EUROPEANISATION OF SCIENCE

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ABSTRACT
Data from the Science Citation Index on scientific collaborations within and between European countries are used to address the question of whether the European science system is integrating over time. It is argued that a simple comparison of the number of national collaborations and European collaborations is misleading as a means of analysing European integration, as this procedure does not control for differences in countries' sizes. The larger a country, the more collaboration is expected to be oriented nationally because there are more opportunities to interact within the national borders. An alternative statistical analysis is proposed that compares the observed propensities to collaborate with the propensities that would occur when partner selection is random. The results show that, typically, larger countries are better integrated in the European system when size is controlled for, which suggests that scale advantages render larger countries more attractive partners than smaller countries.

Key words: Research collaboration, knowledge production, European integration, localisation, network externalities, science policy

INTRODUCTION

Academic science is often regarded as a prime example of the increasing globalisation of human interaction. Due to the high degree of codification of scientific knowledge, the increased mobility of researchers, and the use of electronic communication systems, scientists are able to collaborate on a worldwide scale. Part of this process, with which we are concerned here, concerns the Europeanisation of science. Collaborative networks of scientists within the EU have proliferated rapidly in recent times, and the further enhancement of these networks has become a cornerstone of EU science policy. An important question is how to assess quantitatively the process of Europeanisation in science.

In this study, it is argued that a simple count of the number of collaborations between European countries is a misleading procedure to indicate European integration. What is needed is an indicator that relates the propensities of scientists to collaborate in European networks to the propensities of scientists to collaborate in national networks. It is argued that only by controlling for differences in countries' sizes, can a comprehensive indicator of Europeanisation be developed.

EUROPEAN COLLABORATION IN SCIENCE

Following a more general trend of research collaboration in science, European countries increasingly collaborate in scientific research projects. Collaboration is achieved through a variety of mechanisms including joint finance of research infrastructures, training and mobility programmes of researchers, and most importantly through joint research projects involving several European research institutes.

Researchers expect a mutual benefit from collaborations, which include combining complementary knowledge inputs, a wider diffusion of results, and a higher level of quality control (Katz & Martin 1997).

Historically, the institutionalisation of joint research initially emerged from inter-governmental programmes of European countries (Banchoff, 2002; Leydesdorff 2003). Only more recently has the enhancement of research collaboration become a primary goal of EU science policy. In particular, Framework Programmes have been set up to stimulate European research in designated areas as well as training and mobility programmes for individual researchers. One would expect these efforts to have contributed to the integration of the European research system. However, the emergence of a more integrated system remains an empirical question. The answer to this question thus provides important information to assess the success and failures of European science policy with regard to the integration of national research systems into a European one.

Data – In quantitative studies of the development of science, research collaboration is generally indicated by publications that contain multiple addresses referring to participating institutes. In the large majority of studies data are taken from the Science Citation Index (SCI). This database covers all major journals in natural and life sciences, and can be used to retrieve address information on the institutes that contributed to a publication. Note that addresses refer to institutes and not to individual researchers. Co-occurrences of addresses in publications records thus refer to inter-institutional collaborations and not to co-authorships (Katz & Martin 1997).[1]

The data on country–country research collaboration are selected from the SCI by taking into account only the first three addresses listed (for computational reasons). A national collaboration is counted each time a country name occurs twice in a publication record while a EU collaboration is counted each time two EU countries are co-occurring in a publication record. This gives us a sample of observed propensities for each country to collaborate either nationally or within the EU.

Descriptive statistics – Using the data gathering procedure as outlined above, we collected data for eight years during 1993–2000. As it becomes clear from the descriptive statistics as given in Table 1, the number of EU collaborations has increased rapidly and consistently during the period considered. The rise from 16,715 collaborations among EU countries in 1993 to 30,306 collaborations in 2000 implies an increase of 81% in eight years.

