If Regions could choose their Neighbours
a panel data analysis of knowledge spillovers
between European regions

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Abstract

This paper aims at investigating interregional knowledge spillovers. After a review of the related literature, we construct a regional knowledge production function that allows for extra regional innovation-generating inputs. Accounting for regional specific “social capability”, this knowledge production function is applied to an extended sample of 153 European NUTS I and NUTS II regions over the period 1989-1996. Interregional knowledge spillovers are shown to exist but turn out to be relatively weak. A technology gap approach provides evidence that not only the “home” technology gap but also the “neighbourhood” one significantly influence “home patenting activity”. It also confirms that interregional knowledge spillovers are rather limited. These findings lead us to conclude that there is little place for technological free riding among regions. Therefore regional development strategies aiming at upgrading technological capability should basically focus on the simultaneous strengthening of the region’s human, physical and knowledge capacities.

1. Introduction

According to the endogenous growth literature, innovation does not fall as manna from heaven. Innovation feeds on the existing stock of knowledge on one side, and contributes to the creation of new knowledge on the other. In an open economy, the inputs to innovation production are domestic as well as foreign. Similarly, in the context of regional economics, inter- and intra-regional knowledge spillovers should be considered as driving forces in the innovation process. If the issue of intra-regional knowledge spillovers has been largely developed in the literature, little attention is paid to inter-regional spillovers especially in the European context.
The aim of this paper is precisely to investigate inter-regional knowledge spillover effects for an extended sample of 153 European regions over the period 1989 – 1996 (that is a sample of regions about twice as large as the ones used in related studies). The basic question that we wish to answer may be formulated as follows: “Does regional neighbourhood matter for the creation of new knowledge within the European regional landscape?”

In order to answer this question, after a review of most prominent literature in the related field of research presented in section 2, we consider in section 3 a regional knowledge production function in the spirit of the endogenous growth theory that integrates not only “home” innovation generating inputs but also “foreign” ones and that admits a balanced growth path which is locally stable. Its empirically testable translation is developed in section 4 where we also account for the decrease of spatial interaction as distance raises. Section 5 presents and discusses the panel data estimates of our regional knowledge production function allowing for interregional spillover effects in terms of R&D expenditures. Alternatively to this approach, section 6 investigates the interregional implication of “foreign” and “home” technology gaps. Finally, in the conclusive part of this article we summarise the most striking findings, point at the most important policy implications and suggest some exciting topics for future research.

2. Related literature and theoretical considerations

Over the years, a lot of attention has been paid to explaining regional differences in economic growth. Less attention was directed towards the issue of knowledge diffusion, at least by economists. This was mainly due to the enormous impact of neo-classical theory in all segments of economic theory.

Under the neo-classical model, technology was assumed to spread immediately and be “under competition available to all” (BORTS and STEIN, 1964). Among the various assumptions underlying the neo-classical theory, the one most commonly questioned as to its realism in a regional model is precisely that of immediate diffusion of knowledge. It is considered hard to maintain this assumption, taking into account the distance between the place of invention/innovation and the rest of the territory (RICHARDSON, 1973).

On the other extreme, within the theory of circular and cumulative causation, MYRDAL (1957) and KALDOR (1970, 1975) assume
technology to be completely immobile. These authors argue that increased investment resulting from higher growth in a region is located in the same region. Part of the investment will be devoted to R&D. The benefits of this increased R&D-investment are assumed to be reaped only in this very same region, thus only in this region productivity grows and therefore output raises. Of course, by assuming technology to be completely immobile, as opposed to the neo-classical view of complete mobility, KALDOR advocates another extreme and therefore unrealistic assumption. Approaches based on imperfect mobility and diffusion of technology might match reality much better.

More recently, divergences in growth rates among countries or regions have been considered to be the result of increasing returns to knowledge (ROMER, 1986). Geographic concentration of knowledge facilitates information searches, increases search intensity and, in general, eases task co-ordination. The presence of the external economies associated with knowledge creates spatial differences in the distribution of economic activity (LUCAS, 1988; GROSSMAN and HELPMAN, 1991). The idea that innovative output is determined by a set of knowledge input has gained acceptance (NELSON and WINTER, 1982; FREEMAN, 1989). As noted by DOSI, (1988), LUNDVALL, (1988) and THOMAS, (1985), innovation may have a strong geographic dimension due to the specific and cumulative nature of knowledge-based innovative inputs. JAFFE (1989) demonstrates that spillovers from industrial R&D and university research are geographically mediated and influence the location of innovative output such as patenting. FELDMAN, (1994); ACS, AUDRETSCH and FELDMAN (1991) and VARGA (1998) for example came to the same conclusion.

