UNIVERSIDAD CARLOS III DE MADRID working papers

Working Paper
Economic Series 12-11
April 2012

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FROM THE *"EUROPEAN PARADOX"* TO A EUROPEAN DRAMA IN CITATION IMPACT

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Abstract

This paper has two main aims: (i) to criticize the diagnosis about the research performance of the EU contained in the so-called "*European Paradox*", according to which Europe plays a leading world role in terms of scientific excellence, but lacks the entrepreneurial capacity of the U.S. to transform this excellence into innovation, growth, and jobs; and (ii) to study the heterogeneity among the 15 member countries of the EU prior to the 2004 accession. For the first aim, we use a Thomson Scientific dataset with 3.6 million articles published in 1998-2002 with a five-year citation window, and a partition of the world into three large geographical areas including the U.S., the EU, and the rest of the world. For the second aim, we use a dataset with 800,000 articles more published in 2003, and a partition of the world into 38 countries and eight geographical areas. The main results are the following two. Firstly, the European Paradox hides a truly *European Drama*: judging from citation impact in the periodical literature, the dominance of the U.S. over the EU is almost universal at all aggregation levels. Secondly, since the UK and six small European countries (Austria, Belgium, Denmark, Finland, Netherlands, and Sweden) perform relatively well, the explanation of this European Drama must be found in the relative poor performance of Germany and France and, above all, Italy and Spain among the four larger continental countries.

JEL Classification: 031, Y80 and Z00

Keywords: citation analysis, Web of Science categories, journal classification, research performance, normalization, European Paradox

Acknowledgements

The author acknowledges financial support from the Santander Universities Global Division of *Banco Santander*, as well as from the Spanish MEC through grant SEJ2007-67436. This paper is part of the SCIFI-GLOW Collaborative Project supported by the European Commission's Seventh Research Framework Programme, Contract number SSH7-CT-2008-217436. Conversations with Pedro Albarrán, Juan A. Crespo, and Ignacio Ortuño are gratefully acknowledged. Remaining shortcomings are the author's sole responsibility, and any opinions expressed here are those of the author and not those of the European Commission.

I. INTRODUCTION

In science, as elsewhere, there is no good policy without an appropriate diagnosis. This paper is a criticism of the so-called "*European Paradox*", according to which Europe plays a leading world role in terms of scientific excellence, but lacks the entrepreneurial capacity of the U.S. to transform this excellence into innovation, growth, and jobs.[1]

The problem with the European Paradox is that it is exclusively based on the number of publications. Indeed, since the mid-1990s the EU –namely, the 15 countries forming the European Union before the 2004 accession– has published somewhat more scientific papers in the periodical literature than the U.S. However, as soon as one takes into account the citation impact per publication the relative situation of the EU and the U.S. is completely reversed. Moreover, the EU performs particularly badly among highly cited papers.

Our diagnosis rests on a number of papers written for the SCIFI-GLOW Collaborative Project.[2] The empirical work exploits a large dataset, indexed by Thomson Scientific, consisting of about 3.6 million articles published in 1998-2002 in more than 8,000 academic or professional journals in 36 languages, as well as the approximately 28 million citations these articles have received after a common five-year citation window for every year in the 1998-2002 period. For our first result, we use a partition of the world into three geographical areas: the U.S., the EU, and the rest of the world (RW hereafter). In a nutshell, we confirm that there is no connection between publication shares and high- or low-impact levels at any aggregation level. Instead, what we find is that the European Paradox hides a truly *European Drama*: judging from citation impact, the dominance of the U.S. over the EU in the basic and applied research published in the periodical literature is almost universal at all aggregation levels.

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1 Apparently, the paradox was launched in the executive summary of the first REIST (R*apport européen sur les indicateurs scientifiques et technologiques*) published separately in 1994 by Ugur Muldur and Luc Soete. One year later, the European Commission *Green Paper on Innovation* popularized the idea (see Delanghe, Sloan, and Muldur, 2011). See Albarrán *et al.* (2010) for a review of the official European reports, as well as the academic literature where we find rather different views about the first axes of the Paradox.

2 Albarrán and Ruiz-Castillo (2011, 2012), Albarrán *et al.* (2010, 2011a, b, c, d), Herranz and Ruiz-Castillo (2011 a, b, c, d), and Ruiz-Castillo (2012). In the same vein, see also Dosi *et al.* (2006, 2009) and Leydesdorff and Wagner (2009).

On the other hand, using a larger dataset of 4.4 million articles published in 1998-2003, Albarrán and Ruiz-Castillo (2012) study a partition of the world into 38 countries, including the 15 members of the EU, and eight geographical areas. Among other interesting results, we should emphasize that since the UK and six small countries (Austria, Belgium, Denmark, Finland, Netherlands, and Sweden) exhibit a reasonably good showing, the cause of the European Drama can be traced to the relatively poor performance of Germany and France and, above all, that of the other two large continental countries, Italy and Spain, together with Greece and Portugal.[3]

The paper is organized as follows. Scientists may justifiably have reservations, even serious doubts, about the role of citation in the evaluation of research. Therefore, Section II briefly discusses the relevance of citation analysis for our purposes (see Ruiz-Castillo, 2012, for further details). Section III is devoted to several methodological problems, including the organization of science at different aggregation levels, and the justification of new indicators of citation impact in view of the high skewness that characterizes citation distributions. Section IV discusses several implementation problems, presents some descriptive statistics, and summarizes our empirical results concerning the European Paradox for a partition of the world into three large geographical areas. Section V extends this work to a partition of the world that includes the most important individual countries and eight geographical areas. Section VI concludes, stresses the potential importance of some extensions, and offers some policy recommendations.

II. WHAT ARE CITATION COUNTS GOOD FOR?

The notion of scientific “quality” is virtually impossible to operationalize. The evaluation of the cognitive, methodological, and esthetic quality components of any research contribution can only be based on intrinsic scientific criteria assessed by qualified colleague researchers under the peer review system. However, communication is a crucial aspect of scientific endeavor. Work of at least some importance provokes reactions of colleagues that constitute the international forum, the “invisible college”

[3] Interestingly enough, this is exactly the same conclusion reached in Drèze and Estevan (2007) in a detailed analysis of the U.S./EU academic gap in Economics.

that is permanently discussing research results. One aspect of successful research performance consists of actively presenting research findings to other researchers. As a matter of fact, it can be argued that scientists have a professional obligation to disseminate their results. (Moed *et al.*, 1985). In this view, together with basic quality, scientific quality includes what we may call *scientific influence*.

Although scientific influence is essentially an unobservable variable, we may take into account that members of the invisible college often play their role as critics by referring in their own work in the periodical literature to earlier work of other scientists. Robert Merton, the founder of the modern sociology of science, argues that citations represent intellectual or cognitive influence on scientific work (Merton, 1973). However, a large literature has developed which holds that the probability of being cited depends on many factors different from the accepted conventions of scholarly publishing, to say nothing of constructivist sociologists of science for whom the cognitive content of articles has little influence on how they are received by scientific communities (see Cole, 2000, and Bornmann and Daniel, 2008, for an excellent surveys). For our purposes it suffices to admit that, in principle, citation distributions are worth investigating.

Bibliometric studies using citation counts are complementary to peer review judgments in at least two ways. (i) They may reveal macro-patterns in the communication process that cannot be seen from the limited perspective of the individual researcher. This is exactly our aim in this paper when evaluating the EU's research performance in all sciences in terms of its world citation impact. (ii) Citations may work as a control of peer review. When the results of the two evaluation exercises disagree, those responsible for peer review must provide an explanation, whereas when supported by bibliographic methods, peer review judgments gain outside credibility. The conjunction of the two modes forms what Weingart (2005) calls "*informed peer review*", a commendable evaluation procedure to which we would like to be able to contribute.

Finally, as we will see in the next Section, there is systematic evidence about the existence of fundamental regularities in the shape of reference and citation distributions at different aggregation levels. This calls for a single theoretical explanation –equally valid for all sciences– of the decentralized process whereby scientists make references that a few years later give rise to a highly skewed citation distribution crowned in many cases by a power law. The fact that, against all odds, citation distributions share some stylized features in all sciences, shows that, regardless of the myriad motives guiding specific citations by individual researchers, they are social institutions that perform the same role everywhere, namely, providing a vehicle to separate the most influential articles, at the very top of citation distributions, from the remaining publications with an intermediate or very low citation impact. Consequently, citation distributions constitute a useful instrument for the evaluation of research units of any size.

III. SOME METHODOLOGICAL PROBLEMS

III. 1. The Organization of Science into Sub-fields, Disciplines, and Fields

To examine whether citation distributions are similar or not, we must first confront what we should understand by a scientific field, and how it should be identified in practice. From an operational point of view, a scientific field is a collection of papers published in a set of closely related professional journals. A field is said to be *homogeneous* if the number of citations received by its papers is comparable independently of the journal in which each has been published. Consequently, if one paper has twice the number of citations as another in the same homogeneous field, then it can be said that it has twice as much scientific influence as the other.

Naturally, the smaller the set of closely linked journals used to define a given research field, the greater the homogeneity of citation patterns among the articles included must be. Moreover, when questioned, most scientists would answer that they belong to one, or at most a few, well-defined research areas. Therefore, ideally one should always work at the lowest aggregation level that the data allows. In the sequel, research areas at that level are referred to as *sub-fields*. Given the plethora of scientific sub-fields that easily reach between two and three hundred, for many practical problems the interest of investigating larger aggregates is undeniable. Above sub-fields, we distinguish between an intermediate category –referred to as *disciplines*, such as Internal Medicine or Dentistry; Particle and

Nuclear Physics or Physics of Solids, Fluids and Plasmas; and Organic or Inorganic Chemistry– and traditional, broad fields of study such as Clinical Medicine, Physics or Chemistry, referred to simply as *fields*. The task of deciding what a sub-field should be at the lowest aggregation level, as well as the drawing of the lines that connect each sub-field to a single discipline and a single field, constitute formidable practical problems that must be solved prior to the study of citation distributions at different aggregation levels. With our dataset, there are basically two options.

On one hand, we may identify sub-fields with the 219 Web of Science (WoS hereafter) categories distinguished by Thomson Scientific. However, articles are assigned to WoS categories through the assignment of the journals where they have been published. Many journals are unambiguously assigned to one specific category, but many others receive a multiple assignment. As a result, only about 58% of the total number of articles published in 1998-2007 is assigned to a single WoS category.