The explosive rise in the number of European collaborations does not provide in itself any indication of the 'Europeanisation' of science. A first step to come to a measurement of Europeanisation is to take into account the rise in national collaborations to control for the general increase in collaboration as a structural phenomenon in science. Table 1 shows that the number of national collaborations also increased rapidly, but at a lower rate than EU collaborations. The number of

Table 1. *Descriptive statistics of the sample drawn from the Science Citation Index*

Year	Inter-EU (1)	National (2)	Total EU (3) (3) = (1) + (2)	Fraction (4) (4) = (2)/(3)
1993	33,430	210,540	243,970	0.863
1994	36,536	227,042	263,578	0.861
1995	40,960	248,266	289,226	0.858
1996	45,660	264,868	310,528	0.853
1997	49,986	282,412	332,398	0.850
1998	55,216	302,754	357,970	0.846
1999	58,466	312,466	370,932	0.842
2000	60,612	314,944	375,556	0.839

national collaborations within EU countries increased from 210,540 to 314,944, an increase of almost 50% over the eight years. Thus, the number of national collaborations as a fraction of both EU and national collaborations fell from 0.863 in 1993 to 0.839 in 2000. Put another way, the share of inter-European collaborations rose by 2.4% during 1993–2000.

When we look at the relative share of national collaborations as a fraction of all collaborations for each EU member state in Figure 1, it becomes clear that the relative share of national collaborations has decreased in most countries.[2] Interestingly, larger countries tend to collaborate more often within the national boundaries compared to smaller countries (though exceptions exist). These results are consistent with another study that correlated the number of international collaborations to country size to test for a power-law relationship (Katz 2000). It was found that country size correlates negatively to the propensity to collaborate internationally, which means that smaller countries collaborate relatively more often internationally than larger countries.

The argument being made in this study holds that the propensities to collaborate either nationally or within the EU 'naturally' differ between countries dependent on countries' size. Larger countries are statistically expected to collaborate more often at the national level compared to smaller countries, because a larger number of research institutes exist to interact with at the national level. The low EU participation rate of the larger countries and the high EU participation rate of smaller countries should not be a surprise. An indicator of integration should therefore control for differences in size to give a more comprehensive picture of the integration of countries within the EU.

MEASURING NATIONAL BIASES

The descriptive statistics show that both the absolute and relative number of collaborations between European research institutes has consistently grown over 1993–2000. The relative number of EU participations has also grown for the large majority of individual Member States. However, these results cannot be considered to provide sufficient proof that European integration has indeed occurred. Since larger countries are expected to collaborate more often nationally, one is in need of
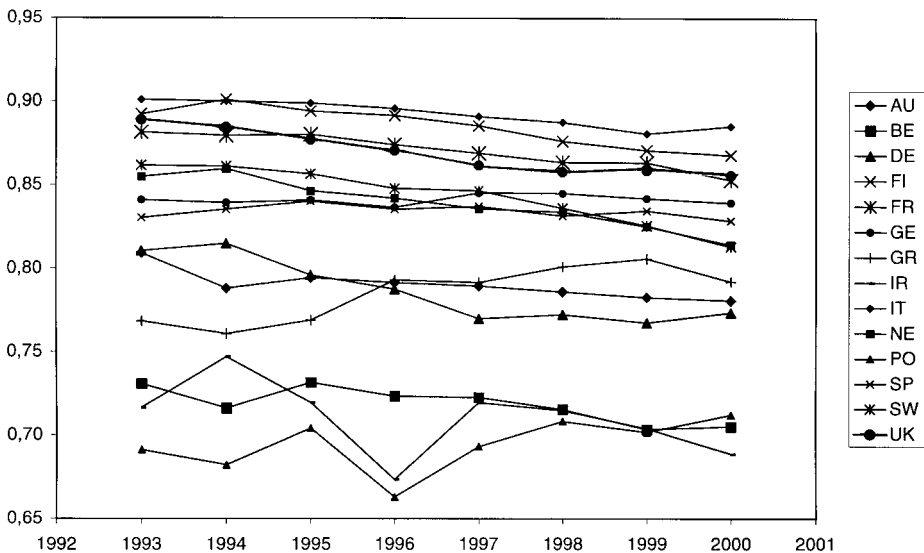

Figure 1. *Number of national collaborations as a fraction of the total number of collaborations of a country (Luxembourg not shown).*

an indicator that controls for differences in country size. Such an indicator can be derived from a comparison of the observed propensities to collaborate nationally and within the EU to the hypothetical propensities that would have occurred when the selection of a national or European partner in research collaboration is random (Frenken 2002).

