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**Proximity and Stratification in European
Scientific Research Collaboration Networks:
A Policy Perspective**

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Abstract In this chapter we introduce a framework to understand the geography of scientific research collaboration with an emphasis on empirical studies that evaluate the policy efforts to create a ‘European Research Area’ (ERA). We argue that the geography of scientific research collaboration follows a logic of proximity that provides researchers with solutions to the problem of coordination, and a logic of stratification that provides researchers with differential means to engage in collaboration. The policy efforts to create ERA can then be understood as strategic policy interventions at the European level that affect the form and nature of both structuring principles. More specifically, the aim of reducing ‘*fragmentation of research activities, programmes and policies*’ affects the importance of several forms of proximity vis-à-vis each other, while the promotion of ‘*research excellence*’ results in new forms of network stratification at multiple spatial scales. We provide an overview of recent empirical findings to illustrate these claims, and discuss potential implications for future ERA policies.

Keywords: collaboration, science, geography, proximity, stratification, Europe

1. Introduction

Probably the largest transnational policy effort affecting the current geography of scientific research collaboration is the effort by the European Commission (EC) to create a European Research Area (ERA). The objective of ERA policy is to overcome “*fragmentation of research activities, programmes and policies across Europe*” (Commission 2007, p. 2) by removing “*barriers to the free flow of knowledge*” (European Council 2008, p. 5). This aim is pursued through direct funding of collaborative research projects, mobility schemes and streamlining of research policies. The Framework Programmes (FPs) of the European Commission (EC) constitute one of the main instrument to realize the ERA vision. They are specifically designed to pool resources and promote international scientific collaboration between EU member states by enabling and intensifying interactions among researchers. Ever since its inception, research budgets for the FPs have been on the rise and the budget for Horizon 2020 indicate a substantial increase over previous FPs (Commission 2013).

Despite the substantial resources supporting ERA policy, clarity is still lacking about what the ERA vision entails and about the rate of progress in moving towards this vision. Reading from EC policy documents, ERA is conceived as “an ‘internal market’ in research, an area of free movement of knowledge, researchers and technology” (Commission 2002, p. 4). From a geographical perspective, this vision is expressed in policy efforts to reduce the significance of spatial barriers that hinder European-wide research collaboration such as those following from regional and national boundaries. Yet, the intended geographical effects of these efforts are uncertain and the abstract nature of the vision masks the fact that there are trade-offs between more specific objectives defined under the heading of ERA policy. For instance, there has been much concern that competitive research policies compromise the cohesion objective of the European Union (Sharp 1998; Begg 2010) as those policies are not intended to intervene in the European scientific and technological landscape at large, but to bundle resources with the purpose of supporting collaborative efforts between ‘*excellent*’ researchers in a few strategic scientific fields.

Against this background, the goal of this chapter is *first* to introduce a conceptual framework that can be used to understand the geography of scientific research collaboration and *second* to review recent empirical studies on the structuring principles of this framework in the context of ERA. Our conceptual framework starts from the observation that the geographical structure of scientific collaboration networks can be understood from the joint outcome of a logic of proximity and a logic of stratification (Hoekman et al. 2009). In the review we specifically focus on empirical studies that have addressed research collaboration in the scientific domain using (co-)publication data.

The remainder of this chapter is structured as follows. In the next section we provide a theoretical introduction to the geography of research collaboration. We subsequently pay attention to proximity and stratification as two organizing principles of research collaboration and show how they are affected by the European policies to create ERA. The implications of our findings are discussed in the concluding section.

2. Geography of research collaboration

The geography of research collaboration deals with the question how space structures collaborations between researchers, and how aggregates of such collaborations constitute spatial networks between locations that can be studied using spatial scientometric tools (Frenken et al. 2009). In this framework, research collaborations are structured according to a logic of proximity that provides solutions to the problem of coordination, and a logic of stratification that provides differential means to engage in collaboration (Hoekman et al. 2009). These logics are not stable over time but change as a consequence of globalisation. Globalisation follows from a process of time-space compression (Harvey 1990), which is made possible by advancements in transportation and ICTs. At the same time, globalisation is governed by institutional harmonisation at the transnational level as envisaged for instance by transnational institutions such as the European Commission. These institutions may directly affect the geography of collaboration through funding of international collaborative research, but also indirectly through the alignment of research agenda's and infrastructures between territories.