Using US patent citation statistics, JAFFE, TRAJTENBERG and HENDERSON (1993) found intra-national citations (national patents citing national patents) and intra-state citations (citations to patents originating in the same state) to occur more often than expected from the distribution of patenting activity. Similar results were obtained by JAFFE and TRAJTENBERG (1996) who also found that the geographical concentration of spillovers decreased over time. In the case of Sweden, SJÖHOLM (1996, 1997) found citations to patents in neighbouring countries to occur more often than to patents originating in more distant countries. Whether these findings extend to Europe as a whole was examined by MAURSETH and VERSPAGEN (1999) who found evidence that there are clearly some
regions or clusters of regions that can be characterised as ‘high-tech, and others as ‘low-tech’.

While nowadays general agreement prevails on the importance of knowledge spillovers within or between sectors of activity or within a given country or region, few attempts have been undertaken to explicitly test interregional spillovers on the European level in a knowledge production function framework. To our knowledge, the only study that investigates this field of research was carried out by BOTTAZZI and PERI (1999) who consider a model in the spirit of the endogenous growth literature and allow knowledge spillovers across 86 European regions at the NUTS I level. Using the average number of patents over the period 1977-1995 and the average total R&D employment / expenditures for the same period, they focused on the estimation of a spatial diffusion pattern. In dividing space into intervals (from 0 to 400 km) and estimating the impact of each interval on patenting, they find evidence that spillovers of R&D activity across regions exist, are significant but decrease rather quickly with distance. The aim of this paper is to test for global interregional R&D spillover effects within a knowledge production framework allowing for “foreign” innovative inputs. We use a panel data model which covers the period 1989-1996 and work with per capita values of patents and R&D expenditures but also with different kind of measures of the technology gap.

A regional production function of knowledge taking into account regional spillovers

The seminal contribution of ROMER (1990) can serve as a starting point to formulate a production function of innovation. Innovation, in a region, could be represented as an aggregate process, whose most important inputs are R&D efforts (spending or employment) and the existing stock of technological knowledge. A key feature of the model relies in the fact that knowledge is non-rival and therefore everyone engaged in R&D has free access to the entire stock of knowledge.

In its simplest form, the knowledge-generating process is driven by the stock of knowledge (\(A\)) and the level of R&D efforts (\(D\)). This relation can be expressed as follows:

\[
\dot{A} = \delta AD
\]  
(1)
where $\delta$ is a constant and $\dot{A}$ is the time derivative of $A$.

In equation (1) it is assumed that everyone engaged in R&D has free access to the entire stock of knowledge. A more plausible formulation in the context of regional economics consists to introduce a distance-decay function associated with access to R&D, which lead us to the following reformulation of (1):

$$\dot{A}_R = \delta A D_{A,R} \theta_R$$

(2)

and

$$\theta_R = D_{A,R}^\alpha \text{ with } \alpha > 0$$

(3)

where $R$ denotes the region and $\theta_R$ stand for knowledge spillovers received by region $R$ from other regions. The parameter $\alpha$ measures the concentration of R&D efforts within a region and therefore represents the opportunity for productive contacts. In combining (2) and (3) one obtains:

$$\dot{A}_R = \delta A D_{A,R}^{\alpha \phi}$$

(4)

Now, the knowledge production function is characterised by increasing returns to scale due to the introduction of spillover effects. The logical consequence of such a process is that all R&D resources would ultimately end up in the region with the fastest rate of knowledge production.

In contrast to the above setting, in a highly influential paper JONES (1995) argues for decreasing returns in the production of knowledge. To accommodate such decreasing returns, he proposes to modify equation (1) in the following way:

$$\dot{A} = \delta A D_{A,R}^\lambda A^{\phi-1} = \delta D_{A,R}^\lambda A^\phi$$

(5)

with $\lambda \leq 1$ and $\phi < 1$.

