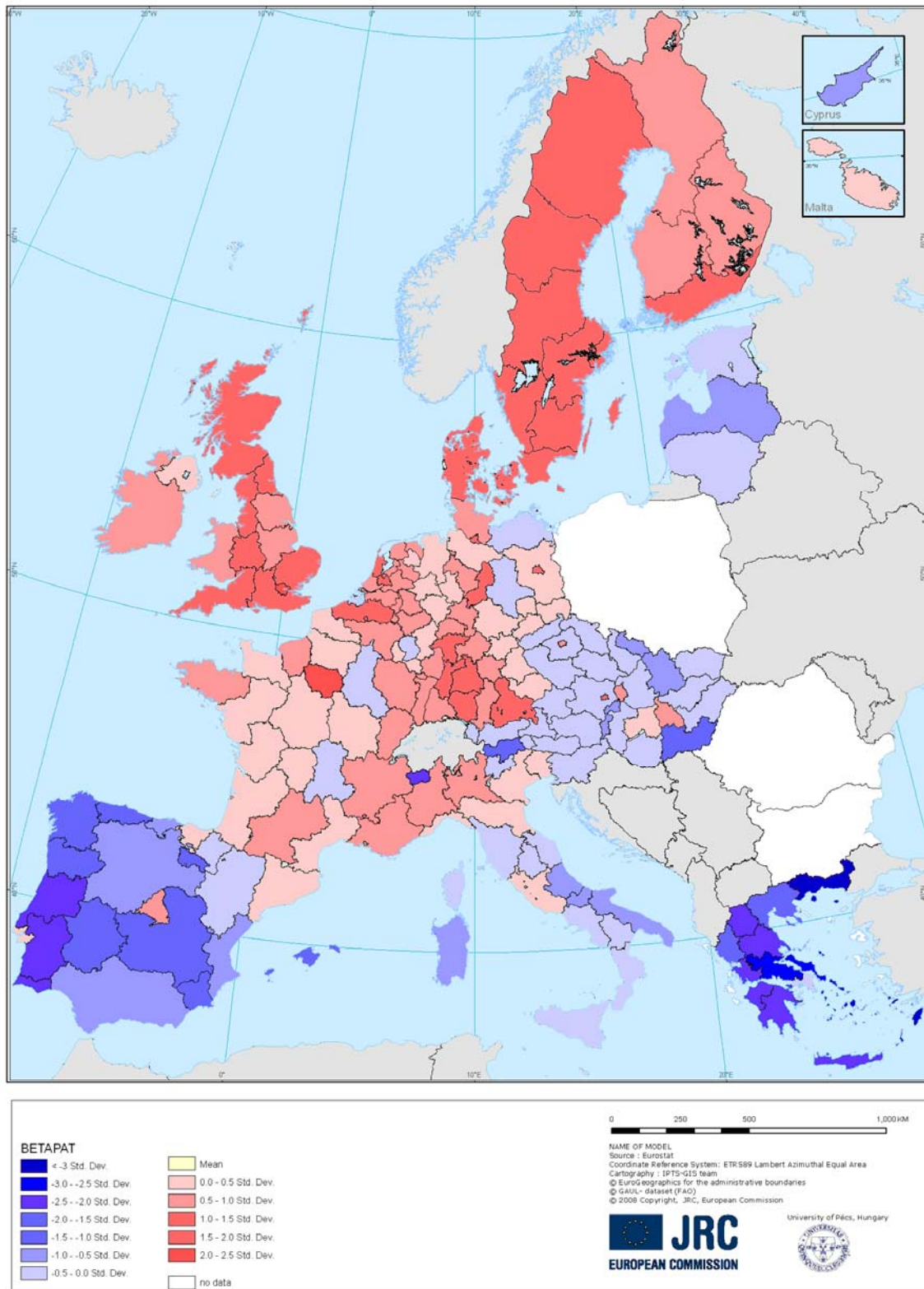
Figure 3: Regional R&D productivity in publications

(expressed in standard deviations from the European average)

4. Conclusions

We find that both regional innovation capacity and scientific networking are important for regional R&D productivity. They are however neither complements nor substitutes but have different functions according to the type of research concerned.