The understanding of space needs to be explicated in this context as contemporary geographers have provided multiple conceptions of place and space which refer to material as well as to perceptual dimensions (e.g. Lefebvre 1991; Massey 2004). We start from the physical location of individuals on the Euclidean surface and their media of communication and movement. Given these general elements, space can be defined as a fundamental material dimension that provides settings of interaction as a time-sharing activity between individuals (Hägerstrand 1970; Giddens 1984; Harvey 1990). This materiality can be both conceived in terms of places where researchers are co-present, as well as in terms of flows which allow for time-sharing activities at a distance (Castells 1996).

One can argue that research collaborations always involve some form of time-sharing activity between individuals, although it has been notoriously difficult to provide more exact definitions (Katz and Martin 1997). Traditionally, these settings of interactions

follow from moments of physical co-presence when researchers meet at certain locations and interact with one another face-to-face. The complex nature of scientific activities makes this form of interaction essential as some aspects of knowledge are tacit, implying that they “*cannot be put into words*” (Polanyi 1958, p. 4) or “*cannot be or - have not been - set out or passed on in formulae, diagrams or verbal descriptions and instructions for actions*” (Collins 2001, p 72). Acquisition of this knowledge therefore necessitates ‘enculturation’ between researchers ranging from short-time visits to institutionalization in ‘master-apprentice relations’ (Collins 1985). Furthermore, moments of co-presence facilitate the establishment of trust through the sensory effect that individuals have on one another when they are co-present (Simmel 1997; Urry 2000) which is essential to establish the credibility of research findings (Shapin 1995).

The materiality of space and the indivisibility of the body set limits on the co-presence of individuals in these settings of interaction. Individuals can only be at one location at the same time and movement in space involves movement in time (Hägerstrand 1970). Research collaborations that rely on moments of co-presence are thus structured by the location of scientists vis-à-vis each other and their means of mobility when they intend to meet. It follows that collaborating scientists may need to co-locate depending on the necessary frequency of co-presence and the advancement of media of mobility. More specifically, when either the necessary frequency of co-presence is high or the means of mobility are low, it becomes a necessary condition that researchers work in close physical proximity on a permanent base. In time-space geography this condition is visualised using time-space prisms that show the absolute boundaries of individual movement in space given that he/she needs to ‘bundle’ with other individuals at a particular moment in the future (Hägerstrand 1970).

Technological advancements provide the possibility to relax the necessary overlap between co-presence and co-location (Torre and Rallet 2005). Transportation technology, the development of related material infrastructure and a relative decline in the costs of mobility have rendered a ‘shrinking of distance’ (Janelle 1969) in terms of the time and money needed to travel from one location to the other. As a result individuals can travel

longer distances than in the past without necessarily travelling longer. This process extends the spatial range that a researcher can cover given that s/he wants to return to his/her permanent location within a particular time-frame. Spatial range is not a simple function of the kilometric distance between the permanent location of researchers because the material infrastructure that supports differential means of mobility (e.g. highways, airports) is unequally distributed in space. Moreover, the actual perception of distance is a subjective matter and differs between individuals according to their mental maps (Milgram and Jodelet 1976).

Information technologies also make physical proximity on a permanent base less of a necessity, since researchers can interact through the material infrastructure that supports flows of communication between distant locations (Torre and Rallet 2005). In this context, Castells (1996) notes that these technologies create new spaces of their own which are not constituted by traditional settings of interactions based on co-presence, but are materialised in ‘circuits of electronic exchange’ that support time-sharing practice without physical proximity. As such, space can no longer be conceptualised based on physical proximity alone but its materiality should also be conceived in terms of flows and their particular spatial forms.

However despite technological advancements, the substitution of communication technologies for moments of co-presence is limited. Olsen and Olsen (2000) question in this respect whether this substitution process can ever be perfect as modern media hinder the unique establishment of common reference frames and mutual understanding through amongst others rapid feedback, pointing and referring to objects in real space (i.e. acquiring ostensive knowledge), subtle communication, informal interaction before and after ‘meetings’ and a shared local context. Thus, a main tenet of the geography of research collaboration holds that despite technological advancement, the friction of distance still exerts gravitational force on collaborative knowledge production.

3. Logic of proximity

Physical proximity between researchers provide solutions to the problem of coordination in actual collaborative practices which is a main concern surrounding the uncertain activity of knowledge production. Coordination involves the creation of alignments between researchers by integrating different pieces of a research project in order to accomplish collective tasks (Cummings and Kiesler 2005). As argued above, moments of co-presence are essential to create such alignment.