This suggests focusing on the above “semi-endogenous” regional production function for new knowledge which eliminates the long-run growth effects of policy:

$$\dot{A}_R = \delta D_{A,R}^{\lambda + \alpha} A^\phi$$

(6)
In equation (6), the steady state growth rate is exclusively determined by exogenous factors. It can be shown that under this condition of decreasing return to total knowledge spillover, the system of $N$ differential equations in (6) admits a balanced growth path which is locally stable\textsuperscript{32} and the effects of an increase in R&D effort do not last forever.

The empirical translation of equation (6) can be expressed in the following way:

$$\log(\dot{A}) = c + a \log(D) + b \sum \log(D_{R-1}) + u$$  \hspace{1cm} (7)

Equation (7) is the key equation for the empirical implementation of the model. Each underlined variable is an $N \times 1$ vector of regional variables: $\dot{A}$ is a vector of “regional innovative output”, $c$ is a vector of constant capturing all the common terms affecting regional innovation, $D$ represents the vector of R&D efforts within a region and refers to all but the considered region if indexed by $R-1$. Finally, $u$ stands for the vector of error terms.

The interpretation of (7) is intuitive and says that two factors are determinants of innovation of a region (on its balanced growth path):

- The R&D efforts in the region itself, which affect innovation directly and via the spillover effects of the locally generated stock of knowledge.

- The R&D activities realised in all the other regions, filtered by a matrix which weights depend on geographical distance from the considered region.

Equation (7) can be considered as the “reduced-form” production function of knowledge.

4. A knowledge production function for European regions

In the empirical implementation of (7) we use patent\textsuperscript{33} per capita ($pat$) of each region over the period 1989 – 1996 as measure of the flow of profitable innovation. R&D efforts are approached by total R&D

\textsuperscript{32} For an entire theoretical development see BOTTAZZI L. and PERI G. (1999).

\textsuperscript{33} Source of data: EUROSTAT-REGIO.
expenditures\(^{34}\) per capita (\(R&D\)) over the same period. The basic equation can therefore be expressed as follows:

\[
\log(\text{pat}_{it}) = c + a(\log(\text{R & D}_{it})w_{ii}) + b(\sum_{j=1}^{R} \log(\text{R & D}_{jt})w_{ij})
\]  

(8)

where \(w_{ij}\) represents the different weights attributed to the \(j\) regions (\(j \neq i\)).

Within a region, we assume that innovative activity is equally distributed and no weight is applied. The computation of interregional effects assumes that R&D efforts are concentrated in the centres of the (R-1) regions. The intensity of interaction declines with increasing distance \(d_{ij}\) between centres of the regions \(i\) and \(j\) according to the negative exponential function with distance decay parameter \(\beta\).

\[
\log(\text{pat}_{it}) = c + a \log(\text{R & D}_{it}) + b(\sum_{j=1, j \neq i}^{R} \log(\text{R & D}_{jt}) \exp(-\beta d_{ij}))
\]  

(9)

At this stage, it is worth opening two important parentheses. The first concerns the choice of the decay function and the second the measure of interregional distance.

As far as the decay function is concerned, there is no evidence in the economic literature for “best candidates”. The justifications for the adoption of a given distance function is never clear-cut and carried out in an ad hoc manner and / or governed by convention. Our choice for an exponential decay function is essentially based on the parametric estimates of BOTTAZZI et PERRI (1999) who tested for different decay functions. The exponential decay function turns out to be the best fitting one.

More precisely the parameter \(\beta\) of equation (9) was computed in the following way:

\(^{34}\) R&D expenditures are expressed in PPS deflated by the GDP deflator with respect to the price level of 1990. Source of data: EUROSTAT-REGIO
\[ \beta = \frac{(\ln(1 - \gamma))}{\bar{d}_{in}} \]  

(10)

with \(0 \leq \gamma \leq 1\) and where \(\bar{d}_{in}\) denotes the average distance between the centres\(^{35}\) of immediately neighbouring regions. The parameter \(\gamma\) measures the percentage decrease of the spatial interaction, i.e. the decline of the weights as distance expands by the unit \(\bar{d}_{in}\). With increasing \(\gamma\), geographical impediments gain in strength, so that the decline of spatial interaction becomes more pronounced. In order to determine the strength of spatial interaction that fits best our analysis, we have estimated equation (9) with different values of \(\gamma\) within the “0 to 1 range”. The value of \(\gamma\) that maximised the t-statistic relative to the coefficient of “extra-regional R&D spending” turned out to be 0.4 and has been retained in what follows.