On the other hand, Thomson Scientific distinguishes between 20 broad fields for the natural sciences and two for the social sciences. Although this firm does not provide a link between the 219 WoS categories and the 22 broad fields, it assigns each article in our dataset to a single broad field. Therefore, in a number of papers for this project we have identified a homogeneous field with one of these 22 broad fields (see Albarrán and Ruiz-Castillo, 2011, 2012, as well as Albarrán *et al.*, 2010, 2011, c, d). In this way, the problems raised by the multiple assignments of articles to WoS categories, as well as the difficulties involved in the aggregation from the WoS to higher aggregate levels, are provisionally avoided. Although valuable, results from this option may be contested on the grounds that these 22 "sub-fields" are possibly too broad and heterogeneous. Consequently, in this Section and the next we will concentrate on the second option that identifies sub-fields with 219 WoS categories. This option is possible because, as we will presently see, there are reasonable ways to cope with the assignment of articles to multiple sub-fields.

There are two ways of handling this problem. One can follow a fractional strategy according to which each publication is fractioned into as many equal pieces as necessary, with each piece assigned to a corresponding sub-field, or one can follow a multiplicative strategy according to which each paper is wholly counted as many times as necessary in the several sub-fields to which it is assigned. Fortunately, it appears that the similarity of citation characteristics of articles published in journals assigned to one or several sub-fields guarantees that choosing the fractional or the multiplicative strategies may not lead to a radically different picture in practical applications like the ones pursued in this paper (see Herranz and Ruiz-Castillo, 2011a, b, c, d). In any case, for reasons explained in Herranz and Ruiz-Castillo (2011a), we prefer a multiplicative strategy where each article is classified into as many sub-fields as WoS categories in the original dataset. For example, an article assigned to three WoS categories is wholly counted three times, once in each of the corresponding sub-fields. In this way, the space of articles is expanded as much as necessary beyond the initial size. However, this is not that worrisome in the sense that, since this strategy does not create any interdependencies among the sub-fields involved, it is still possible to investigate separately every sub-field in isolation, independently of what takes place in any other sub-field.

It would be very convenient to have a hierarchical Map of Science organizing sub-fields, disciplines, and fields in a way agreed upon by the international scientific community. However, the prevalence of extreme doses of scientific inter-disciplinarity has made it impossible to count on such a Map (see Albarrán *et al.*, 2011a, for some of the main references in this particularly active research field in Scientometrics). Among the many alternatives, Albarrán *et al.* (2011a) borrow from the schemes recommended by Tijssen and van Leeuwen (2003) and Glänzel and Schubert (2003) with the aim of maximizing the possibility that a power law represents the upper tail of each of the corresponding citation distributions. The resulting scheme consists of 80 disciplines, and 20 fields.[4]

III.2. The Skewness of Science

Tables D.I and E in the Appendix of Herranz and Ruiz-Castillo (2011a) present the information about the mean citation rate (MCR hereafter) at the sub-field level, and the number of articles at all aggregate levels. Two points should be noted. Firstly, publication practices across sub-

[4] It is not claimed that this scheme provides an accurate representation of the structure of science. It is rather a convenient simplification for the discussion of aggregation issues in this paper.

fields are known to be very different. In some research areas, authors publishing one article per year would be among the most productive, while in other instances authors –either alone or as members of a research team– are expected to publish several papers per year. On the other hand, since the WoS categories are not designed at all to equalize the number of articles published in a given period of time, distribution sizes are expected to differ greatly. In particular, in our dataset mean sizes (and standard deviations) are 26,180 (23,390) for sub-fields, 67,145 (44,642) for disciplines, and 243,840 (164,032) for fields. Secondly, given the differences in citation practices across sub-fields, MCRs vary widely. The mean (and standard deviation) is 5.8 (3.5). The maximum MCR is reached in the following four sub-fields: Cell Biology; Development Biology; Hematology, and Biochemistry & Molecular Biology with 21.4; 19.4; 16.4, and 16.3 citations, respectively. The minimum is in Pure Mathematics; Materials Science, Characterization & Testing; Area Studies, and Engineering, Marine with 1.9; 1.4; 1.3, and 1.0 citations each.

In conclusion, the high values of absolute and relative dispersion measures clearly indicate that *within* sub-fields these distributions are very different indeed. This diversity seems to be compatible with the belief among Scientometrics practitioners that citation distributions share some fundamental characteristics. In particular, as originally suggested in Price (1965) and afterwards analyzed in Seglen's (1992) seminal contribution, it is generally believed that citation distributions are highly skewed. The problem is that the empirical evidence sustaining these beliefs is, although valuable, not conclusive. Consequently, we have tried to set the record straight using the large dataset mentioned in the Introduction. The question we investigate is whether citation distributions are similar or not at the sub-field level, and whether the common features that are found are preserved in aggregation. The main results can be summarized as follows.

Size- and scale-independent descriptive tools permit us to focus on the *shape* of distributions. In particular, the Characteristic Scores and Scales (CSS hereafter) approach, pioneered by Schubert *et al.* (1987) in citation analysis, permits the partition of any distribution of articles into classes according to the citations they receive. Let s_1 denote the mean citation, and s_2 the mean citation of articles above s_1.

Consider the partition of citation distributions into three broad classes of articles that (i) receive no or few citations below s_1, (ii) are fairly well cited, namely, with citations between s_1 and s_2, and (iii) are remarkably or outstandingly cited with citations above s_2. Table 1 gives information about average values and standard deviations for this partition at different aggregate levels.

Table 1. Characteristic Scores and Scales. Means (and Standard Deviations) of the Partition Into Three Broad Classes at Different Aggregate Levels

	Percentage Of Articles In Categories:		**Percentage of Citations In Categories:**	
	1 + 2	**4 + 5**	**2**	**4 + 5**
A. 219 SUB-FIELDS[1]	68.6	10.0	21.1	44.9
	(3.7)	(1.7)	(5.0)	(4.6)
B. 80 DISCIPLINES[2]	68.4	10.0	22.3	43.9
	(2.6)	(1.3)	(3.2)	(2.9)
C. 20 FIELDS[2]	68.7	9.7	21.6	44.6
	(1.8)	(1.0)	(3.4)	(3.3)

[1] See Table 1 in Albarrán *et al.* (2011a)
[2] See Table 1 in Herranz and Ruiz-Castillo (2011a)

It is found that citation distributions at the sub-field level are highly skewed in the sense that approximately 69% of all articles receive citations below the mean and account for, at most, 21% of all citations, while articles with a remarkable or outstanding number of citations represent about 9% or 10% of the total, and account for approximately 44% of all citations. In the words of Lehmann *et al.* (2003), *"The picture which emerges is thus a small number of interesting and significant papers swimming in a sea of dead papers"*. Since sub-field shapes are so similar, any reasonable aggregation scheme should preserve its main characteristics. This is exactly what is found when sub-fields are aggregated into what we call disciplines and fields.

III.3. High- and Low-impact Indicators

Given the skewness documented in the previous Section, average-based indicators may not adequately summarize citation distributions. There are several ways of taking into account this feature. For example, Albarrán *et al.* (2010) compare the publication shares of the U.S. and the EU at every percentile of the world citation distribution in the 22 broad fields distinguished by Thomson

Scientific. The evidence indicates that among the most influential articles, in 21 out of 22 fields the dominance of the U.S. over the EU is overwhelming.

Nevertheless, this evidence suffers from the following two weaknesses. Firstly, as indicated before, the 22 fields considered in this study are possibly too broad and heterogeneous. Thus, most of the empirical evidence reported in the next Section refers to the aggregation scheme consisting of 219 sub-fields, 80 disciplines, and 20 fields. Secondly, the mere percentage of articles satisfying some interesting condition only captures what can be referred to as the *incidence* aspect of the phenomenon in question. Albarrán *et al.* (2011b) introduced a novel methodology for the evaluation of research units of a certain size that overcomes this shortcoming. The starting point is that, due to their skewness, the upper and lower parts of citation distributions are typically very different. Consequently, it seems useful to describe a citation distribution by means of two real valued functions defined over the subsets of articles with citations above or below a *critical citation line* (CCL hereafter). These are referred to as a *high-* and a *low-impact indicator*, respectively.

Economists will surely recognize that the key to this approach is the identification of a citation distribution with an income distribution. Once this step is taken, the measurement of low-impact, which starts with the definition of low-citation papers as those with citations below the CCL, coincides with the measurement of economic poverty. In turn, once low-impact has been identified with economic poverty, it is equally natural to identify the measurement of high-impact with the measurement of a certain notion of economic affluence.

The question of which low-impact indicators might be used is answered in terms of a family of indices –originally suggested by Foster *et al.* (1984)– that satisfies a number of desirable properties, and has been widely used for the measurement of economic poverty over the last 25 years. These same properties lead to the selection of an equally convenient class of high-impact measures. Among the properties enjoyed by these indicators, we will emphasize only two groups of them. In the first place, our indicators are size- and scale-invariant. In view of the large differences in size and MCR exhibited by sub-fields (see Section IV.2), this is a very convenient property to have. In the second place, certain members of these two families are capable of simultaneously taking into account not only the incidence, but also what we call the *intensity*, and the *citation inequality* that affect the high-and low-impact phenomena they attempt to measure. Given any CCL, the high-impact level according to our preferred indicator increases with (i) the proportion of high-impact papers (incidence), (ii) the average gap between the number of citations received by high-impact papers and the CCL (intensity), and (iii) the citation inequality among high-impact papers (citation inequality). In turn, the low-impact level increases with (i) the proportion of low-impact papers (incidence), (ii) the average gap between the CCL and the number of citations received by low-impact papers (intensity), and (iii) the citation inequality among low-impact papers (citation inequality).

For reasons of space, in this paper we focus on high-impact aspects. The class of high-impact indicators that will be used in the empirical sections is defined by

$$H_\beta(c) = [1/n(c)]\ \Sigma_{i = l(c) + 1}^{n(c)} (\Gamma^*_i)^\beta,\ 0 \leq \beta,$$

where β is a parameter identifying the members of the family, and Γ^*_i = max {(c_i - CCL)/CCL, 0} is the *normalized high-impact gap*. Note that $\Gamma^*_i > 0$ for high-impact articles, while $\Gamma^*_i = 0$ for low-impact articles. Only high-impact indicators for parameter values β = 0, 1, 2 will be used. Firstly, note that H_0 coincides with the proportion of high-impact papers. Secondly, denote by $\mu_H(c)$ the MCR of high-impact articles. It can be shown that

$$H_1(c) = H_0(c)H_I(c), \qquad (1)$$

where

$$H_I(c) = [1/h(c)]\ \Sigma_{i = l(c) + 1}^{n(c)} \Gamma^*_i = [\mu_H(c) - CCL]/CCL.$$

The index H_I is said to be monotonic in the sense that one more citation among high-impact articles increases H_I. Therefore, while H_0 only captures what we call the incidence of the high-impact aspect of any citation distribution, H_1 captures both the incidence and the intensity of these phenomena. Thirdly, H_2 can be expressed as:

$$H_2(c) = H_0(c)\{[(H_I(c)]^2 + [1 + H_I(c)]^2 (C_H)^2]\}, \tag{2}$$

where $(C_H)^2$ is the squared coefficient of variation (that is, the ratio of the standard deviation over the mean) among the high-impact articles. Therefore, H_2 simultaneously covers the incidence, the intensity, and the citation inequality aspects of the high-impact phenomenon it measures (see Albarrán *et al.*, 2011d, for a full discussion of other properties).

