Chapter 18

INTERNATIONALISATION IN SCIENCE IN THE PRISM OF BIBLIOMETRIC INDICATORS

Journals, Collaboration, and Geographic Distribution

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Abstract: Powerful engines tend to support internationalisation: self-organisation of scientific communities regardless of national borders; international and supra-national top down programmes; side effects of economic globalisation; all these trends being boosted latterly by the ICT/Internet revolution. However, internationalisation meets several obstacles: resistance of the national structure in most aspects of innovation systems; proximity effects anchored in infra-structural factors; inertia of personal and institutional networks. Internationalisation of competition and cooperation does not necessarily imply fewer discrepancies in national performances. Bibliometric studies of scientific journals profiles, collaborative and other scientific networks, spatial distribution of scientific activity, tend to validate a real but slow process of the fading of borders. In the last decade advances appear more in globalisation of scientific communication and increase of aggregate collaboration figures than in the geographic distribution of knowledge sources, the reshaping of co-operation networks and the modification of interdisciplinary balances in connection with new growth regimes of science.

1. INTRODUCTION

Internationalisation in science is often taken for granted. Powerful engines tend to support internationalisation: self-organisation of scientific communities regardless of national borders, international and supra-national top down programmes, side effects of economic globalisation, all these trends being boosted latterly by Information and Communication Technology (ICT) progress and Internet revolution. However, internationalisation meets several obstacles: resistance of the national factor

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in most aspects of innovation systems, proximity effects anchored in infrastructural factors, inertia of personal and institutional networks. This context is recalled in section 2. Results of these antagonistic mechanisms can be empirically studied. As far as outputs of scientific activities are concerned, bibliometric measures help to assess the degree of achievement of various forms of internationalisation, not necessarily convergent: reduction of barriers to competition; international co-operation and coordination; reduction of inequalities in scientific output. Section 3, devoted to the internationalisation of media, especially the scientific journals, exemplifies the first form. Section 4 addresses the internationalisation of interdependence networks, with a focus on international collaboration. Section 5 addresses the process of homogenisation and convergence of scientific production. The final section is devoted to discussion and conclusions.

2. BACKGROUND

A Republic of Science unconstrained by political borders has been a dream of many scientists and various steps of progress toward a self-organisation of communities beyond national and cultural differences have been celebrated by observers of research as a social object, among many others Merton (1973) and Price (1963).

2.1 Engines of Internationalisation

History of science teaches that scientists consider it natural and profitable to freely communicate and collaborate, and professionalisation of science in the XIXth and XXth centuries has fostered this trend (DeBeaver and Rosen, 1978). This self-organisation is the first engine of science internationalisation. The creation of the Nobel Prize in 1901 was a symbol of internationalism in the Republic of Science (Crawford, 1992). The history of physics in the early 20th century, for example, is tightly linked to the development of international meetings and exchanges, despite nationalist pressures' interference. Border–free competition and co-operation are at the heart of the self-organisation of science.

The second engine of internationalisation lies in the top down processes, which gained full power after WWII. Multinational programmes associate clubs of countries with reasonably converging political objectives, either on an occasional or permanent basis. Top down processes and self-organisation interact in many ways in large scale programs: cost sharing of large facilities[1] (physics/ astrophysics), co-ordination of large programs (the genome). Supra-national entities, first of all the EU, became an important source of coordination and funding of programs aiming at convergence and integration of member countries, with a heavy Science–Technology–Innovation folder. Framework programmes, incentives to networking and mobility, efforts to harmonise higher education systems, and currently the European Research Area initiative are expected to enhance the cohesion and competitiveness of Europe.

A third engine has gained force in the last decades, namely the general movement of financial and economic globalisation. It has been celebrated as a strong mechanism of diffusion of knowledge, in particular through multinational firms. R&D services' implementation and their articulation with local research are often viewed as an important internationalisation engine. Academic research is enrolled through tighter linkages with technology and markets. An echo of the increasing pressures on Mertonian model is found in the 'new economics of science' (Dasgupta and David, 1994, David and Foray, 1995, Stephan, 1996; for a contrasting view see Callon, 1994).

Bringing drastic cuts in communication costs, the new Information and Communication Technology (ICT) and Internet revolution has boosted non-physical exchanges and especially scientific work. The prototype at the European Organisation for Nuclear Research (CERN) which turned into the world web was already aimed at communication between scientists. More generally, the ICT revolution and the explosion of electronic networks have been acclaimed as abolishing distances and announcing 'the death of geography'.

2.2 Adverse Mechanisms

Actors are connected by proximity networks in various dimensions: geographical and geopolitical, cultural and linguistic, institutional, thematic. Although these networks stretch across borders, the nation is the locus where several types of proximity tend to be high simultaneously.

The first example is the strength of cultural and institutional linkages within nations. The nationalist resistance to globalisation of scientific communities, which peaked in the periods of world wars and also of cold war, is out of fashion, although the enrolment of science in strategic technology, not only military, is stronger than ever in this early XXIst

[1] On the scientific infra-structure see Irvine et al.(1997)

century. The national level has nevertheless been the main level of decision in the past and there are some clues that the inertia rooted in cultural traditions (a strong instance of proximity), specific mechanisms and political institutions make the 'National systems of innovation' (NSI, Lundvall, 1992, Nelson, 1993) more resistant than expected to the new momentum[2]. Even for the non-physical flows of knowledge, scientific communication, national borders still exist in many respects. The national level remains a major level of governance and funding; the institutional framework is still mainly national; the cultural and linguistic habits are also largely based on national specificity; multinational firms, as Pavitt and Patel have shown in several works (especially 1991), bring fewer internationalisation than expected: know-how is the less internationalised aspect of firms and most Multi-National Enterprises research remains firmly anchored in their home base — with perhaps signs of change in the recent period. National structures of Industrial Property Rights are also a resistant core (Foray, 1995). Internationalisation of systems of innovation has been discussed, for example, by Nosi and Bellon (1994), Carlsson (e.g. 1997, 2003), Archibugi et al. (1999). A grouping into families of NSI rooted in political and institutional heritage is found in Amable et al. (1997).

A second instance of a proximity based mechanism is the concentration and agglomeration processes at short distance. Complex short range relations between science, technology, industry, manpower and services, nourish spillovers and sustain local clusters, a new version of Marshallian districts (Beccatini, 1990) adapted to a knowledge based society, widely discussed in the economic literature. Particularly, the localised externalities from academic research have received much attention from scholars in the last decade (Jaffe, 1989; Audretsch and Feldman, 1996; Anselin et al., 1997). Proximity–sensitive exchanges of tacit knowledge are given a key role in these processes. Though based on codified publication, scientific communication does not escape the process, since science in action also requires exchanges of tacit knowledge exchange and fruitful face-to-face interactions (DeBeaver, op.cit.; Storper and Venables, 2004). At a wider scale, large regions have reinforced their co-ordination potential and funding capabilities. This may result in a changing prospect of world competition, where the 'regional system of innovation' (Cooke, 1998; Storper, 1997) as well as NSI compete in the knowledge–based markets.