The second parenthesis refers to the choice of interregional distances. The latter were calculated using spherical trigonometry, or more in particular the “Law of Cosine” for the spherical triangle:

\[ \cos BC = \cos AC \cdot \cos AB + \sin AC \cdot \sin AB \cdot \cos \alpha \]  

(11)

where \(\alpha\), \(\beta\) and \(\gamma\) are angles of a spherical triangle ABC with BC, AC and AB as respective opposite sides measured as angles from the centre of the globe.

If B and C are two points on the Northern hemisphere with given latitude and longitude expressed in radians, then the distance between these points can be calculated as follows. Taking A to be the North Pole, equation (11) can be applied to the spherical triangle ABC, for which:

\[ AB = 0.5\pi - \text{latitude}B \]  

(12)

\[ AC = 0.5\pi - \text{latitude}C \]  

(13)

\[ \alpha = \text{longitude}B - \text{longitude}C \]  

(14)

\(^{35}\) The centres of regions has been supposed to be the respective economic centres approached by the geographic location of capital cities.
According to (11)

$$BC = \cos^{-1}(\cos AC \cdot \cos AB + \sin AC \cdot \sin AB \cdot \cos \alpha)$$

(15)

Multiplication by 6366 (the radius of the globe) gives the distance between B and C in kilometres.

In the next section we test our regional knowledge production function such as described in equation (9) in controlling for certain variables important for the process of innovation.

5. Testing for interregional R&D spillover effects

The model is tested on the European regional landscape over the period 1989 - 1996. A total of 153 European regions are covered by the sample which is composed of 120 NUTS II regions, 31 NUTS I regions and 2 NUTS 0 regions. For the latter - The Netherlands and Ireland - no regional data on R&D is available. This is also the case for Açores and Madeira. Belgian regions could only be covered at the NUTS I level. As far as Danish regions are concerned, aggregations of NUTS III regions have been performed since R&D data are only available in this aggregated form. Germany’s new Länder as well as Luxembourg were excluded as R&D data does not exist for these regions.

Table 1 summarises the estimation results allowing for random effects. It is worth mentioning that the fixed effect panel method is not appropriate in our case since we wish to control for a certain number of variables which are crucial for the innovation process but for which changes over time are extremely slow or absent. In order to determine whether the common or the random effect model should be applied, we used the Lagrange multiplier test for the random effects model based on the OLS residuals derived by BREUSCH and PAGAN (1980). The result of the test is in favour of the random effects model. However, it should be noted that the estimates remain almost the same when the common effect model is applied.
Table 1: Panel data estimates of the regional knowledge production function allowing for interregional R&D spillover effects

<table>
<thead>
<tr>
<th>Dependent variable: log(pat)</th>
<th>1.I</th>
<th>1.II</th>
<th>1.III</th>
<th>1.IV</th>
<th>1.V</th>
</tr>
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<tbody>
<tr>
<td>const.</td>
<td>-6.99</td>
<td>-2.59</td>
<td>-6.58</td>
<td>-5.21</td>
<td>-1.31</td>
</tr>
<tr>
<td></td>
<td>(-60.39)</td>
<td>(-4.35)</td>
<td>(-48.28)</td>
<td>(-14.42)</td>
<td>(-2.09)</td>
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<tr>
<td>log (R&amp;D)</td>
<td>0.91</td>
<td>0.67</td>
<td>0.86</td>
<td>0.75</td>
<td>0.54</td>
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<tr>
<td></td>
<td>(14.98)</td>
<td>(10.09)</td>
<td>(14.34)</td>
<td>(11.01)</td>
<td>(7.85)</td>
</tr>
<tr>
<td>log (Q)</td>
<td>3.08</td>
<td>2.91</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td></td>
<td>(7.62)</td>
<td>(7.33)</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>log (K)</td>
<td>0.09</td>
<td>0.08</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td></td>
<td>(5.63)</td>
<td>(5.44)</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>log (I)</td>
<td>0.57</td>
<td>0.38</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td></td>
<td>(4.05)</td>
<td>(2.96)</td>
<td></td>
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<tr>
<td>log (S)</td>
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<td>0.81</td>
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<td></td>
<td>(5.17)</td>
<td>(3.25)</td>
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<td></td>
<td></td>
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<tr>
<td>log (R&amp;D_{R.t})</td>
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<td>0.02</td>
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<td></td>
<td>(9.07)</td>
<td>(7.19)</td>
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<td>0.02</td>
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<td></td>
<td>(7.44)</td>
<td>(7.49)</td>
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<td>0.01</td>
<td>0.01</td>
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<td></td>
<td>(4.72)</td>
<td>(4.72)</td>
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<tr>
<td>R²a.</td>
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<td>0.93</td>
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<td></td>
<td>0.93</td>
<td>0.93</td>
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<td>St.E</td>
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<td>0.24</td>
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<td>0.24</td>
<td>0.24</td>
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Number of observations: 1224 (8 years and 153 regions)
Heteroskedasticity-consistent t-statistics between brackets
Estimation method: GLS
For regions without any patenting activity namely Ionia Nisia, Voreio Aigio, Corse, Alentejo and Algarve a minimum value of 0.1 patents per year has been supposed.

