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Territorial concentration and evolution of science and technology activities in the European Union: a descriptive analysis

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Abstract

This article aims at exploring the geographical patterns of scientific and technological activities across the European regions, and comparing these patterns in order to suggest some hypotheses concerning the spatial relationship between science and technology (S&T). This paper proposes a descriptive account of basic spatial features of European Union (EU) countries for S&T activities, respectively, measured by Science Citation Index (SCI) publications and European Patent Office (EPO) patents. It addresses concentration measures at various levels (regions within EU, within countries, countries within EU) and their evolution during the period 1988–1995, in relation with geographic convergence issues for S&T. These knowledge-based activities appear as much more concentrated than economic activities, but countries' patterns are quite contrasted in terms of concentration values as well as of territorial coincidences or 'co-concentrations' between science and technology. Analysis of short-term evolution of concentration suggests an overall but slow tendency towards geographic homogenization in science, and a more chaotic picture in technology. © 1999 Elsevier Science B.V. All rights reserved.

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1. Introduction

The aim of the present paper is to provide a basic exploration of science and technology (S&T) concentration in the European Union, and its trend over the 1988–1995 period. It addresses the question of the geographic concentration both at the regional and national levels within the European Union (EU) for S&T with the background of gross domestic product (GDP) and population; the short-term evolutions of concentration; a tentative typology of country patterns based on these spatial features.

Regional localization has received a great deal of attention by geographers and urban economists. The confluence with the localization problematics in international trade theories was advocated by Krugman. In his famous conferences on 'Geography and Trade' (1991), this author starts with the question: ''what is the most striking feature of the geography of economic activity? The short answer is surely concentration,'' seen as ''a clear evidence of the pervasive influence of some kind of increasing returns '' (p. 5), and renews Marshall's ternary explanation of industry localization: skilled labor pooling,

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intermediate goods production, technological and knowledge spillovers. In this perspective, knowledge is an integral part of the scheme, and, as soon as ''the ability to receive knowledge spillovers is influenced by distance from the knowledge source, the geographic concentration should be observed'' (Audretsch and Feldman, 1996). Somewhat paradoxically, the interest for spatial mediation of *knowledge* is growing while the electronic media make the circulation of *information* less and less constrained. The problem of increasing returns in S&T and knowledge spillovers has become an important question since the early works of Jaffe (1986), at the crossroad of industrial economics, technical change studies, and new economics of science. [4]

It may, therefore, be expected that knowledge-based activities exhibit strongly concentrated patterns: first, because of mechanisms internal to science: the historical rooting of universities in metropolitan areas, with the feedback of student attraction on cities size, is reinforced by spillovers between laboratories; then because of mechanisms internal to technology, with spillovers between firms favouring agglomeration processes; and finally, because of territorial interaction between academic laboratories and knowledge-based innovative industry.

More generally, S&T are recognized to play an important role in the shaping of 'regional innovation systems' (for an overview, see Cooke, 1998). If this infra-national level is particularly suitable to observe some classes of relationships between science, technology and economic development, namely endogenous growth phenomena, it also adds to—and does not supersede—the 'national innovation system' view. The frame of national traditions and research systems (Lundvall, 1992) shapes behaviors and regulation patterns in higher education and science, but also labor relation and the financial system (Amable et al., 1997). Beyond the embedded territorial breakdowns (national, regional, etc.), other spatial structures, such as the networks of inter-metropoles linkages ('archipelago economics', Veltz, 1993) are of equal importance. When addressing concentration features for S&T, we can expect that the infra-country patterns—that are meaningful in terms of territorial interactions—may be modulated by countries specificities.

Whatever the particular wording (increasing returns, 'Matthew effect'), the positive feedbacks and related concentration processes are a Janus face, promises of excellence on one side, omens of unequal development and associated threats on the other. The evolution of distributional patterns, especially at the international level, gave rise to a vast economic literature in the economics of growth about 'convergence' of GDP or income per capita. [5] Convergence appears as an important aspect of economic growth studies, with some theoretical controversies about the convergence rates and the underlying mechanisms, e.g., the ability of liberalization to favour convergence. Introducing technology and innovation (Posner, 1961), many studies have addressed technological gaps, imitation lags, and dynamic linkages between technology and economic development; for an overview, see Pavitt and Soete (1982) and Fagerberg (1987).

In this literature, convergence essentially concerns long-term trends in per capita GDP or income distribution. Convergence processes in Europe received a particular attention in the recent years of transition towards EMU, with a series of econometric studies (e.g., Hénin and Le Pen, 1995; Neven and Gouyette, 1995) on a sample of European regions. On the time range where regional figures of S&T could be built,

[4] Several aspects of the triangle science/patents/industry in its territorial dimension have been investigated in economics, e.g., Jaffe (1989) explored the geographically mediated spillovers from university research to industrial R&D (patents); Acs et al. (1994) found a reinforced evidence of facilitation of spillovers by the geographic coincidence of universities and research labs. A study of geographic aspects of knowledge behavior (Jaffe et al., 1993) made use of bibliometric tools such as patent citations. Audretsch and Feldman (1996) studied the concentration of innovation in relation to production, especially the propensity of knowledge-based sectors to cluster geographically. Perspectives of the new economics of science are addressed by Dasgupta and David (1994).

[5] See, e.g., Baumol (1986), Abramovitz (1986), Fagerberg (1987), Barro and Sala-I-Martin (1992), Quah (1996), with many difficulties and debates, e.g., about the role of internal dynamics of countries, or the existence of convergences within limited clubs of countries, and the overall 2% convergence-rate uniformity. International comparability of income data in the long-run are addressed by, e.g., van Ark et al. (1998).

we could only try a crude characterization of short-term trends of S&T concentration. [6]

After a source and methods account (Section 2), we will address some basic features of territorial concentration of science, through Science Citation Index (SCI) publications, and technology, through European patents which were also compared to the economic activities (assessed by the GDP) in the background; several aggregation levels are considered (Section 3). Then, looking at the short-term evolution of these concentration patterns, we will try to sketch short-term convergence movements in S&T area (Section 4), coincidences of science, technology and GDP concentration patterns in EU countries (Section 5). We will then shortly discuss a few points and conclude.

2. Sources and methods

2.1. Sources and data

This empirical study is partly based on a research recently conducted by Observatoire des Sciences et des Techniques (OST), where sources and data are detailed (Barré et al., 1997). It covers the period 1988–1990/1993–1995.

Science figures are based on 'citable' publications from ISI's SCI and Computer and Mathematics Citation Index (CMCI). A basic hypothesis of 'evaluative bibliometrics,' title of a seminal work in this field (Narin, 1976), is that publication (and citation) counts are an acceptable statistical measure of science output. In some instances, restrictions appear and some biases can hardly be avoided, mainly due to the coverage of the reference database SCI in terms of fields/countries, and to field or actor-dependent publication and citation behaviors (e.g., under-estimation of 'corporate science' vs. 'academic science'). The limits of these indicators that have been studied many times (recently by Moed, 1996).