Though particularly dense within a nation, cultural and linguistic proximity, as well as self-maintaining networks of sociability, shape preferential channels of communication at the international level.

[2] As discussed in NSI literature, these systems may not strictly coincide with national borders.

Knowledge does not travel as fast as information. Whilst some scholars anticipate a drastic reduction of ICT costs — including those of tacit knowledge exchanges — able to reduce the role of proximity (Foray and Mairesse, 2002), others (Morgan, 2001) strongly react at the thesis of the 'death of geography'. The ability of ICT of getting rid of proximity effects and/or strong inertia of socio-political structures should not be overstated. Reshaping of communication networks will probably be slower than expected. A new impulse, somewhat paradoxically, may come from the regional systems of innovation, and especially from attractive high-tech districts which initially stemmed from short-range mechanisms, can reveal attractive for foreign actors and rich in long-range interactions. In the long term competition and cooperation amongst districts will perhaps erode the national borders and eventually turn into an internationalisation engine.

2.3 Some Internationalisation Measures Amenable to Bibliometrics

Internationalisation and internationalism in science take a variety of forms (Crawford et al., 1992; Elzinga and Landstrom, 1996). They encompass all dimensions of research systems: economic resources (programmes and funding systems; shared infrastructures, bilateral and multilateral agreements); human resources (teaching system and labour market of skilled manpower: PhD, postdoc, scientists; migrations, diasporas and networks, brain drain and brain gain); rules and norms of the community; general policy and governance levels.

In each area various modalities of internationalisation can be observed. One concerns the reduction of particular market imperfections owing to the national factors. Examples are progresses in international skilled labour mobility and reduction of nationally oriented publishing behaviour. Another axis concerns coordination and cooperation mechanisms, with sometimes a focus on reduction of international unevenness (EU structural funds and framework programs). Whether the reduction of barriers to competition and collaboration leads to a more equal distribution of final outcomes — the convergence question — is a crucial issue of globalisation studies. The question arises in a critical manner for the brain–drain, where internationalisation of skilled labour market has resulted so far in a strongly asymmetrical flow between the US and the rest of the world, with high benefits for the centre (Stephan and Levin, 1999). More generally, bibliometric distribution studies provided overwhelming evidence that scientific competition does produce skew distributions. Internationalisation is far from being a consistent process where removing barriers would necessarily mean a reduction of discrepancies.

In the following we will address three forms of internationalisation involving publications, and thus amenable to bibliometric measures at the macro-scale:

a) Internationalisation as a reduction of national barriers to competition: is scientific communication internationalised? We will focus on the core of 'certified' communication, scientific journals, which are a central locus of communication and competition among scientists.
b) Internationalisation as a reduction of national barriers to cooperation: it is generally admitted that the fabric of scientific interdependence networks, at the international level, is ever tighter. Does it mean a more open space? Here we will have a look at co-publication networks.
c) Internationalisation as a reduction of the national factor in final outcome distribution: are empirical convergence phenomena observed for the output of all (or groups of) countries? Convergent evolution and catch up processes are expected from targeted policies within supra-national economic communities (EU). We will report a few partial observations on this phenomenon.

3. IS SCIENTIFIC COMMUNICATION INTERNATIONALISED? THE CASE OF SCIENTIFIC JOURNALS

A basic fact about science is 'publish or perish'. Sociologists of science have devoted much effort to studying the role of publication in central aspects of self-organisation of the scientific community: circulation and archiving of information, priority issues, evaluation, etc. As a result the main media of communication, the scientific journal, has attracted many works, especially the impact factor issue (recent review by Glänzel and Moed, 2002). Rigidity and national enclosure in the main media of communication would mean a serious obstacle to internationalisation of science.

3.1 Marginal, Eroding but Still Alive: the National Model of Communication

The ideal type of 'nationally centred' model of science can be defined by the exclusive relation of domestic authored publication with domestic publishers and domestic language, symbolised by the prevalence of the 'nationally oriented' journals. Hence strong barriers to communication, competition and cooperation on three areas: among scientists; among publishers; among languages. The 'international' or 'trans-national model' assumes the disconnection between the three aspects (Zitt et al., 1998b): scientists compete for access to most visible media; publishers, either scientific societies or commercial publishers, try to push their influence by attracting visible authors; even languages compete for the largest international audience.

The long-term evolution since WWII of scientific communication in various disciplines can be seen as the transition from the first model to the second one. This national model has long lasted in countries such as the USSR, but also to a certain extent in certain disciplines of 'second–best' countries with strong editorial traditions, as the influential Garfield's diagnosis (1976) of the French situation demonstrated in the mid seventies. This transition process is largely advanced at the turn of the XIXth century, but the question can be extended to large emerging countries such as China. The competition game then redistributes roles and positions, not necessarily in the form of a more even distribution. For example, competition between languages has resulted in the quasi-monopoly of English as the *lingua franca* of primary communication, other languages being mostly confined to transfer purposes in particular geographical areas. The publishers' market is concentrated within operators, commercial publishers and/or societies, in a few countries (first of all the UK, the US, the Netherlands). Most publishers promote international journals, sometimes by merge between complementary national media, for example to form 'European journals'. Researchers tend to select a journal for their publications in terms of international visibility and citation rewards rather than national audience, as far as primary communication is concerned (transfer literature is another question, see also Chapter 20 by Lewison in this Handbook).

3.2 National Orientation of Journals: Static Measures

The international model predicts that journals, as spaces of competition for the authors, and themselves in competition, should increasingly welcome authors from various origins, and finally reflect the international profile of their scientific speciality in the world rather than their mother country's production. This deviation to the international profile of the discipline/speciality, used as the reference, operationalises 'relative internationalisation measures' of individual journals (Zitt and Bassecoulard, 1998a)[3]. A journal will be termed 'international' (static definition) if it reflects the national balance of the reference set at a given time. Many variants of internationalisation indices can be proposed: for example, by using a regional (geopolitical zones) breakdown instead of a national breakdown[4], by introducing a stratification by impact levels, by picking different statistical indices, relative or absolute[5]. Correlation of internationalisation indices with the journal impact is quite moderate (Bassecoulard and Zitt, 2004)[6]. These families of indicators can be extended to the study of the national profile of authors citing the journal, of authors cited by the journal, of editorial committees (studied for example by Braun and Bujdoso, 1983, see also Chapter 4 by Braun in this Handbook). Other measures, bibliometrics–based or not, include the scope of subscribers or readers (Wormell, 1998, Rey-Rocha and Martin-Sempere, 2004).

The distribution of relative internationalisation indices distribution for journals belonging to the *Science Citation Index* (SCI) or SCI–Expanded (Figure 18.1) suggests a mix of two populations, a majority class of international journals, and a small minority class of nationally oriented journals. The coexistence of two populations has some consequences in bibliometric comparative studies, briefly recalled below.