Besides the basic regional knowledge production function with interregional spillover effects (1.I), equations 1.II, 1.III and 1.IV control respectively for the qualification of the working age population (Q)\(^{36}\), the endowment of physical infrastructure (K)\(^{37}\) and the employment concentration in industry (I)\(^{38}\) and services (S)\(^{39}\) whereas equation 1.V controls simultaneously for all of these variables. The rationale behind the introduction of the above

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\(^{36}\) The qualification variable of the working age population is approached by an indicator defined as follows:
\[
Q = \frac{(8y/Q)+(12*mQ)+(20*hQ)}{40}
\]
where \(IQ, mQ\) and \(hQ\) refer respectively to the proportion of the working age population with low, medium and high qualification. (Source of data: EUROPEAN COMMISSION, 1999)

\(^{37}\) The indicator of physical capital infrastructure is defined as the number of kilometres of motorways per 1000 inhabitants. (Source of data: EUROSTAT-REGIO)

\(^{38}\) The variable I represents the percentage of employment in industry with respect to total employment. (Source of data: EUROSTAT-REGIO)

\(^{39}\) The variable S represents the percentage of employment in services with respect to total employment. Since for the great majority of European regions, the desegregation of the service sector is not available, the variable also includes public services. However, this component is supposed to have little influence on technological progress. (Source of data: EUROSTAT-REGIO)
mentioned variables into the basic framework is to capture what ABRAMOVITZ (1986) calls the region’s “social capability”. “Social capability” refers to factors such as education, an appropriate financial system, business enterprise linkages or market relations and endowment of physical capital. Since these factors are assumed to facilitate not only innovation but also technological imitation and the implementation of technology spillovers, it is worth to introduce them into the basic framework.

As can be seen from Table 1, all the estimated coefficients are significant at least at the 5% level and overall goodness of fit is acceptable. From equation 1.I, one can observe that “foreign R&D effort” significantly influences “home patenting activity”. This result suggests that regional neighbourhood is important and may partially explain why peripheral regions, potentially exposed to little knowledge spillovers from close regions, produce, with a same amount of R&D spending far less patents than do central regions. Another partial explanation is certainly related to differences in R&D productivity since our estimates indicate that the elasticity of “home R&D efforts” is much more important then that of “foreign R&D”.

The progressive introduction of the qualification level of the working age population (Q), physical capital endowment (K) and employment concentration in industry (I) and services (S) does not alter the influence of “foreign R&D spending” to “home patenting”. However the simultaneous introduction of these variables as shown by equation 1.V significantly reduces this influence. This finding suggests that interregional spillovers do exist but are not as high as expected compared to the impact of own R&D efforts and own “social capability”.