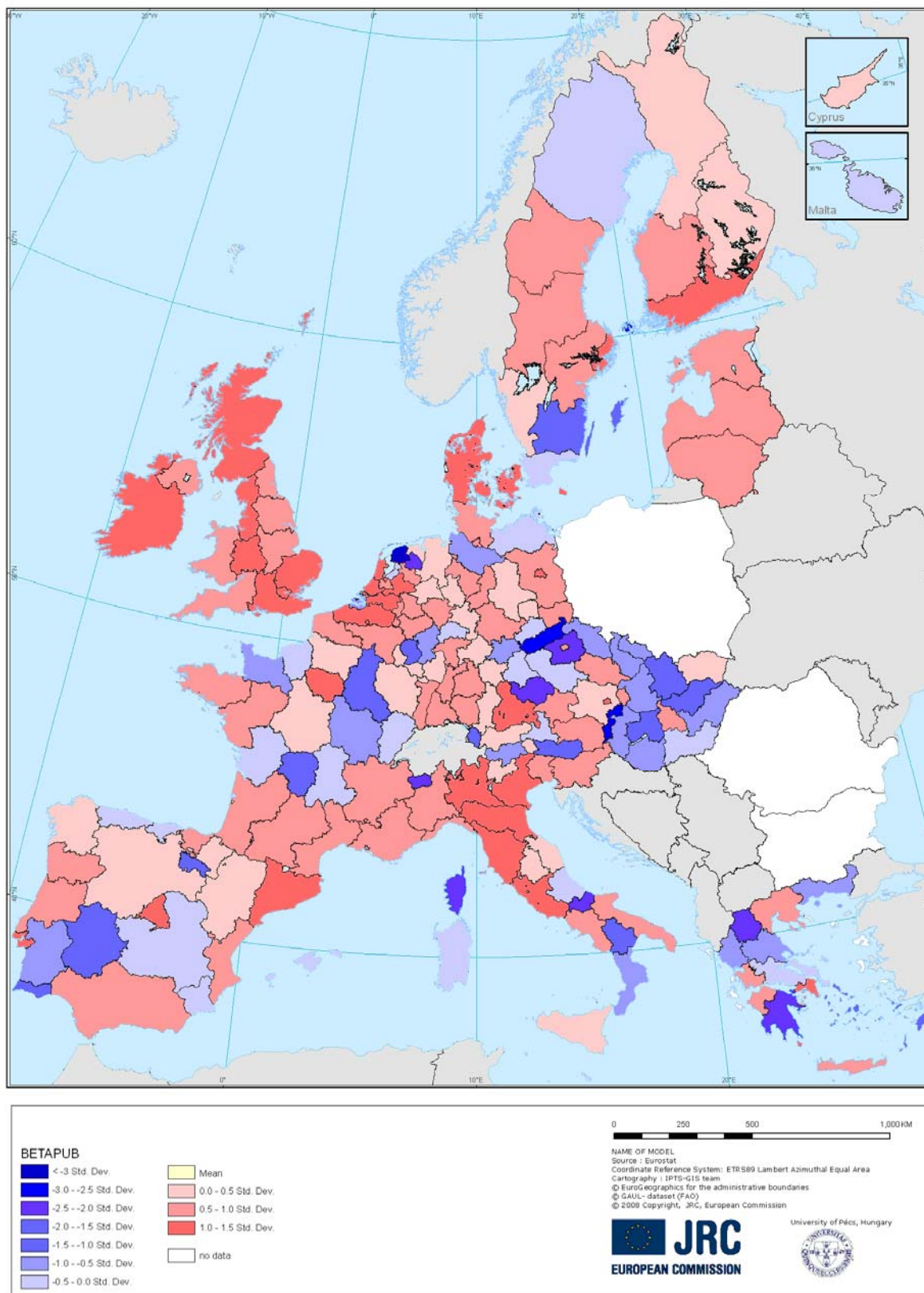Our findings indicate that there are distinct paths to obtaining "critical mass" for scientific and technological research. The regional agglomeration of innovation capacity is important for the productivity of technological research whereas this is not the case for scientific research; likewise, scientific research is more productive in regions that are well connected in interregional knowledge production networks, but the same networking has no discernible effect on technological research.