The ability of patents measures to operationalize technological activities is a far more controversial subject, raised on many occasions since the pioneering works of Schmookler (1966), which already stressed the patents as a proxy measure of invention. In a given system, patenting reveals strategic choice in a particular market context, as much as inventive potential, and the linkage patent–technology is a very complex one. The use of patents as indicators was discussed, for instance, by Pavitt (1985), Griliches (1990), OECD (1994), Grupp and Schmoch (1999). In this context, 'technology,' in the following, stands for 'EPO-patented technology'. Data come from the EPO and counts include international patents designating European countries as EURO-PCT; it can be expected that EU countries have equal access conditions to European patents. Territorial assignments are based on inventor's addresses, with fractional count.

EUROSTAT data were used for economic data (GDP for normalized regions NUTS). For publications, figures are 3-year averages, respectively, 1988–1990 and 1993–1995; for patents, 3-year averages for 1988–1990 and 1994–1996. Background GDP figures are for 1990 and 1994. In tables, dates are, respectively, noted 1989 and 1994.

2.2. Definition of the regions

The first task was to assign scientific publications and patent to NUTS regions, through a correspondence table between EU-countries postal codes and the NUTS-3 regions. National administrative breakdowns vary in underlying rationales (leaning towards iso-surface, iso-population...), and introduce various biases: it should be recalled that geographic features such as concentration or correlations are specific of a given observation level and breakdown—even though weighting by population lessens some problems. Sensitivity to the breakdown design may be particularly severe for countries with a small number of regions. Spatial auto-correlation, that partly reflects the proximity effects studied by economists, brings about further difficulties (on these points, see Hagget et al., 1977; Cliff and Ord, 1981). As Hagget et al. point it (p. 352), ''several properties of spatial data (...) make difficult their analysis using conventional statistical methods. Locational data are generally spatially autocorrelated, non-stationary, non-normal, irregularly spaced, and discontinuous... the great variety of grids upon which spatial data are measured implies that, wherever

[6] The provisional limitation to a short period 1988–1995 is due to the current availability of S&T data at the regional level.

possible, methods must be developed conditional upon the lattice used.''

In order to conduct easier international comparison of concentration levels, we have made reaggregations of NUTS-3 and NUTS-2, according to the country, to achieve a quite homogeneous breakdown into 416 regions (noted EU-415), and also an aggregated lattice into 175 regions (EU-175), only fit for large countries comparisons. The breakdown of Europe into countries is noted EU-15. [7] The intra-country figures, such as concentration, are hardly interpretable for Ireland figures (four regions in this particular breakdown at 415-level), and should be cautiously taken for Denmark and Finland (six regions).

Population plays a central role in geographic models, both as a determining and determined variable; in the following descriptions, both perspectives (a) direct and (b) per capita were used.

2.3. Measures of concentration

(a) The first perspective may be more appealing in terms of regional management, since it crudely reflects the territorial occupancy. A large scope of concentration measures is proposed in the literature: variances, coefficient of variation, Theil index, Gini index, etc. Here, we limited ourselves to the Gini index, based on the mean differences of pairs of values and directly related to the Lorenz diagram, which is generally considered having good properties (Egghe and Rousseau, 1990); originating in income distribution studies, it is often used in the study of skew distributions in economics and bibliometrics. An approach based on the coefficient of variation provides a globally similar view. The direct (not weighted) Gini is appropriate for giving a rough idea of the territorial concentration, with an obvious sensitivity to the particular breakdown that is being practiced, if only the delineation of the upper tail entities such as the Paris region.

(b) In the second perspective, we used a weighted Gini, based on the discrepancy between the cumulated variable and the cumulated normalization factor, namely the population. [8] Though not unsensitive to breakdown effects, this index is more stable than the direct one.

Concentration was first measured at the regional–national level, considering each country as a collection of regions, with two zooming levels, corresponding to 415 and 175 regions in EU; then at the regional–European level (considering Europe as a collection of 415 and 175 regions); finally, at the national–European level (considering Europe as a collection of countries, EU-15 level).

2.4. Homogenization and catch-up processes

The evolution of concentration indexes is an indirect approach to 'convergence' issues. A fairly large apparatus of measures was developed by economists, often in direct relation to theoretical schools of thought. [9] In this particular study, we limited ourselves to the evolution of concentration indexes (in loose connection to 'sigma-convergence') and alter-

[7] The breakdown into 415 regions as used here reproduces administrative NUTS lattice for a few countries, but makes aggregations necessary for others (e.g., some French 'departments' are merged). The number of regions by country is set proportional to the national population, with a very small range of variation for average regional population (which is around 900,000), without constraining infra-country variety. Luxemburg, mono-regional at these scales, is not part of the study.

[8] In geometric representation, let y be the variable (say a volume of publication) and Y its cumulated value, X the cumulated number of items (regions), with items ranked by increasing order. Y and X are expressed in proportions. $Y(X)$ defines the Lorenz curve and (direct) Gini index is twice the area between the curve and the first diagonal. In weighted Gini, x is the normalizing variable (e.g., population), X its cumulated value, and items are ranked by increasing order of y/x. Another type of weighted Gini used in economic geography studies is the 'locational Gini' in sectoral approaches (Krugman, 1991), where the normalization factor is an all-industry value. A definition of weighted Gini is found in (Rousseau, 1992). Further information on extended Gini indexes, in connection with correlation measures, is found in the works of Yitzhaki (1983).

[9] The regression between growth rate and initial level of income (Baumol, 1986) defines 'beta-convergence,' with 'conditional convergence' variants by adding variables within a neoclassical model. 'Sigma-convergence' is measured by the evolution of dispersion indexes. The basic definitions are due to Barro and Sala-I-Martin (1992). Refinements and development of controversies about the role and interpretation of beta and sigma-convergences are found in the works of Quah (1996) and Barro and Sala-I-Martin (1992).

nately on a visual representation of regions in a 'per capita value'/'changes' diagram, in rank form.

First let us consider the evolution of Gini measures, at various levels (EU-415, EU-175, EU-15): a convergence process on Gini measure, for regions within Europe, although in a less simple way than on variances, may be related to a reduction of dispersion for regions within countries, and of countries within Europe. A tentative visualization of the overall process for a given variable (publications or patents) combines the evolution of intra-country concentrations and of countries position around European average.

Secondly, an alternate view of convergence movements is proposed, using for each variable a 'per capita value'/'changes' (in ranks) plot of regions. Each region at the 415-level was given a ranking (1 to 415 for the region with the highest value) for the per capita value and the relative changes of this value over the period (ordinates). Strong regions that are still growing, in relative terms, are plotted in the North–East quadrant, while decreasing weak regions are located in the opposite South–West quadrant. Both quadrants account for increased discrepancies ('Matthew effect'). North–West (increasing weak regions) and South–East (decreasing strong regions) can, respectively, be termed 'catch-up' and 'catch-down' areas. A set of indexes outlining the evolution can be built after quadrant counts. [10] In this representation, weak regions are implicitly given the same weight as strong ones, and may be more likely to exhibit the strongest relative changes.

