Scientometrics, Vol. 31, No. 3 (1994) 261-292

INTERNATIONAL SCIENTIFIC COOPERATION: THE CONTINENTALIZATION OF SCIENCE

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(Received April 12, 1994)

By transforming science into a vast single market for the exchange of research products, the globalization of scientific activity affects the mechanisms by which countries enter into mutual relations. It is no longer sufficient to conduct research jointly; research must also, and perhaps above all, be conducted within the strategic space of the network. In practice, the network takes the form of a cluster of nations and emerges in response to various determining factors or constraints. This does not, however, result in arbitrary criteria of association with the network: the distance from one country or group of countries able to play a regional or continental "governance" role, cultural or linguistic affinities, geographic proximity, the recognition of common interests, the existence of political agreements on cooperation are all grounds for linkage or association. In short, the geography of exchanges is changing before our eyes. This study describes as "world-science" marked by the collectivization of the centre, "centrality" being defined not by a national monopoly, but by the "hard core" of a transnational network, stratified on a continental or subcontinental basis.

1. Introduction

National innovation systems are becoming international in more ways than one. In particular, over the past 20 years, scientific exchanges between countries have gradually become entrenched and more flexible, no doubt because an increased desire for access to foreign markets has quickly become one of the primary reasons for international collaboration,[1] as has the obligation to remain competitive on domestic markets. Given this, the globalization of technical knowledge and of networks for the production and distribution of goods and services have sorely tried national innovation policies designed to procure gains for local institutions alone.

In this context, the conditions governing word scientific activity are becoming increasingly akin to those that determine economic activity. The concentration of economic production is naturally accompanied by a concentration of scientific production.[2] Hence, we can rightly speak of the emergence of a true "world-science",[3]

Elsevier, Amsterdam – Oxford – New York – Tokyo
Akadémiai Kiadó, Budapest

the main features of which are not without similarity to the "world-economy" described by *Braudel*.[4]

However, the building of a global science, after technological innovation has triggered an international technological development race, makes the location of a "centre" and a "periphery" less and less apparent. If, as *Schils*[5] and *Moravcsik*[6] have written, the "centre" is where scientific activity is highly concentrated, and more intensively and significantly practised, while the "periphery" designates scattered, dependent scientific zones,[7] these terms reflect less and less the true nature of the relations now being formed within the scientific community, which *Schott*[8] has dubbed the "global scientific community".

In this new global network, each national scientific community participates in the advancement of science. Therefore, the centre is no longer a single dominant pole that "governs" world scientific activity, but a common authority or jurisdiction to which each member adheres while attempting to preserve its autonomy. In practice, according to Schott "the centrality of a national scientific community refers to its attraction of collegial relations from abroad".

Although at one time the centre was a zone toward which the various national scientific communities converged,[9] today it particularly represents that which lends legitimacy.[10] As for the world-science described by *Polanco*, it has the following features: (1) it develops slowly, through successive mutations; (2) as a zone whose scientific primacy is recognized, it "steers" scientific activity, according to "centerings" that are sometimes weak and sometimes strong; (3) lastly, it is a "hierarchical" space[11] and an immense network in which the periphery may be a neighbour of the centre, but in which the nature of activities is nonetheless determined by distance.

In fact, there is said to be a vast sovereign scientific market in which the general preeminence of an omnipotent centre to which states are subjugated is being supplanted by the establishment of a competitive world scientific market. To describe this market, one must return to the model proposed by *Polanyi*.[12] Like the economic market, this market is the scene of a triple transformation: *unification*, i.e. the merging of national markets, defined as the concrete entities of science, into a vast, unified but abstract world market; *extension*, by which scientific results, which have become one form of good among others, are traded; lastly, *emancipation*, the process by which national research systems reject any subjugation to central control, while continuing to refer to a more or less dominant scientific State.

In this article, we seek to describe a few of the components of this "world-science" on the basis of bibliometric indicators. We will first discuss the phenomenon of the internationalization of science in relation to the size of national scientific communities. We will then attempt to visually reconstruct the bonds forged between the principal national scientific systems. Lastly, we will see how three major economic units and subunits built on closer geopolitical and economic affinities jointly mobilize into continental mega-networks.

2. Description of the bibliometrics indicators used in this study

2.1. Database

The statistical data used in this study were provided by on-line querying of the CD-ROM Science Citation Index (SCI) database of the Institute for Scientific Information (ISI). The primary data were processed to attribute a distinct field and subfield to each of the documents indexed. This operation was carried out with the help of the classification by discipline of Computer Horizon Inc. (CHI), using the Carpenter classification.[13]

The CHI classification distinguishes nine disciplines, divided into 106 subfields.[14] We eliminated from the database the field related to psychology, which only has a few documents and is more systematically counted in the *Social Science Citation Index* (SSCI) of the ISI. All the existing overlapping in the SCI database was eliminated from the matrix. Lastly, only "articles", "notes" and "reviews" have been retained, in accordance with the choice made by the National Science Foundation.[15] The half a million publications surveyed in 1990 were produced in 131 countries.

2.2. Counting of publications

Publications are counted and attributed to a nation according to two principles. They are counted as a function of and in proportion to the origin of the authors, each article being indexing according to the number of origins. This is the so-called "fractional counting" method. The second method, the so-called "whole counting" method advocated by the Information Science and Scientometrics Research Unit, is inspired by the "one author, one country" principle, according to which each article is attributed to the nation of the first author.[16] Both methods underestimate the global activity of national communities of researchers, on the pretext of measuring the sum of world publications more accurately.

We have chosen a third solution: multiple counting. In the matrix that we constructed, one article has as many national references as it has authors from different countries. Consequently, the "sum" of world publications is greater that the number of publications actually produced during a given year, since the articles produced in cooperation with other countries are added, for each country, to the articles produced singly. Countries are identifyed according to the institutional address of each author. In the following example, the article is thus attributed to both Canada and the United States:

Authors: Sirois-P Borgeat-p Lauziere-M Dube-L Rubin-P Kesterson-J
Title: Effect of Zileuton (A-64077) on the 5-Lipoxygenase Activity of Human Whole-Blood Exvivo
Source: AGENTS AND ACTIONS
Language: English
Document type: Article
TGA No.: GJ048
Cited references: 3
Addresses:
UNIV-SHERBROOKE, FAC MED, DEPTPHARMACOL, SHERBROOKE J1H-5N4, QUEBEC CANADA
ABBOTT-LABS, N-CHICAGO, IL 60064, USA

Like many experts in scientometry,[17] we prefer the whole counting method to the fractional counting method. What we feel must truly be measured is less the overall production of collective scientific work than the *actual contribution* or *participation of national scientific communities in the "knowledge construction cycle."*[18] But international scientific cooperation, the coauthored articles of which reflect the scope as well as the real extent of exchange networks, has a decisive function and a growing share of scientific activity.