IV. EMPIRICAL RESULTS ABOUT THE U.S./EU GAP

IV. 1. Implementation questions

Using the dataset already described, this Section studies the evaluation of the citation impact in three geographical areas: the U.S., the EU, and the RW. There are three issues that must be addressed in this Sub-section: the English bias of the data; the assignment of articles to geographical areas, and the selection of the CCL.

IV.1.a. The English Bias in the Data

Before continuing any further, it is important to recall that Thomson Scientific databases suffer from an English bias. This might very well influence the results one can obtain in two different directions. Some might argue that as far as the Social Sciences, and perhaps also as far as Psychology and Psychiatry and the Behavioral Sciences are concerned, the Thomson Scientific database favors the U.S. versus the EU.[5] On the other hand, van Leeuwen *et al.* (2001), and van Raan *et al.* (2011) studied the role of publications in non-English language journals covered by Thomson Scientific. These are counted as part of the output of countries, but they generally have a very low impact because, for example, only a limited number of scientists outside Germany, Austria and Switzerland are able to read German; there is a similar situation for French. Thus, these non-English publications will considerably 'dilute' the impact of countries such as Germany, Austria and France. This is particularly the case for the more application-oriented fields such as Clinical Medicine and Engineering, and also

[5] As an economist, I can inform that members of the European Economic Association and many other colleagues in Economics accept the information in the Social Citation Index and the Social Sciences Citation Index as valid in our field.

for the Social Sciences and the Humanities. Therefore, in comparing the citation performance of English and non-English countries it might be desirable to eliminate non-English journals altogether –a possibility beyond the scope of this paper because our dataset lacks information on journals. Taking also into account that English can be considered the international language of science, in this paper we have followed the usual practice of using the Thomson Scientific data under the reasonable assumption that "*the international journal publications in these databases provide a satisfactory representation of internationally accepted ('mainstream') research, especially high-quality 'laboratory based' basic research in the natural sciences, medical sciences, and life sciences conducted in the advanced industrialized nations*" (EC, 2003, p. 439).

IV.1.b. The Assignment of Articles to Geographical Areas

Articles are assigned to geographical areas according to the institutional affiliation of their authors as recorded in the Thomson Scientific database on the basis of what had been indicated in the by-line of the publications. The assignment of internationally co-authored papers among areas is problematic (see *inter alia* Anderson *et al.*, 1988). From a U.S. geopolitical point of view, for example, we want to give as much weight to an article written in a U.S. research center as we give to another co-authored by researchers working at a U.S. and a European university. Thus, we side with many other authors in recommending a multiplicative strategy according to which in every internationally co-authored article a whole count is credited to each contributing area (see *inter alia* the influential contributions by May, 1997, and King, 2004, as well as the references in Section II in Albarrán *et al.*, 2010). Only domestic articles, or articles exclusively authored by one or more scientists affiliated to research centers either in the U.S., the EU, or the RW alone, are counted once. In this way, the space of articles is expanded as much as necessary beyond the initial size arriving at what we call the *geographical extended count*. The total number of articles, N_G, is 4,142,281 is 13.5% larger than in the original dataset.

IV.1.c. The Selection of the CCL

In economics, there is a general agreement that the measurement of economic poverty involves an irreducible, absolute core that should be addressed by fixing an *absolute* poverty line common to all countries in the world. For example, at present the World Bank sets that absolute poverty line at two dollars per day of equivalent purchasing power in any country of the world. However, after World War II it was observed that, at any reasonable absolute poverty line, there would be no absolute poverty in the developed part of the world. Therefore, a notion of *relative* poverty was introduced where the poverty line is fixed at a certain percentage –typically 50% or 60%– of mean or median income.

As explained in Albarrán *et al.* (2011c), in citation space there are also two alternatives in every homogeneous field. Firstly, a relative approach in which a CCL for each geographical area is fixed, for instance, as a multiple of the mean or the median, or at a given percentile of the area's citation distribution. Secondly, an absolute approach in which a CCL for the entire field is fixed as a function of some characteristic of the world citation distribution. In our experience, it is generally agreed that what happens at the world level in any scientific field constitutes a natural reference for the evaluation of the performance of any type of research unit in that field. Therefore, we suggest fixing the CCL at some percentile of the original world distribution in every science. Since we learned in Section III.2 that the MCRs at all aggregate levels are approximately located at the 70th percentile of citation distributions, we focus on the case where the CCL is fixed at the 80th percentile (see also Albarrán *et al.*, 2011c, d, and Herranz and Ruiz-Castillo, 2011a, b).

IV. 2. Some Descriptive Statistics

It can be argued that in the study of any sub-field all articles should count equally regardless of the role some of them may play in other sub-fields. In this way, the space of articles is expanded as much as necessary beyond the geographical extended count in what we call the *double extended sub-field count*, which in our case reaches 6,512,031 articles, or 57.7% more than the number of articles in the geographical extended count. At the next aggregation level, whenever two or more sub-fields belong to the same discipline no multiplication of the article is necessary. Therefore, the total number of articles at this level will be closer to the initial one than in the sub-field case. A similar process for the assignment of articles to fields should lead to a still lower number of expanded articles. Thus, the number of articles for disciplines, and fields are N_D = 6,107,509, and N_F = 5,538,760, totals which are 47.4%, and 33.7% greater than the total number of articles in the geographical extended count.

Table A in the Appendix presents the information about the number of articles, the MCR and the CCL in the double extended sub-field count, while Table B does the same at higher aggregate levels. We find it useful to classify sub-fields, disciplines, and fields into four large grand-fields. At the lowest aggregate level, for example, there are 77 sub-fields in the Life Sciences, 36 in the Physical Sciences, 73 in Other Natural Sciences, and 33 in the Social Sciences. As before, distribution sizes and MCRs differ greatly. At the sub-field level, for example, the mean size is 29,735 articles and the standard deviation is 33,826, while the average MCR and the standard deviation are 6.1 and 3.7. CCL values are always greater than the MCRs, but the difference is relatively small: on average, the 80th percentile is reached at 8.8 citations. The reason is that, as we know, the MCR is approximately located at the 69th percentile.

Table B in Appendix I in Herranz and Ruiz-Castillo (2011d) gives information about publication shares and publication effort by geographical area. Two points should be noted. Firstly, the share of all articles is approximately 29%, 33% and 38% for the U.S., the EU, and the RW, respectively. More importantly, the EU has more articles than the U.S. in 113 of 219 sub-fields, or about 52% of them. The allocation of these 113 sub-fields over grand-fields is the following: 35 out of 77 sub-fields in Life Sciences, 30 out of 36 sub-fields in Physical Sciences, 47 out of 77 sub-fields in Other Natural Sciences, and only one out of 33 sub-fields in the Social Sciences. Secondly, the correlation coefficients between the geographical areas' publication effort across sub-fields indicate that there is little difference in the way all areas allocate such effort.

IV. 3. Results at the Sub-field Level

In the remaining part of this Section we report high-impact results according to the indicator H_2 defined in equation (2) in Section III.3.[6] Let c^k be the citation distribution in geographical area k, and

[6] To study the effect on the U.S./EU gap according to the high-impact indicators H_0 and H_1 rather than H_2, see Albarrán et al. (2011c).

denote by $H_2(\mathbf{c}^k)$ the high-impact indicators for the world as a whole and for k = U.S., EU, RW. To assess the high-impact gap between the U.S. and the EU it is appropriate to use the ratios $H_2(\mathbf{c}^{US})/H_2(\mathbf{c}^{EU})$ which are in Table D in the Appendix to Herranz and Ruiz-Castillo (2011d). A summary of results is in Table 2.

Table 2. Summary of the U.S./EU High-impact Gap at the Sub-field Level

Number of Sub-fields in which:	**EU IS AHEAD**	**U.S. IS AHEAD:**				**TOTAL**
		0 - 50%	**51% - 100%**	**> 100%**	**Total**	**(6) =**
	(1)	**(2)**	**(3)**	**(4)**	**(5)**	**(1) + (5)**
A. Life Sciences	**8**	21	30	18	**69**	77
B. Physical Sciences	**1**	7	12	16	**35**	36
C. Other Natural Sciences	**12**	22	16	23	**61**	73
NATURAL SCIENCES = A + B + C	**21**	50	58	57	**165**	186
D. Social Sciences	**9**	7	3	14	**24**	33
TOTAL = A + B + C + D	**30**	57	61	71	**189**	219

It is observed that the EU is ahead of the U.S. in 21 sub-fields within the Natural Sciences and nine within the Social Sciences. The details are interesting. (i) Within Life Sciences, the EU is ahead in Biology (sub-fields 1 and 2 in Table A in the Appendix), some behavioral sciences (sub-fields 65, and 66), Integrative and Complementary Medicine (sub-field 43), and a few sub-fields of lesser importance in Clinical Medicine III. (ii) Within the 36 sub-fields in the Physical Sciences, the EU is ahead only in Acoustics (sub-field 90). (iii) Among the Other Natural Sciences, the EU is ahead in three Engineering sub-fields (120, 130, and 131), two in Materials Science (140, and 141), Mining and Mineral Processing (sub-field 155) in Geosciences, and five sub-fields in Agricultural and Environment and Plant and Animal Sciences. (iv) Among the Social Sciences, the EU is ahead in Linguistics, Geography, and Urban Studies (sub-fields 212, 200, and 203), as well as seven other lesser sub-fields. This is a truly poor showing when compared with the record achieved by the U.S. in the remaining 189 sub-fields. It suffices to note that in 57 natural sciences and 13 social sciences the U.S. has a high-impact indicator at least twice as large as that of the EU.

IV. 4. Results at Higher Aggregate Levels

In Scientometrics, it is generally agreed that widely different citation practices at the sub-field level require some normalization when considering aggregate categories consisting of closely related but nevertheless heterogeneous sub-fields. Herranz and Ruiz-Castillo (2011 a, b) present a novel normalization procedure to take into account differences in MCRs across sub-fields at the lowest aggregation level in the construction of aggregate categories in the multiplicative case. Table E in the Appendix in Herranz and Ruiz-Castillo (2011c) presents the results for the U.S./EU high-impact gap for normalized disciplines and fields. A summary of results concerning disciplines is in Table 3, while the corresponding information for higher aggregation levels is presented in Table 4.