Controlling for country size – Let q_i ($i = 1,...,15$) be the size of country i. Size is simply measured by the number of both national and EU collaborations in which country i is involved as a fraction of all national and EU collaborations. From the size of a country one can readily derive the hypothetical propensity to collaborate nationally and to collaborate with other EU countries when the selection of a partner within the whole of the EU would be random. Random choice of partner by country i implies that the probability that partner selection results in a national collaboration equals q_i^2 and the probability that partner selection results in an EU collaboration thus equals $q_i \times (1 - q_i)$. Comparing the random probability of national collaboration with the observed frequencies of national collaboration indicates the bias of research institutes in country i to collaborate nationally.

Example – Consider the UK and Portugal in 1993. The UK was involved in 46,664 national collaborations and 5,831 EU collaborations, totalling 52,495 collaborations. The total number of all national and EU collaborations in 1993 equalled 243,970, which implies that the relative size of the UK equalled (52,495/243,970) = 0.21517. Random partner selection by UK research institutes would have resulted in $(0.21517)^2 \times 243,970 = 11,295.3$ national collaborations, which is less than the observed 46,664 national collaborations. The UK bias to collaborate nationally can be expressed by dividing the observed number of national collaborations by the number of random national collaborations: (46,664/112,95.3) = 4.131. This indicator means that in 1993 the UK research institutes collaborated 4.131 times more often at the national level than they would have if partner selection had been random.

Considering Portugal, its relative size equalled only (1,357/243,970) = 0.005562 in 1993. Cor-respondingly, random partner selection would mean that the Portuguese would engage in only $(0.0056)^2 \times 243,970 = 7.55$ national collaborations. The observed number of national collaborations in Portugal in 1993 equalled 938, which means that Portuguese research institutes showed a bias to collaborate nationally of (938/7.55) = 124.3. In other words, they tended to collaborate nationally 124.3 times more often compared to the hypothetical case in which partner selection would have occurred randomly. Following this reasoning, the UK was far better integrated within the EU in 1993 compared to Portugal, contrary to what is suggested by Figure 1.

Results – We repeated this analysis for all 15 EU Member States and for all eight years. The results are plotted in Figure 2 for the set of seven countries with the lowest bias (using a range of 0–20) and in Figure 3 for the set of seven countries with the highest bias (using a range of 20–140). The bias values show a very different picture compared to the results on the shifts in shares of national collaborations in Figure 1.

The bias to collaborate nationally, now controlled for country size, turns out to be lowest for the largest countries. The six largest countries, UK, France, Germany, Italy, The Netherlands and Spain, have the lowest bias values. And the three smallest countries (after Luxembourg), Ireland, Portugal and Greece, have the highest bias values to collaborate nationally. This finding points to the fact that the analysis of shares of national collaboration in Figure 1 is misleading as an inverse indicator of integration. When one controls for the differences in the *expected* propensity to collaborate nationally depending on country size, larger countries prove to be less oriented towards the national level and thus to be better integrated in the European system.