Regardless of the method chosen, the results are generally very similar, as shown in Table 1. Five of the G−7 countries have seen their share increase according to the multiple counting method. In contrast, in the case of countries whose international scientific activity is relatively little developed, such as the United States and Japan,[19] the multiple counting method shrinks their relative share. In fact, this negative disparity tends to intensity as international activity develops, as shown in Table 1. On the other hand, the fractional counting method may − and this is its major disadvantage − indicate a "decline" simply because of growth in the number of articles coauthored internationally.[20] In short, both methods involve an inevitable bias, which should be kept in mind when interpreting results.

Table 1
Share of world publications according to counting method, 1985 and 1990

	1985 (A) Multiple counting	1985 (B) Whole counting	1985 (A−B) Difference	1990 (A) Multiple counting	1990 (B) Whole counting	1990 (A−B) Difference
United States	35.3	35.8	−0.5	33.4	36.9	−3.5
Japan	7.2	7.5	−0.3	7.8	8.8	−1.0
United Kingdom	8.2	7.7	0.5	7.4	7.2	0.2
Germany	7.2	6.8	0.4	7.2	6.4	0.8
France	4.9	4.4	0.5	5.0	4.5	0.5
Canada	4.4	4.0	0.4	4.4	4.2	0.2
Italy	2.5	2.2	0.3	2.9	2.7	0.2

2.3. Definitions

In this paper, we will refer to a succession of bibliometric indicators, quantitative measurements and concepts, whose basic definitions follow.

Cooperation (COOP)

The term *cooperation* designates, for each country, the number of international "collaborations" or international "cooperation" involved in articles prepared in cooperation with foreign researchers. Consequently, we feel there is a significant equivalence between the concept of "international scientific cooperation" (ISC) and the empirical variable that determines it, i.e. "international coauthorships".[21] Furthermore, one article may be the result of several "collaborations". Hence, an article coauthored by researchers in Canada, the United States, France and Italy generates six collaborations, the number of collaborations being equal to $N(N-1)/2$, where N is the number of countries.

Articles coathored internationally (ACI)

Designates, for each country, the articles that are the result of international collaboration, i.e. the articles coauthored internationally (ACI). Regardless of the number of countries involved in its production, an article can give rise to only one ACI. Therefore, an article coauthored by researchers in Canada, the United States, France and Italy is counted as only one ACI, although it had six collaborators.

Internationalization index (INI)

The *internationalization index* (INI) indicates the rate of internationalization of research in a country, a research field or a research subfield. It is obtained by comparing the number of ACIs to the number of total publications:
ACI X 100/TOTAL PUBLICATIONS

Proximity index (PRI)

The *proximity index* indicates the intensity of scientific exchanges between two countries, according to coauthored articles measured and collaborations theoretically expected. An index above 1 reflects higher collaboration intensity between two countries than their respective weight and propensity to collaborate would indicate. The index therefore shows the symmetry of relations between the countries.

The proximity index is calculated on the basis of an observed/expected ratio of proximity, the formula for which is[22]:

$$(Cx,y \cdot T)/(Cx \cdot Cy)$$

Cx,y = number of articles coauthored internationally by countries X and Y,

Cx = total number of articles coauthored internationally by country X with the 130 other countries in the database,

Cy = total number of articles coauthored internationally by country Y with the 130 other countries in the database,

T = total number of articles coauthored internationally by the 131 countries in the database.

Affinity index (AFI)

The *affinity index*[23] indicates the relative volume of articles coauthored by two countries during a given period and in a given field, in proportion to the total number of articles coauthored with the world for each country in the same field and during the same period. This index therefore shows the asymmetrical relations between countries.

The affinity index is calculated according to the following formula:

$$AFI\ (A \rightarrow B) = COOP\ (A \leftrightarrow B) \cdot 100 / COOP\ (A \leftrightarrow WORLD)\ \text{or}$$
$$AFI\ (B \rightarrow A) = COOP\ (A \leftrightarrow B) \cdot 100 / COOP\ (B \leftrightarrow WORLD)$$

Weighted affinity index (WAI)

The *weighted affinity index* also indicates the relative and mutual affinity between countries. In contrast to the affinity index, the weighted affinity index weights the measured links between two countries on the basis of a observed/expected ratio.

The WAI is calculated according to the following formula:

$$[(Cx,y \cdot (T - Cx)] / (Cx \cdot Cy)$$

3. Analysis results

3.1. Size and internationalization of research

Figure 1 shows the relation between the internationalization index (INI) of 131 countries and their size, measured by the share of world publications in 1990. Although a number of authors have observed a weak correlation between size and the internationalization index,[24] the existence of a positive correlation has been demonstrated countless times.[25] Figure 1 clearly shows the existence of such a positive correlation, expressed as $R^2 = 0.093$, which confirms that the larger the country measured by the number of publications, the lower the INI and vice versa.

It is actually as if the small countries were seeking in collaboration the means they lack locally. In some countries, recourse to external means counts more than their own means: in 1990, the INI reached at least 60% in Algeria, the Philippines, Colombia, Cameroon, Ghana and Zambia; elsewhere more than 70% (Morocco, Peru, Costa Rica, Iceland, Tanzania and Niger), and even over 80% (Jordan, Ivory Coast and Indonesia).

At the other extreme are the United States and Japan of course. In the case of Japan, which is, however, one of the countries where the internationalization of marketing, sales and the financial system is most advanced,[26] the INI was only 10%, the lowest among industrialized countries. In fact, only the former USSR (CIS) (6.4%) and India (10.4%) recorded equal or lower rates, whereas the index varies from 20% to nearly 30% in the main producing countries (Table 2) and is 20% worldwide. The internationalization rate for the United States is 12.9%.

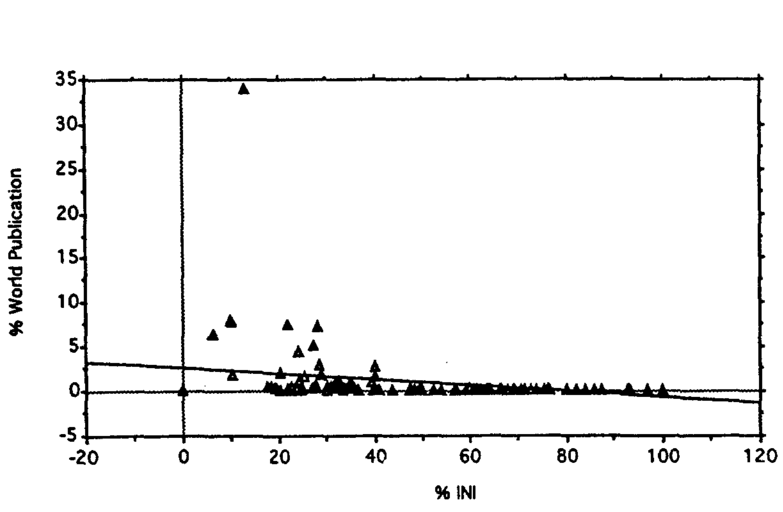

Fig. 1. Relation between internationalization index (INI) and size for 131 countries, 1990

It will be noted that the earth and space sciences (EAS) recorded the highest INI on a world scale (32.4%), and nearly 64% in the Netherlands and 50% in Italy. Among the next most highly internationalized fields are mathematics (28.9%) and physics (26.6%). With more than 26% of total international scientific exchanges, compared with 24,5% for clinical medicine, physics accounts for the largest share of international scientific collaborations. With an internationalization index equal to 51.4% in 1990 (compared with 40.3% in 1985), nuclear and particle physics is the most highly internationalized scientific field, followed by astronomy and astrophysics (47.6%) and, in the field of clinical medicine, the INI of which is only 16%, tropical medicine, with an index of over 46%.