However, the exact intensity and duration of moments of co-presence that is necessary for successful coordination is conditioned by proximities other than physical proximity, which may already exist between collaborating researchers (Boschma 2005). Already established proximities mediate the success of coordination given a certain amount of co-presence. For example, researchers that already collaborated in the past created social and cognitive proximity which facilitates future collaborations. They will be more effective in communicating by means of ICTs because trust and common references frames have already been established (Amin and Roberts 2008). Hence, the need for co-presence is expected to decline over time in repeated collaborations. It has also been shown that there is less need for co-presence in research collaborations between universities than in university-industry research collaborations as in the former institutional proximity is already established at different locations, whereas in the latter it is not (Ponds et al. 2007).

Physical proximity between researchers is in itself neither a necessary nor a sufficient condition for successful research coordination, although it facilitates the establishment of other forms of proximity *via* moments of co-presence (Boschma 2005). As a result, most forms of proximity are geographically localized as they are established through recurrent moments of co-presence between researchers. For instance, socio-cognitive proximities established on the basis of previous moments of co-presence are often sustained in localised networks. Breschi and Lissoni (2009) show for instance that researchers' embeddedness in social networks decays with geographical distance. Storper and Venables (2004, p. 367) consider cities a main stage where socio-cognitive proximities

are sustained by making reference to their importance for “*getting into loops which are associated with collocation*”. Others have in this context pointed towards “*being there*” (Gertler 2003) and “*buzz*” (Bathelt et al. 2004) as organising principles for socio-cognitive systems that are bounded in space (see also Howells 2002).

Moreover, institutional proximities as defined by common ‘rules of the game’ (North 1990) that are enforced in particular locations are almost by definition geographically localised. In science, institutional proximity has historically been created at the national level by building national education systems and creating specific technological capabilities in order to stimulate economic growth (Lundvall 1988; Crawford et al. 1993). As a result there are many key institutional settings with national significance in research funding schemes, research infrastructures, research assessments, education systems, intellectual property regimes and labour markets, amongst others (Crescenzi et al. 2007). In addition to these national institutions, the emphasis on regional competitiveness as an important policy goal has also contributed to a plethora of regional institutions that create institutional proximity between researchers at the sub-national level (Bristow 2005).

Proximity and ERA

European policy interventions to create ERA affect the spatiality of proximity dimensions in multiple ways. *First*, direct funding of transnational research projects and mobility schemes is expected to facilitate moments of co-presence between European researchers that are often not located in close physical proximity to each other. The main policy instruments to achieve this goal are FP projects with a temporal character, but also long-term collaboration networks such as the Virtual Knowledge and Innovation Communities that have recently been created under the heading of the European Institute of Innovation and Technology’s (EIT) are important in this respect. The European character of these efforts follows from formal allocation criteria of funding that require the inclusion of researchers from multiple European member states. Given the pervasive effect of geographical localization on research collaboration, these collaborative projects are unlikely to emerge in similar structure without strategic policy intervention. Hence,

funding of collaborative research projects is instrumental in the creation of ERA through the establishment of novel socio-cognitive proximities between physically distant researchers. In doing so the EC aims to remove spatial barriers – especially national borders - that hamper collaboration between different nation-states within Europe.

Second, ERA policy is also expected to be instrumental in aligning regional and national institutions in which new forms of research collaboration may eventually become embedded. Initiatives to achieve this goal include ERA-NET that aims to counteract the fragmentation of national research policies and funding schemes between separate member states by networking and streamlining activities; ERA-WATCH that benchmarks information on the research policies and research systems of member state; ESFRI that coordinates investments in pan-European research infrastructures; and the Joint Programming Initiatives in which member states reach agreements on Strategic Research Agendas to address major societal challenges. In these programmes institutional alignment is realised through an Open Method of Coordination (OMC) which is characterised by soft regulations such as guidelines, indicators, benchmarking and learning through best practice. There are no official sanctions in OMC as it is believed that the method's effectiveness is ensured through a form of peer pressure and a process of 'naming and shaming'. As such this instrument functions as a catalyst for harmonisation between national policies.

The rate of progress towards the creation of ERA in science has been assessed by monitoring the evolution of spatial collaboration networks constructed from publication as well as from FP project data. The empirical results presented in these studies demonstrate that the incidence of cross-border research collaboration in Europe is increasing over time which goes at the expense of scientific research collaborations within sub-national regions and nation-states. More specifically, co-publication activities in Europe show a gradual tendency towards European integration judged from the observation that the importance of territorial borders reduces over time (Matsson et al. 2008; Hoekman et al. 2010; Chessa et al. 2013). There is evidence that (part of) this process of integration results from funding provided through the FPs. Hoekman et al.