Table 3. Summary of the U.S./EU High-impact Gap at the Discipline Level

Number of Disciplines in which:	EU IS AHEAD	U.S. IS AHEAD:				TOTAL
		0 - 50%	51% - 100%	> 100%	Total	(6) =
	(1)	(2)	(3)	(4)	(5)	(1) + (5)
A. Life Sciences	**2**	5	14	7	**26**	28
B. Physical Sciences	**0**	6	3	8	**17**	17
C. Other Natural Sciences	**0**	12	8	6	**26**	26
NATURAL SCIENCES = A + B + C	**2**	23	25	21	**69**	71
D. Social Sciences	**1**	0	2	6	**8**	9
TOTAL = A + B + C + D	**3**	23	27	27	**77**	80

The contrast between the U.S. and the EU is huge. The EU contribution to high-impact levels is below its publication share in 55 out of 80 disciplines, and by more than 50% above its publication share in a single occasion (Integrative & Complementary Medicine). These figures are one and 43, respectively, for the U.S. (see Table 1A in Herranz and Ruiz-Castillo, 2011c). The dismal performance of the EU is particularly serious in the Life, Physical, and Social Sciences. The consequences for the

Table 4. The U.S./EU Gap at the Field and All Sciences Level, Measured With Normalized High-impact Indicators, As Well As the Mean Normalized Citation Score

FIELDS	HIGH-IMPACT (1)	MNCS (2)	(3) = (1) – (2) In %
I. BIOSCIENCES	1.794	1.281	40.0
II. BIOMEDICAL RESEARCH	2.200	1.223	79.8
III. CLINICAL MEDICINE I (INTERNAL)	1.985	1.367	45.3
IV. CLIN. MED. II (NON-INTERNAL)	1.863	1.328	40.2
V. CL. MED. III (HEALTH & OTHER SCS.)	1.401	1.093	28.2
VI. NEUROSCIENCE & BEHAVIOR	1.975	1.251	57.9
VII. CHEMISTRY	2.363	1.307	80.8
VIII. PHYSICS	2.029	1.268	60.1
IX. SPACE SCIENCES	1.418	1.285	10.4
X. MATHEMATICS	2.953	1.181	150.1
XI. COMPUTER SCIENCE	2.439	1.255	94.4
XII. ENGINEERING	1.897	1.163	63.1
XIII. MATERIALS SCIENCE	2.389	1.258	89.8
XIV. GEOSCIENCES	1.444	1.187	21.6
XV. AGRICULTURAL & ENVIRONMENT	1.376	1.086	26.7
XVI. PLANT & ANIMAL SCIENCE	1.596	1.118	42.7
XVII. MULTIDISCIPLINARY	2.215	1.352	63.8
XVIII. RESIDUAL SUB-FIELDS	1.150	1.316	-12.6
XIX. SOCIAL SCIENCES, GENERAL	1.797	1.171	53.5
XX. ECONOMICS & BUSINESS	2.017	1.392	44.9
ALL SCIENCES	**1.609**	**1.248**	**28.9**

U.S./EU gap are dramatic. The EU is ahead in only two disciplines among the Natural Sciences: Integrative & Complementary Medicine, a single sub-field discipline, and Other Clinical Medicine, which includes the sub-fields of lesser importance already mentioned. The EU is ahead of the U.S. in one discipline among the Social Sciences: Geography, Planning, and Urban Studies. In turn, the U.S. dominates the EU by more than 100% in 27 out of 80 disciplines (see Table 3).

On the other hand, the U.S./EU high-impact gap is greater than one in all fields, and greater than two in eight of them. Finally, in the important all-sciences case the U.S. high-impact indicator is about 61% greater than that of the EU (see the last row in column 1 in Table 4).

IV. 5. A Comparison with Average-based Indicators

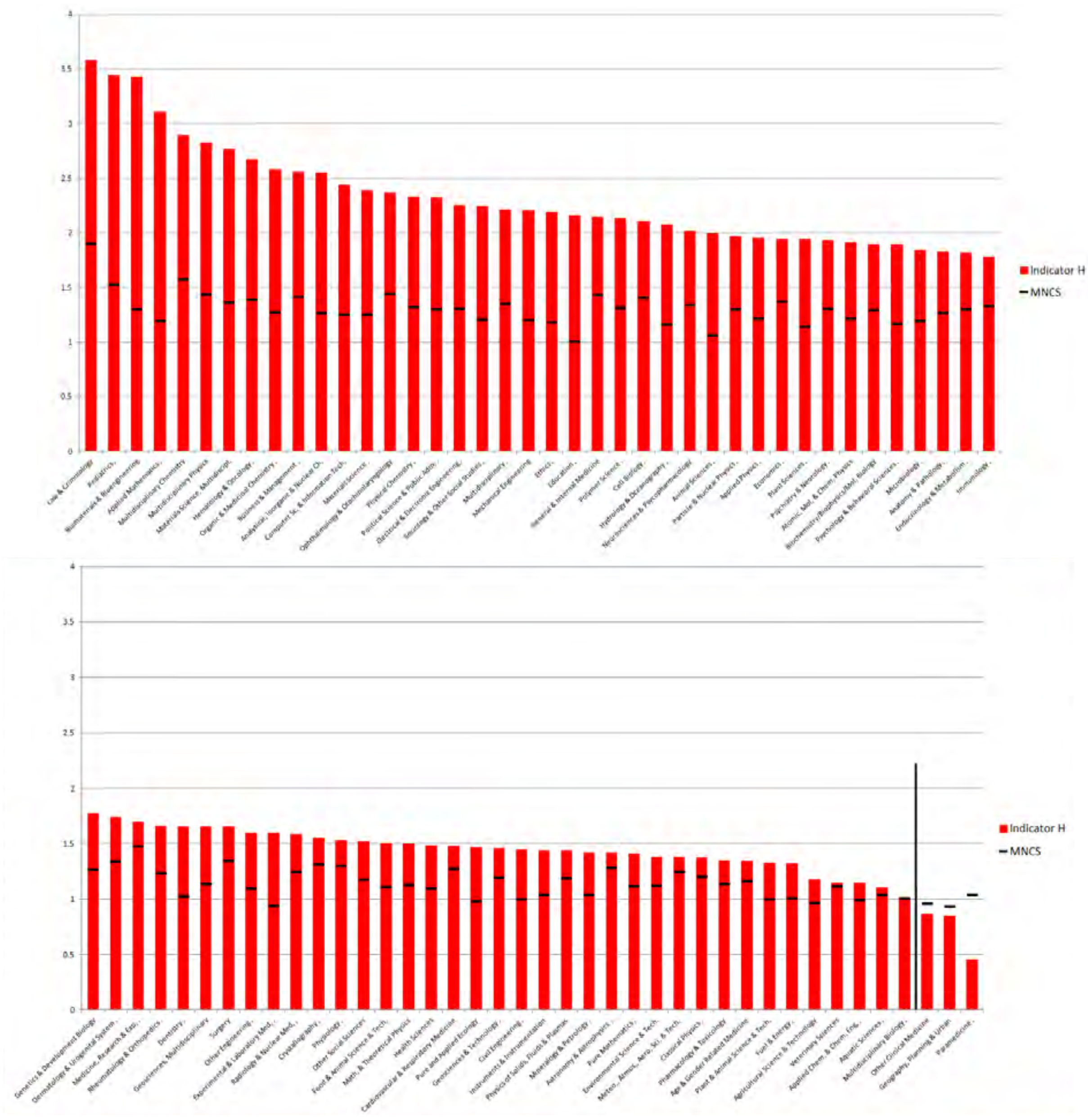
It must be recognized that our high-and low-impact indicators are very recent. Therefore, it is very convenient that we compare the previous results with those obtained using average-based indicators. As with high-impact indicators, we must distinguish between two cases. Firstly, when we consider the 219 sub-fields as homogeneous, the U.S./EU gap is simply measured by the ratio of the corresponding MCRs for the two geographical areas. Secondly, at higher aggregation levels we must take into account that any discipline or any field consists of a number of closely related but heterogeneous sub-fields characterized by different citation practices. At present, for sub-field normalization using average-based indicators the main mechanism in contention is the *mean normalized citation score* (*MNCS* hereafter). The *MNCS* indicator first performs normalization at the level of individual articles, and then obtains the average of the normalized articles. The normalization factor for any article is the MCR of the sub-field to which it belongs.

Table 3 in Herranz and Ruiz-Castillo (2011d) includes the results according to the MCR for the U.S./EU gap in the sub-field case, while Table E in the Appendix of Herranz and Ruiz-Castillo (2011b) contains the results about the U.S./EU gap according to the *MNCS* at higher aggregate levels. The resulting picture is quite dramatic. Firstly, the U.S. MCR is greater than that of the EU in 174 of the 219 sub-fields. The U.S./EU gap is greater than 20% in 105 cases, and greater than 40% in 31. Secondly, only in six out of 80 disciplines –but in no field at all– is the EU still ahead of the U.S. In contrast, the normalized U.S./EU gap according to the *MNCS* is greater than 20% in 44 out of 80 disciplines, and 13 out of 20 fields. Finally, in the all sciences case the U.S. *MNCS* is about 25% greater than that of the EU.