Longitudinal series of relative measures of national orientation based on deviations from an average world value are directly interpretable in terms of 'internationalisation' in a dynamic sense, i.e. a convergence process at the world level between journals authoring profiles. A clear upwards trend of internationalisation measures is observed in all disciplines of SCI (Zitt and

[3] Relative measurements are sensitive to artefacts in the delimitation of the reference, especially: the definition of the perimeter of specialities or disciplines; the coverage of the database. For example, strong biases in the coverage of SSCI and A&HCI in some disciplines prevent relative measurements, for lack of sound reference in these disciplines.

[4] For example, many European journals result from the merging of national journals from two or more countries (e.g. Astronomy and Astrophysics, European Physical Journal). Undoubtedly these were 'international journals' at the time they were created. Today, depending on the way the EU is considered (a mere club of countries or a real entity), a journal should probably be 'triadic' or multi-continental to be considered as truly international.

[5] Examples of the latter: number of distinct countries (of institutions) publishing in the journal; share of the country ranked number one -- or quantile-based share; concentration indices of authoring countries in the journal (for a review of the use of concentration indices in a bibliometric context see Egghe and Rousseau, 1990). The absence of a term of comparison in such indices can lead to undesirable results for journal assessment.

[6] Although there is a large overlap between top (respectively bottom) classes of impact and internationalisation. Moreover, the correlation between the level of internationalisation and the level of co-authorship (rate of co-authorship in the journal) is lower than +0.5 in most disciplines.

Bassecoulard, 1999a; Bassecoulard and Zitt, op.cit.), a trend not only owed to the erosion of the nationally oriented class which decreases but does not disappear.

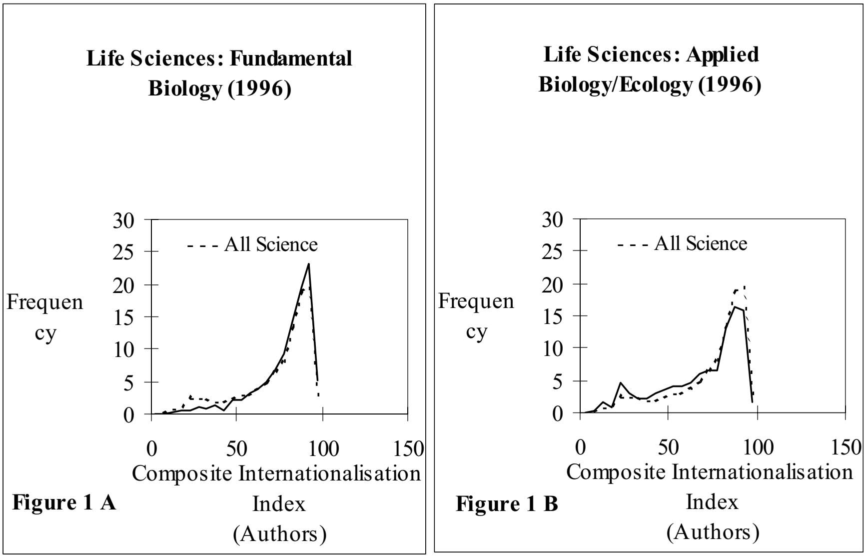


Figure 18.1. Distribution of journals by level of internationalisation (two disciplines).

The distribution shows a long tail or bi-modal shape, suggesting a mix of two populations, nationally oriented journals (minority) and a core of international journals. This finding is robust for a large variety of indices. Source: Z&B, ISI data (SCI), processing OST and INRA, first published in Scientometrics, 1999

An example of evolution is given Figure 18.2, for fundamental biology and applied biology. ISI keeps the perimeters of SCI or SCI–Expanded beyond the borderline of international journals. The survival of the nationally oriented category can be attributed to several factors: resistance of the ‘national model’ especially in (non English speaking) ‘second best’ countries with national editorial traditions; ISI policy towards emerging countries’ promising journals while they still show little internationalisation; marginal generosity of ISI towards secondary communication. The figures of average deviations (variance as well as maximum deviation measures) confirm a steady trend towards internationalisation (*ibid.*).

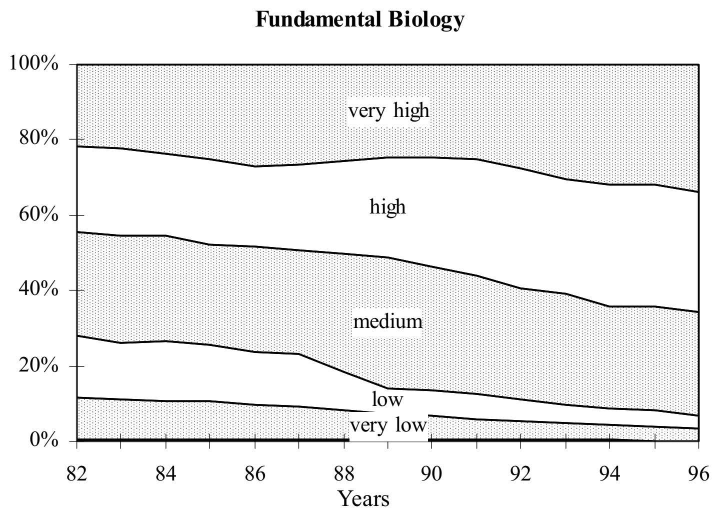


Figure 18.2a. Distribution of publications amongst journals by level of journal internationalisation: Fundamental Biology

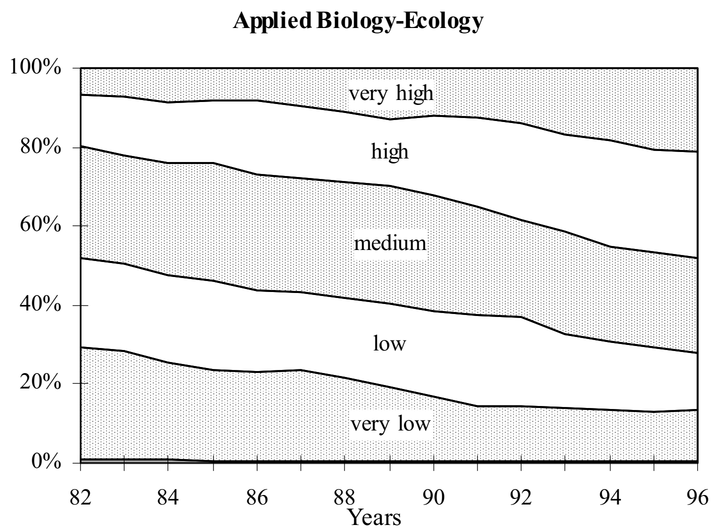


Figure 18.2b. Distribution of publications amongst journals by level of journal internationalisation: Applied Biology – Ecology. These figures illustrate the trend towards internationalisation, with strikingly contrasted profiles and top-classes gaining importance. Source: *ibid.*

3.3 Consequences for Interpretation of Bibliometric Indicators, Static and Dynamic: the Rent of Transition

Indicators are based on databases, and each database has its own statistical characteristics. It is generally considered that SCI (or now the '*Web of Science*') gives a good image of international science, based on a careful selection of journals, but is not bias–free. The interpretation of national bibliometric indicators, amongst other problems, should care for two related issues.