2.5. Territorial science–technology coincidences and country profile characterization

The separate description of S&T concentration schemes provides the basic features of the landscape. The coincidence between S&T maps is also of interest, in direct values carrying the population effect, or in a per capita rationale. Several methods were used for this exploratory study: we mainly used linear and Spearman rank correlations, general or partial, and also co-concentrations through weighted Gini indexes (e.g., Gini on patents weighted by technology; in this case, a weak value expresses a co-localization phenomenon, a strong value shows a spatial discrepancy or an uneven concentration of the two distributions).

This finally suggests a few patterns summarizing main spatial characteristics. Country profiles were established on concentration levels on the three criteria (technology, science, economic activity), and additionally territorial co-incidence between the three variables. Groupings were carried out using an average linkage hierarchical clustering on Euclidian distances.

3. Concentration of S&T activities

3.1. Background

The European center–periphery picture of economic levels of development is well-known, with mainly southern (Greece, Portugal, southern Italy and Spain) and also western (Ireland, north of Scotland) and eastern (German Eastern Länder) peripheries. This also appears in direct concentration measures that characterize the general landscape of territorial distribution (Table 2, direct Gini; country details in Table 4). When considering human resources (column population) and overall economic activity (regional GDP), high concentration patterns for regions within countries are exhibited by Mediterranean countries (Spain, Greece, Portugal), with strong centers–peripheries oppositions. France and Italy come next, the global index reflecting different territorial images, the polarity North–South in Italy and the scattering of rural areas in France. The low concentration (but high-density) patterns are found in North–Central countries (Germany, Denmark, Netherlands), and also Sweden. The proportionality of GDP and population within countries is strongly

[10] For instance, a quadrant divergence index, based on discrepancy between divergence quadrants (Matthew effect) NE and SW, and remaining convergence quadrants (catch-up or down). $I_1[-1,+1] = (([NE]+[SW])-([SE]+[NW]))/([NE]+[SE]+[SW]+[NW])$. Another interesting ratio is the proportion of catching-up regions among the weak ones: $I_2=[NW]/([NW]+[SW])$. Central zones $[Q_0]$ may be discarded on both dimensions for best reliability.

Table 1
Overlook at EU poles (science and technology together)

Volume S&T act (%)	Nb of regions	Regions	Characteristics
5% to 4%	two regions	Paris agglomeration and Greater London	capital cities of large and centralized countries
3.1% to 1.9%	six regions, ranks 3 to 8	Munich, Düsseldorf, Frankfurt, Stuttgart, Köln, Karlsruhe	large cities of Germany
1.6% to 1.0%	13 regions, ranks 9 to 21	Stockholm, Milan, Rotterdam/The Hague, Helsinki, Madrid	five largest cities of S&T middle sized EU countries
		Berlin, Ludwigshafen, Freiburg, Tubingen, Dortmund	five German cities
		Cambridge, Oxford, Essonne	three 'Campus regions' (UK, France)
1.0% to 0.7%	19 regions, ranks 22 to 40	• four German cities • Vienna, Copenhagen/Frederiksberg: capital city of smaller but S&T significant EU countries • Lyons and Grenoble; Manchester and Birmingham: next to France/UK capital cities and 'Campus regions' • three in Netherlands (Eindhoven, Amsterdam, Arnheim/Nimegue) • three in Sweden (Uppsala, Göteborg, Malmö) • one in Spain (Barcelona), Italy (Rome) and Finland(Turku/Tampere)	

Source: OST TSER report, 1998.

Table 2
Concentration (direct Gini index, 1994)

	Publications	Patents	GDP	Population
Level 415				
EU-415	0.71	0.64	0.43	0.37
EUIC-415	0.65	0.53	0.38	0.33
Level 175				
EU-175	0.57	0.63	0.39	0.34
EUIC-175	0.53	0.56	0.39	0.34
EU-15	0.54	0.64	0.53	0.50

EU-415: Europe as a collection of 416 regions.
EU-175: Europe as a collection of 175 regions.
EU-15: Europe as a collection of 14 countries.
EUIC-415: non-weighted mean of 14 countries values.
EUIC-175: non-weighted mean of 6 countries values.

respected (Pearson $r > 0.95$ excepted for Austria, Belgium, and especially Germany, as an effect of Eastern Länder).

3.2. S&T: intra-country and inter-country concentration

Geographic concentration of S&T has the strength of evidence. In the ranked list of European 'superpoles' (Table 1), 10 top regions account for about one quarter of global S&T production. On the other side, peripheral regions suffer from a quasi-absence of knowledge-based activities.

Is this massive phenomenon of S&T concentration the mere reflection of the overall economic activities distribution? How large is the gap between strongly concentrated zones and regions left aside, especially in southern Europe? Is the inequality mainly rooted in interregional disparities or international disparities? Is there a large difference between S&T patterns?

The direct concentration index (Tables 2 and 4) provides us with a first information. The comparison of rows (countries) should be handled with care for

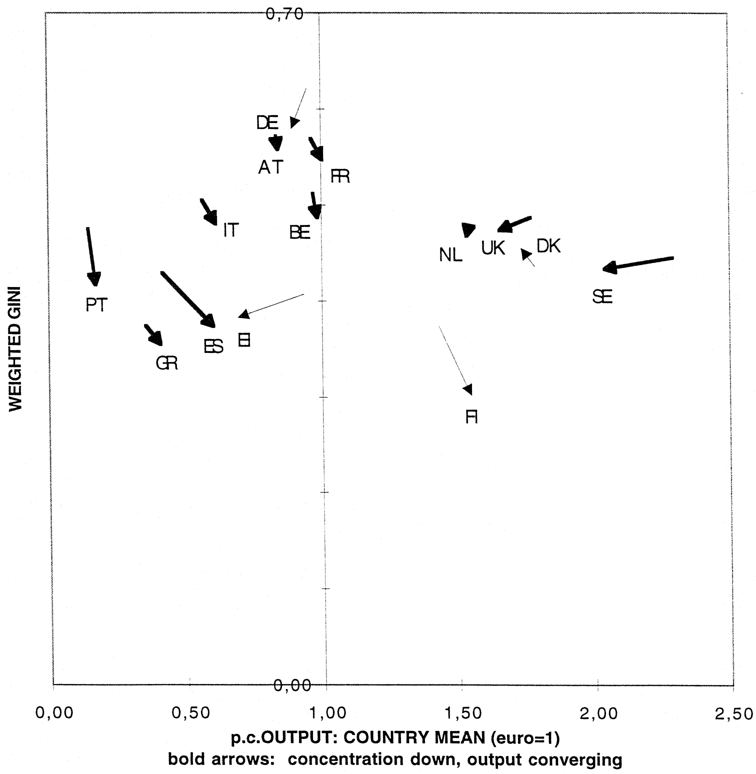

Fig. 1. Publications: intra-country concentration vs. per capita output: 5 years change.

this index is very sensitive to the breakdown. At the 175-level, only six major countries can be considered.