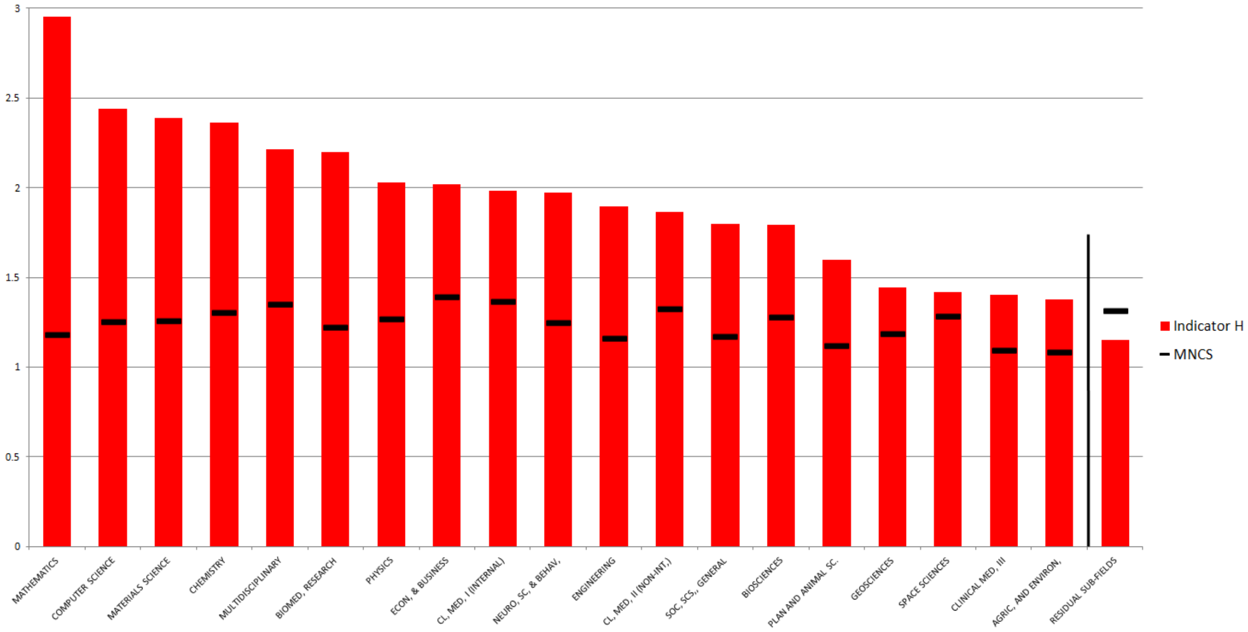
The differences between the U.S./EU gap according to average-based indicators and our high-impact indicator are important. The comparison at the discipline and the field levels is illustrated in Figure 1. In spite of a rather high coefficient of correlation –of 0.71 in the discipline case, for example– the differences between the results obtained with the two approaches are of a large order of magnitude. Firstly, among the 195 sub-fields for which the U.S./EU high-impact gap is greater than the gap according to the MCR, in 110 cases the difference is between 20% and 50%, and 32 additional cases the difference is greater than 50%. Secondly, among the 77 disciplines for which the U.S./EU high-impact gap is greater than the gap according to the *MNCS*, in 29 cases the difference is between

20% and 50%, and in 35 additional cases the difference is greater than 50%. Finally, recall that at the highest aggregate level the normalized U.S. high-impact indicator is about 61% greater than that of the EU, rather than 25% as in the *MNCS* case. This is the consequence of the different properties of the two indicators: the MCR and the *MNCS* are average-based indices defined over the entire distribution, while the high-impact indicator is defined on the top 20% of highly-cites articles, values the gap between them and the CCL, and responds positively to citation inequality among high-impact articles.

Figure 1. The U.S./EU gap at the discipline and field level according to H_2 and the *MNCS*



A. Disciplines



B. Fields

IV. 6. The End of the European Paradox

We may conclude that the European Paradox has been definitely put to rest. It is true that the EU has more publications than the U.S. in 113 out of 219 sub-fields, 54 out of 80 disciplines, and 15 out of 20 fields. Overall, the EU has 3.2% more publications than the U.S. However, judging from the high-impact perspective, the EU is ahead of the U.S. only in 30 sub-fields, three disciplines, and no field at all. The U.S. has a high-impact indicator which is at least twice as large as the EU in 71 sub-fields, 27 disciplines, and eight fields (Mathematics, Computer Science, Materials Science, Chemistry, Multidisciplinary, Biomedical research, Physics, and Economics & Business). For all sciences as a whole, the US high-impact indicator is 61% greater than that of the EU.[7]

As is well known, the problem with the European Paradox is that it is exclusively based on the number of publications. However, it turns out that in our partition of the world into three large geographical areas the more frequent high-impact ranking –the U.S. above the EU, and the EU above the RW– holds in 166 sub-fields. However, the RW or the EU leads in publications in 136 out of 186

[7] It should be noted that when we measure the U.S./EU gap by low-impact indicators the EU situation is somewhat more favorable. For example, the EU is ahead of the U.S. in 56 out of 219 sub-fields, in 14 out of 80 disciplines, and one out of 20 fields (Clinical Medicine III, Health and Other Sciences). In the all-sciences case, the U.S. low-impact indicator is only 12.2% smaller than that of the EU. However, the impact on our high- and low-impact results of raising the CCL from the 80^{th} to the 95^{th} percentile of world citation distributions is of a small order of magnitude.

sub-fields in the natural sciences, but only in two out of 33 cases in the social sciences. This contrast should serve to conclude without further statistical analysis that for any geographical area the connection between having a large publication share in a given field and a good index of high-impact is practically non-existent.

A different matter is the relationship between the publication effort devoted to the various sub-fields in each geographical area and the high-impact levels achieved across sub-fields. The correlation coefficient between publication efforts and high-impact levels is only 0.036 for the U.S., 0.056 for the EU, and 0.011 for the RW. Thus, there is practically no connection between these variables. As a matter of fact, geographical areas do not seem to specialize in these sub-fields where they enjoy a comparative advantage measured by MCR: the correlation coefficients between this indicator and an area publication effort are – 0.52, – 0.08, and – 0.13 for the U.S., the EU, and the RW, respectively. Forces explaining publication efforts are different from those explaining relative success measured by citation impact.

The conclusion is inescapable: a substantial publication effort by a geographical area in a given sub-field does not guarantee a good performance by this area in terms of a large high-impact level or a small low-impact index in that category. Similarly, a large volume of publications in specific sub-fields by any of the three large geographical areas does not guarantee a relatively good high-impact performance in those sub-fields. This is very damaging indeed for the proponents of a European Paradox where the good health of European science is assessed in terms of large publication shares. In this scenario, this paper establishes that the European Paradox masks a truly *European Drama*: judging from citation impact, the dominance of the U.S. over the EU in the basic and applied research published in the periodical literature is almost universal at all aggregate levels.

V. THE RELATIVE PERFORMANCE OF THE EU MEMBER COUNTRIES

As indicated in the Introduction, Albarrán and Ruiz-Castillo (2012) study a partition of the world into 38 countries, including the 15 members of the EU, and eight geographical areas using the

4,472,332 million articles published in 1998-2003 and a five-year citation window. Articles are classified into the 22 broad fields distinguished by Thomson Scientific, divided into 20 natural sciences and two social sciences. Using a multiplicative approach for internationally co-authored articles, the geographically extended count is 5,450,309, a total that is 21.9% larger than the original dataset. The CCL is fixed at the 90th percentile of the world citation distribution in every field.

V. 1. The Role of Citation Inequality

In order to understand the consequences of allowing citation inequality to influence country ranking, we will compare H_2 with H_0 that is equal to the proportion of articles above the CCL, namely, the top 10% of most cited articles. All high-impact indicators in the family H_β introduced in Section III.3 are additively decomposable in the following sense. Given any partition of a world citation distribution $\boldsymbol{c}$ into K sub-groups, $\boldsymbol{c}^k$, indexed by k =1,…, K, the overall high-impact level, $H_\beta(\boldsymbol{c})$, can be expressed as the sum of the sub-groups' high-impact levels, $H_\beta(\boldsymbol{c}^k)$, weighted by the corresponding publication shares, w^k, namely, the ratio of the number of articles in distribution $\boldsymbol{c}^k$ over the number of articles in distribution $\boldsymbol{c}$. Thus, we have:

$$H_\beta(\boldsymbol{c}) = \Sigma_k \, w^k \, H_\beta(\boldsymbol{c}^k).$$

Consequently, the ratio $H_\beta(\boldsymbol{c}^k)/H_\beta(\boldsymbol{c})$ is greater than, equal to, or smaller than one whenever the observed relative contribution of sub-group k to the worldwide high-impact level, $w^k \, H_\beta(\boldsymbol{c}^k)/H_\beta(\boldsymbol{c})$, is greater than, equal to, or smaller than its expected contribution measured by its publication share, w^k. For every field, column 1 in Table 5 includes the top five countries according to $H_2(\boldsymbol{c}^k)/H_2(\boldsymbol{c})$, while column 2 records the ranking that these countries have according to H_0 (Table D in the Appendix in Albarrán and Ruiz-Castillo, 2012 includes all countries in all fields).

Two features are apparent. Firstly, relative to H_0, H_2 causes radical ranking changes. In the first three fields, for example, Ireland and Singapore win 15 and 12 positions in Biology & Biochemistry

Table 5. First Five Countries According to H_2 *versus* Ranking Occupied According to H_0

Biology & Biochemistry

		(1)	(2)
1	Ireland	13 93	16
2	Switzerland	2 84	2
3	Singapore	1 68	15
4	USA	1 24	1
5	Germany	1 15	8

Clinical Medicine

		(1)	(2)
1	Denmark	1 62	2
2	Norway	1 58	11
3	Finland	1 56	7
4	Belgium	1 46	4
5	Canada	1 40	5

Immunology

		(1)	(2)
1	Japan	1 55	13
2	USA	1 33	2
3	Switzerland	1 30	1
4	Israel	1 07	22
5	Germany	0 96	4

Microbiology

		(1)	(2)
1	Switzerland	2 13	1
2	USA	1 41	2
3	Denmark	1 33	10
4	Austria	1 16	5
5	Belgium	1 12	8

Molecular Biology & Genetics

		(1)	(2)
1	Ireland	2 75	4
2	Denmark	1 68	9
3	Sweden	1 40	15
4	USA	1 27	3
5	Switzerland	0 97	2

Neuroscience & Behavioral

		(1)	(2)
1	Austria	2 06	8
2	USA	1 26	2
3	Sweden	1 21	13
4	UK	1 16	1
5	Norway	1 07	6

Phar. & Toxicology

		(1)	(2)
1	Switzerland	2 44	2
2	UK	1 64	4
3	Sweden	1 51	6
4	Singapore	1 44	18
5	Ireland	1 36	22

Psychiatry & Psychology

		(1)	(2)
1	Argentina	6 42	20
2	Italy	1 19	2
3	USA	1 18	6
4	Canada	1 14	8
5	New Zealand	1 05	12

Agricultural Sciences

		(1)	(2)
1	Finland	3 42	2
2	Sweden	2 76	8
3	Netherlands	1 70	4
4	Singapore	1 56	3
5	Norway	1 54	7

Engineering

		(1)	(2)
1	Norway	2 23	9
2	Switzerland	1 63	1
3	Denmark	1 47	2
4	USA	1 36	8
5	Finland	1 28	10

Environment & Ecology

		(1)	(2)
1	France	3 49	14
2	Sweden	1 61	5
3	New Zealand	1 38	16
4	Belgium	1 29	9
5	Switzerland	1 18	2

Geoscience

		(1)	(2)
1	Netherlands	3 81	8
2	UK	1 60	10
3	France	1 43	14
4	Germany	1 43	5
5	SAS	1 32	45

Materials Science

		(1)	(2)
1	Austria	4 71	20
2	Netherlands	2 65	2
3	USA	1 95	4
4	Sweden	1 66	19
5	Switzerland	1 22	1

Multidisciplinary

		(1)	(2)
1	USA	1 63	2
2	Italy	0 91	4
3	Japan	0 82	17
4	Sweden	0 82	3
5	Ireland	0 81	11