The first issue holds that the mix of two journal populations, with, for national oriented journals population, an uneven distribution among countries, has heavy consequences in the international benchmarking of outputs, including in static assessment. There is a serious risk of the overestimation of publication share and the underestimation of impact for the couples country–discipline, still marked by a national model reflected in SCI tail (Zitt et al., 2003). A similar effect for the presence of journals not using the English language was analysed in Van Leeuwen et al. (2001).

Discarding the national oriented class and the source of noise, allows one to correct series of classic indicators as a function of the database perimeter (*ibid.*) and to uncover nice bibliometric regularities which give another approach of international benchmarking. However, attention should be paid to applied field researches with possible national or regional specific targets (medicine, agriculture, etc.), with models that have been hardly received by the international literature, especially in developing areas. Secondly, in the case of countries in transition, emerging from a quasi-autarchic model, there may be a risk of discarding important media of primary communication.

The second issue holds that a related phenomenon, mentioned in Zitt et al. (1998b), affects the interpretation of longitudinal series of indicators. We can rephrase it as the 'rent of transition' for countries (or for disciplinary sub-system in countries) with strong scientific traditions, converting their scientific potential from national to international literature (adoption of English language, targeting of visible journals). All things equal, the consequence is a lasting upwards trend in the 'market share' of publications measured in the SCI. When the conversion to the international model is completed, the rent of transition disappears. For impact measures the case is much more complex.

It cannot be excluded that temporary or lasting decreasing return in 'visibility', measured by impact, is the price to be paid for a strong effort to increase volumes of publications in journals covered by ISI. We find again the trade-off between market share of publications and visibility (relative impact)[7]. These diminishing citation returns, in the long term, will halt if the benefits of worldwide competition extend to the newcomers. *Mutatis mutandis*, the case of swiftly catching up countries such as China is rather interesting to witness in this respect (see Chapter 22 by Jin and Rousseau in this Handbook).

When interpreting comparative long-term series, these mechanisms should be kept in mind. For example, an increasing trend in the world share of a particular country can be owed to actual progress of the research and innovation system (funding, capacity building, efficiency, etc.) in this country; to changes in communication strategy with a deliberate target on international media and language; to a particular policy of the database producers towards the country.

3.4 Communication in the Electronic Era

This chapter is focused on 'certified' media, and does not address the on-going revolution of scientific communication which is the object of a large literature. Let us only recall that in the electronic era, pre-prints, self-archives and other modes of quick communication, which pervade biology after physics, may alter the nature of the scientific article and the peer review process. Although a variety of alternative communication modes exist (books in some social sciences and Arts and Humanities, conference proceedings, with a low ratio of transformation into articles, in those disciplines and computer sciences), peer reviewed journals draw their legitimacy, as an intermediation, from the organisation of certification and archiving. For the first time, perhaps, anticipation of the mid-term future of the system becomes difficult, since alternative models can emerge both for certification and archives, on principles of self-organised and decentralised science (Ginsparg, 2000; Harnad, 2001). An indisputable progress in internationalisation of communication, besides the web posting of many types of scientific documents and teaching material, is the online availability of journal articles through electronic portals, which can be a bonanza for countries or provinces deprived of easy access to literature (see in particular

[7] Such trade offs are also observed when the behaviours of scientists change; for example under an external pressure. A quasi-experimental case has been recently discussed by Butler (2003, and her Chapter 17 in this Handbook), about the Australian policy of funding research in proportion of publications, with, as a result, a significant drop in impact.

the RFBR[8] initiative in Russia). The role of the Internet in access of peripheral countries to information and knowledge is a stake at the planetary level[9]. Free or easy access to many sources contributes to open competition, with obvious limits for tacit knowledge exchanges.

4. INTERDEPENDENCE NETWORKS

We will mainly focus on co-authorship networks, which represent an instance of collaboration strong enough to receive the sanction of the 'certified' literature — as mentioned above many other types of collaboration networks exist.

4.1 Co-authorship Networks

Owing to their richness of interpretation and their documentation at the institutional level in several databases, co-authorship networks have given birth to a huge number of contributions from the theoretical, methodological and political point of view. The reader is referred to Chapter 11 in this Handbook by Glänzel and Schubert for methodological points and a bibliography. In this section we will focus on some determinants and limits of international collaboration. Basically collaboration is driven by the same engines as other internationalisation mechanisms, in the framework of strong cultural and national constraints. The need for collaboration, the first engine of internationalisation, inherent in the scientific community, is anchored in the complementarity of competences. Collaboration is generally seen as a natural response to specialisation and increasing competition pressure, and brings better citation returns (Herbertz, 1995), even contributing to an inflation of citation figures (Persson et al., 2003). The term 'coopetition' was coined to reflect the mixes or changeovers of collaboration and competition. It applies quite well to scientists' behaviour. Top down initiatives back this trend for more collaboration, but sometimes take a form of coordination of large programs, leading to juxtaposed rather than co-authored articles/reports. Some tension may exist between bottom-up and top down processes (Ziman, 1994; Georghiu, 2001, with some special attention paid to European programs).

[8] Russian Foundation for Basic Research.

[9] The first phase of UN WSIS (the World Summit on the Information Society) was held in Geneva 10-12 December 2003, with a moderate success however.

4.2 The Evidence of Increasing International Collaboration

The evidence of a steady increase in international co-authorship has been stated by many scholars, on the basis of ISI data, using various counting methodologies (see the abovementioned chapter). The trend is quite strong, by and large the proportion of internationally co-authored papers is roughly doubled in a decade's span, 1990–2000 (OST figures on ISI data, ca. 7% in annual growth rate) without any apparent sign of saturation. Several remarks lead us to weigh this statement: first, not only foreign collaboration but all collaboration has developed in science, with a steady trend on bilateral and multilateral co-authorship; secondly, the 'within country' collaboration remains overwhelming in most large countries; thirdly, we observe a remarkable inertia of channels, which needs a few comments.