For individual countries, as well as for Europe seen as a collection of regions (EU-415 row), a strongly more concentrated pattern for S&T (20 or 30 points) than for GDP and population is recorded. In ascending order of concentration, we regularly find population, GDP, technology, science, with very few exceptions (in Spain and Italy, technology is more concentrated than science). Spain and France show high values for all the variables, Belgium and Netherlands mainly low values; but homogeneity is not a general rule: Germany, for instance, combines a low concentration index on population and GDP and a quite high concentration on S&T activities. Greece and Portugal are particular cases, especially for European patents: the small patent activity of Greece is concentrated in the Attic region, and the same in Lisboa/Setubal area for Portugal.

The international row (Europe as a collection of countries, EU-15) shows little difference between science, GDP and population figures, but a somewhat higher value for technology: the relative positions of S&T are reversed when shifting from intra-country to inter-country (EU-15) perspective. This supports a common sense hypothesis, that technological concentration is anchored in unequal international development while scientific concentration first reflects uneven distribution, within each country, between academic metropolitan areas and other regions. If this holds, the smoothing effect due to regional aggregation process between 415 and 175 level should affect science more than technology: as expected, at the 175-level, the scientific concentration is much lower, while international dispersion that prevails in technology remains unaffected. In the same line, individual intra-countries concentration measures are more balanced between S&T than at the 415-level.

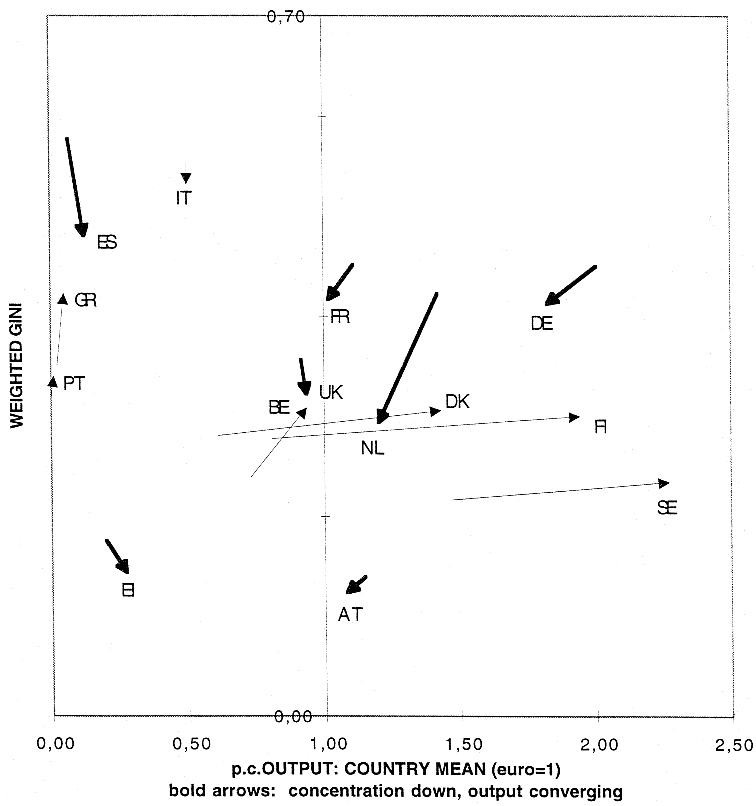

Fig. 2. E-patents: intra-country concentration vs. per capita output: 5 years change.

Now, let us turn to the per-capita rationale. The main feature of the European landscape (EU-15) is the dispersion of national S&T 'productivity'. The relative position of countries appears in the abscises of Figs. 1 and 2, respectively, for S&T, illustrating the well-known polarities: the North–South contrast, aggravated in technology; the traditional preferences towards science in UK, for instance, and towards technology in Germany.

The dispersion is expressed in the Gini indexes corrected for the population of regions (Tables 3 and 5). The international inequalities for science appear relatively low, and technology still shows a fairly uneven international distribution.

At the European–regional level (EU-415), the demographic weighting reduces the concentration figures, but the density of scientific and technological activities remain very unevenly distributed. For individual countries, the correction is mechanically lower for countries with even population distributions (Germany, Netherlands, Sweden . . .). It strongly affects Mediterranean countries with concentrated population (Greece, Spain, Portugal) that now appear in the low Gini area, with Finland. The correction has a moderate effect on France, Italy, UK, Finland. Germany, Austria and France are in top ranking in weighted concentration indexes (see also the ordinates of Fig. 1). In such cases, correlation analysis suggests a non-linear linkage between socio-demographic substrate and science distribution. Highly productive areas tend to superpose to GDP and (except in Germany) population agglomerations. In other words, science distribution gives an overexposed image of eco-demographic distribution.

Now for technology: in spite of a large difference with direct measure, Spain remains, next to Italy, the most concentrated country for per capita patenting. France comes next. Again, a non-linear effect of GDP and population is particularly clear in such cases. The cases of Greece and Portugal cannot be considered as significant. As for science, Germany, north–central and northern countries are weakly sensitive to the population weighting. Looking at the final values (see also Fig. 2), it is worth noting that the range of intercountry variation of Gini is much larger than for science. The more even distributions tend to be observed in small countries, especially Austria, Sweden, with respect to the size caveats.

As for non-weighted measures, aggregating regions are needed to observe more concentrated pattern for technology than for science: this already occurs at the 175-level, and is emphasized at the European–national level (EU-15, Europe as a collection of countries).

Table 3
Concentration (weighted Gini index)

	Publications	Difpub	Patents	Difpat
Level 415				
EU-415	0.55	−3.9	0.53	−4.5
EUIC-415	0.45	−2.6	0.33	−1.2
Level 175				
EU-175	0.41	−5.2	0.50	−4.7
EUIC-175	0.34	−3.2	0.36	−6.2
EU-15	0.23	−3.6	0.35	−2.4

EU-415: Europe as a collection of 416 regions.
EU-175: Europe as a collection of 175 regions.
EU-15: Europe as a collection of 14 countries.
EUIC-415: non-weighted mean of 14 countries values.
EUIC-175: non-weighted mean of 6 countries values.
Difpub, difpat: change over the period 1989–1994 (multiplied by 100), respectively, for publications and patents; positive for an increase of concentration.

4. Short-term convergence in S&T?

Are the gaps increasing or do we see some signs of homogenization through relative 'catch-up' or 'catch-down' in S&T? To introduce this point, it may be recalled that for the general landscape of economic activity, there is some indication that in the recent years, in the European Union, the convergence at the national level would not be confirmed at the regional level. Krugman and Venables (1990) already warned about uneven growth patterns. The prevalence of the North–South polarity, and the succession of sub-periods with different trends on the 1975–1990 period, and the slowdown of the convergence process in the 1980s is stressed by Neven and Gouyette (1995). A similar diagnosis is found in (Fagerberg and Verspagen, 1996). As far as our short-term series is interpretable for GDP, in terms of relative positions of regions, a majority of regions in the southern group (Portugal, Greece and Spain) seem to be on a catch-up trajectory. Let us now turn to S&T.