The above suggests that a single-pronged instrument that does not distinguish between the two will miss part of its target. The increases in interregional networking that are promoted by the FP appear to have a substantial effect on the productivity scientific research, but more will need to be done to promote technological research. Appropriately adjusted contracts for industry support introduced in FP6 appear to be a step in the right direction: As data for later years[13] becomes available, further work could extent this analysis to FP6 and examine the role of such newly introduced instruments as IPs, STREPs (for industry) and NoEs (for science).

Supporting the development of regional innovation capacities in lagging regions will not be easy: Our study suggests that regional innovation capacity takes time to develop and comprises a cognitive (knowledge stocks) element as well as an economic element (knowledge-intensive employment). The involvement of diverse policy domains (education, industrial, labour, fiscal policy), the constructive deployment of complementary instruments (direct funding, fiscal incentives, awareness raising) and an intensified coordination of interventions at various levels (European, national, regional) seem necessary.

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[13] The additional indicators that would be needed to evaluate the impact of FP6 (covering the period 2002-2006) are still not available as there is a considerable lag between the time research was actually done and the time by which it leaves a measurable trail (e.g. in scientific publications, patents).

Annex: Data and Methodology

Data Sources

The study draws on data from DG RTD's Regional Key Figures[14] (RKF) database (which uses combined Eurostat, OECD and CTWS data) and Eurostat's New Cronos database. Our estimates are based on regional-level data for 190 European regions (a mixture of NUTS2 and NUTS1 regions) where information was complete enough for the purposes of our study (see Figures 1 and 2). The study also makes use of original data, extracted from the Commission's internal FP participations databases (containing information not only on projects but also on details of the participants) to construct an indicator of interregional collaboration in FP5 networks[15]: An n by n matrix has been constructed (where n=number of NUTS regions in the sample) where a matrix element with a value 1 means a common FP project of two regions and zero otherwise. This matrix is used to calculate the average R&D expenditures of network partner regions for each region[16]. We use counts of patents[17] as a proxy of new technological knowledge and counts of scientific journal publications as a proxy of new scientific knowledge.

We use a cross-section of EU regions as opposed to a panel, due to limited data in the time-series dimension. A quick glance over the regional R&D and patenting data for Europe indicates that, even where the data is complete, variation in the time-series dimension is small. Dependent variables are lagged by one period, reflecting the dynamic nature of our system. Temporally lagged dependent variables have the added advantage of partially countering potential endogeneity problems. Spatial econometric tests and, where appropriate, adjustments have been made in all estimates.

Three different types of national patent stocks were constructed and tested empirically: patent stocks with no depreciation (Porter and Stern, 2000; Furman, Porter and Stern, 2002), and, using the perpetual inventory method (PIM), patent stocks with a 13 per cent (Park and Park, 2006) and a 15 per cent annual depreciation rate (Hall, 1993) respectively. Non-depreciated stocks are simply the cumulative number of patent applications from 1992 on, while PIM estimates of contemporary patent stocks are based on the following formula:

$$PSTCK_t = PSTCK_{t-1} * (1 - d) + PAT_t$$

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[14] RKF is a novel database combining publicly available science, technology and innovation indicators from various disparate sources with indicators that have been developed for Commission use. The database has been commissioned by DG RTD and is implemented by Fraunhofer ISI. Data on scientific publications in particular are Thomson's ISI and were compiled by CWTS, Leiden University.

[15] We are indebted to our colleague George Chorafakis for providing us with this measure.

[16] The binary approach was preferred to say, a numerical count of pairwise collaborations, given the small number of observations in many pairs of European regions.

[17] Although patent counts are far from a perfect proxy of innovation (Griliches, 1990), they are the only measure that is available for a large number of European regions and over a number of years. Comfortingly, previous research has shown that at the level of regions, patent counts correlate well with innovation counts (Acs, Anselin and Varga, 2002) and both measures provide very similar results in the knowledge production function context.