4.3 The Global Inertia of Channels

A fairly high contrast exists between the fast growing intensity of international collaboration flows and the relative inertia of collaborative channels. Complementing gross flows and the Salton measures (see Glänzel and Schubert's maps in Chapter 11 in this Handbook), size–normalised measures, especially the probabilistic affinity index or 'mutual preference' with appropriate setting[10], are particularly aimed at the detection of privileged channels, often mirroring cultural and geopolitical relations in a spectacular way. Although this type of index is extremely sensitive, it shows a remarkable stability, at least for large countries' pattern: flows keep swelling but in stable river beds. For example, over a decade, whilst the total intra-European co-authorship activity followed the world trend, the international preferences of France, Germany, and the UK remained relatively stable, with a strong cultural and historical (sometimes colonial) imprint, and this was also true for the USA and Japan (Zitt et al. 2000). These structures of co-authorship bring some evidence that cultural and geopolitical proximity — along with domination effects — supersedes

[10] Relative indices were advocated for example by Luukkonen et al. (1993). The index PAI= (n(..) × n(i,j)) / (n(i.) × n(.j)), on the contingency table of transaction, is the ratio of observed to expected flow. It needs some correction if one wants to ignore self co-authorship that inflate diagonals at the expense of other cells, yielding undesirable effects from skew distribution of actors: an iterative process of diagonal calculation towards the neutral value is recommended. A renormalisation of the interval is also useful. PAI-based networks, as well as gross flows, can be used as bases for various social network characterisation.

geographical proximity amongst infra-structural factors. Importance of the cultural factor was put forth in the earliest works on collaboration (De Beaver and Rosen, op.cit) and stressed by many authors (for example Okubo, 1996). Moreover, the voluntarist process at work in the European Union still seems far from bringing about an ineluctably homogeneous collaboration space, as shown with other methods by Leydesdorff, 2000, Grande and Peschke 1999 (for an earlier picture see Moed et al., 1991). However, some changes in affinity profiles of European peripheral countries is noted (Bassecoulard et al., 2001). Of course, in the long run geopolitical, if not cultural, relations rearrange networks. Political decisions or geopolitical earthquakes have transformed the historical affinity between the US and Japan, between the Western and the Eastern-Europe countries (Braun and Glänzel, 1996), or to a lesser extent between France and Russia or South America. But the stability in the medium run is quite remarkable. Infra-structural factors are a first natural explanation of the inertia of channels. The literature addressing the various determinants of collaboration flows usually retains geographical proximity, cultural/geopolitical proximity, inclusion in the same innovation system or nation. A detour by 'within countries' observation may be helpful.

4.4 A Regional Detour

Studies at the regional level within a country gave evidence of geographical proximity effects (Katz, 1993). Addressing international exchanges with a finer (infra-national) breakdown allows one to surmount a limitation of purely international measures in assessing the specific role of national borders. Their effect can be tested against a reference, namely, within-country regional borders. Studying the case of France and its neighbour countries, Okubo and Zitt (2004) show the overwhelming role of national borders, even in the case of border regions such as Alsace with bicultural traditions. The relative inertia of channels observed at the international level is also witnessed to a large extent at the inter-regional level. Within more closely connected countries (Scandinavia) cross-border regions with strong incentives, such as Oresund, may result in trans-border systems, but it is perhaps too early to assess such developments.

The regional detour corroborates the hypothesis that proximity factors underpinning collaboration networks rank as follows: institutional/national system (which also embody historical and cultural imprints); geopolitics and culture; geographic proximity. Other factors, less stable such as thematic alignment, also matter. Various factors have been combined in regression/gravity models (Nagpaul, 1999, see also in this Handbook Chapter 29 by Guellec and Van Pottelsberghe on technology).

A second explanation of stability should probably be sought at the individual level. The 'quasi-neuronal' persistence of inter-individual or inter-institutional linkages is a form of uncertainty reduction behaviour, with lasting linkages based on trust and maintained through face-to-face interactions in meetings and conferences. Combined with the infra-structural background, this factor could account for much of the relative inertia observed at the aggregate level, including at the international level.

4.5 Other Scientific Networks

Co-authorship is only a window on co-operation modes. For memory's sake let us recall a few others also measurable by bibliometrics, either internal to science or hybrid, where the hypotheses of internationalisation can be tested: the network of scientific dependencies, as measured by citation flows between countries; the network of science–technology mutual interdependences (see the chapters and bibliographies on the Science–Technology Interface in this Handbook); the networks of Internet links, among them hyperlinks with the analogy 'citation–sitation' (see Chapter 15 by Ingwersen and Björneborn).

The study of linkages at individual and institutional level, especially, benefit from the 'Social network' toolbox borrowing from graph theory (amongst the early promoters Barnes, 1969), with recent developments (Watts and Strogatz, 1998; Zimmerman and Kirman, 2001). The social networks way of thought was also present in the pioneering works of 'sociology of translation' (early sketch of the actor–network theory, Callon et al., 1986, Turner et al., 1988). An example of application of social networks to technology is found in Chapter 28 by Breschi and Lissoni. These techniques are, for example, applied to co-authorship linkages (Erdös project among mathematicians; a growing number of works in physics literature), and bibliometricians are increasingly paying attention to social networks properties (Egghe and Rousseau, 2003).

5. GEOGRAPHICAL DISTRIBUTION OF KNOWLEDGE PRODUCTION: CONVERGENCE ISSUES

We have illustrated by a few examples the fading of national barriers in scientific competition and in gross cooperation flows (but with rather stable preferential channels). On the output side the acid test of internationalisation would be a more even distribution of knowledge production worldwide. This outcome is not precluded in internationalisation of 'coopetition' which could even lead to a reinforcement of inequalities and dominant positions. Do we witness a convergence in per capita scientific production? Do we witness a convergence in scientific specialisation? We limit ourselves to a few empirical indications on the movements within a decade.

5.1 International Concentration of Scientific Output

a) Big versus small scientific countries.

The simplest concentration indicators are the output shares of the first countries' decile(s). The top-decile accounts for 89% of output in 1991, dropping regularly to 85% in 2000/2001[11]. The second decile increases its share, from 8 to 11%, so does the third decile. A synthetic indicator of the cumulated distribution, the Gini index, also shows a slow and regular downwards trend of concentration (0.92 to 0.90), a trend confirmed by the coefficient of variation (standard deviation/mean).

Is this trend confirmed by citation distribution? We might observe an internationalisation of competition which eventually reinforces 'Matthew effect' and acquired positions; for example, conceding significant new publication markets for newcomers, but much smaller opportunities in the citation market still dominated by a few mainstream actors. Internationalisation has a completely different meaning if it covers an increasing concentration of scientific power or at the opposite if it yields, through transfers of competences, a more equal distribution of visibility. The figures confirm that concentration remains very high (still higher, as expected, than for publications), the ten major cited countries represented 95% in 1991 and 92% in 2000/2001, against a rather steady trend. Gini indices and CV confirm the very slow but real increase of evenness.

b) Mainstream versus emerging countries.

We may have a look at several sets of countries including more active or more productive countries. We paid attention to following perimeters: OECD, OECD plus countries with largest output (29 countries) noted OECD+, plus a tentative 'mainstream' perimeter (noted OECD–[12]).

[11] Source of indicators: INRA-Lereco; of output figures: OST, based on ISI ICF data.

[12] 'Mainstream' class has been defined as OECD, plus Israel, minus overlaps with an 'Emerging' class (Europe: accession and candidate countries, Turkey; Latin America: Mexico, Chile, Argentina, Brazil; Africa: South Africa; Asia: China, India, Taiwan, Singapore, South Korea). 'Peripheral' class groups other countries.