4.1. Science: moderate changes with an indication of convergence

It appears from Table 4 (annex) that intra-countries' Gini indexes are down for almost all countries. Inter-country concentration (EU-15) is also decreasing, the landscape remaining heterogeneous, however; regional–European concentration (EU-415) is logically down. Concentration at the 175-level show quite similar trends. The graphical representation introduced in Section 1 allows an easy visualization of both intra-country and inter-country levels and trends. Fig. 1 for science (Fig. 2 for technology) compares internal concentration evolutions (weighted Gini changes, from Table 5, in ordinates) vs. evolutions of country per capita values, normalized to the

Table 4
Detailed concentration by country (direct Gini index, 1994)

	Number of regions	Publications	Patents	GDP	Population
Level 415					
Austria	9	0.69	0.35	0.37	0.31
Belgium	11	0.53	0.37	0.32	0.26
Germany	92	0.64	0.46	0.27	0.17
Denmark[a]	6	0.62	0.47	0.27[c]	0.23
Spain	43	0.74	0.79	0.55	0.52
Finland[a]	6	0.53	0.53	0.39	0.36
France	66	0.78	0.67	0.50	0.41
Greece	13	0.74	0.78	0.50	0.46
Ireland[a]	4	0.54	0.28	0.25	0.17[c]
Italy	63	0.70	0.73	0.45[b]	0.41
Netherlands	17	0.56	0.44	0.26	0.21
Portugal	11	0.76	0.69	0.52	0.47
Sweden	10	0.55	0.41	0.28	0.23
UK	65	0.69	0.49	0.46	0.42
EU-415	416	0.71	0.64	0.43	0.37
EUIC-415	416	0.65	0.53	0.38	0.33
Level 175					
Germany	38	0.51	0.54	0.36	0.30
Spain	18	0.58	0.69	0.45	0.40
France	28	0.61	0.56	0.41	0.32
Italy	27	0.53	0.63	0.38	0.37
Netherlands	7	0.48	0.47	0.37	0.34
UK	27	0.50	0.46	0.38	0.33
EU-175	175	0.57	0.63	0.39	0.34
EUIC-175	(145)	0.53	0.56	0.39	0.34
EU-15		0.54	0.64	0.53	0.50

EU-415: Europe as a collection of 416 regions.
EU-175: Europe as a collection of 175 regions.
EU-15: Europe as a collection of 14 countries.
EUIC-415: non-weighted mean of 14 countries values.
EUIC-175: non-weighted mean of 6 countries values.
[a] Countries with 6 or fewer regions.
[b] Estimated data at NO S-3 level.
[c] Estimated data for a few regional units.

Table 5
Detailed concentration by countries (weighted Gini index, 1994)

	Publications	Difpub	Patents	Difpat
Level 415				
Austria	0.56	−0.9	0.12	−1.2
Belgium	0.49	−1.8	0.31	7.2
Germany	0.58	−4.2	0.41	−4.1
Denmark[a]	0.45	1.8	0.31	2.4
Spain	0.37	−5.5	0.48	−9.6
Finland[a]	0.30	−7.2	0.30	2.4
France	0.55	−2.0	0.42	−3.3
Greece	0.36	−1.8	0.42	7.1
Ireland[a]	0.38	−2.4	0.14	−3.0
Italy	0.48	−2.7	0.53	−2.4
Netherlands	0.46	−1.2	0.29	−13.0
Portugal	0.42	−5.8	0.34	2.1
Sweden	0.43	−1.1	0.23	1.7
UK	0.48	−1.1	0.32	−3.7
EU-415	0.55	−3.9	0.53	−4.5
EUIC-415	0.45	−2.6	0.33	−1.2
Level 175				
Germany	0.38	−7.7	0.38	−3.3
Spain	0.29	−4.1	0.44	−10.2
France	0.43	−3.8	0.38	−4.3
Italy	0.34	−1.7	0.50	−3.4
The Netherlands	0.29	−0.8	0.20	−12.4
UK	0.31	−1.0	0.25	−3.5
EU-175	0.41	−5.2	0.50	−4.7
EUIC-175	0.34	−3.2	0.36	−6.2
EU-15	0.23	−3.6	0.35	−2.4

EU-415: Europe as a collection of 416 regions.
EU-175: Europe as a collection of 175 regions.
EU-15: Europe as a collection of 14 countries.
EUIC-415: non-weighted mean of 14 countries values.
EUIC-175: non-weighted mean of 6 countries values.
Difpub, difpat: change over the period 1989–1994 (multiplied by 100), respectively, for publications and patents; positive for an increase of concentration.
[a]Countries with six or fewer regions.

average European value at the date. [11] This is one of the many possible representations (among them variance components, coefficient of variation, etc.) combining internal and external trends. The arrow figures the short-term trajectory, combining the signs of change towards interregional evenness and international evenness.

The general shape of the cloud shows a maximum of internal concentration reached by medium-density countries. However, the context is too different to see this empirical configuration as a remote transposition of the dynamic scheme of Williamson (1965). As almost all countries show a decrease of their internal Gini index, with moderate changes (the most noticeable for Germany, Spain, Finland, Portugal), and a majority get their average densities values closer to the European mean, the clearer evidence on this short-term period is that of a general and slow movement of convergence, both through intra-country and inter-country homogenization. [12]

The alternate visualization, using the 'values'/'changes' diagram described above, provides a quite similar landscape within a 'regional–European' perspective. In this particular representation, all regions are implicitly given the same weight. In Fig. 3, one can find the proportion of quadrants for each country. For science, the proportion of growing regions among weak ones is particularly high in Mediterranean countries (Spain, Portugal, Italy) and also Germany and the UK. A quite high proportion of Swedish, Dutch, British and German regions are located in the 'catching-down' quadrant. This again illustrates the general trend towards European convergence. A typical example of a catching-up country (Spain) is shown in Fig. 4, with a dominant inverse relationship between relative dynamism and initial level. On a general European configuration using average ranks of regions for countries positions (not shown), the down-divergence quadrant is empty and only Finland is on the border of up-divergence.

4.2. Technology: a more chaotic evolution

At the regional–European level, concentrations EU-415 and EU-175 are clearly down. Inter-country Gini (EU-15) is slightly down. But the evolution of intra-country concentration is less marked than it was for science (see individual country values and row EUIC-15), and several countries show increases in concentration. As a result, the visualization of

[11] Average country values, and not unweighted average of the country's regions.

[12] The slight deviation of Germany on this particular point is likely to be due to the aftermath of reunification.