Where PAT_t are contemporary patent flows and d is the depreciation rate (0.13 or 0.15). Like other independent variables all patent stock variables are lagged by one period. Initial stocks are set in year 1998 taking into account compound annual growth in the five preceding years[18].

As most measures of absolute concentration of economic activity introduce multicollinearity, they are likely to be problematic in a regression context with interaction terms. We overcome this problem by using a novel index of regional innovation capacity, δ, proxied by the agglomeration of knowledge intensive employment. Our index is a size-adjusted (in the spirit of the index developed by Elison and Glaeser (1997)) variant of the popular location quotient (LQ) measure and is calculated as:

$$\delta_i = [(EMPKI_i / EMPKI_{EU}) / (EMP_i / EMP_{EU})] / [(1 - \Sigma_j (EMPKI_{ij} / EMPKI_{j,EU})] [1 - (EMP_i / EMP_{EU})]$$

Where EMPK is employment in knowledge intensive economic sectors[19], EMP is total employment and the subscripts *i* and *EU* stand for region and EU aggregate respectively. Just like the LQ, δ has the interesting property of taking a value of 1 for regions with a level of agglomeration close to the EU average. However, unlike the LQ, in δ the denominator is designed in such a way as to penalise small regions, by yielding higher values for regions with a higher level of employment. As δ captures economic activity that is heavily involved not only in the production but also in the diffusion, assimilation and productive deployment of knowledge, we consider it an appropriate indicator of regional innovation capacity.

Analytical Framework

A spatial econometric methodology has been employed to model the relationships between R&D and other variables. We employ a multiple equation system[20] encompassing a knowledge production function (KPF), a function modelling the parameter (beta) of the R&D variable in the KPF, a function estimating the spatial location of R&D expenditures and a function estimating the spatial location of regional innovation capacity.

Our starting point is the basic KPF initially specified by Romer (1990) and parameterised by Jones (1995):

$$\text{Eq.1} \quad dA = \delta \, H_A^{\lambda} \, A^{\varphi},$$

Where H_A refers to research inputs (e.g. number of researchers or research expenditures), A refers to the total stock of technological knowledge (codified knowledge component of knowledge production in books, patent documents etc.), dA refers to the

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[18] Initial stock equals flows for first year divided by the sum of compound growth for the preceding five year period and the depreciation rate. As all patent stock variables are time t-1, annual compound growth rates for the PIM variables were calculated for the 5 year period 1992-1997. Exceptions are Malta and Lithuania, where due to lack of data in the time series dimension, the preceding 4 year period (1993-1997) was used instead. For the non-depreciated stocks, a value of 1 was assumed in the case of Lithuania for 1992 (which is close to the average for that country in the following two years), while the 1998 value was estimated as the average of 1997 and 1999.

[19] The classification of knowledge intensive economic sectors (devised by Eurostat) includes: high and medium high technology manufacturing (NACE 1.1 sectors, 24, 30, 32, 33, 35.3, 29, 31, 34, 35 (excluding 35.1 and 35.3)), high technology services, knowledge intensive market services (NACE 1.1 sectors 61, 62, 70, 71, 74), financial services (NACE 1.1 sectors 65, 66, 67), amenity services – health, education, recreation (NACE 1.1 sectors 80, 85, 92).

[20] This framework draws heavily from Varga (2006), where the rationale for the specification of equations is explained in further detail.

change in technological knowledge, δ is the "research productivity parameter" ($0<\delta<1$), **φ** is "**codified knowledge spillovers** parameter" (reflects spillovers with unlimited spatial accessibility) and λ is the "**research spillovers** parameter" (reflects the geography of knowledge spillovers).

Eq. 1 suggests that an increase in the resources devoted to research (H_A) or to the amount of existing knowledge accessible to researchers (A) will have a positive effect on technological change (dA). We adopt here the spatial interpretation of the Romer equation outlined in Varga (2006: 1175) which, drawing from literature on regional and urban economics and the new economic geography, assumes that the parameter of H_A, λ *changes with the geographic concentration of economic activities.* The size of the parameter could vary, depending on the balance between positive and negative agglomeration economies.