On a worldwide basis, the internationalization index grew from 11.3% in 1980 to 20% in 1990 (Fig. 3). The level of internationalization during the period has proportionally doubled in the fields of biology (BIO), of clinical medicine (CLI) and of the engineering sciences (ENT). In the field of biomedical research (BIM), the INI rose 9 points; 7.3 in chemistry (CHM), more than 12 in the earth and space sciences, and approximately 11 and 10 points respectively in the two fields of mathematics (MAT) and physics (PHY).

Table 2
Internationalization index (INI) of the first 10 producing countries, 1990

	CLI	BIM	BIO	CHM	PHY	EAS	ENT	MAT	Total
USA	9.6	14.4	10.9	11.9	19.2	20.6	10.8	21.0	12.9
JPN	9.2	13.1	9.2	6.2	10.6	27.3	8.2	20.8	10.0
GBR	15.4	25.7	19.8	22.9	33.0	43.5	16.3	28.4	21.9
DEU	20.4	33.4	23.3	24.5	39.0	43.6	17.7	38.2	28.2
CIS	4.0	6.3	6.4	3.9	8.9	11.6	4.5	8.4	6.4
FRA	19.4	30.3	22.6	24.5	37.1	43.1	22.8	38.0	27.5
CAN	20.6	24.0	15.8	22.1	34.8	28.9	19.8	41.4	23.1
ITA	20.7	32.6	24.3	22.0	43.2	50.1	24.6	29.6	28.6
NLD	34.3	44.0	32.6	35.9	50.9	63.8	31.5	50.2	40.1
AUS	15.0	24.2	15.9	22.8	26.4	35.2	23.2	34.0	20.6
WORLD	16.0	22.1	18.1	16.5	26.8	32.4	16.1	28.9	20.1

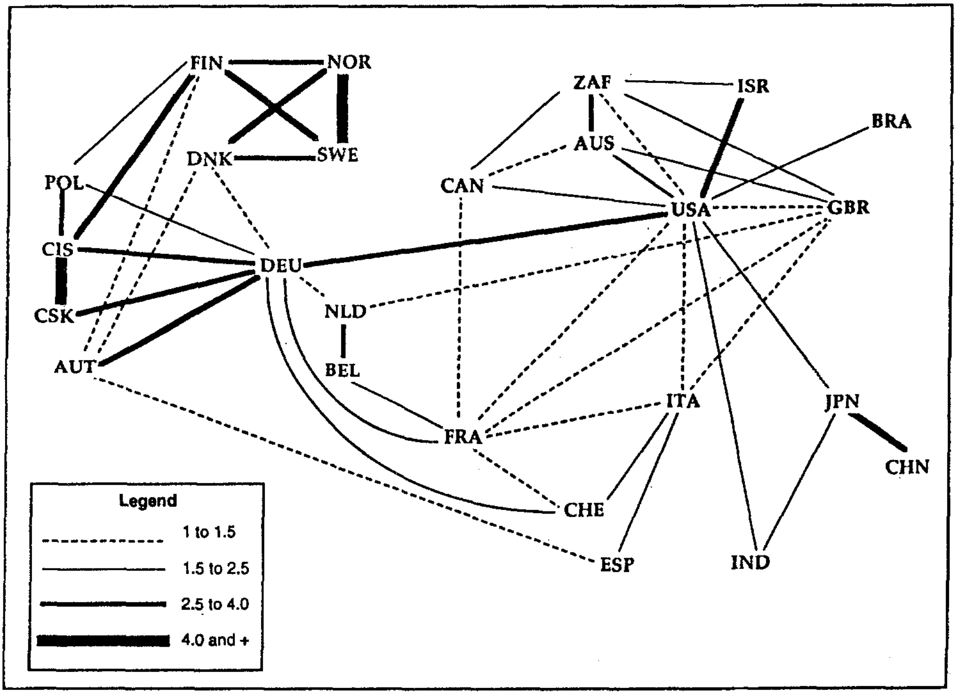

Fig. 2. Map of international scientific cooperation by the first 25 producing countries, 1990

3.2. Geography of international relations

Figure 2 indicates, on the basis of the observed/expected ratio of international coauthorship, the geography of supranational scientific exchanges among the 25 main producing countries in 1990. These countries alone account for more than 90% of world scientific production and cooperation. The geography indicated by the calculation of proximity indexes (PRIs) shows the real geopolitical configuration of the main world-science networks. The map reveals the following main phenomena:

(1) *The dominance of the United States in the establishment of transnational exchange systems*. The United States (USA), which accounts for one-fifth of international scientific exchanges, is an essential partner of most scientific nations, whether they are industrialized or not. Out of a group of 130 countries, 77 have the United States as their main partner. The PRI with Germany (DEU) is equal to 2.75, that with Israel (ISR) is 2.60, while those with Japan (JPN) and Canada (CAN) are

2.15 and 2.17, respectively. In fact, the American research system is a central reference for the main national research systems, as confirmed by Table 3, which deals with the nine foremost scientific nations. The share of scientific exchanges carried out by these countries as a proportion of their total ISC, as expressed statistically by the affinity index (AFI), is high everywhere: more than 40% in Canada and Japan, more than 30% in India (IND) and Australia (AUS), nearly one-fourth in the United Kingdom (GBR) and Italy (ITA) and about one-fifth in Germany, France (FRA) and the Netherlands (NLD). The weighted affinity index (WAI) also shows the existence of special relations between the United States, on one hand, and Canada, Japan, Australia and India, on the other. Among the 10 leading countries, only Germany recorded a negative WAI with the United States, whereas the index was 2.07 in France and Canada;

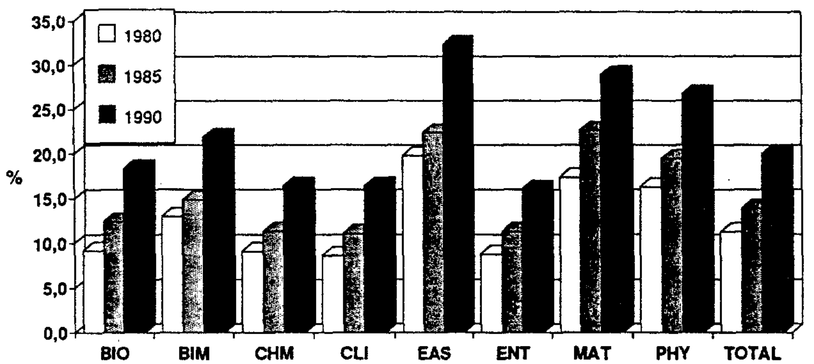

Fig. 3. Internationalization Index (INI) by field, for the all countries, 1980 – 1990