(2013) show for instance that the number of co-publications between international European regions is positively affected by joint participation of these regions in FP projects, even after controlling for prior co-publication activity.

Although these empirical results indeed suggest that ERA policy reduces fragmentation of scientific research activities across Europe, the findings have been qualified in a number of different ways. *First*, although there seems to be a tendency towards European integration, Europe's scientific landscape continues to consist mainly of a collection of regional and national research systems. This finding has been observed in studies using gravity models indicating that in the European context regional, national and language borders continue to have a large and independent negative effect on co-publication activity (Maggioni and Uberti 2009; Hoekman et al. 2009).

Second, although we observe that there is an increase in cross-border collaboration in the last decade, there is no evidence that the influence of physical proximity on structuring research collaborations is decreasing over time. This result may be surprising as we would expect internationalisation to go hand in hand with a decreasing effect of distance. However, although ERA policy is effective in reducing the importance of national borders, researchers continue to orient themselves mainly towards physically proximate, but possibly cross-territorial, partners. This observation particularly holds for the new member states of the European Union, which are rapidly catching up in scientific activity (Hoekman et al. 2010).

Third, when using co-publications to compare the growth of international scientific research collaboration between EU member states and non-EU OECD members, Chessa et al. (2013) observes that ever since 2003, international research collaboration within the EU is not growing at a more rapid pace than international collaboration between other OECD members. This result raises doubt on the extent to which ERA policy is effective in stimulating cross-border research collaboration and suggest that (part of) internationalization of science should be rather explained by a more general process of time-space compression following from mobility and ICT advancements.

4. Logic of stratification

Science is a stratified institution as evidenced by the observation that “*power and resources are concentrated in the hands of a relatively small minority*” (Cole and Cole 1972, p. 368). Expressed in quantitative terms, the productivity of scientists follows a rank-size distribution where there are only a few scientists with very high productivity and many with low productivity (Price 1963; Stephan 2012). According to the sociology of science the unequal distribution of productivity reflects itself in the reward system that gives credit where credit is due, therefore effectively providing productive researchers with more recognition (Merton 1973). Recognition is not an isolated property based on past achievement alone. Rather, it is part of a cumulative cycle of conversion that conditions “scientist’s abilities actually to do science” (Latour and Woolgar 1986, p. 198). Within this cycle, recognition can be transformed in instrumental assets such as money, equipment and data. Researchers ‘invest’ in these assets to produce new scientific knowledge with the intention of ‘earning back’ recognition with ‘interest’ after a complete cycle (Hessels 2010). Positive feedback mechanisms exist in the system and they may increase the interest rate to investments based on already established reputations of researchers (Merton 1973; Stephan 2012). Such positive feedback mechanisms are for instance observed when studying the attribution of reward as visible in scientific citations (Peterson et al. 2010)

Research collaboration is also a way to gain and sustain recognition as collaboration provides access to resources such as research infrastructure, information and training. Moreover, collaboration creates networks through which scientific knowledge and researchers’ own reputation diffuses (Beaver and Rosen 1978). In doing so, the embeddedness of researchers in networks is a medium to mobilise ‘allies’ and to convince peers about the significance of research results (Latour 1987).

The structure of research collaboration that follows from this reward system can be considered an emergent, self-organising system insofar the selection of research partners is based upon choices made by researchers themselves, irrespective of their locations (Wagner and Leysdesdorff 2005). However, these ‘footloose’ choices can only be made

when researchers have the resources to organise the settings of interaction that are necessary for successful coordination of research collaboration in the first place. In this respect, the unequal distribution of rewards and its reinforcement through positive feedback mechanisms makes some researchers more footloose than others because it provides researchers with differential means to access mobility technology and ICTs. It follows that physical distance becomes relatively less of a concern for researchers with higher reputation as they have the resources to organise moments of co-presence on a temporal base. Reputable researchers are also more attractive collaborators and as a result other researchers have a higher preference to be co-present with them (both for training and collaboration).