Eq. 2 describes regional knowledge production, specifying K_r, the amount of new knowledge produced in region r as some function of R&D inputs and other factors Z_r such as the level of regional agglomeration[21].

$$\text{Eq.2} \quad K_r = K (RD_r, Z_r)$$

As emphasised by as diverse strands of literature as endogenous growth accounting, innovation systems and the new economic geography, knowledge production is a dynamic, **cumulative process**. This process is described by Eqs. 3 and 4a,b. In a static context (Eq. 3), research already in the region (RD) and agglomeration (Z_r) affect R&D productivity across regions ($\partial K_r/\partial RD_r$).

$$\text{Eq.3} \quad \partial K_r/\partial RD_r = f (RD_r, Z_r)$$

However, changes in RD_r and Z_r (dRD_r and dZ_r) are themselves determined by manifested R&D productivity and research already in the region respectively. This dynamic effect is described in equations 4a and 4b: in Eq. 4a the geographic distribution of R&D expenditures is a function of R&D productivity across different regions whereas in Eq. 4b the level of regional agglomeration is a function of research already in the region.

$$\text{Eq.4a} \quad dRD_r = R(\partial K_r/\partial RD_r)$$

$$\text{Eq.4b} \quad dZ_r = Z(RD_r)$$

At the national level, the magnitude of λ, reflecting the impact that the same number of researchers has on technological change, depends on the geographic structure of H_A (where $H_A = \Sigma_r RD$).

$$\text{Eq.5} \quad \lambda = \lambda (GSTR(H_A))$$

Correspondingly, the rate of national technological change may be described in the Romer-Jones fashion as:

$$\text{Eq.6} \quad dA = \delta H_A{}^\lambda A^\varphi$$

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[21] Alternatively Z may reflect network effects: its precise specification is an empirical matter.

The above equations may be tested empirically, subject to the availability of appropriate data. We proxy R&D inputs with data on regional R&D expenditures and new knowledge flows with data on patent applications to the EPO with at least one inventor based in the region.

In order to test empirically these relationships we use the following econometric specifications. In terms of functional form we opt for a (natural) logarithmic conversion of all our variables, which has the appealing quality of allowing the interpretation of coefficients as elasticities[22]. Using subscripts i and N to denote individual regions and nations (in our case EU member states) respectively, the regional KPF may be specified as:

Eq. 7. $Log(K_i) = \alpha_0 + \alpha_1 Log(RD_i) + \alpha_2 Log(PSTCK_N) + \varepsilon_i$

Eq. 8. $\alpha_{1,i} = \beta_0 + \beta_1 Log(\delta_i) + \beta_2 Log(NET_i) + \varepsilon_i$

Eq. 9. $Log(K_i) = \alpha_0 + \beta_0 Log(RD_i) + \beta_1 Log(\delta_i)Log(RD_i) + \beta_2 Log(\delta_i)Log(RD_i)$

$\qquad \alpha_2 Log(PSTCK_N)$

where $\alpha_{1,i}$ is regional research productivity, δ_i is regional innovation capacity, NET_i is interregional research networks and $PSTCK_N$ is national patent stock. The above are essentially empirical tests of equations 2 and 3.

Following on, the determinants of the location of R&D expenditures (RD_i) and regional innovation capacity (δ_i) may be empirically tested by:

$$Eq.\ 10\quad Log(RD_i) = \lambda_0 + \gamma_1 Log(\alpha_{1,i}) + \lambda_1 Log(PSTCK_{N,i}) + u_i$$

$$Eq.\ 11\quad Log(\delta_i) = \xi_0 + \xi_1 Log(RD_i) + \xi_2 Log(PSTCK_{N,i}) + \mu_i$$

Econometric Estimation

Estimation results are presented in Tables 1 (effects on the production of patents) and 2 (effects on the production of scientific publications). Since both sides of the equation are expressed in logarithms, the regression coefficients may be interpreted as elasticities.