(2) *The marginalization of the Eastern bloc countries, virtually all of whose strong ties to countries outside the former Communist zone of Central European have been severed.* Hence, the countries of Eastern Europe form a separate network within continental Europe, to which they are mainly connected through Germany. Within this zone, proximity indexes vary from 2.5 to 4.0, and even top 10.0 in the case of relations between the Commonwealth of Independent States and Czechoslovakia (CIS-CSK);

Table 3
Cooperation between the United States and the main scientific countries, 1990

	USA-Other countries			Other countries-USA	
	AFI (%)	PRI	WAI	AFI (%)	WAI
Canada	10.8	2.17	1.75	42.4	2.07
Germany	10.1	2.75	0.81	19.6	0.91
United Kingdom	9.8	1.20	0.96	23.3	1.10
Japan	7.6	2.15	1.73	41.9	2.07
France	7.6	1.09	0.87	21.2	1.01
Italy	5.4	1.20	0.96	23.4	1.14
Netherlands	6.3	1.12	0.90	21.9	1.06
Australia	3.1	1.61	1.30	31.5	1.58
India	1.6	1.62	1.30	31.6	1.60

AFI = Affinity Index.
PRI = Proximity Index.
WAI = Weighted Affinity Index.

(3) *The aloofness of a Scandinavian scientific Europe, not yet well integrated in a European scientific space.* Endowed with relatively substantial human, material and financial resources, which guarantee perfect competitiveness with the rest of Europe, the Scandinavian countries are mobilizing primarily to safeguard a distinct identity within a scientific Europe whose integration is under way. Hence, these countries, sustained by cultural and geopolitical affinities that mould the structure of their exchanges, form a configuration that is relatively autonomous, if not genuinely self-centred, in world exchanges. As proof, scientific exchanges reflect almost perfectly the structure of an economic market bounded by member countries of the European Free Trade Association (EFTA). It should be noted, however, that the collaboration with the United States, in absolute terms, account for the greater part of the international exchanges of Scandinavia. Moreover, the scientific relations with the countries of the European Union are actually more frequent than between the Scandinavian countries themselves;

(4) *The isolation of South Africa and Israel.* Located in the confines, so to speak, of the main exchange networks, South Africa (ZAF) and Israel are distinctly part of international networks. In the case of South Africa, the political framework of the Commonwealth provides a stable – and natural, as it were – foundation for the forging of scientific alliances with the outside, notably with Canada, Australia and the United Kingdom. The PRIs of Israel, located on the periphery of the

dominant exchange currents, link it significantly only with the United States (2.60) and South Africa (2.20). Hence, one can readily understand the more marked influence of the United States of Israel's research system than on other national research systems. As Schott has shown, for example, "American influence on research in Israel is nearly twice as strong as American influence on research in the German Democratic Republic"[27];

(5) *A Japanese scientific system that continues to be eccentric compared with world activity.* Still little integrated into the traditional scientific exchange networks, Japan recorded negative proximity indexes with most of the main industrialized countries. China (CHN), according to this indicator, is its main partner (2.93), while India and the United States are significant partners. Australia must indubitably be added to this list, since Japan recorded a proximity index of 1.14 with it.

In addition to these phenomena, there is the emergence of a vast North American science market, favoured particularly by the ratification of the North American Free Trade Agreement (NAFTA), on the heels of the coming into force on January 1, 1989 of the Canada-U.S. Free Trade Agreement (CAFTA). NAFTA, which bolsters technological protectionism and provides for the exemption from customs tariffs of high technology products manufactured or processed in the NAFTA member countries, should make it possible for its members to strengthen their competitive position in regard to other GATT countries. However, scientific exchanges between NAFTA members are still highly vectored or asymmetrical.

Of course, according to 1990 data, the United States accounts for more than 40% of Canada's scientific cooperation, while Canada accounts for 10.8% of American scientific cooperation. On the other hand, Mexico accounts for only a modest fraction of Canada's ISC (0.5%), while 6.4% of Mexico's scientific exchanges are with Canada. In other words, Canada and the United States form a solidly integrated scientific space, as confirmed by the proximity index for the two countries. Mexico has strong bonds with its northern neighbour: the United States accounts for nearly 45% of Mexico's total cooperation, while their common PRI is 2.25. In contrast, the Canada-Mexico PRI is only 1.27. In short, in this still unevenly balanced tripartite bloc, where the United States plays the role of an indispensable intermediary on which each of the other parties depends, bilateral arrangements still predominate.

3.3. Cooperation by economic zone

Using our initial database, which consists of the publications of 131 countries, we produced a matrix composed of the 73 foremost producing countries. For analysis purposes, these countries were grouped in three distinct economic zones: Zone 1, formed of so-called "large economy" countries, whose GDP is equal to or greater than US $ 500 billion; "medium-sized economies", or countries whose GDP is from US $ 100 billion to US $ 500 billion; and "small economies", a term designating countries whose GDP is below US $ 100 billion (see Table 4).

Table 4

Cooperation between the various economics zones, 1990

Zone 1: Large economies (G-7)

	Total coop.	Coop. zone 1%	Coop. zone 2%	Coop zone 3%
United-States	26 760	52.0	33.7	14.3
Japan	4 921	68.5	25.1	6.5
Germany	13 017	46.8	39.1	14.1
France	9 523	54.9	32.6	12.5
Italy	6 248	58.0	33.6	8.4
United-Kingdom	11 252	52.9	33.6	13.5
Canada	6 876	69.6	20.8	9.7
Total zone	78 597	54.7	32.8	12.6
Médiane		54.9	33.6	12.5

Zone 2: Medium-sized economies

	Total coop.	Coop. zone 1%	Coop. zone 2%	Coop. zone 3%
Total zone	38 350	67.2	29.8	3.0
Médiane		65.1	24.9	8.6

Zone 3: Small economies

	Total coop.	Coop. zone 1%	Coop. zone 2%	Coop. zone 3%
Total zone	14 957	65.8	26.5	7.7
Médiane		64.5	22.6	9.4

In the absence of a satisfactory conceptual framework for the grouping of countries on the basis of a number of bias-free, discriminating criteria adapted to the formation of mutually exclusive zones, we opted for a "neutral" classification linked systematically to the economic size of the different countries. Although each zone thereby constituted is homogeneous as a whole according to the level of scientific development of the various countries in it, there may subsist certain national development disparities within a zone, particularly in the case of the so-called "medium-sized economies". However, these few cases have only a marginal impact on the whole of the results within the zone.

The member countries of the G-7, which make up the so-called "large economy" zone, account for 59.6% of all collaborations, whereas the share of "medium-sized economies" total 29.1% and that of "small economies" is 11.3%.