OECD (in its current perimeter, retropolated) represented 85% of world publication in 1991 vs. 83% in 2000/2001, slight contraction confirmed by citation shares (95%–93%).

'Mainstream' countries accounted for 83% of publications in 1991 and 79% in 2000/2001 (95%–92% of citations). The 'Emerging' class gathers most of the difference, jumping from 15% to 18% (citations 5%–8%). 'Periphery' remains marginal and stable.

Among a group of major countries (OECD current perimeter + countries with strongest output in the decade), concentration is falling more rapidly (Gini 0.71–0.65, citations 0.79–0.75). The picture is similar for OECD alone (0.73–0.68).

c) The EU.

If we turn now to the EU15, the world share is slightly growing (31 to 33%). Within EU15, Gini on publications looses four points over the period (0.58–0.54) and three points on citations (0.61–0.58).

d) Global picture.

There is a slight and regular drive toward reduction of concentration, both on publications (Figure 18.3) and citations. The slow contraction of mainstream, especially North America, is mostly captured by a class of emerging countries, especially in Asia, with the spectacular case of China, for example, rather than by periphery.

5.2 Convergence in Per Capita Publications (OECD Countries)

Per capita output data yield a complementary view. Using demographic series available for OECD we observed changes in per capita output, which can be held as a convenient basis for assessing convergences. Publication output growth rate (1998–2000 versus 1991–1993) decreases with level of output, as shown in Figure 18.4 that suggests catch up processes for smaller science producers. This is also true for the EU subgroup. Korea, Turkey, Portugal, Mexico, Greece and Poland have enjoyed important relative growth. In medium sized countries, Spain and Italy are on a remarkable upwards trend.

But the pace of catch up is slow. If the coefficient of variation is decreasing, the standard deviation amongst countries remains almost stable. Given the skew distributions, weighting by country size (output) does not allow a clear move to be recorded. The hierarchy of per capita scientific output in OECD, with Nordic countries, Switzerland, and the US ahead, is not likely to be deeply altered in a midterm future. Interchanges in ranks of per capita output are rare (Kendall tau > 0.87 for OECD, > 0.88 for EU15).

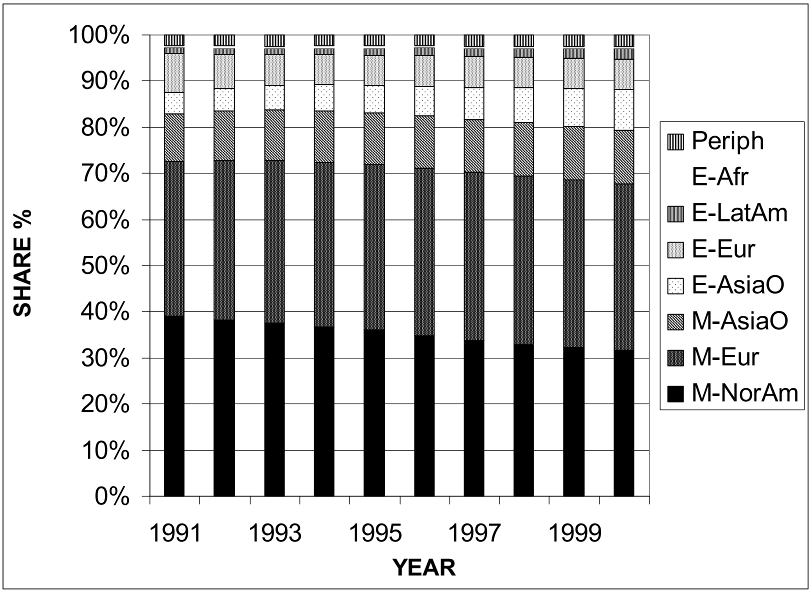


Figure 18.3. Distribution of publications by geopolitical area.
Source: ISI data, processing OST and INRA

The prefix M stands for mainstream, E for emerging. M-AsiaO comprises Japan, Australia, NewZealand. E-LatAm : Argentina, Brasil, Chile and Mexico. M-Eur: EU and northwestern Europe. E-Afr: South Africa. E-AsiaO is the great winner of the rearrangements. M-Eur is also expanding, US and Canada are on a downwards trend. Figures may be sensitive to artefacts in the coverage of the ISI database**.**

Evolution is similar in the EU15 sub-group: same relation between growth rates and output, evidence of decreasing non-weighted CV but imperceptible downwards trend of weighted indicators. These results tend to confirm our earlier observations (1999b). These data on per capita output tend to support the hypothesis of a slow move towards evenness. Again results of citation data confirm the slight progress in the reduction of inequalities.

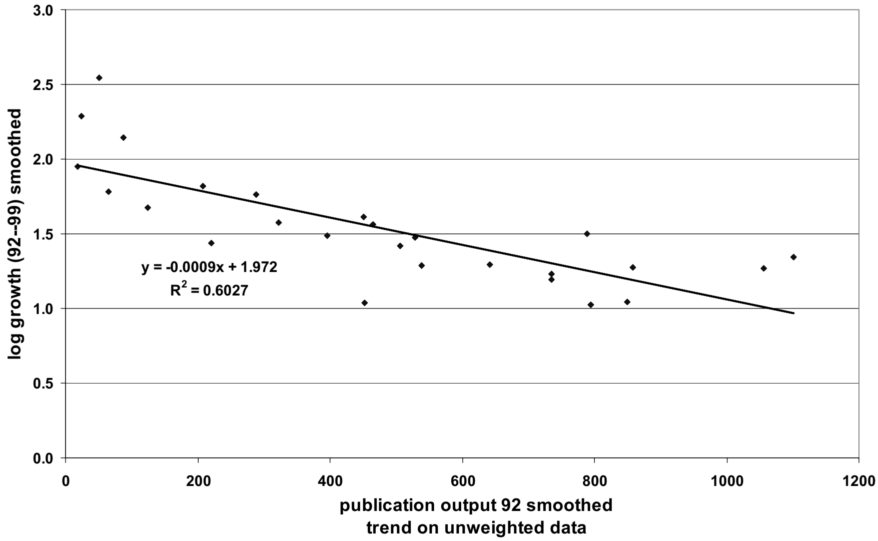


Figure 18.4. Growth versus Output.
Source: ISI data, processing OST and INRA

Not represented: USA, Canada, Czech Republic and Slovakia. World growth rate of publications cannot be interpreted as such, since it reflects the ISI database coverage policy. Only the country comparative trend should be considered, with respects to biases studied in literature.

5.3 Convergence in Thematic Specialisation

The third aspect of the homogeneity trend we consider here is the convergence of scientific specialisation. If internationalisation of output is assimilated to homogenisation at the world level, its empirical measure is by and large a reduction of discrepancies among countries, including in their specialisation patterns. Scientific specialisation is a complex phenomenon, linked to internal dynamic factors and public policy choices combined with agglomeration and learning processes. In some cases comparative advantages in terms of factor costs may also play a role, especially for developing countries, that can be restricted to disciplines requiring less funding and equipment. Analogies with international trade and patent economics in the explanation of specialisation should be carefully handled. The globalisation engine also conveys priorities external to academic science, towards profitable areas of technology and social needs, following a trend à la Schmookler, revised in more interacting fashion (Gibbons et al., 1994; Etzkowitz and Leydesdorff, 1997).