As far as equation 1.II is concerned, it clearly indicates the crucial importance of qualification for the process of innovation. The technical competence of the labour force and the availability of various skills are essential to integrate technologies developed elsewhere as well as developing one’s own. Physical capital infrastructure introduced in equation

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40 For instance, the peripheral region of Madrid, produced in 1996 about one tenth of the patenting per capita one observes for the central region of Düsseldorf with a same amount of R&D spending. Similarly, the central region of Unterfranken produces with a same amount of R&D spending about seven times more patents per capita than the relatively peripheral region of Lazio.
I.III turns out to have a positive impact on patenting. This finding suggests that an efficient physical infrastructure is likely to increase the profitability / to reduce the cost of introducing new technologies and therefore speeds up the process of technology diffusion. With regard to the employment concentration in industry and services introduced in equation I.IV, both variables turn out to influence positively and significantly patenting activity. Traditionally, industry has been considered as an “engine of growth” (KALDOR, 1966). However, technological progress in recent years has been more sustained by the service sector than by industry (OECD, 1996 and OECD, 1997). This fact which is partly a consequence of the current process of meta-industrialisation seems to be confirmed by our estimation results since the coefficient of services is about twice as large as the one of industry.

At this stage we wish to open an interesting parenthesis. Although dependent on the retained decay function and on the importance of spatial interaction as captured by the decay factor, it is worth to consider Figure 1. Its aim is not to determine the spatial extent of R&D spillovers – this should be done without imposing any parametric structure on the diffusion on knowledge in space – but only to show within the limits of our setting, the rapid decrease of “foreign” R&D spillover effects. As observed previously, interregional spillovers exist but globally, they are not very important. However, in the theoretical case where space were limited to a circle of 100 km around the “home region”, our estimates relative to the elasticity of “home patenting activity” with respect to “foreign R&D expenses” turns out be about 0.09, that is about three times and a half the global, non space limited impact. Similarly, when one considers the case where space were limited to a circle of 200 km around the considered region, then the elasticity of “home patenting” to “foreign R&D expenditures” falls down to 0.04. Within the 600 km radius, one finds the global elasticity of about 0.02 meaning that R&D expenditures realised by regions situated more than 600 km away from the “home region” do not influence any more “home patent activity” despite a significant coefficient.
Figure 1:
Evolution of the influence of “foreign” R&D expenditures on “home” patenting

Controlling for qualification, physical capital infrastructure as well as the structure of the productive system, the influence of “foreign R&D expenses” on “home patenting” is not only lower but also declines faster. Moreover, regions which are geographically separated by more than 1000 km from the “home” region, the coefficient of “foreign R&D expenditures” is not significant any more.

6. Testing for interregional technology gap spillover effects

There is no reason that interregional spillovers only occur in terms of R&D expenditures. In this section we wish to test for the interregional interaction in terms of two different measures of the technology gap.

The first measure is defined as $G_{i} = 1 - \left( \frac{GDP_{Ri}}{\frac{pop_{Ri}}{GDP_{Li}}} \right)$
and the second as \( G2_t = 1 - \frac{R \& D_{Rt}}{pop_{Rt}} - \frac{R \& D_{Lt}}{pop_{Lt}} \)

with \( 0 < G1_t, G2_t, < 1 \) and where the index \( R \) and \( L \) respectively refer to the considered region and the leading regions and \( t \) refers to time. As far as the first measure (\( G1 \))\(^{41}\) is concerned, the leading regions in terms of GDP per capita are Bruxelles, Île-de-France and Hamburg\(^{42}\). For the second measure (\( G2 \))\(^{43}\), Stuttgart, Oberbayern, Île-de-France, Stockholm and Östra Mellansverige are the leaders. From the above definitions it is quite clear that the closer a region is to the performance level of technological leaders, the lower turns out to be the gap and the value of the indicator. As in the case of interregional spillovers in terms of R&D expenditures, we apply the exponential distance decay function defined previously.

Considering the same regional data set and time period as in section 5 and allowing for random effects for reasons explained previously, one obtains the estimates reported at Table 2. The existence of a “foreign technology gap” turns out to influence negatively and significantly the “home patenting activity”. Put differently, a region whose neighbours are technologically backward is likely to patent less. This observation prevails for both measures of the technology gap but is more pronounced for the one based on R&D expenditures per capita. An opposite effect can be observed for the “home technology gap”. The latter positively influences patenting activity. This finding may seem paradoxical but is entirely coherent in the spirit of the technology gap literature. Indeed, as shown by FAGERBERG (1987), ABRAMOVITZ (1986), AMABLE (1993) and FINGLETON (2000) at the country level and by GREUNZ (2001) at the European regional level, the

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\(^{41}\) Within this measure of the technology gap, the regional level of real GDP per capita is expressed in terms of PPA deflated by the GDP deflator with respect to the price level of 1990.