Three main conclusions may be drawn from the data in Table 4: *firstly*, intra-zone scientific cooperation is proportionate to the relative weight of each of the zones in the whole of transnational cooperation. The G-7 countries carry out 54.7% of the ISC within their zone. The intra-zone cooperation of countries in the "medium-size economies" group accounts for 29.8% of their international scientific exchanges. Lastly, the countries in Zone 3 carry out 7.7% of their ISC with countries in their own zone. Hence, the greater the dependency of countries in the economically advanced zones, the more the local scientific infrastructures will lack the necessary or adequate resources. Scientists in countries with less developed economies "are likely to find few, if any, colleagues in their own country".[28]

Secondly, because of its weight within the world scientific system, the G-7 is a dominant partner of all the zones, if not of all countries taken singly. The countries in Zone 2, which is constituted for the most part by advanced European countries or countries with a relatively organized scientific infrastructure, carry out more than 67% of their ISC with the G-7 countries, while this proportion falls to 65.8% in the countries in Zone 3. These results cannot simply be an artifact of the SCI database, which is said to underrepresent Third World countries.[29] Developing countries, many of which are in Zone 3, accounted for about 4% of world R & D in 1990, Africa's share being 0.25%.[30] This chronic underinvestment in research is a decisive factor in "technological dependency",[31] and a major obstacle to any independent scientific development. Cooperation with the G-7 accounts for more than 80% of the ISC of the following countries: Turkey, Algeria, Morocco, Cameroon, Tunisia, Ivory Coast and Jamaica, and for more than 70% of the ISC of such countries as South Africa, Yugoslavia, Egypt, Peru, Panama, Nigeria and Zambia. In contrast, for 25 of the 47 countries in Zone 3, intra-zone scientific cooperation accounts for less than 10% of their total cooperation. Among the 19 countries with medium-sized economies, only South Korea devotes less than 10% of its overall cooperation to intra-zone activities, and in 14 of these countries, intra-zone cooperation accounts for more than 20% of the ISC. In Zone 3, barely 8% of the 47 countries carry out at least 20% of their ISC within their own zone.

Thirdly, the scientific development of the small economies is almost completely determined by external forces, whose action is dictated primarily by the scientific communities of the major economic powers. In short, economic determining factors, the practical limits of which depend on national wealth as it were, seem to have more of a role to play in the formation of collaboration networks *worldwide* than geographical proximity or political or cultural affinities.

3.4. Dynamics of cooperation within major geopolitical units

In this section, the phenomenon of proximity (geographical, cultural or other) will be examined in more detail and the impact of the geopolitical environment on the constitution of transnational scientific networks will be measured. To this end, we have grouped a number of countries in three geopolitical units that are coherent from the standpoint of political alliances, geographical location, cultural affinities or economic bonds. These units consist of (1) the countries of the Triad (the United States, Japan and the European Economic Community, (2) the countries of the European Economic Community (EEC) and (3) the countries of the Nippo-Asiatic Zone (NAZ), constituted by Japan and the Four Lesser Dragons (Singapore, South Korea, Hong Kong and Taiwan).

3.4.1. The Triad.

The sign of a new model of global competitiveness, the Triad reflects[32] the emergence of a world market organized around three zones characterized by their wealth, level of technological development and capacity to form a central pole of reference for the internationalization process. According to 1990 data, the Triad accounts for more than 65% of the ISC (Table 5), i.e. a share equal to that recorded in 1985. In regard to cooperation within the Triad, it represents more than 11% of world cooperation. The Triad also accounts for nearly 71% of world cooperation in biomedical research and for more than 65% of cooperation in mathematics, physics and chemistry. A more detailed examination of the data reveals the existence of clearly asymmetrical relations between the EEC and the other members of the Triad. For example, the EEC conducts 22.8% of its ISC with the other Triad members; on the other hand, the Triad accounts for 67% of the national scientific exchanges of the United States and 70% of those of Japan.

US-EEC cooperation accounted for 20.5% of total EEC cooperation in 1990 and 25.4% in 1985. In contrast, the EEC accounts for 45.6% of US cooperation, compared with 43.7% in 1985. Japan-EEC cooperation accounts for 28% of the ISC of Japan, nearly 2% more than in 1985. Japan's proportion of Europe's cooperation remained almost completely stable between 1985 and 1990, a period during which the proportion rose from 2.4% to 2.9%.

The relative importance of the partners has evolved differently in Japan and the United States. The American share of Japanese cooperation rose from 7.4% to 7.6% between 1985 and 1986, while cooperation with the United States accounted for 41.8% of Japan's international cooperation in 1990, a decline of 5.2% since 1985.

The development of scientific cooperation among Triad members clearly shows that irregular economic growth or a disparity in the pace of economic change in Triad countries over the past decade has had decisive – and undoubtedly long-term – consequences for the relative strategic position of the main states, while marking the end of the dual hegemony from a scientific and economic standpoint.[33]

Nonetheless, as the statistics on articles coauthored internationally show, the Triad is still a compact, stable bloc on the world scientific exchange market. However, the strategic dominance of the United States seems to have been shattered: whereas the weight of Japan in world scientific cooperation remained stable between 1985 and 1990, that of the United States dropped by 3.1% and that of the EEC grew by 4.4%. The relative share of scientific exchanges with the United States decreased by 5.2% in Japan and by 4.9% in the EEC.

Table 5

Indicators of scientific cooperation in the Triad, 1990

	EEC				United-States				Japan			
	EEC COOP	%EEC COOP	%World COOP	COOP with Triad as a % of EEC COOP	USA COOP	%USA COOP	%World COOP	COOP with Triad as a % of USA COOP	Japan COOP	%Japan COOP	%World COOP	COOP with Triad as a % of Japan COOP
BIO	2991	5.0	32.5	18.2	1806	6.7	19.6	32.5	305	6.2	3.3	51.0
BIM	10030	16.7	43.4	28.5	5377	19.9	23.3	57.7	963	19.5	4.2	78.8
CHM	5792	9.6	46.4	17.7	1980	7.3	15.9	55.6	493	10.0	4.0	60.6
CLI	14424	24.0	8.8	23	6920	25.6	20.4	52.1	1197	24.2	3.5	73.2
TES	5639	9.4	43.4	26.3	2727	10.1	21.0	55.7	407	8.2	3.1	69.5
GET	2315	3.9	33.4	28	1690	6.2	24.4	43.6	358	7.2	5.2	63.4
MAT	1165	2.0	36.6	39	866	3.2	27.2	51.3	82	1.7	2.6	72.0
PHY	17630	29.4	47.9	19	5670	21.0	15.4	58.0	1135	23.0	3.1	70.0
Total	59986	100.0	43.3	22.8	27036	100.0	19.5	67.0	4940	100.0	3.6	70.0

3.4.2. The European Economic Community (EEC)

The European scientific community of 1990 counts increasingly on its own resources to ensure its technological and scientific development, on which its long-term competitiveness depends. It is true that beginning in the 1980s, directed R & D programs developed in the community framework extended, to the field of innovation, already established programs in the technological sectors of nuclear science, aerospace, space science and basic research.[34]

Table 6
Intra and extra scientific cooperation in the EEC, by field, 1985 and 1990