Plant & Animal Science

		(1)	(2)
1	Switzerland	2 04	3
2	Singapore	1 56	24
3	UK	1 48	2
4	USA	1 29	9
5	Belgium	1 19	11

Chemistry

		(1)	(2)
1	Netherlands	12 14	4
2	Canada	2 41	8
3	France	1 14	15
4	UK	1 03	9
5	USA	1 01	1

Computer Science

		(1)	(2)
1	Sweden	11 99	7
2	Japan	3 44	41
3	USA	1 52	2
4	Spain	1 06	31
5	South Africa	0 87	38

Mathematics

		(1)	(2)
1	Australia	10 04	14
2	USA	1 72	4
3	Sweden	0 94	10
4	UK	0 83	7
5	Israel	0 74	13

Physics

		(1)	(2)
1	Finland	6 07	15
2	Sweden	2 91	14
3	Switzerland	2 54	2
4	Canada	2 51	9
5	Spain	1 87	13

Space Science

		(1)	(2)
1	Hungary	5 46	2
2	Canada	4 12	5
3	AM	1 35	9
4	UK	1 29	8
5	Portugal	1 24	15

Economics & Business

		(1)	(2)
1	Switzerland	1 93	2
2	USA	1 33	1
3	Mexico	1 10	29
4	AM	0 86	22
5	Singapore	0 74	11

Social Sciences, General

		(1)	(2)
1	Greece	3 94	15
2	Denmark	2 81	1
3	Italy	2 39	2
4	Norway	2 01	8
5	Spain	1 70	14

Norway wins 10 in Clinical Medicine, and Japan and Israel win 12 and 18 in Immunology. Except in four fields (Microbiology, Agricultural Science, Engineering, and Space Science), in all remaining instances large rank reversals take place. Secondly, top countries very often have a $H_2(c^k)/H_2(c)$ ratio well above one. The conclusion is inescapable: H_2 is very sensitive to extreme observations of articles with a very large number of citations. We have checked that this is a local phenomenon. For example, if we eliminate successively the top one, two, or three articles in every country in Biology & Biochemistry –where Ireland has 87 articles– the Irish ratio falls from the original extraordinary value of 13.93 to 3.83, 1.40, and 0.72, respectively. It should be noted that these three articles are highly cited but not among the most cited in the field in question.

We can conclude that H_2 is a useful instrument to detect the role of a handful of highly cited articles that generate a large citation inequality within any specific country. For example, Sweden does much better with H_2 than H_0 in eight fields (Molecular Biology & Genetics; Neurosciences and Behavioral Sciences; Agricultural Sciences; Environment & Ecology; Materials Science; Computer Science; Mathematics, and Physics); Denmark, Finland, France, and Ireland in three; Austria, Belgium, Netherlands, Spain, and UK in two, and Greece in one.

V. 2. An Alternative World Ranking for Every Field

On the other hand, precisely because of its local sensitivity to citation inequality H_2 is not a good global indicator of high-citation impact when small research units are involved. Consequently, it is natural to focus on the indicator H_1, defined in equation (2) in Section III.3, which is sensitive both to the proportion of high-impact articles and to the average gap between the number of citations received by high-impact papers and the CCL, but not to the citation inequality among high-impact papers. Detailed information for every field and every country can be found in Table C in the Appendix in Albarrán and Ruiz-Castillo (2012). To construct a summary of these massive results, we grade all countries as follows: an *A* means that the country contributes to the world H_1 level above its publication share, while a *B* means that its contribution is between 0 and 20% below its publication share. Contributing above what is expected is indeed an excellent result. However, judging from the few countries capable of such performance, the *B* grade should be considered a relatively good one.[8] Top countries getting at least some good grades are listed in Table 6.

Table 6. Top Countries According to H_1: Good Marks Across the 22 Fields

		A	*B*
1	**US**	22	0
2	**SWITZERLAND**	20	2
3	**UK**	12	8
4	**DENMARK**	12	5
5	**SWEDEN**	11	5
6	**NETHERLANDS**	10	8
7	**AUSTRIA**	7	3
8	**NORWAY**	7	3
9	**FINLAND**	6	3
10	**GERMANY**	5	10
11	**ISRAEL**	5	7
12	**BELGIUM**	5	5
13	**SINGAPORE**	5	1
14	**IRELAND**	4	4
15	**CANADA**	3	14
16	**ITALY**	2	6
17	**AUSTRALIA**	2	5
18	**LUXEMBOURG**	2	0
19	**FRANCE**	1	10
20	**NEW ZEELAND**	1	5
21	**SPAIN**	1	2
22	**PORTUGAL**	1	2
23	**GREECE**	1	0
24	**JAPAN**	1	0

In agreement with previous findings in the literature, according to H_1 the world can be partitioned into the following groups. Firstly, the U.S. and Switzerland appear to belong to a different league. Secondly, the UK, Denmark, Sweden and the Netherlands form, say, the first division. Thirdly, from Austria to Canada nine countries form the second division, while from Italy to Japan nine other countries form the third division. The rest do not ever get a single good grade in 22 opportunities.

Section IV has provided ample evidence about what we call a European Drama: the almost complete dominance of the U.S. over the EU in the basic and applied research at all aggregation levels.

[8] Six or fewer countries receive an *A* grade in twelve fields, and from eight to thirteen countries in the remaining ten fields.

Consequently, we find it interesting to study the possible causes within the EU with information for individual member countries. For that purpose, we have introduced two more grades in the results according to H_1: a *C* means that the country contributes to the world level between 20% and 40% below its publication share, and a *D* means that the country does worse than that. As we know, the U.S. gets an *A* in every field. Grades for the 15 countries in the EU appear in Table E in the Appendix in Albarrán and Ruiz-Castillo (2012), while a summary of results is in Table 7.

Table 7. Ranking In the EU According to H_1. Summary of Marks In All Sciences

COUNTRIES	A	B	A + B	C	D	C + D
I. United Kingdom	12	8	**20**	2	0	**2**
II. Six Small Countries*	51	31	**82**	30	20	**50**
Germany, France	6	20	**26**	16	2	**18**
Italy, Spain	3	8	**11**	12	21	**33**
III. Four Large Cont. Countries	9	28	**37**	28	23	**51**
IV. Remaining Countries						
Greece, Portugal	2	2	**4**	11	29	**40**
Ireland	5	4	**9**	11	3	**14**
Luxembourg	2	1	**3**	0	19	**19**

A = Above what is expected from the country's publication share **B** = 0%- 20% below what is expected
C = 20%- 40% below what is expected **D** = More than 40% below what is expected

***** Austria, Belgium, Denmark, Finland, Netherlands, and Sweden

As is well known in the literature, there is a lot of heterogeneity within the EU. For our purpose, it is useful to distinguish between four groups: *I*-the UK; *II*-Six Small Relatively Successful Countries (Austria, Belgium, Denmark, Finland, Netherlands, and Sweden); *III*-Four Large Continental Countries (Germany, France, Italy, and Spain), and *IV*-Four Remaining Countries (Greece, Portugal, Ireland, and Luxembourg). Judging from the distribution of good (*A*, *B*) and bad (*C*, *D*) grades in Table 7, we can conclude that both the UK and the Six Small Countries exhibit a reasonably good citation impact performance. Therefore, the cause of the European Drama should be found in the relatively poor performance of the Four Large Continental Countries. As a matter of fact, given the Germany and

France do somewhat better, we should emphasize the special poor performance of Italy and Spain (together with the remaining Latin countries, Greece and Portugal).

V.3. The All-sciences Case

Quite apart from the interest in separate rankings by field, it is important to know how countries fare in the all-sciences case. We are interested in aggregating from the sub-field level consisting of 219 WoS categories. As explained in Herranz and Ruiz-Castillo (2012a), in this case differences in citation practices across sub-fields are taken into account normalizing each article by the corresponding fractional sub-field mean. Table 8 presents the ranking results according to H_0 and H_1.

Table 8. Normalization Results for the All-sciences Case According to H_0 and H_1

	H_0		H_1
SWITZERLAND	1.46	**SWITZERLAND**	1.44
USA	1.36	**USA**	1.29
DENMARK	1.34	**DENMARK**	1.22
NETHERLANDS	1.30	**NETHERLANDS**	1.20
UK	1.16	**UK**	1.03
BELGIUM	1.14	**SWEDEN**	1.02
SWEDEN	1.13	**BELGIUM**	1.00
CANADA	1.11	**FINLAND**	0.99
FINLAND	1.08	**CANADA**	0.99
NORWAY	1.07	**GERMANY**	0.91
GERMANY	1.06	**NORWAY**	0.91
AUSTRALIA	1.01	**IRELAND**	0.88
AUSTRIA	1.00	**ISRAEL**	0.88
ISRAEL	0.99	**AUSTRIA**	0.87
IRELAND	0.98	**FRANCE**	0.84
FRANCE	0.98	**AUSTRALIA**	0.83
SINGAPORE	0.93	**ITALY**	0.80
ITALY	0.93	**SINGAPORE**	0.76
NEW ZEALAND	0.91	**NEW ZEALAND**	0.71
LUXEMBOURG	0.89	**SPAIN**	0.66
PORTUGAL	0.85	**PORTUGAL**	0.61
SPAIN	0.84	**HUNGARY**	0.60
JAPAN	0.72	**JAPAN**	0.58
SOUTH KOREA	0.70	**LUXEMBOURG**	0.57
OC	0.68	**SOUTH KOREA**	0.56
GREECE	0.68	**CHINA**	0.52
HUNGARY	0.66	**GREECE**	0.50
CHINA	0.65	**CZECH REPUBLIC**	0.48
TAIWAN	0.64	**TAIWAN**	0.47

CZECH REPUBLIC	0.64	**POLAND**	0.47
AM	0.58	**AM**	0.45
SOUTH AFRICA	0.57	**SOUTH AFRICA**	0.43
RAS	0.56	**ARGENTINA**	0.39
AFSB	0.52	**BRAZIL**	0.39
IRAN	0.52	**RAS**	0.38
ARGENTINA	0.51	**EU**	0.37
POLAND	0.51	**AFSB**	0.36
BRAZIL	0.50	**MEXICO**	0.35
EU	0.47	**SAS**	0.34
MEXICO	0.47	**IRAN**	0.31
TURKEY	0.41	**RUSSIA**	0.29
INDIA	0.37	**TURKEY**	0.29
SAS	0.36	**INDIA**	0.28
RUSSIA	0.33	**OC**	0.28
ISLAM	0.29	**UKRAINE**	0.19
UKRAINE	0.26	**ISLAM**	0.18

This information deserves the following three comments. Firstly, in the top positions differences between the two rankings are minor. For example, Belgium and Sweden, Canada and Finland, Norway and Germany interchange their positions, while differences are well below 10% for the top four countries. However, differences tend to increase as we proceed downwards: for the eight countries from the UK to Ireland average differences are around 10%, for the eleven countries placed from Israel to Japan differences are about 20%, and from Luxembourg to the bottom they become very large. Secondly, the H_1 rankings in Tables 6 and 8 are quite different. Perhaps the most important difference is the relative improvement shown by the Netherlands, Belgium, France, Hungary and above all, Canada, as well as the relative decline of the UK, Austria, Singapore, and Luxembourg. Finally, a possible grouping into equivalent classes would be: Switzerland, U.S., Denmark, and Netherlands on top, from the UK to Italy in a second class, from Singapore to Greece in a third class, plus the remaining countries at the bottom.