\(^{42}\) It should be noted that the selection of the best performing regions was based on the regional desaggregation level NUTS II. However, at the more desagregated level NUTS III, other regions may perform better. For the first measure of the technology gap for instance, München, Frankfurt and London clearly perform better than Bruxelles and Hamburg. Since data at the NUTS III level are scarce or, as in the case of London, only available since recently, the analysis is carried out at the NUTS II level.

\(^{43}\) Within this measure of the technology gap, the regional level of total R&D expenditures per capita is expressed in terms of PPA deflated by the GDP deflator with respect to the price level of 1990.
existence of a technology gap opens up the possibility for faster growth through the imitation and the integration of technologies developed elsewhere. In the technology gap literature this process is called “catching up”. However, technology is not assumed to be a public good in the sense that it is equally available to everybody free of charge. On the contrary, it is argued that successful adoption of new technology is generally costly and requires a sufficient endowment of “social capability” such as defined previously. An important part of “social capability” is innovative capacity. An effort in innovation is often a precondition for successful imitation in so far as it feeds the “knowledge base” (DOSI, 1988) upon which the region builds its technical competence. Having an innovative activity confers an expertise that facilitates the assimilation of knowledge developed elsewhere, the creation of one’s own and thus magnifies R&D spillovers, both inter- and intra-regional ones. Put differently, the existence of a “home technology gap” when “social capability” is sufficiently developed constitutes a kind of incentive to foster innovative activities in order to exploit technologies developed elsewhere. The regional “knowledge base” increases and confers to the region the ability to create new knowledge for its own.

As far as the coefficients on the qualification level of the working age population, physical capital endowment and the structure of the productive system are concerned, the coefficients do not differ significantly from those of Table 1. The progressive introduction of these variables change significantly the impact of the “foreign technology gap”, especially when the latter is measured in terms of R&D spending per capita. Similarly, the “home technology gap” effect is relatively sensitive to their introduction. The qualification level of the working age population turns out to be highly important for “catching up”. Adding this variable to the basic framework raises significantly the impact of the “home technology gap” while it lowers the effect of the “foreign” one. When simultaneously controlling for all the above mentioned variables, it is interesting to notice that, as in the case of interregional spillovers from R&D expenditures, the effect of the “foreign” technology gap is halved compared to the basic framework results.
Table 2: Panel data estimates of the regional knowledge production function allowing for interregional technology gap spillover effects

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Number of observations: 1224 (8 years and 153 regions)
Heteroskedasticity-consistent t-statistics between brackets
Estimation method: GLS
\(\textsuperscript{c}\) For regions without any patenting activity namely Ionia Nisia, Voreio Aigaio, Corse, Alentejo and Algarve a minimum value of 0.1 patents per year has been supposed.

7. Conclusion

If regions could choose their neighbours, it is likely that most peripheral regions would move towards technological leaders spending high amounts on R&D such as the South-German regions Oberbayern and Stuttgart as well as the French region Île-de-France. Why would they move there? The answer to this question lies in the existence of interregional knowledge spillovers for which we found evidence in our paper. More precisely, we aimed at investigating whether regional neighbourhood matters for the creation of new knowledge within the European regional landscape. Using an extended sample of 153 European regions and covering the period 1989-1996, we tested by means of panel data methods a regional knowledge production function that allows for extra-regional knowledge-generating inputs. While the latter were approached by R&D expenditures realised by “foreign regions”, we considered “home patents per capita” as innovative outputs. Since spatial interaction is assumed to decrease as distance raises,
"foreign R&D spending" was weighted by an exponential distance decay function. The estimates of the basic regional knowledge production function indicate that the elasticity of "home patents per capita" with respect to "extra-regional R&D expenditures" are positive and significant but not as high as one might expect. A one percentage increase in R&D spending per capita realised by "foreign regions" raises the level of "home patents per capita" by about 0.02 percent which is rather minor compared to the influence of "home R&D spending". In the theoretical case where space were limited to a circle of 100 km around the "home region", the elasticity of "home patenting" to "foreign R&D expenses" would be about three times and a half the global, non space limited impact. However regional knowledge spillovers decrease rather quickly as distance raises and regions situated more than 600 km away form the "home region" do not influence any more "home patenting activity".