	EEC-World COOP	1985 Intra COOP	Extra COOP	EEC-World COOP	1990 Intra COOP	Extra COOP
BIO	1733	552	1181	2991	1096	1916
BIM	5018	1954	3064	10030	4476	5657
CHM	3152	1272	1880	5792	2830	3108
CLI	6776	2634	4142	14424	6632	7944
TES	2514	978	1536	5639	2452	3203
GET	1189	342	847	2315	914	1426
MAT	910	270	640	1165	388	792
PHY	7892	3150	4742	17630	8176	9710
TOTAL	29184	11152	18032	59986	26964	33756

	EEC-World COOP	1985 Intra COOP	Extra COOP	EEC-World COOP	1990 Intra COOP	Extra COOP
BIO	5.9	31.9	68.1	5.0	35.9	64.1
BIM	17.2	38.9	61.1	16.7	43.6	56.4
CHM	10.8	40.4	59.6	9.6	46.3	53.7
CLI	23.2	38.9	61.1	24.0	44.9	55.1
TES	8.6	38.9	61.1	9.4	43.2	56.8
GET	4.1	28.8	71.2	3.9	38.4	61.6
MAT	3.1	29.7	70.3	2.0	32.0	68.0
PHY	27.0	39.9	60.1	29.4	44.9	55.1
TOTAL	100.0	38.2	61.8	100.0	43.7	56.3

Europe now has the means to aspire to relative scientific independence: for example, it now accounts for more than half of world production in physics and chemistry, more than 40% of global activity in biomedical research, clinical medicine, earth and space sciences and mathematics. Just a few years after the adoption of the first European Framework Program covering the period from 1984–1987, which responded to the desire for a common independent research policy that would make it possible for Europe to adequately meet economic, industrial and technological challenges,[35] the share or intra-Community cooperation in the whole of the ISC of the Twelve of Europe rose from 38.2% to 43.7% between 1985 and 1990 (Table 6). In chemistry, more than 46% of EEC cooperation was with Community countries, compared with 40.4% in 1985. In physics and clinical medicine, the proportion approached 45%. In contrast, more than 68% of EEC research in mathematics was conducted in cooperation with countries outside the Community, while in biology, the proportion reached 64.1%. It is significant that the relative decline in extra-Community cooperation involves all research fields and that in engineering and technology the decline was about 11% in the five years observed.

Table 7
Intra and extra scientific cooperation in the EEC according to country, 1990

	Intra	Extra	Total coop.	% of coop. intra	% of Coop extra
DEU	4 634	9 265	13 899	33.3	66.7
GBR	4 559	6 821	11 380	40.1	59.9
FRA	4 229	5 489	9 718	43.5	56.5
NLD	3 812	3 920	7 732	49.3	50.7
ITA	2 901	3 397	6 298	46.1	53.9
ESP	1 773	1 368	3 141	56.4	43.6
BEL	1 814	1 147	2 961	61.3	38.7
DNK	1 050	1 306	2 356	44.6	55.4
PRT	641	372	1 013	63.3	36.7
GRC	516	480	996	51.8	48.2
IRL	290	189	479	60.5	39.5
LUX	11	2	13	84.6	15.4
Total	26 230	33 756	59 986	43.7	56.3

Table 7 illustrates the dynamics of European cooperation with the various member countries of the EEC. Germany is conspicuous in that only one-third of its cooperation was conducted with EEC countries. This result, the lowest among the Twelve, is explained in particular by the extent of relations between the former Democratic Republic of Germany and Comecon members. Cooperation with these countries accounted for 16% of Germany's total cooperation. Intra-Community cooperation of the former GDR and the Federal Republic of Germany before reunification accounted for 17,5% and 36.7%, respectively, of their total ISC.

It will be noted that intra-Community cooperation accounts for proportionately more in the small European countries (Luxembourg, Portugal, Belgium, Ireland and Spain) and in the United Kingdom, the recalcitrant partner of the EEC. Less able than the major countries of the EEC to become involved in non-European cooperation projects, the small EEC states seem proportionately better integrated into the EEC scientific networks.

Table 8, which profiles exchanges between EEC countries on the basis of PRIs, clearly shows the EEC's continental solidarity. The United Kingdom, which is particularly close to Ireland (3.03), has intensive relations, all things being equal, with the smaller EEC countries in terms of scientific activity, i.e. with Portugal (2.18), Greece (1.41) and Spain (1.40). However, the PRI for cooperation with the Netherlands is 1.33.

The foremost scientific player of the EEC, Germany maintains close relations, as France does, with Luxembourg (3.84), and with such other small countries as the Netherlands (1.33) and Denmark (1.42), whose research effort is particularly intensive on a European and world scale. In addition to Luxembourg (4.39), France has close ties with Belgium (2.07) and Spain (2.05), its immediate neighbours, and with Portugal (1.59) and Italy. Maintaining close relations with Spain (1.72), France (1.38) and Greece (1.35), Italy is also a relatively important partner of the United Kingdom (1.28). The Netherlands, which is relatively less involved in cooperation with the small scientific communities of the European continent, gives priority to relations with Belgium, but also with Ireland (1.57), the United Kingdom and Germany (1.33).

Table 8
Proximity Index (PRI) in EEC Countries, 1990

	GBR	DEU	FRA	ITA	NLD	ESP	BEL	DNK	PRT	GRC	IRL	LUX
GBR		0.80	1.00	1.28	1.33	1.40	0.97	1.24	2.18	1.41	3.03	
DEU	0.80		1.03	0.95	1.33	0.95	0.85	1.42	0.98	1.06	0.92	3.84
FRA	1.00	1.03		1.38	1.02	2.05	2.07	0.82	1.59	1.43	0.95	4.39
ITA	1.28	0.95	1.38		1.13	1.72	1.16	1.06	1.06	1.35	0.41	
NLD	1.33	1.33	1.02	1.13		1.01	3.28	1.14	0.80	0.40	1.57	
ESP	1.40	0.95	2.05	1.72	1.01		0.94	1.08	3.01	1.60	1.01	
BEL	0.97	0.85	2.07	1.16	3.28	0.94		1.03	1.94	1.27	1.17	7.20
DNK	1.24	1.42	0.82	1.06	1.14	1.08	1.03		1.16	1.83	1.60	
PRT	2.18	0.98	1.59	1.06	0.80	3.01	1.94	1.16		2.20	1.71	
GRC	1.41	1.06	1.43	1.35	0.40	1.60	1.27	1.83	2.20		0.58	
IRL	3.03	0.92	0.95	0.41	1.57	1.01	1.17	1.60	1.71	0.58		
LUX		3.84	4.39				7.20					

Table 9
Scientific cooperation between countries in the Nippo-Asiatic Zone (NAZ) and the world, 1990

	Total COOP	% of the NAZ	Intra NAZ COOP	% Total COOP
Japan	4 938	78.9	163	3.3
Taiwan	501	8.0	67	13.4
South Korea	427	6.8	98	23.0
Hong-Kong	234	3.7	29	12.4
Singapore	156	2.5	25	16.0
Total	6 256	100.0	382	6.1

3.5. The Nippo-Asiatic Zone (NAZ)

The rapid and spectacular industrialization of the newly industrialized countries (NICs) beginning in the 1970s not only made it possible to create a true "technological complex" in these countries, but also to arouse growing interest abroad in the scientific progress achieved there. In fact, bibliometric indicators show a real explosion of mainstream scientific production in these countries.[36]

Does this emergence of the NICs on the international scientific scene, inasmuch as it reflects greater dependency or subjection to the international imperatives[37] of world-science, which tends to limit certain non-conformist behaviour, as *Price* has shown,[38] favour the weakening of local or regional collaboration networks or will they remain dynamic exchange networks?