What this result suggests is that scale effects favour the involvement of larger countries in European research collaborations. One possible explanation for the existence of scale advantages holds that the large scale of research in larger countries allows them to be more specialised and to invest in specialised research infrastructures, thus attracting researchers from foreign countries. Furthermore, larger
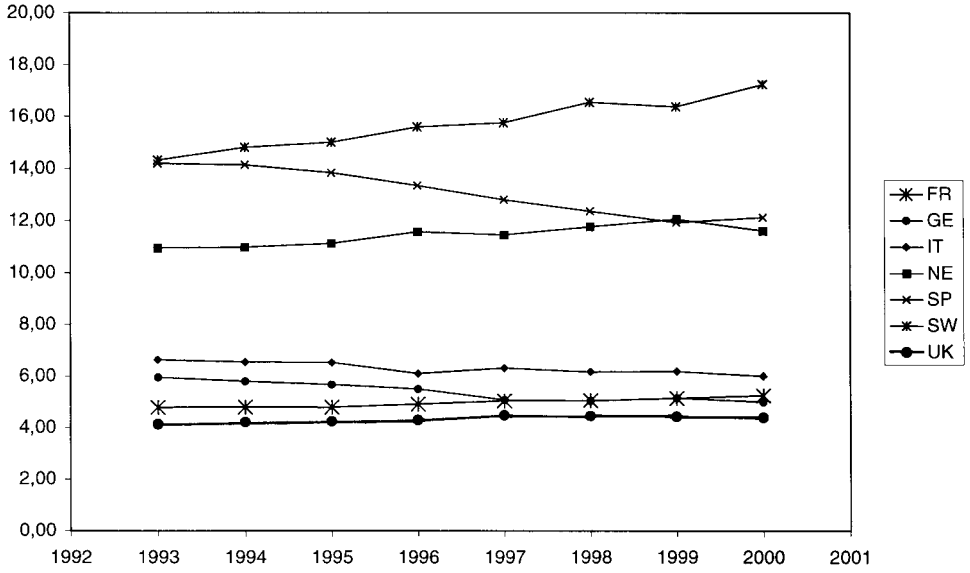
Figure 2. *Indicators of bias to collaborate nationally in the range 0–20 (France, Germany, Italy, The Netherlands, Spain, Sweden, UK).*
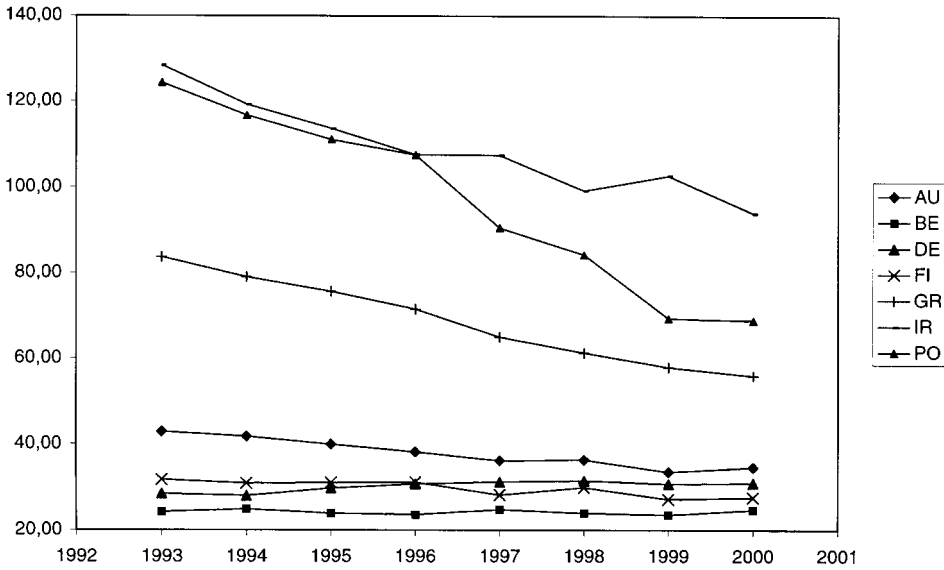

Figure. 3. *Indicators of bias to collaborate nationally in the range 20–140 (Austria, Belgium, Denmark, Finland, Greece, Ireland, Portugal).*

countries in Europe are expected to benefit from their network externalities stemming from their natural languages, which are being spoken more often outside their borders (Arthur, 1989; cf. De Swaan, 2001).