The value of R&D coefficient in Model 1 indicates that innovation flows throughout European regions are on average about proportionate to R&D inputs. Model 2 includes the product of lagged R&D expenditures and δ, our index of regional innovation capacity. Model 2 suggests that regional innovation capacity has a positive, statistically significant and quantitatively distinct effect on R&D productivity, confirming the significance of agglomeration effects. Interpreted from an innovation systems perspective, this finding reflects the importance of knowledge interactions between different institutional actors engaged in knowledge-intensive economic activities (e.g. users versus producers, academic institutions, government actors etc) for the innovation[23]. The importance of collocation is also suggestive of the significance of tacit knowledge[24]. Taken together with

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[22] This functional form is common in empirical specifications of Romer-type KPFs (see Porter and Stern, 2000; Furman et al., 2002; Varsakelis, 2006). Taking logarithms also has the added advantage of minimising the influence of outliers and normalising measures expressed in different units of measurement.

[23] Andersen (1992); Nelson (1993); Edquist (1997); Cooke (2001)

[24] Malmberg and Maskell (1997)

the fact that the inventive performance of adjacent regions does not seem to affect a region's innovation flows (as Neighb is not statistically significant) this seems to be consistent with the idea of national boundaries as a brake to knowledge spillovers, though of course it is does not conclusively demonstrate its veracity.

Models 3 and 4 test the significance of network effects, by including the product of gross regional R&D expenditures times the average value of the R&D expenditures with which region *i* had at least one joint research project in FP5 (Log(GRD2001)*Log(NET)). The product term is statistically insignificant with (4) or without (3) the agglomeration product. This result suggests that the average R&D expenditures of collaborating regions do not affect R&D productivity in the region.

Model 5 introduces national patent stocks (PSTCK2001, PIM depreciated by 13%), indicating that historically accumulated technological knowledge has a positive, statistically significant and quantitatively distinct effect on regional patenting. Interestingly, the coefficient of Log(GRD2001)*Log(δ) drops from around 2.6 in models 2 and 4 to about 1.7, suggesting that codified knowledge spillovers capture at least some of the effect attributed to agglomeration in the previous models.

In models 1-5, tests for spatial dependence indicated no influence from adjacent proximity (Neighb), but some role for distance (INV1 and INV2). In model (6), controlling for spatial dependence, the substantive results remain, although the value of the coefficient for the agglomeration interaction term is smaller and its statistical significance drops to 95 per cent. Overall, the inventive performance of adjacent regions does not seem to affect a region's innovation flows. However, the statistical importance of distance hints at some other important spatial limitation, possibly national boundaries. It is worth noting that all models explain 70 per cent or more of the variation in regional patenting. In all models there is no indication of a problem with multicollinearity, as the Multicollinearity Condition Number is below the rule-of-thumb value of 30

Table 1. Regression Results for Log (Patents) for EU regions, 2002
(N=190)

Model	(1)	(2)	(3)	(4)	(5)	(6)
Estimation	OLS	OLS	OLS	OLS	OLS	IV-Spatial Lag
Constant	-2.06***	-0.951***	-2.377***	-1.274**	-2.475***	-2.677***
	(0.316)	(0.416)	(0.431)	(0.502)	(0.445)	(0.429)
W_Log(PAT2002)						0.041***
						(0.010)
Log(GRD2001)	1.131***	0.941***	1.283***	1.096***	0.830***	0.837***
	(0.054)	(0.071)	(0.150)	(0.152)	(0.067)	(0.064)
Log(GRD2001)*Log(δ)		0.267***		0.268***	0.171***	0.139**
		(0.068)		(0.068)	(0.064)	(0.062)
Log(GRD2001)*Log(NET)			-0.0001	-0.0001		
			(0.0001)	(0.0001)		
Log(PSTCK2001)					0.238***	0.159***
					(0.037)	(0.040)
R^2-adj	0.70	0.72	0.70	0.72	0.77	0.79
Multicollinearity Condition Number	7	10	22	24	13	
Jarque-Bera test on normality of errors	3582***	5778***	3529***	5662***	12822***	
White test for heteroskedasticity	0.195	0.537	2.842	5.506	1.619	
LM-Err						
Neighb	4.165	2.591	3.259*	1.912	0.671	0.052
INV1	59.915***	46.40***	65.397***	40.966***	10.502***	1.445
INV2	62.669***	34.699***	58.886***	32.400***	12.896***	6.027**
LM-Lag						
Neighb	0.157	0.123	0.133	0.151	0.489	
INV1	52.502***	43.583***	51.876***	42.536***	18.388***	
INV2	67.106***	42.889***	64.697***	40.952***	10.439***	