The configuration of science also evolves in deep movements, and the increasing role of ICT, and mainly biology, at the expense of physical sciences has been seen as featuring a 'new regime' for science, pioneered by most advanced countries especially the US. Bonaccorsi (2002), renewing Price's perspective, proposes a few characteristics of regimes and sees the compliance with the new trends as a key predictor of institutional success. A sketch of the new regime is found in Laredo (2002). Holding specialisation advantages in historic areas of specialisation or turning to new avenues is a crucial issue for policy makers. Despite a widely echoed internationalisation of priorities conveyed both by US policy and EU initiatives (biotechnology, nanotechnology, ICT), the worldwide convergence of specialisation is likely to be curbed by barriers to entry, irreversibility effects, and dynamics of geographical clustering.

Thematic convergence has been addressed in the literature, for example Doré et al. (1996). To sketch general orientations at the country level, it is convenient to aggregate academic disciplines into three large groups, respectively life/ physical/engineering. It should be noted that at the world level the balance between the groups, in the ISI database and the particular breakdown used[13], is fairly stable in the decade, ca 55% for life, 32% for physical, and 13% for engineering. Slight changes over the decade benefit the latter, a perhaps unexpected trend. It must be said that a representative balance is very difficult to achieve for database producers, including on theoretical grounds, and artefacts are unavoidable.

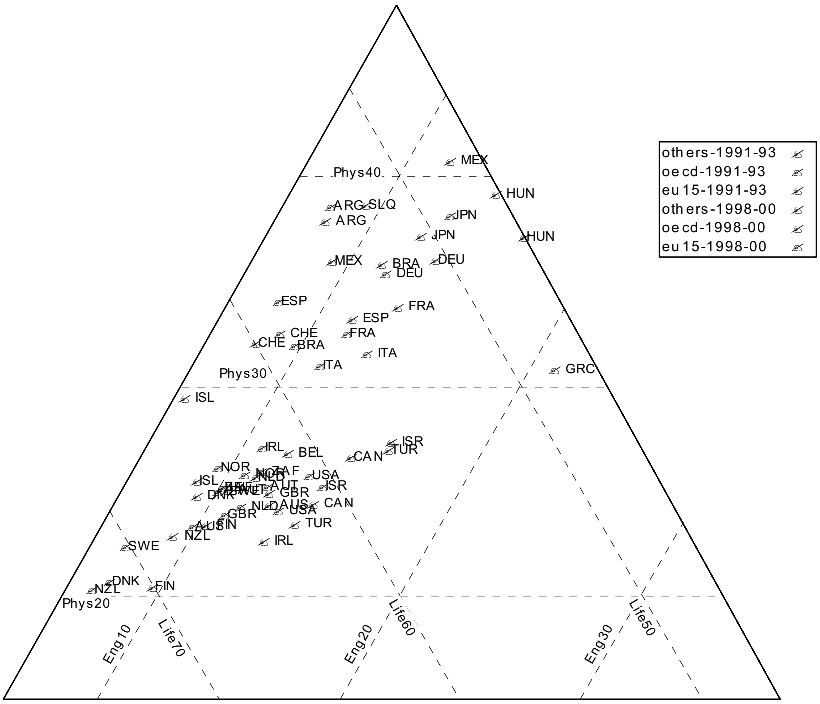
The balance for OECD and a set of selected countries is plotted in a triangular diagram Figure 18.5. Specialisation is very clear amongst actors, and clusters are relatively stable, few spectacular changes are recorded in the decade for large countries.

This relative stability is confirmed by quantitative measures. Two indicators, both based on discrepancies between country profiles and the world profile, were calculated: standard deviation on normalised activity indices (revealed advantage measure); quadratic distance to the average profile. Both were considered with and without country weights. Two disciplinary breakdown were used, the abovementioned three groups (D3), and the 8 academic disciplines (D8). The eight measures were calculated for each year.

At the world level no trend for homogeneity appears on the eight criteria, except moderately for variance in D8. All weighted measures (activity

[13] Life sciences entails medical research; fundamental biology; applied biology. Physical sciences: physics; chemistry; earth and space. Engineering sciences: engineering; computer science; mathematics has been joined to this group.

indices and inertia) revealed a slight divergence. On the perimeters including major countries (OECD, OECD+), convergence is noted on non-weighted indices and divergence on weighted indices, which suggests that important actors do not get closer.



Source: Z&B, 1999 - ISI data, processing OST and INRA. Graph by Tri-Draw software.

Figure 18.5. Disciplinary balance (1998 – 2000) vs. (1991 – 1993) – percentages ISI data, processing OST and INRA

This triangular diagram shows the shares of the three disciplinary groups (by country) summing at 100% as a result of fractional counting. Each country is represented at two periods. OECD countries and a few selected others are shown. For legibility only the bottom of the diagram is represented. Within the diagram two clusters appear: mainstream in the lower triangle, with Nordic and Anglo-American countries, biology oriented; large European and Latin America countries in the upper triangle: Life 55%, Physics 35%, Engineering 10%. Some movements are noted but the clusters remain stable. Outsiders (not shown): on the upper right of the diagram (much less than 50% in Life sciences), some countries of Eastern tradition keep the strong traditional involvement in physical sciences, between 50 and 70% and often less than 20% in Life Sciences (Poland, Russia, Ukraine, China); Korea and Taiwan, remote outsiders, have exceptionally high involvement in Engineering, ca. 20–30% and less than 35% in Life Sciences.

In contrast, the EU15 perimeter records a convergence on all measures, except weighted activity index which is fairly stable. Although these results should be confirmed on longer series and finer disciplinary breakdowns, a slow homogenisation process seems to be at work in Europe.

5.4 Convergence at the Regional Level

Let us focus on the European landscape. As seen above, inter-country unevenness is quite large for science, and this is also true for technology as measured by patents. But compared with technology, overall territorial inequality in science output has a strong regional component, owing to the scattering (and size – performance variability) of universities; in contrast, unevenness in patent output relies more on country international differences. There is some evidence (Zitt et al., op. cit. 1999b) that as far as science is concerned, regional inequality over EU15 is also on a downwards trend, but the landscape can differ among disciplines. Numerous works and reports address the stakes of EU convergence in STI issues (see for example Denozios, 1997) and the issue is topical within the new EU25. The above mentioned literature on spillovers has examined many sectors and case studies in regions. Understanding of dynamic phenomena of regional S&T clustering is a wide area for future research.

6. CONCLUSION

We have described various aspects of scientific internationalisation amenable to bibliometric measures based on published outputs. There is much evidence that internationalisation is growing but with contrasted facets.