Given this logic of stratification, the structure of scientific collaboration networks follows a ‘preferential attachment’ process which is especially observed for early-career researchers and young talent (e.g. PhDs, post-docs). The minority of researchers with a high reputation are in this case like ‘magnets’ for the (yet) less reputable ones which makes it relatively easy for the former to hire new personnel, potentially over large distances. Mahroum (2000, p. 372 and p. 376) notes in this respect that “*mobility is a premier agent of scientific expansion [where] highly talented scientists flow to scientific institutions that are reputed for their excellence*”. In this collaboration structure, reputable researchers have the means to collaborate over large distances and they can also organize the conditions to efficiently collaborate with peers in close vicinity. In contrast, it is expected that less reputable researchers will collaborate in closer proximity to their permanent location and that they choose more often to move on a permanent base to another location where they can be co-present with more reputable researchers.

ERA and stratification

ERA policy on the stratification of scientific research collaboration networks starts from the observation that current research activities are already unevenly spatially distributed in Europe, even more so than economic activity (see Frenken et al. 2007; Matthiessen et al. 2010). Figure 1 and Figure 2 show for instance that scientific publication output as

well as scientific publication output per capita is concentrated in a group of ‘core’ regions located in a Western European axis stretching south-east from London towards Rome, in Scandinavian regions and in some large city-regions located in other parts of Europe (e.g. Berlin, Budapest, Glasgow/Edinburgh, Madrid, Vienna). This spatial pattern of knowledge activities was already present before the initiation of ERA policy (Moreno et al. 2005; Crescenzi et al. 2007).

A key question of ERA policy is whether it should further support those agglomerative tendencies by strengthening collaborations network between these agglomerations or whether it should allocate funding to peripheral actors as to provide these actors with opportunities to connect to the already established core of knowledge producing actors. The trade-off is reminiscent of the more general tension between EC’s cohesion policy and research policy which both constitute significant shares of the European budget. In this respect, place-based cohesion policy provides resources to Europe’s poorest regions. A major goal of these efforts is to strengthen the scientific capabilities of these cohesion regions through various instruments focused on scientific research infrastructures, network development and knowledge transfer (Musyck and Reid 2007; Begg 2010). In doing so, cohesion policy intends to support structural conditions that facilitate participation in ERA.

However, the actual participation rates in ERA is dependent on the allocation of research funds which is determined by EC’s research policy rather than cohesion policy. As a result there have been worries that over the subsequent FPs the rationales and goals of the FPs have changed to such an extent that the cohesion objective no longer plays a role in the selection of FP projects that are being funded (Sharp 1998; Breschi and Malerba 2009). Rather ERA policy is increasingly focused on stimulating ‘*virtual centres of excellence*’ (Commission 2007, p. 15) that strive to maximize the research potential of the European territory as a whole. It follows that over the successive FPs, funding has become increasingly based on criteria of research quality (i.e. scientific excellence), socio-economic relevance (i.e. tackling societal challenges and innovation potential) and critical mass, rather than on a redistribution criterion.

Turning to the empirical evidence on allocation of funding, Sharp (1998) found that funding in FP3 and FP4 favoured core regions only in absolute terms which was expected given the sheer number of researchers in these regions. Yet, after controlling for size peripheral countries managed to acquire more funding relative to their total research capacities. This finding was in line with the redistribution objective of the FPs at that time which treated proposals that included researchers from less developed regions as more favourable. In a more recent analysis, Hoekman et al. (2013) did not find the same result for FP5 and FP6; instead, they even observed that allocation of FP funds marginally increases with prior co-publication activity. Compared to earlier FP funding this finding can be interpreted as a move towards excellence, although the observed effect of 'excellence' funding is limited as of yet.

Part of the success of policy efforts to create more cohesive collaboration structures between researchers also depends on the extent to which funding is allocated to already established performers in terms of scientific collaboration networks. A number of empirical studies show in this respect that - similar to existing scientific research collaboration structures - the number of links between organisations in FP projects tends to decay with geographical distance and language barriers (Scherngell and Barber 2009, 2011; Maggioni and Uberti 2009), although these effects become less important over the successive FPs (Scherngell and Lata 2012). Importantly concerning stratification, it seems difficult for unconnected actors to acquire a central position in the FP funding networks. Breschi and Cusmano (2004), Autant-Bernard et al. (2007) and Wanzenböck et al. (2012) analyse the social network structures among FP participants and find that the funded collaboration networks are dominated by a small '*oligarchic core*' (Breschi and Cusmano 2004, p. 748) of research actors, whose central network positions in the programme have only strengthened over the successive funding rounds. This implies that participants are much more likely to acquire FP funding when they were already participating in previous FPs (Paier and Scherngell 2011), and that peripheral participants experience difficulties to enter the FP networks.