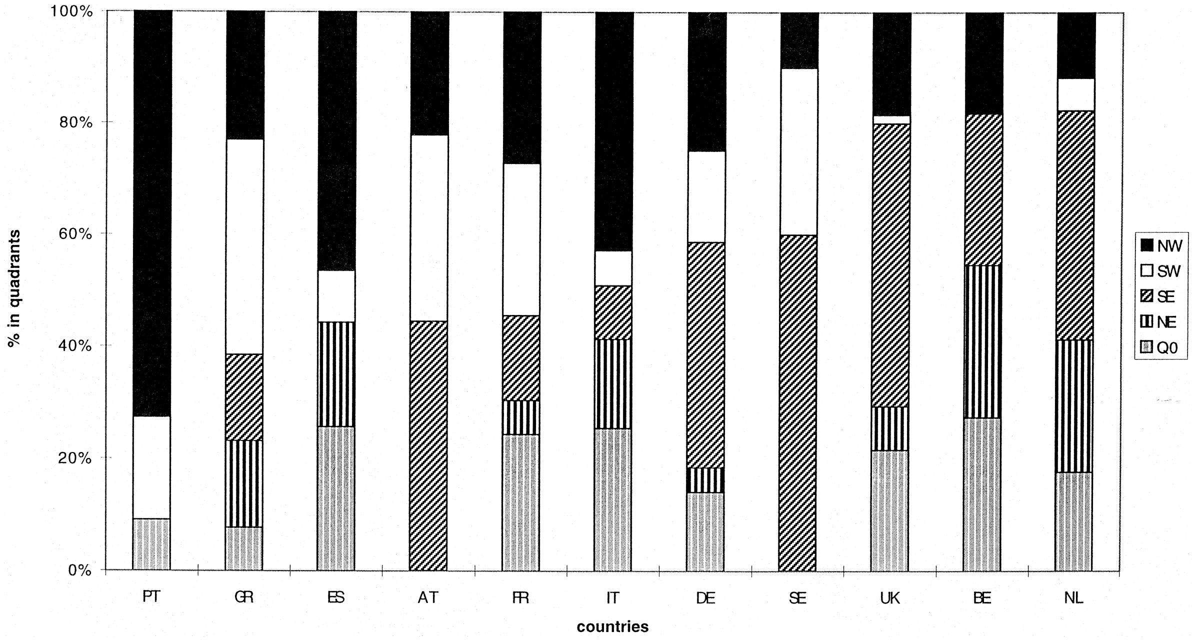

Fig. 3. Publications: countries' profiles (ranked by percentage of weak regions). Percentage of regions in NE: up-divergence, SE: 'catch-down,' SW: down-divergence, NW: catch-up, QO: excluded.

intra-national changes (country Gini) vs. international changes (countries per capita values) in Fig. 2 reveals a more chaotic picture for technology than for science. Individual changes may be important: Nordic countries strongly improve their average national position (abscissas). There is some connection between the size of countries and the amplitude of movements: the trajectories of major countries (Germany, France, UK, Italy) are short and globally converging on Fig. 2, in contrast with spectacular changes recorded for a few smaller countries. Amplitudes in intra-country concentrations (ordinates) are large for Spain and the Netherlands. Some Southern countries do not appear to be on a catch-up trajectory (Greece and Portugal).

The 'values'/'changes' view confirms these general trends (Fig. 5). This representation is more sensitive to the progress of small regions. Spain appears clearly on a catch-up process, in contrast again with Greece and Portugal, starting from very low levels: for these particular countries, a similar concern about technology in relation with economic development is found in (Deniozos, 1997).

The overall result supports the common idea of a higher variability of technology production, especially for small countries. Many factors can interplay in such variations in patent series, tightly connected in some cases to a few dominant actors' activity: random fluctuations in the short run, echoes of economic climate, transition phenomena (evolution of propensities to patent, inflection of strategies towards patenting into european system), and real change of innovative capabilities and technological market conquest. As mentioned above, interpretation must be careful and longer series are obviously needed.

5. S&T territorial connections and country profiles

It can be noticed (see Tables 1 and 2; Fig. 6) that intra-country Gini indexes for science vs. technology are weakly correlated over the European countries; their comparison allows us to group countries in contrasting families showing similar level of concentrations (see below) for the various activities. How-

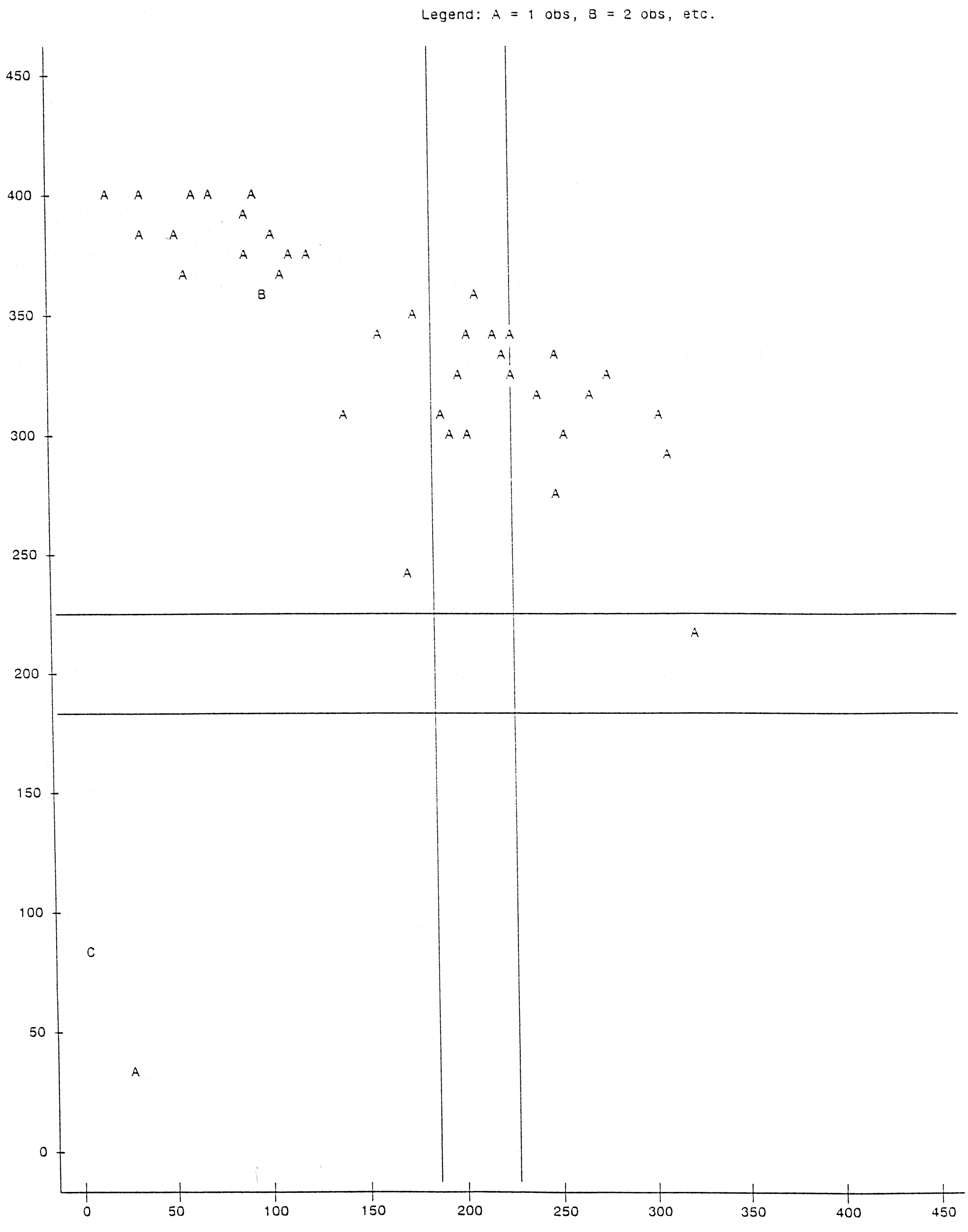

Fig. 4. Publications: relative change vs. initial per capita values: ex. European ranking of Spanish regions (1 = lowest value). Abscissas: relative change, ordinates: p.c. publications, 'quadrant' NE: up divergence, SE: 'catch-down', SW: down-divergence, NW: catch-up, QO: unas.