The NAZ consists of Japan and four newly industrialized countries, also known as the Four Lesser Dragons: Taiwan, South Korea, Hong Kong and Singapore. Japan, which accounts for nearly 80% of the ISC of the NAZ (Table 9), is undeniably the dominant player in this zone, followed by Taiwan (8%), South Korea (6.8%), Hong Kong (3.7%) and Singapore (2.5%).

The technological leader in this region of the world, Japan still maintains rather tenuous ties with the NAZ countries. Its affinity index (AFI) with this zone is only 3.3%. On the other hand, the AFI of South Korea with regard to the NAZ is 23%, while the AFI of Singapore is 16%. The indexes for Taiwan (13.4%) and Hong Kong (12.4%) are twice as high as the index for the whole of the NAZ (6.1%).

In regard to scientific cooperation within the NAZ, the statistics yield contradictory results. Table 10 shows, first of all, the lack of apparent affinity among the NAZ countries, despite their geographic proximity, cultural and political bonds, and similar economic and scientific concerns. South Korea accounts for less than 2% of the ISC of Japan. Taiwan carries out 10.2% of its cooperation with Japan, but less than 2% with the other NAZ countries. South Korea maintains major links with Japan, which accounts for nearly 22% of its ISC, but has practically no relations with the other Lesser Dragons. Hong Kong carries out approximately 4% of its cooperation with each of the countries in the zone, with the exception of South Korea. Lastly, Singapore gives priority to exchanges with Japan (2.6%) and South Korea (1.6%).

Table 10
Scientific cooperation within the NAZ, as a % of total cooperation of each country, 1990

	Japan	Taiwan	South Korea	Hong-Kong	Singapore	NAZ Total
Japan		1.0	1.9	0.2	0.2	3.3
Taiwan	10.2		0.6	1.8	0.8	13.4
South Korea	21.8	0.7		0.5	0.0	23.0
Hong-Kong	3.4	3.9	0.9		4.3	12.4
Singapore	7.1	2.6	0.0	6.4		16.0
NAZ Total	2.6	1.1	1.6	0.5	0.4	6.1

However, calculation of the proximity index suggests that this judgement is true only to a certain degree, as shown in Table 11. According to this table, NAZ countries are closer to each other, given their respective relative weight in world scientific cooperation, than indicated by the affinity indexes. According to the PRI, the NAZ is highly integrated from a scientific standpoint. Although the proximity index between Japan and Hong Kong is indeed fragile, the PRI for Japan with Korea is 6.11 and that with Taiwan is 2.86. While Hong Kong and Taiwan, and Singapore and Taiwan seem singularly linked to one another, Hong Kong and Singapore form a truly interconnected unit.

Japan, which accounts for nearly 43% of total intra-zone cooperation (IZC) in this region, carries out more than half of the IZC in engineering and technology and in the earth and space sciences. Japanese cooperation as a proportion of IZC represents nearly 50% in physics, but accounts for barely 18% in mathematics, while South Korea accounts for nearly 63.4% (Table 12).

Table 11
Proximity Index (PRI) in the NAZ, 1990

	Japan	Taiwan	South Korea	Hong Kong	Singapore
Japan	–	2.86	6.11	0.96	1.98
Taiwan	2.86	–	1.94	10.64	7.09
South Korea	6.11	1.94	–	2.77	–
Hong Kong	0.96	10.64	2.77	–	37.98
Singapore	1.98	7.09	–	37.98	–

On the other hand, as a proportion of all its cooperation, Japan conducts its priority scientific exchanges with the NAZ countries in biology (7.54%), engineering and technology (5.6%) and chemistry (5.07%).

Taiwan stands out in intra-zone cooperation in biology (28% of the total IZC in this field), chemistry (24.2%) and clinical medicine (22.3%). Its IZC is specialized in chemistry, which accounts for 36.6% of Taiwan's total cooperation with the world, and in biology (26.9%) and clinical medicine (22.3%).

Besides mathematics, South Korea excels mainly in physics, where it accounts for nearly 45% of the IZC in the Nippo-Asiatic Zone, as well as in engineering and technology (28.2%). Of all the countries in this zone, it is the one in which intra-zone cooperation in all fields, with the exception of chemistry, remains greatest as a proportion of its total cooperation. In half the research fields (CLI, BIO, CHM, MAT), its IZC accounts for at least 35% of its entire cooperation.

In contrast, IZC in chemistry and mathematics alone accounts for at least one-fourth of Hong Kong's total cooperation. Like Korea, Hong Kong accounts for 25% of the intra-zone cooperation of the NAZ in the earth and space sciences. The last country in this zone in numerical importance, Singapore nevertheless accounts for 12% of IZC in biomedical research and nearly 10% in clinical medicine, although as a proportion of its total cooperation, it is biology (27.3%) that accounts for the largest proportion of its IZC, followed by clinical medicine (21.6%), and chemistry and physics (20%).

Table 12
Scientific cooperation in the NAZ, by field, 1990

		CLI	BIM	BIO	CHM	PHY	TES	GET	MAT	Total
	Total coop.	1195	963	305	493	1135	407	358	82	4938
Japan	Intra NAZ coop.	41	20	23	25	26	6	20	2	163
	1	24.20	19.5	6.18	9.98	22.99	6.24	7.25	1.66	100.00
	2	36.61	47.62	46.0	40.32	48.15	50.0	51.28	18.18	42.67
	3	3.43	2.08	7.54	5.07	2.29	1.47	5.59	2.44	3.30
	Total coop.	112	58	52	41	109	26	63	40	501
Taiwan	Intra NAZ coop.	25	7	14	15	2	0	3	1	67
	1	22.36	11.58	10.38	8.18	21.76	5.19	12.57	7.98	100.00
	2	22.32	16.67	28.00	24.19	3.70	0.00	7.69	9.09	17.54
	3	22.32	12.07	26.92	36.59	1.83	0.00	4.76	2.50	13.37
	Total coop.	65	43	27	51	110	18	85	28	427
South Korea	Intra NAZ coop.	21	9	9	14	24	3	11	7	98
	1	15.22	10.07	6.32	11.94	25.76	4.22	19.91	6.56	100.00
	2	18.75	21.43	18.00	22.58	44.44	25.00	28.21	63.64	25.65
	3	32.31	20.93	33.33	27.45	21.82	16.67	12.94	25.00	22.95
	Total coop.	85	20	11	24	30	22	38	4	234
Hong-Kong	Intra NAZ coop.	14	1	1	6	1	3	2	1	29
	1	36.32	8.55	4.70	10.26	12.82	9.40	16.24	1.71	100.00
	2	12.50	2.38	2.00	9.68	1.85	25.00	5.13	9.09	7.59
	3	16.47	5.00	9.09	25.00	3.33	13.64	5.26	25.00	12.39
	Total coop.	51	37	11	10	5	4	28	10	156
Singapore	Intra NAZ coop.	11	5	3	2	1	0	3	0	25
	1	32.69	23.72	7.05	6.41	3.21	2.56	17.95	6.41	100.00
	2	9.82	11.90	6.00	3.23	1.85	0.00	7.69	0.00	6.54
	3	21.57	13.51	27.27	20.00	20.00	0.00	10.71	0.00	16.03
	Total coop.	1508	1121	406	619	1389	477	572	164	6256
NAZ Total	Intra NAZ coop.	112	42	50	62	54	12	39	11	382
	1	24.10	17.92	6.49	9.89	22.20	7.62	9.14	2.62	100.00
	2	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
	3	7.43	3.75	12.32	10.02	3.89	2.52	6.82	6.71	6.11