Some barriers to international competition are being lifted. The national model in scientific communication is gradually being limited to secondary (transfer) communication, and scientific journals tend more and more to reflect the international variety of contributions in their discipline and level. Transition mechanisms between the national and the trans-national model, as well as the persistence of national media, should be taken into account for the interpretation of bibliometric time series. It should be stressed, however, that the disappearance of some market rigidity does not mean perfect competition, nor does it imply a trend toward more evenness. Dominant positions in editorial committees for example can still convey national power of mainstream countries.

Cooperation, coordination and interdependence are another target of internationalisation processes in science. In co-authorship relations, we observed an apparent paradox. On the one hand, gross flows show the most impressive changes amongst all other manifestations of internationalisation, but on the other hand changes occurring in the topography of preferential collaboration channels are rather slow. This relative inertia can be attributed to stable infrastructural factors, as well as feedback loops on existing individual relations. The landscape of collaboration draws more a ‘network’ rather than a homogeneous ‘space‘. The national and cultural barriers are resistant. Even in an activity where exchanges are mostly non-physical, geography is far from dead. For example, the degree of EU integration on this criterion has not followed the political impulse (Head and Mayer, 2000, show the same findings on intra-EU commercial exchanges). From the methodological point of view, progresses are expected from the new tools of social networks theory which could help to bridge micro and macro-approaches of scientific networks.

Turning to the world distribution of scientific output, the geographical distribution of knowledge production shows a decline of concentration, but at a very slow pace, in the universes considered (World, OECD, EU15). The evolution of concentration of output and citations on the one hand, the convergence in per capita publication and citation on the other suggest that the picture of world science production is slowly becoming less unequal. Whilst ‘emerging countries‘, especially in Asia and also in Europe, are on a catch up trajectory in the latter decades, the periphery does not participate in the movement. The pressure of newcomers mechanically shrinks the relative share of dominant countries in the scientific communication, but to a very moderate extent. If the case of China is spectacular, relative rankings of OECD countries in per capita output have changed little in the decade. The other major phenomenon, the intensive draining of human resources by the US, also limits the long term prospect of convergence. The thematic specialisation, measured at the level of discipline, does not give evidence of a convergence process. Scientific specialisation, rooted in historical trajectories of NSI, resists, except a slow homogenisation process within EU15. Let us conclude with a few interrogations.

Interaction of internationalisation modes

The above perspectives on internationalisation are not independent. Collaboration as a merging of complementary skills can be interpreted as a response to the diversity of subjects and specialisation — in addition to rewards in terms of visibility. The relation of international collaboration, output growth, and geographical distribution of output is complex. Large countries offer a variety of in house collaboration targets so that they can afford low levels of foreign linkages (USA, Japan). At the opposite end peripheral countries exhibit very high rates of international collaboration, as a response to scarcity of local resources (for the African case Gaillard et al., 2002). Emerging countries use abroad linkages in catch up processes, but at the same time collaboration within the mainstream helps to keep high standards and advance. International collaboration also has ambivalent relations with scientific manpower migration, of both substituability and complementarity. Circulation of students and scholars, probably more than collaboration, and the related brain drain/brain gain balance, determine the dynamics of catching up.

New barriers to communication due to appropriation of science?

A particular concern is the connexion between science and technology internationalisation. There is growing evidence that the frontier between science as a public good and technology as a private good is becoming fuzzy, especially in the area of biotechnology and new ICT. The academic model of free communication can be threatened in various ways by the pressure of property rights (Nelson, 2004). If globalisation fosters appropriated forms of knowledge, it can delay exchanges or restrict their content. The biotech area exemplifies this new pressure on the traditional model of science.

For example, we have watched the slowly and regularly decreasing world share of the US in articles' output (at a much lower pace for citations). At the same time the share of the US in patents, including the European or PCT, is steadily increasing, without mentioning the defense area. This leaves some interpretations open: is it a simple consequence of emerging countries' differential pressures in basic and applied research? Or the consequence of a competition publication – IPR in knowledge diffusion, watched at the university level (Dasgupta and David, op.cit., Mowery and Ziedonis, 2002) and decreasing incentives to publish open science in some areas?

Lon-term dynamics: geopolitics and scientific regimes

Internationalisation has to be placed in the evolution of innovation systems and, in the long run, in the perspective of geopolitics. We have emphasised the role of infra-structural factors in shaping scientific collaboration networks, factors responsible for a relative inertia in the medium run but submitted in the long period, through the geopolitical component, to drastic changes. The transition to open political and/or economic systems (case of Spain and Portugal in the seventies, more recently of former Eastern block countries, of dragons and China, etc.) has deeply contributed to the competitiveness and sometimes to the emergence of scientific communities in these countries. The supra-national policy of the EU, first through structural funds, then through Framework Programs, probably explains why EU countries tend, albeit very slowly, to converge.

The EU is also a laboratory where supra-national, national and regional levels compete and complement each other in the shaping of the research and innovation system. Perhaps the most appealing question is whether the new 'regime' in the leading edge of science – biotech, information, nano – with agglomeration and coopetition amongst science districts, beyond national borders, will be able to destabilise the factors of inertia rooted in history and culture.

Internationalisation of topics

The drifts of nationalism and ideology in science dramatically curbed scientific exchanges during the XXth century. The Republic of Science wishes to ignore borderlines, but at the same time elitism and concentration are consubstantial with the community's norms and habits, expressed in skew distributions of output and 'Matthew effect'. As we have stressed, internationalisation of competition or cooperation does not promise a fading of borderlines in productivity maps. Neither do they warrant that variety will be safeguarded, especially in terms of heterodox thought and research topics. A particular question is about topics specific to developing/emerging countries, which may not find an echo in the international community. 'Nationalism in science' which found some prestigious advocates, for example Raman[14] in India, in the past century, can be seen as a refuge for addressing domestic issues (Arunachalam, 1997). The thematic orientations of domestic research, international research on the country's specific topics, and diaspora have been found very different in the case of an ultra-peripheral country (Bassecoulard et al., 2003). The marginalisation of periphery's preoccupations in agriculture, biology, and medicine would be a failure of internationalisation, which on other aspects brings hope for scientists and students to be able to access information from everywhere.

Whilst restrictions on international communication, competition, collaboration – and skilled manpower circulation – tend to fade, infrastructural factors, proximity effects, inertia of networks constrain the rearrangements. Like other globalisation processes, internationalisation in science is a *Janus Bifrons*, conveying antagonistic forces: on the one hand, through the reinforcement of (imperfect) competition and the Matthew effect, it may secure or enhance dominant positions; on the other hand, actors in transition or in emergence benefit from the circulation of information and skilled manpower. The empirical evidence is in favour of more evenness, but the trend is quite moderate. In the next decade one will observe whether the new regime in the leading edge of science is able to

[14] Sir C.V. Raman, Nobel Prize for physics (1930).

shake factors of inertia and to challenge — or reinforce — international inequality in the production of knowledge.

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