When compared, the bias values of countries and the rank size of countries, do not, however, give a perfect match. Scale does not 'determine' integration. To give one example, Belgium is smaller than Finland in terms of share of collaborations, but Belgium research institutes have a lower bias to collaborate nationally compared to Swedish research institutes.

A second conclusion that can be drawn from the results is the fact that the most peripheral countries have lowered their national bias at a rapid pace. Ireland, Portugal, Greece, Austria and Finland all show a consistent decreasing trend in their bias levels. This result indicates that research institutes in these countries have been increasingly successful in aligning to European networks previously dominated by the larger countries. Moreover, as the data refer to publication (rather than projects), these collaborations have proven successful in that they have resulted in output in international journals listed in the SCI.

A third observation that can be made from the trends in bias of countries is that, though most countries show a decreasing bias to collaborate nationally, some countries show an increasing bias over time to collaborate nationally (Denmark, Sweden, The Netherlands, France). Compared to other countries that increasingly contribute to Europeanisation of science, these three countries appear deviant. These anomalies deserve further research. For example, it may be that national science policy has successfully enhanced collaboration at the national level, which explains why the bias towards national partners has increased. A case in point is the recent establishment of national research schools in the Netherlands, which has been actively promoted by the national government.

DISCUSSION

A simple comparison of the number of national collaborations and EU collaborations is misleading as a way to analyse European integration and to assess which countries are most integrated in the European science system. These indices do not control for difference in countries' sizes. Larger countries are expected to be less oriented towards foreign countries as there are more opportunities to interact within national borders. Similarly, so-called globalisation indices typically find smaller countries to be most globalised, but also do not control for differences in size (Kearney 2001).

An alternative analysis has been proposed, which compares the observed propensities to collaborate nationally with the propensity that would occur when partner selection in the EU would have been random. The results show that, typically, the larger countries are better integrated in the European system as evidenced by the lowest bias values to collaborate nationally, when size is controlled for. This principle can be further generalised for country–country matrices of research collaborations to understand the network structure within the EU as has been done by Frenken (2002).[3]

From a policy perspective, the results have shown that although larger countries are better integrated, smaller and peripheral countries tend to have reduced their national orientation over time. This suggests that the scale effect favouring the involvement of large countries in research collaboration has become less important over time. Smaller countries 'catch up' in terms of their involvement in European collaboration.

Theoretically, however, one is still in need of a satisfactory explanation of why larger countries have a persistently smaller bias to collaborate nationally. Hitherto, very little theoretical work has been done on the rationales of international research collaboration, and thus provides a promising research avenue (Wagner 2002). One possible explanation is that scale advantages are operating, causing larger countries to be more often involved in EU collaboration. Some suggestions of why scale effects have been given above, yet without further theoretical elaboration. Only when there are available sufficiently well-developed explanations for these differences, can more sophisticated science policies be developed that aim at integrating all participating countries.

Notes

1. Note that national collaborations refer to publications containing two addresses of two research institutes from the same country. It does not mean that the researchers involved in the national project have the same nationality. It may well be the case that national projects involve researchers from different EU countries. An analysis of the mobility of researchers within and between EU member states would complement the analysis on inter-institutional collaboration presented here.

2. EU member states concern Austria (AU), Belgium (BE), Denmark (DE), Finland (FI), France (FR), Germany (GE), Greece (GR), Ireland (IR), Italy (IT), Luxembourg (LU), The Netherlands (NE), Portugal (PO), Spain (SP), Sweden (SW), and United Kingdom (UK). Luxembourg is not shown in the figures.

3. Note that the indicator of national bias can equally be used to other social domains including labour market mobility, traffic flows, and economic trade data. Furthermore, the indicator can also be used to lower-level geographical units of analyses (regions within a country or cities within a region) as well as to higher-level geographical units (for example, continents within the world).

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