1: Distribution by field of the country's IZC.
2: Country's share in IZC total, by field.
3: Intra-zone cooperation as a % of total cooperation of country.

Conclusions

The proliferation of bonds of dependency has shown the inadequacy of bilateral scientific relations. EUREKA-type multilateral scientific programs are indeed the product of a new world scientific order. This new order, as we have tried to illustrate, is no longer based on a classic centre/periphery asymmetry. In less than a quarter of a century, the unicity, it not the universality of the "centre", has gradually disappeared. The old scientific order, which required a stable central hegemony, long embodied by the sovereign authority of the United States, has given way to centres of gravity and coherence organized on a continental scale – North America, Europe, Asia and so on – or on an intercontinental scale – the Triad.[39] These network centres, which are true clusters of nations whose composition is, in some cases, heterogeneous, are formed on the basis of various affinities and often act from a distance. This is, indeed, true *collectivization* of the centre, whose fulcrum, which has shifted, is vague, for collectivization of the centre also means the gradual dissolution of a centre of gravity with strictly national borders. Thus, paradoxically, one could say that the world-science contemplated by some is essentially a "denationalization" process, this global science being in fact coexistence with the nation state.[40] This shift has been to the benefit of a "network centre", which establishes its own system of exchange. The need for still greater integration into a unified global network of scientific exchanges seems to have as a corollary a continental fragmentation of the players, as if a regionalized or continentalized world-science were gradually being built.

For countries that are more or less dependent, the collectivization of the centre means the rejection of a traditional model for the establishment of relations based on the vertical stratification[41] of relations between the "centre" and the "periphery". Of course, countries are not evenly matched, but within the new scientific frontiers, being on the periphery of science no longer necessarily means exclusion from scientific networks. In fact, world-science is characterized by the advent of a true "continentalization"[42] of world research.

The spectacular result of this "continentalization" of science is the relativization of the United States' position in the regulation of scientific activity throughout the world. Nonetheless, the United States is clearly one of the strategic poles in a world-science left to the contradictory currents of forces increasingly aspiring to autonomy. Now playing the role of *primus inter pares*, the United States is, without a doubt, no longer in a position to demand its former scientific supremacy. It still has, however, the capacity to weigh decisively in the strategic choices of a technical and scientific nature made by the advanced countries of the G-7 or the *Triad*, and as a corollary, in the decisions of developing economies.

Far from theoretical, this capacity has materialized through the dominant weight of the United States in the international cooperation of most countries, whether industrialized or not. In short, because of its absolute weight, the United States has remained a scientific power whose strategic capacity is still dominant in a multipolarized world-science. This capacity is even more vital for the United States since the European technological supply, which is growing in significance, is in a position to, in turn, affect America's internal choices and to modify its priorities as well as its future successes.

The inequality of the players is also a decisive factor in the establishment of exchanges within the various regional science markets, since the force of attraction of each State is naturally very different from that of other states. The ability to substitute more symmetrical relations between countries for traditionally "vectorized" exchanges could prove essential in pursuing harmonious and durable scientific relations within such geopolitical blocs as NAFTA, in which such dissimilar countries in terms of economic size find themselves compelled to engage in bilateral collaboration where multilateral cooperation would, collectively, be more effective.

Among the other notable consequences of the transnational extension of science, the formation of vast subcontinental exchange networks can certainly be underscored. In the context of a world-science in which roles are redistributed according to the competitive capacities of each of the countries or blocs, the historical determining factors nonetheless continue to predominate in certain countries, in some cases contrary to economic logic. Built on the ruins of the splintered Soviet Empire, the network of Eastern European countries is still, for the time being, outside the competitive science market, to which it is linked, in a still fragile manner, by a quasi-unique bond.

But economic logic continues to gain ground in scientific relations, as witnessed by the ascendency of the G-7 in the flow of world scientific exchanges, despite political conflicts, distance, linguistic barriers, cultural differences and development disparities. Why is it surprising that there is more coauthorship, as *Price*[43] has shown, in a relation of economic dependency than in one of intellectual dependency, which forces major groups of researchers to produce fractional papers only, rather than truly significant full papers.

Although the imperatives of power and wealth mould relations within the Triad, geography and culture provide the best explanation for the formation of an autonomous Scandinavian bloc in a Europe where all forces tend toward unification. In the same way, the Nippo-Asiatic Zone is emerging as a new «archipelago of science»,[44] still closely bound to the main scientific axes, but already on the way to continental integration.

In a new national environment broadened to continental dimensions, Europe tends to anchor its scientific activity more and more solidly in a Community framework. In short, it appears that there and elsewhere, the challenge of globalization, which consists in occupying a competitive scientific position on world markets, cannot be effectively met unless there is a continental foundation, which alone can create economies of scale that foster competitiveness. Hence, globalization could be interpreted as a paradoxical form of national expansionism, for national independence is inseparable from the capacity to operate on the scale of several countries, from a transnational base responsible for the regulation and expansion of the flow of scientific information. Therefore, it is less a question of the end of national scientific activity than one of the geographic extension of the nation, whose objectives – which have become extremely difficult to define because of internationalization[45] – if not its very scientific infrastructure, are being deliberately integrated into those of a strategic continental network.

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The authors would like to acknowledge the assistance of *Daniel Moreau* in many parts of this study.

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Appendix

ISO codes used for countries in study sample

AUS	=	Australia
BEL	=	Belgium
CAN	=	Canada
CIS	=	Commonwealth of Independent States
DEU	=	Germany
DNK	=	Denmark
ESP	=	Spain
FRA	=	France
GBR	=	United Kingdom
GRC	=	Greece
IRL	=	Ireland
ITA	=	Italy
LUX	=	Luxembourg
NLD	=	Netherlands
PRT	=	Portugal
USA	=	United States