Turning to the effect of FP funding on the geography of scientific research collaboration, Hoekman et al. (2013) found that the effect of the FPs on raising co-publication output decreases when funding is allocated to regional pairs with already established scientific collaboration networks. This suggests that the FPs are more effective in establishing ties between poorly connected regions than in further strengthening existing ties between core regions. They conclude on the basis of these findings that the effect of funding on raising co-publication output seems strongest in poorly performing regions, despite the fact that more resources flow to well performing regions.

Conclusion

Scientific research collaboration across territories is believed to be beneficial for the production and diffusion of scientific knowledge. However, long distance collaboration is still significantly hampered by the dominance of localised interactions within national and regional systems and by agglomeration dynamics that put a prime on face-to-face contact. Against this background, the efforts of the European Commission to create a European Research Area (ERA) is a significant attempt to overcome fragmentation and to increase excellence in the European scientific research system.

This chapter introduced proximity and stratification as two organizing principles that can be used to understand the geographical structure of European scientific collaboration networks. Concerning proximity we noted that despite efforts to integrate scientific research activities across borders, Europe remains a loosely connected group of national and regional science systems. With respect to stratification we concluded that there exists a tendency, even if small, towards excellence in funding, but that the effect of this policy in terms of raising cross-border scientific research collaborations remains questionable.

Given the substantial resources that have been spent on realizing ERA since its inception in 2000, it can be argued that this empirical reality is contrary to expectations. A more detailed assessment of the reasons for the observed lack of geographical effect of ERA policy seems therefore warranted. One straightforward explanation may be that despite

substantial funding, European research budgets remain a minor funding source when compared with national and regional research budgets. If this is indeed the case we may expect more from the Horizon 2020 programme that shows an increase in funding over previous programmes and stresses the significance of excellence as evidenced amongst others by the expansion of the European Research Council.

Another reason for the persistence of physical proximity in scientific research collaboration may be that the nature of the problems being studied in scientific collaborations have become increasingly complex over time, necessitating equally frequent moments of co-presence, despite advancements in ICTs and mobility. Such an increase in complexity may follow from the internal dynamic of science where researchers create new forms of ‘complementarities’ between specialised fields of knowledge and heterogeneous groups of organisations (Bonaccorsi 2008). They may also be driven by external pressures of governments and society to come up with solutions to ‘grand challenges’ (Gibbons et al. 1994; Nowotny et al. 2001). The identification of such complex thematic goals in recent ERA policy documents is illustrative of this phenomenon.

In light of our findings, it seems essential to monitor and evaluate the geographical effects of ERA policy efforts in future studies. It is encouraging that evidence based evaluation is slowly becoming an important pillar of EC’s research policy. At the same time, it should be realized that impact assessments based on bibliometric data provide only a partial window on the state and dynamics of ERA. Despite the validity of these indicators in the scientific domain, our conclusions should be interpreted with caution when extrapolating to other contexts. Yet, when treated with appropriate caution such data can provide useful comparative empirical evidence that is both compelling and politically informative.

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Figure 1: Total number of publications in 2000-2007

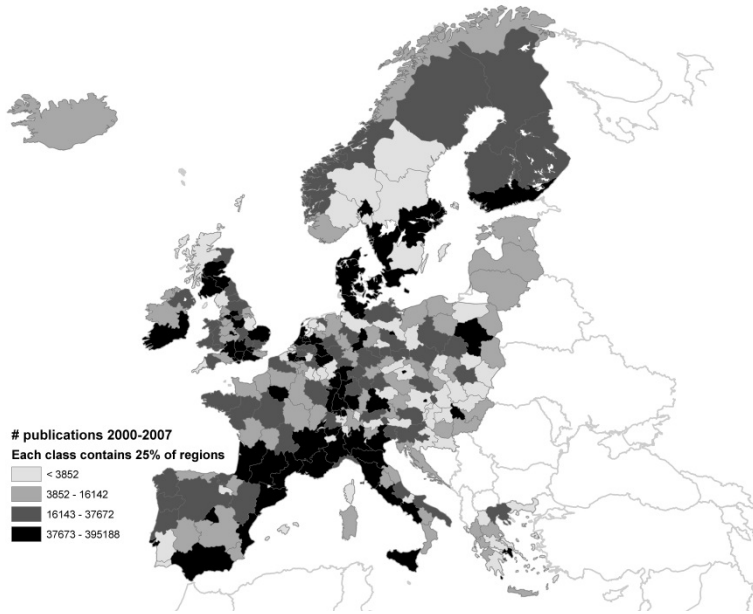


Figure 2: Total number of publications per capita in 2000-2007