Alternatively to the knowledge production function approach, we tested for interregional spillovers in terms of regional technology gaps with respect to technological leaders. The existence of a "foreign technology gap" turned out to negatively affect the "home patenting activity" while the latter is positively influenced by a "home technology gap". This result is entirely coherent in the spirit of the technology gap literature, and suggests that the existence of a "home technology gap" constitutes an incentive to foster R&D activities in order to acquire the necessary capacity to exploit technologies developed elsewhere. Fostering R&D activities raises the "knowledge base" and gradually confers the ability of own knowledge creation. However, such a process can only take place within an environment where "social capability" is sufficiently developed.

"Social capability" is a concept that cannot be measured straightforwardly. In order to control for it we use proxies, that is, we introduced the qualification level of the working age population, the endowment of physical infrastructure and the structure of the region's productive system into the regional knowledge production function but also into the alternative approach based on technology gaps. In both cases, controlling for "social capability" turned out to significantly lower the influence of "foreign" as well as of "home" knowledge-generating inputs on "home patenting activity". This fact confirms that regional R&D productivity is heavily dependent on "region specific capacities", especially on the qualification level of the working age population for which the coefficient turned out to be highly significant.
These last considerations naturally lead us to some reflections in terms of policy implications. Since regional knowledge spillovers were shown to exist, regions would probably move towards technological leaders if they could choose their neighbours. However, since these spillover effects seem to be rather weak, there is only little place for technological free riding among regions. Put differently, in order to acquire or to preserve technological competitiveness, regions have to build up and feed their own "knowledge base". Certainly, trans-regional co-operations programs supported by the European Commission in order to foster technology transfers help to intensify interregional relations and, among others, regional knowledge spillovers. However, we believe that such initiatives may fail to hit the target if not accompanied by policies aiming at upgrading local "social capability". A sufficient level of "social capability" is crucial not only to capture interregional knowledge spillovers but also to integrate them into the locally existing "knowledge base", an indispensable process for the generation of new technological combinations and knowledge creation.

One particular component of "social capability", namely qualification was shown to heavily influence knowledge creation. Improvements in this field increase R&D productivity. Higher R&D productivity enables an increase of GDP and therefore a reduction of the technology gap. Does this consideration mean that policy efforts should be exclusively concentrated on qualification? A real improvement of "social capability" in lagging regions probably cannot be achieved by adopting a dichotomous approach. Firstly, increased public incentives to enhance education and qualification are certainly necessary but should closely respond to (latent or expressed) needs of the business enterprises sector. Secondly, in regions suffering from "technological backwardness", innovation incentives are essential to create or to upgrade the "knowledge base" on which the region can build up but these policies should basically be oriented towards existing fields of specialisation and know-how in order to reach the necessary critical base. Simultaneously to the implementation of innovation incentives, tailored education and formation policies have to be put into action in order to increase local absorptive capacity. Put more generally, any regional development strategy aiming at upgrading sustained technological capability should be systemic in the sense that it has to stimulate simultaneously human, physical and knowledge capacities. Thirdly, human, physical and knowledge capacities ought to be supported by original policies based onto the region's identity and specificity. The implementation of policies purely imitated from other regions is not likely to produce the expected results and
furthermore, embodies the risk of increased inefficient regional competition. Both considerations are prejudicial to socio-economic cohesion within Europe.

Finally, since the topic of interregional spillovers is actually relatively little investigated, this paper raises even more questions than it answers. We showed that interregional knowledge spillovers exist but are rather weak. This finding induces a series of appealing questions and opens a huge field of research. What is the extent of knowledge spillovers between regions with comparable endowments of “social capital”? Do there exist national differences with respect to the intensity of interregional knowledge spillovers? Which are the European regions that contribute most to the overall European knowledge creation? These are some of the questions that constitute one direction of research. Another one, which is worth being explored consists in splitting up total R&D expenditures into its private and public components and to investigate the extent of knowledge spillovers generated by each kind of R&D spending. Lastly, an extremely interesting field of research lies in the exploration of spillover effects based onto technological distances especially when combined to geographical ones.
References