Notes: Estimated standard errors are in parentheses; spatial weights matrices are row-standardized: Neigh is neighborhood contiguity matrix; INV1 is inverse distance matrix; INV2 is inverse distance squared matrix; W_Log(PAT2002) is the spatially lagged dependent variable where W stands for the weights matrix INV1; instruments in the IV-Spatial Lag estimation are W_Log(GRD2001), W_Log(δ), W_[Log(GRD2001)*Log(δ)] and W_[Log(GRD2001)*Log(NET)], where W stands for the weights matrix INV1. *** indicates significance at $p < 0.01$; ** indicates significance at $p < 0.05$; * indicates $p < 0.1$.

Table 2 estimates the KPF with scientific publications for year 2002 as the dependent variable. Gross regional R&D expenditures explain most of the variation, with a coefficient in model 1 (0.94) suggestive of almost constant returns to scale. Strikingly, agglomeration effects appear to have no statistically significant influence on scientific R&D productivity (Models 2 and 4), while network effects (Models 3, 4 and 5) exert a statistically significant and quantitatively distinct influence on scientific R&D productivity.

It appears then that, in the case of scientific research at least, interregional networking is more important than regional agglomeration. In other words, regions can perform research efficiently even in the absence of regional agglomeration. The fact that none of the spatial dependence measures is statistically significant, confirms the importance of codified (as opposed to tacit) knowledge for scientific research. In all models, regression diagnostics indicate no problems with multicollinearity and, as with patents, the KPFs explain more than 70 per cent of variation in the data.

Table 2. Regression Results for Log (Publications) for EU regions, 2002
(N=189)

Model	(1)	(2)	(3)	(4)	(5)
Estimation					
	OLS	OLS	OLS	OLS	OLS
Constant	1.352***	1.113***	2.408***	2.167***	2.378***
	(0.231)	(0.316)	(0.296)	(0.356)	(0.308)
Log(GRD2001)	0.943***	0.984***	0.440***	0.482***	0.422***
	(0.039)	(0.054)	(0.103)	(0.108)	(0.114)
Log(GRD2001)*Log(δ)		-0.058		-0.061	
		(0.052)		(0.049)	
Log(GRD2001)*Log(NET)			0.0004***	0.0004***	0.0004***
			(7.18E-05)	(7.17E-05)	(7.47E-05)
Log(PSTCK2001)					0.011
					(0.030)
R^2-adj	0.75	0.75	0.78	0.78	0.78
Multicollinearity Condition Number	7	10	22	24	28
Jarque-Bera test on normality of errors	35***	44***	37***	45***	37***
White test for heteroskedasticity	18.054***	26.661***	25.774***	19.688***	33.071***
LM-Err					
Neighb	1.681	1.354	2.890	2.599	2.556
INV1	0.612	0.315	0.111	0.041	0.174
INV2	0.545	0.628	0.009	0.006	0.005
LM-Lag					
Neighb	2.777*	2.602	2.056	1.276	2.258
INV1	6.028**	5.40**	2.636	2.062	3.196
INV2	1.421	1.029	0.780	0.449	0.781

Notes: Estimated standard errors are in parentheses; spatial weights matrices are row-standardized: Neigh is neighborhood contiguity matrix; INV1 is inverse distance matrix; INV2 is inverse distance squared matrix. *** indicates significance at $p < 0.01$; ** indicates significance at $p < 0.05$; * indicates $p < 0.1$.