ever, a given concentration level for science, for technology, for economic activities, have very different interpretations depending on the similarity of underlying maps: if, for instance, the maps for S & T coincide, this reveals a situation of co-concentration, possibly favourable to science–technology ex-

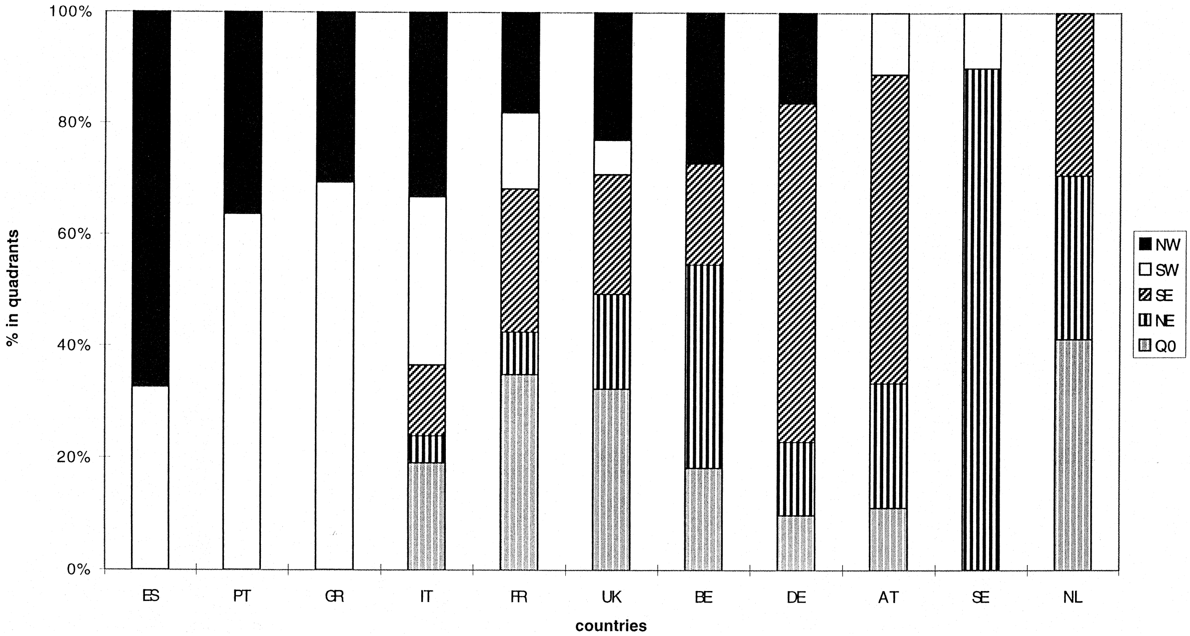

Fig. 5. E-patents: countries' profiles (ranked by percentage of weak regions). Percentage of regions in NE: up-divergence, SE: 'catch-down,' SW: down-divergence, NW: catch-up, QO: excluded.

changes in wealthy areas, but particularly threatening for regions deprived of both components of the 'knowledge society'.

In this section, we only report some exploratory work that can suggest further hypotheses, and propose a tentative grouping of countries, mainly based on the proximities of their concentration figures for the three per-capita variables publications/patents/GDP. A further qualification using the territorial linkages between these variables was tried.

The territorial linkages are mainly studied by correlations and partial correlations analyses (Pearson and Spearman ranks). They express various kinds of co-localization and related superposability of maps. It must be recalled that no specification of industrial production within GDP was practiced at this exploratory stage. Science–technology productivity co-localization is noted $S*T$, GDP-science $G*S$, GDP-technology $G*T$. The $G*T$ coincidence is the prevalent one for Europe as a collection of regions, whatever the aggregation level (EU-415, EU-175). At the European scale, 415-level, the correlations are moderate or low (e.g., per capita values, 1994, direct Spearman $G*T=0.66$, $S*T=0.44$, $G*S=0.39$, all very significant), but specific linkage patterns appear very clearly at individual countries scale.

The country profiles it suggests to delineate a few families with contrasting spatial features (Table 4B).

· Germany and France share a concentrated pattern in a per capita perspective, and also similar profiles of co-concentration, with $G*T$ as the major linkage and $G*S$ as the next one. However, this kinship in overall figures covers contrasted situations. In Germany, a large part of the variety comes from the Eastern Länder, and this effect is likely to be relativized in the long run. In France, low productivity territories are more scattered. Another striking difference: in the upper tail, Germany exhibits a plurimodal structure while the Paris area captures a large fraction of French activity. The two countries also differ in the role of the demographic infrastructure and the gross distributions (direct Gini).

· The Mediterranean group (Spain, Italy) is strikingly more concentrated on technology than on science, with a strong co-localization of economic and technological activities ($G*T$ linkage). This conveys an image of the patent production as the 'excel-