VI. CONCLUSIONS, EXTENSIONS, AND POLICY RECOMMENDATIONS

VI.1. Conclusions

This paper has addressed the following two main topics.

1. In the first place, we have questioned the truth of the European Paradox according to which Europe plays a leading world role in terms of scientific excellence, measured in terms of the number of publications, but lacks the entrepreneurial capacity of the U.S. to transform this excellence into innovation, growth, and jobs. For that purpose we have used a dataset consisting of 3.6 million articles published in 1998-2002 with a common five-year citation window, and a partition of the world into three geographical areas: the U.S. the EU, and the RW. The analysis has proceeded at four aggregate levels: 219 sub-fields identified with the corresponding WoS categories, 80 disciplines, 20 fields, and the all-sciences case. We have used two types of indicators: a high-impact indicator H_2, defined over articles above a CCL that has been fixed at the 80th percentile of the world citation distributions, and average-based indicators defined over the entire citation distributions. Apart from the domain of definition, the main difference is that H_2 is sensitive to citation inequality among high-impact articles. A multiplicative strategy has been followed to solve the problems posed by international co-authorship and the multiple assignments of articles to sub-fields.

The main result is that the EU is ahead of the U.S. in 30 sub-fields, and three disciplines. In the remaining cases the U.S./EU gap is greater than 100% in 71 sub-fields, 27 disciplines, and eight fields. In most instances, when we use average-based indicators the results are more moderate. For example, in the all-sciences case the U.S./EU gap is 61% according to H_2, and 25% according to the *MNCS*. In any case, this paper confirms that there is no connection at any aggregation level between publication shares and high- or low-impact levels. Instead, it has been established that the European Paradox hides a truly *European Drama*: judging from citation impact, the dominance of the US over the EU in the basic and applied research published in the periodical literature is almost universal at all aggregation levels.

2. In the second place, we have reported the main findings in Albarrán and Ruiz-Castillo (2012) concerning a partition of the world into 38 countries and eight geographical areas using a dataset consisting of 4.4 million articles published in 1998-2003 with a common five-year citation window.

The CCL has been fixed at the 90th percentile of the world citation distributions for the 22 broad fields distinguished by Thomson Scientific. In this case, a multiplicative approach has been followed only for international co-authorship. The indicator H_2 has been shown to be very sensitive to the presence of a few articles with a relatively large number of citations in relatively small countries. Hence, it has been used to detect local success cases in which a handful of highly cited articles dramatically improve the ranking of a country. On the other hand, the relative performance of the different countries and areas has been examined with an indicator that is robust to the presence of such highly cited articles, namely, the indicator H_1 that is only sensitive to the incidence and the intensity of the high-impact phenomenon. For our purposes, the main result is about the heterogeneity within the EU. The UK and six small countries perform relatively well. However, Germany and France and, above all, Italy and Spain among the four larger continental countries perform much more poorly.

VI.2. Extensions

The present analysis might be extended in several directions, of which I will mention only the following three.

1. Consider the distinction between domestic publications, whose authors belong to only one of the countries or geographical areas distinguished in this paper, and international publications that involve cooperation between at least any two of them. It is known that domestic and international publications are characterized by very different citation rates. Except for the cooperation between the EU and the RW, international co-authorship in our datasets is vastly successful, especially with the U.S. (see Albarrán *et al.*, 2011c and Albarrán and Ruiz-Castillo, 2012). Two comments are in order. Firstly, it is important to compare in further detail the citation impact consequences of international co-authorship within the EU, and between European countries and the U.S. Secondly, following Aksnes *et al.*'s (2012) recommendation in favor of using fractionalized counts to calculate relative citation indicators at the national level, rather than using whole counts as we have done in this paper, might make a significant difference.

As far as the partition into three large geographical areas and 22 broad fields is concerned, the existing evidence indicates that in each of the six fields in which the EU contributes to the overall high-impact levels above what could be expected from its publication share, the explanation for the success lies in international publications (see Section 4.4 in Albarrán *et al.* 2011c). In turn, with regard to the partition into 38 countries and eight geographical areas, in the Six Small European Countries we treated separately in Table 7 –as well as in comparably successful small countries such as Norway and Switzerland– internationally co-authored articles among the world top 10% represent more than 60% of the total. In contrast, this percentage decreases for the four large European countries, Canada and, above all, the UK (see Table 5 in Albarrán and Ruiz-Castillo, 2012). Therefore, it is important to assess by how much the U.S./EU gap might increase in the first partition, and what re-rankings between small and large European countries are produced in the second as a consequence of adopting a fractional approach for international articles.

2. It has long been thought that two countries with the same citation impact –independently of the indicator used to assess impact– can be considered to have the same merit only if they are also of the same size. Otherwise, the intuition is that it is more likely for a small country to reach a certain citation impact. These ideas, which have been recently implemented by Crespo *et al.* (2012), need to be applied in a world in which a giant like the U.S. and a relatively large country like the UK compete at the top with a set of relatively small countries.

3. Beyond the previous methodological considerations, in order to complete the diagnosis started here, it would be interesting to study research units –universities, laboratories, or research institutes– within the most productive countries in the world. In this way, we may be able to isolate "success stories" within the EU, namely, specific institutions able to compete with the best in the world and, consequently, deserving of further study and support.

VI.3. Policy Recommendations

From the (incomplete) diagnosis of the situation attempted in this paper, it would not be wise to engage in many policy recommendations. Nevertheless, a few observations are in order. In the first place, the following three policy conclusions can be drawn from the previous diagnosis.

1. The EU scientific policy must create incentives for improving the citation impact of European publications rather than simply augmenting publication counts.

2. As eloquently argued in Drèze and Estevan (2007) for the case of Economics, EU research funds for the natural and some of the social sciences should support publications in English, the *lingua franca* of science, rather than in other European languages.

3. More evidence is needed to confirm that international co-authorship within the EU yields less citation impact that the cooperation between European countries and the U.S. However, to maximize citation impact it appears that the EU should promote cooperation with the U.S. rather than within the EU itself.

In the second place, at this point it is only natural to ask what do U.S. research centers have that is lacking in their EU counterparts. An answer to this question would require an entire research project, well beyond the scope of this paper. Therefore, I will limit myself to a couple of personal observations in line with what other analysts have suggested.

1. In the U.S., not every center of higher education conducts the type of research that places U.S. publications on top of the world. On the contrary, apart from a heterogeneous and rich set of research institutes, only so-called "research universities" massively engage in scientific research. The distinction between two types of higher education institutions is not that clearly established in the EU. It should, because not every center can do first rate research.

2. Two recent contributions by Veugelers and van der Ploeg (2008) and Van der Ploeg and Veugelers (2008) fruitfully ask about the lessons that can be drawn from the U.S. experience. The answer comes couched in two, almost magic words: "governance", and "resources". I will finish with a simple suggestion that has aspects of both.

By resources, any sincere commentator can only mean *private* resources. Quite apart from the present crisis in public finances, we cannot expect fundamental increases in public resources for science within the EU. Moreover, a comparison with the U.S. clearly shows that that the main difference is the percentage of total resources originating in the private sector. Raising tuition in the public university system is an obvious and desirable policy in most EU countries where tuition is well below the real cost of higher education. However, there is a complementary measure I would like to suggest: building endowments from private/public funding, whose annual flow must be entirely devoted to promote excellence without strings attached in a limited number of EU centers. A convenient ratio could be, three parts private/one part public.

The participation of the public sector, as well as the commitment in favor of excellence are thought of for breaking away from the present Nash equilibrium where (i) (except for some medical activities) private gifts from the middle-class and the very rich in the EU do not go for science, and (ii) public authorities face serious political difficulties in moving away from a consensus according to which public resources are supposed to help us all, not just a tiny minority of stars. But could we have the best soccer leagues in Spain, England, Italy, and France without stars from all over the world? And could we expect centers of research excellence without privately built endowments as in the U.S.? The presence of the public sector, and the commitment to excellence should provide incentives for the private sector to join in, while the presence of the private sector would provide excuses for the public authorities to do what they should: to devote some resources to favor the very best. Finally, the condition that the funds should arrive to the deserving centers without strings attached is, like the peer review system, a *sine qua non* of how science is successfully conducted in practice.

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APPENDIX

Table A. Number of Articles, Mean Citation Rates, and Critical Citation Lines In the Double Extended Sub-field Count

	Number of Articles (1)	% (2)	MCR (3)	Critical Citation Line (4)
A. LIFE SCIENCES				
I. BIOSCIENCES				
1. BIOLOGY	28,017	0.43	7.9	12
2. BIOLOGY, MISCELLANEOUS	475	0.01	3.6	6
3. EVOLUTIONARY BIOLOGY	13,542	0.21	12.9	19
4. BIOCHEMICAL RESEARCH METHODS	37,350	0.57	9.5	13
5. BIOCHEMISTRY & MOLECULAR BIOLOGY	248,933	3.82	17.0	24
6. BIOPHYSICS	56,436	0.87	11.1	16
7. CELL BIOLOGY	97,545	1.5	22.5	32
8. GENETICS & HEREDITY	74,782	1.15	16.9	24
9. DEVELOPMENTAL BIOLOGY	19,590	0.3	20.2	30
II. BIOMEDICAL RESEARCH				
10. PATHOLOGY	32,518	0.5	9.6	14
11. ANATOMY & MORPHOLOGY	6,756	0.1	5.8	9
12. ENGINEERING, BIOMEDICAL	21,597	0.33	6.9	11
13. BIOTECH. & APPLIED MICROBIOLOGY	69,781	1.07	9.5	13
14. MEDICAL LABORATORY TECHNOLOGY	10,927	0.17	6.4	9
15. MICROSCOPY	4,496	0.07	6.3	10
16. PHARMACOLOGY & PHARMACY	111,320	1.71	8.3	12
17. TOXICOLOGY	34,066	0.52	7.3	11
18. PHYSIOLOGY	49,225	0.76	10.7	17
III. CLINICAL MEDICINE I (INTERNAL)				
19. CARDIAC & CARDIOVASCULAR SYSTEMS	60,300	0.93	12.2	17
20. RESPIRATORY SYSTEM	30,928	0.47	10.5	16
21. ENDOCRINOLOGY & METABOLISM	55,583	0.85	13.3	20
22. ANESTHESIOLOGY	18,037	0.28	7.0	11
23. CRITICAL CARE MEDICINE	14,301	0.22	11.4	17
24. EMERGENCY MEDICINE	6,864	0.11	4.1	7
25. GASTROENTEROLOGY & HEPATOLOGY	37,885	0.58	11.2	16
26. MEDICINE, GENERAL & INTERNAL	66,266	1.02	15.1	13
27. TROPICAL MEDICINE	9,193	0.14	5.7	9
28. HEMATOLOGY	47,323	0.73	17.5	26