On the basis of the above estimates we can calculate how R&D productivity varies according to variation in δ_i and NET_i across Europe. $BETAPAT_i$ and $BETAPUB_i$ reflect the expected percentile increase in research output, in terms of patents and publications respectively, for a one per cent increase in R&D expenditures. In both equations the first number is drawn from the estimated R&D coefficient in each of our final models and the second number from the coefficient of the product of R&D and δ_i and R&D and NET_i respectively (Tables 1 and 2):

$$BETAPAT_i = 0.837 + 0.139 * \log(\delta_i)$$

$$BETAPUB_i = 0.422 + 0.0004 * \log(NET_i)$$

Glossary of terms

BETAPAT – R&D coefficient in patent knowledge production function

BETAPUB - R&D coefficient in publications knowledge production function

EPO - European Patent Office

EU – European Union

FP – Framework Programme for Research and Technological Development

GERD - Gross Expenditure on Research and Development

GRD2001 – Gross regional Expenditures on R&D 2001

ICT - Information and Communication Technologies

INV1 – Inverse distance matrix

INV2 – Inverse distance squared matrix

IP - Integrated Projects

Jarque-Bera test – A test of the assumption that the errors are distributed normally

KPF – Knowledge Production Function

LM-Err - Lagrange Multiplier spatial error dependence tests

LM-Lag - Lagrange Multiplier spatial lag dependence tests

Log - Logarithm

Multicollinearity - Collinearity (linear association) of two or more independent variables

NACE - Nomenclature Generale des Activites Economiques dans l`Union Europeenne (General Name for Economic Activities in the European Union).

Neigb – Neighbourhood contiguity matrix

NET – Index of interregional collaboration in the FP

NoE - Networks of Excellence

NUTS - Nomenclature of Territorial Units for Statistics

NUTS2 - Nomenclature of Territorial Units for Statistics, Level 2

NUTS3 - Nomenclature of Territorial Units for Statistics, Level 3

PIM – Perpetual Inventory Method (a method of depreciating patent stocks)

PSTCK – Patent stock

R&D - Research and Development

R^2 Adj. – Adjusted R-Square (proportion of variance explained by the data, adjusted for degrees of freedom)

STREP - Specific Targeted Research Projects

US - United States

White test for heteroskedasticity – A test of the assumption of constant error variance

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Abstract

A recent debate in the context of the future evolution of the European Research Area is concerned with the optimal spatial and thematic allocation of resources for research. This stems from a concern that EU research funds are spread too thinly across Europe without achieving the impact that is expected of them.
'Smart specialisation' or the spatial and thematic concentration of R&D resources on the basis of existing patterns of technological specialisation, is put forward as one possible policy direction. Agglomeration economies have been shown to be important for research: scientists and technologists tend to be more productive when located in proximity to populous communities of knowledge workers and knowledge-intensive business services. Network effects have also been shown to have a positive influence on regional knowledge production processes. A policy of sustaining or even increasing the degree of connectedness in EU research, or 'networked specialisation' is therefore put forward as a possible alternative.
The present policy note draws from original empirical work attempting to shed some light on the joint importance of regional innovation capacity (proxied by a novel index of regional agglomeration of knowledge intensive employment) and scientific networking (proxied by an index of interregional collaboration in FP5) on R&D productivity and draw comparisons.
We find that regional innovation capacity and scientific networking are neither complements nor substitutes but have different functions according to the type of research involved. Our findings indicate that there are distinct paths to obtaining 'critical mass' for scientific and technological research. The regional agglomeration of innovation capacity is important for the productivity of technological research whereas this is not the case for scientific research; likewise, scientific research is more productive in regions that are well connected in interregional knowledge production networks, but the same networking has no discernible effect on technological research.
These findings suggest that differentiated responses will be needed, with increased networking for scientific research and a strengthening of regional innovation capacity for technological research. In that respect, the adoption of fine-tuned instruments for industry (IPs, STREPs) and science (NoEs) from FP6 onwards appear to be a step in the right direction. Complementary interventions will be needed to support the innovation capacity of lagging regions.

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