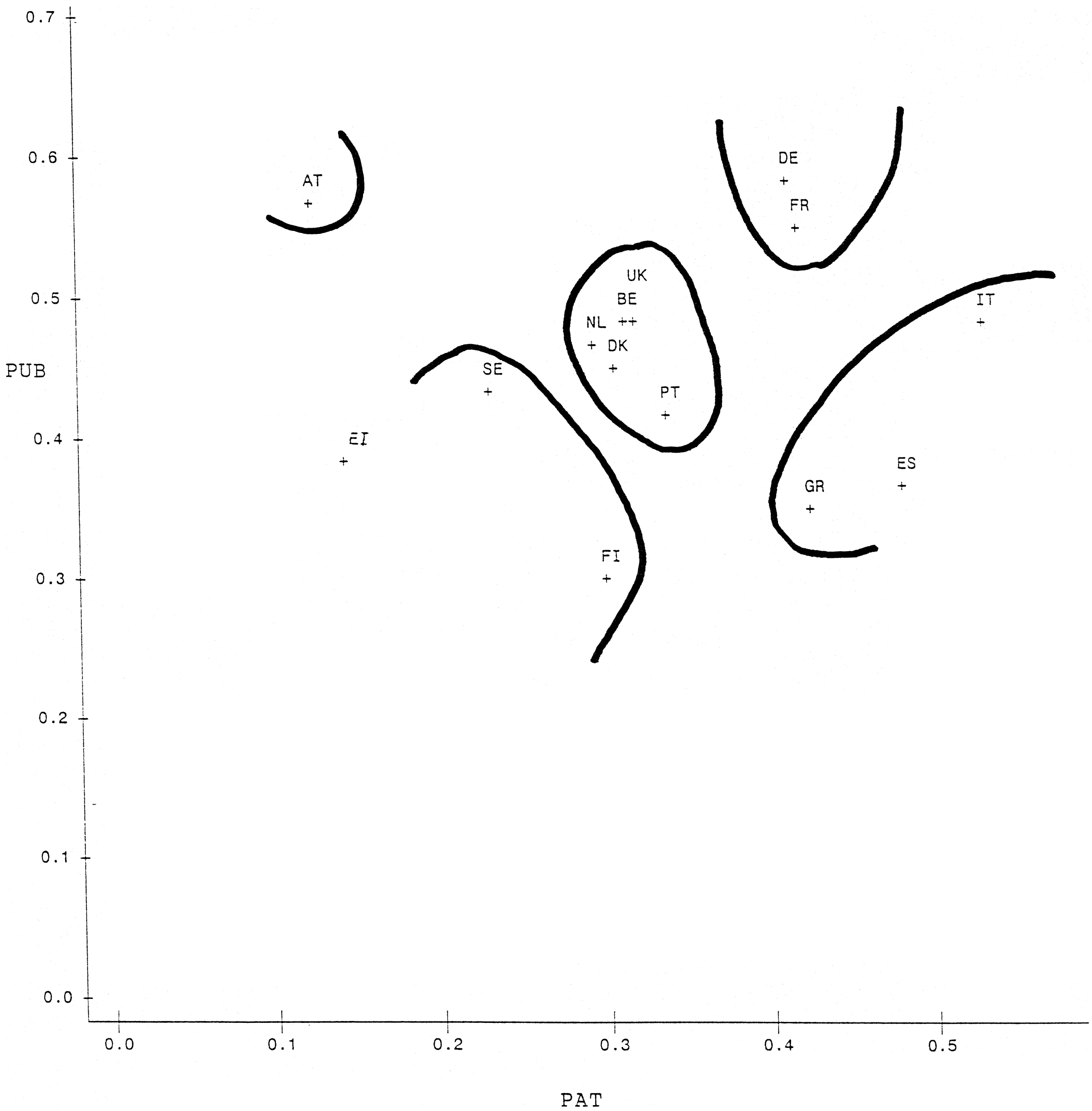

Fig. 6. Concentrations of publications vs. E-patents (415-level, 1994, weighted Gini) and grouping of countries.

lence' stratum of the uneven GDP distribution, with enhanced concentration. The North–South polarization of wealth in Italy and Spain is not reproduced at this extent by the academic map. In Greece and Portugal, the only interpretable connection, $G * S$, is low.

· North-European countries (Belgium, Denmark, the Netherlands, the UK) have moderate concentration levels, within various correlation patterns ($S*T$ dominant in Belgium, $G*T$ in Denmark, $G*S$ in the Netherlands). The correlation pattern of the UK is very much economy-driven, like that of Germany or France ($G*T$ then $G*S$).

· Austria offers a singular pattern, with more concentration in science (in three productivity centers: Innsbrück, Graz, Wien) than in technology, and dominant $G*T$ and $G*S$ linkages.

· Finland and Sweden have remarkably low concentration levels (with the usual warnings about the country sizes). Within this rather even distribution, the very strong $S*T$ territorial correlation recorded for both countries suggests a model favourable for spillovers, but not at the expense of regional balances, since no co-concentration with domestic product is recorded.

Fig. 6 shows the groupings on the plane of S&T concentrations, which is the more discriminant.

These points can be further investigated by an alternate descriptive view, where regions are directly classified into types after their production and productivity balance (S, T, G), the countries' profiles being set in terms of proportion of different region types. A first typology was proposed in (Barré et al., 1997) on a different regional breakdown. It brings a complementary view to the intra-country relationships studied here. Type and 'catch-up' trajectories of the regions may then be compared.

6. Discussion and conclusion

The objective of this study was to provide a first characterization of geographic patterns of SCI publications and EPO patents in Europe, used as proxies for scientific and technological activities. Within this limited scope, we obtained three types of results.

First, the geographic distribution of S&T activities, as expected, appears much more concentrated than population and economic activity in general. S&T concentrations, of similar values when looking at the 'Europe of 415 regions,' rely on different logics: for science, the major source of inequality is regional, with the history-rooted contrast between strong academic areas and others, whatever the country. Technology also shows a concentrated pattern, more anchored in across-countries disparities, and also in regional gaps within Italy and Spain. The spatial distribution of S&T draws some kind of exaggerated picture of economic development and population concentrations, and the fractures between center and peripheries are amplified.

Secondly, a crude characterization in terms of changes was proposed: within the limits of the short period considered, only simple descriptive indexes were used. It appears that both intra and inter-country concentration are decreasing as far as scientific activities are concerned, without clear indication of a plurimodal attraction. For technology, within a general landscape of slightly declining international concentration, especially for large countries, the evolution is somewhat contrasted, and interpretations must remain particularly prudent. On this point especially, an extension of the time window is necessary.

It can be argued that such a short time span is less jeopardizing for science data than for patent series, the latter being more sensitive to fluctuations and lags in national cycles. In this respect, science output measured in publication database is characterized by two factors: first, short fluctuations (month/year) are uninterpretable for technical reasons: periodicity of journals, variance of publication delays, of databases loading delays, variation of coverages of the database. [13] But in return, movements of science, within the context of the relative inertia of academic structures, are less likely to be cyclic on a few years interval than other series—so that trends are generally fairly reliable. These trends are linked to various mechanisms: improvement or deterioration of research systems, transitional phenomena of publishing strategy. [14] However, they cannot be insensitive to structural shocks such as, on the period studied, the German reunification or the changes in Russia. Another fact we should be aware of is the existence of artefact trends in database for countries coverage (a recent example, however non-European, is provided by Basu, 1998). In the short span of time studied here, taking into account the more direct linkage of

[13] The input measure on 'constant journal set' instead of 'variable journal set' solves this problem but at the expense of a loss in long-term relevance.

[14] An example of transitional phenomena is the apparently irreversible conversion to the international system of science (international language, internationally visible journals) through researchers' publishing strategies (Zitt et al., 1998).

patents to economic changes addressed by many authors since Schmookler's work, and their dependence over individual dominant actors' policy in some statistical units, variations on patents should be considered with more precaution than on academic output.

Thirdly, we sketched the spatial coincidence of activities, using a variety of approaches. To summarize, a preferential $S*T$ co-localization was observed in small countries, and $G*T$ in large countries. A tentative grouping of countries, based on similarities in concentration over the three variables, and hardly modified when adding the pattern of coincidences, enlightens some specificities that should be accounted for in further modelling of S&T linkages.

Much additional work is needed: refining the country-dependent territorial connection of S&T to population and GDP structure, adding variables (such as industrial output), and looking at lagged relationships within an enlarged time window; introducing sectoralization, with the issue of the correspondence of science–technology nomenclatures when some detail is needed; introducing the network dimension: the territorial distributions, even with embedded views at several levels, only give one point of view on spatial phenomena. The direct observation of relationships (co-authorship, with more precautions co-patenting, citation linkages) opens a wider perspective, and also allows, within S&T agglomerations, the micro-analysis of spill-overs.

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