29. ONCOLOGY	91,359	1.4	14.8	21
30. ALLERGY	9,706	0.15	9.2	14
31. IMMUNOLOGY	94,351	1.45	14.9	21
32. INFECTIOUS DISEASES	37,806	0.58	12.3	19
IV. CLIN. MED. II (NON-INTERNAL)				
33. GERIATRICS & GERONTOLOGY	10,141	0.16	8.2	13
34. OBSTETRICS & GYNECOLOGY	34,907	0.54	6.9	11
35. ANDROLOGY	1,605	0.02	5.7	9
36. REPRODUCTIVE BIOLOGY	18,956	0.29	9.7	15
37. GERONTOLOGY	7,334	0.11	7.4	12
38. DENTISTRY, ORAL SURGERY	23,294	0.36	5.5	8
39. DERMATOLOGY	22,848	0.35	6.2	10
40. UROLOGY & NEPHROLOGY	36,254	0.56	9.6	15
41. OTORHINOLARYNGOLOGY	18,492	0.28	4.4	7
42. OPHTHALMOLOGY	28,918	0.44	7.2	11
43 INTEGRATIVE & COMPLEMENTARY MED.	2,633	0.04	4.4	7
44. CLINICAL NEUROLOGY	73,322	1.13	9.8	15
45. PSYCHIATRY	47,038	0.72	9.9	15
46. RADIOLOGY, NUCLEAR MED. & IMAGING	58,950	0.91	7.9	12
47. ORTHOPEDICS	25,624	0.39	5.9	9
48. RHEUMATOLOGY	11,821	0.18	11.5	17
49. SPORT SCIENCES	22,548	0.35	6.0	10
50. SURGERY	109,354	1.68	6.5	10
51. TRANSPLANTATION	22,663	0.35	7.0	10
52. PERIPHERAL VASCULAR DISEASE	40,847	0.63	16.4	24
53. PEDIATRICS	45,506	0.7	5.9	9
V. CL. MED. III (HEALTH & OTHER SCS.)				
54. HEALTH CARE SCIENCES & SERVICES	15,058	0.23	5.9	9
55. HEALTH POLICY & SERVICES	9,388	0.14	6.3	9
56. MEDICINE, LEGAL	4,565	0.07	4.5	7
57. NURSING	9,105	0.14	3.0	5
58. PUBLIC, ENVIRON. & OCCUP. HEALTH	56,693	0.87	7.4	11
59. REHABILITATION	14,513	0.22	4.3	7
60. SUBSTANCE ABUSE	8,382	0.13	7.6	12
61. EDUCATION, SCIENTIFIC DISCIPLINES	8,371	0.13	2.9	4
62. MEDICAL INFORMATICS	7,007	0.11	4.3	7
VI. NEUROSCIENCE & BEHAVIOR				
63. NEUROIMAGING	6,826	0.1	10.9	17

64. NEUROSCIENCES	125,782	1.93	13.6	20
65. BEHAVIORAL SCIENCES	16,450	0.25	8.9	13
66. PSYCHOLOGY, BIOLOGICAL	4,429	0.07	7.5	11
67. PSYCHOLOGY	17,977	0.28	7.9	12
68. PSYCHOLOGY, APPLIED	8,732	0.13	4.7	7
69. PSYCHOLOGY, CLINICAL	18,978	0.29	7.5	12
70. PSYCHOLOGY, DEVELOPMENTAL	10,994	0.17	7.8	12
71. PSYCHOLOGY, EDUCATIONAL	5,601	0.09	5.2	8
72. SYCHOLOGY, EXPERIMENTAL	17,565	0.27	7.6	12
73. PSYCHOLOGY, MATHEMATICAL	1,930	0.03	5.1	8
74. PSYCHOLOGY, MULTIDISCIPLINARY	19,785	0.3	4.9	7
75. PSYCHOLOGY, PSYCHOANALYSIS	2,504	0.04	2.7	4
76. PSYCHOLOGY, SOCIAL	10,717	0.16	6.3	9
77. SOCIAL SCIENCES, BIOMEDICAL	6,669	0.1	5.4	8

B. PHYSICAL SCIENCES

VII. CHEMISTRY

78. CHEMISTRY, MULTIDISCIPLINARY	107,816	1.66	8.9	13
79. CHEMISTRY, INORGANIC & NUCLEAR	55,337	0.85	6.7	11
80. CHEMISTRY, ANALYTICAL	73,439	1.13	7.5	11
81. CHEMISTRY, APPLIED	37,068	0.57	5.6	9
82. ENGINEERING, CHEMICAL	64,146	0.99	4.3	7
83. CHEMISTRY, MEDICINAL	27,721	0.43	7.5	11
84. CHEMISTRY, ORGANIC	84,274	1.29	7.9	12
85. CHEMISTRY, PHYSICAL	143,582	2.2	7.8	12
86. ELECTROCHEMISTRY	22,040	0.34	7.6	12
87. POLYMER SCIENCE	61,649	0.95	6.2	9

VIII. PHYSICS

88. PHYSICS, MULTIDISCIPLINARY	101,780	1.56	9.3	12
89. SPECTROSCOPY	35,126	0.54	5.8	9
90. ACOUSTICS	15,991	0.25	4.0	6
91. OPTICS	61,373	0.94	5.6	8
92. PHYSICS, APPLIED	143,531	2.2	5.8	8
93. PHYSICS, ATOMIC, MOLECULAR & CHEMIC/	74,351	1.14	8.6	13
94. THERMODYNAMICS (CLASSICAL PHYSICS)	19,276	0.3	3.5	5
95. PHYSICS, MATHEMATICAL	41,061	0.63	5.9	9
96. PHYSICS, NUCLEAR	33,146	0.51	5.6	8
97. PHYSICS, PARTICLES & FIELDS	50,532	0.78	10	14

98. PHYSICS, CONDENSED MATTER	130,377	2	5.7	9
99. PHYSICS OF SOLIDS, FLUIDS & PLASMAS	29,720	0.46	7.3	11
IX. SPACE SCIENCES				
100. ASTRONOMY & ASTROPHYSICS	82,073	1.26	12.5	18
X. MATHEMATICS				
101. MATHEMATICS, APPLIED	61,964	0.95	2.8	4
102. STATISTICS & PROBABILITY	27,188	0.42	4.7	6
103. MATHEMATICS,INTERDISC. APPL.	19,976	0.31	4.2	6
104. SOCIAL SCIENCES, MATH. METHODS	6,078	0.09	4.3	6
105. PURE MATHEMATICS	76,078	1.17	2.1	3
XI. COMPUTER SCIENCE				
106. COMP. SC., ARTIFICIAL INTELLIGENCE	26,462	0.41	4.0	6
107. COMPUTER SCIENCE, CYBERNETICS	4,865	0.07	2.7	4
108. COMP. SC., HARDWARE & ARCHITECTURE	14,163	0.22	3.2	4.4
109. COMP. SC., INFORMATION SYSTEMS	22,925	0.35	3.5	5
110. COMP. SC., INTERDIS. APPLICATIONS	30,920	0.47	4.8	6
111. COMP. SC., SOFTWARE ENGINEERING	19,570	0.3	2.8	4
112. COMP. SC., THEORY & METHODS	37,783	0.58	2.5	4
113. MATHEMATICAL & COMPUT. BIOLOGY	8,621	0.13	9.0	10

C. OTHER NATURAL SCIENCES

XII. ENGINEERING				
114. ENG., ELECTRICAL & ELECTRONIC	131,115	2.01	3.6	5
115. TELECOMMUNICATIONS	21,591	0.33	2.9	4
116. ONSTRUCTION & BUILDING TECH.	9,010	0.14	2.4	4
117. ENGINEERING, CIVIL	23,183	0.36	2.4	4
118. ENGINEERING, ENVIRONMENTAL	22,096	0.34	6.6	10
119. ENGINEERING, MARINE	417	0.01	1.0	2
120. TRANSPORTATION SC. & TECHNOLOGY	6,365	0.1	1.5	2
121. ENGINEERING, INDUSTRIAL	13,858	0.21	2.2	4
122. ENGINEERING, MANUFACTURING	14,516	0.22	2.4	4
123. ENGINEERING, MECHANICAL	40,995	0.63	2.9	5
124. MECHANICS	48,002	0.74	3.8	6
125. ROBOTICS	3,231	0.05	2.6	4
126. INSTRUMENTS & INSTRUMENTATION	43,348	0.67	3.9	6
127. IMAGING SC. & PHOTOGRAPHIC TECH.	5,449	0.08	5.6	8
128. ENERGY & FUELS	26,298	0.4	3.5	6
129. NUCLEAR SCIENCE & TECHNOLOGY	42,406	0.65	3.4	5

130. ENGINEERING, PETROLEUM	6,974	0.11	1.2	2
131. AUTOMATION & CONTROL SYSTEMS	18,140	0.28	3.0	5
132. ENGINEERING, MULTIDISCIPLINARY	22,062	0.34	2.8	4
133. ERGONOMICS	3,299	0.05	3.3	5
134. OPERATIONS RES. & MANAG. SCIENCE	20,897	0.32	2.8	5
XIII. MATERIALS SCIENCE				
135. MATERIALS SCIENCE, BIOMATERIALS	7,382	0.11	9.6	15
136. MATERIALS SCIENCE, CERAMICS	21,255	0.33	3.5	6
137. MAT. SC., CHARAC. & TESTING	6,606	0.1	1.5	2
138. MAT. SC., COATINGS & FILMS	24,592	0.38	5.5	9
139. MATERIALS SCIENCE, COMPOSITES	10,368	0.16	2.5	4
140. MATERIALS SCIENCE, PAPER & WOOD	6,577	0.1	2.0	3
141. MATERIALS SCIENCE, TEXTILES	4,923	0.08	2.0	3
142. METALLURGY & METALL. ENGIN.	42,534	0.65	3.5	5
143. NANOSCIENCE & NANOTECHNOLOGY	22,069	0.34	5.8	8
XIV. GEOSCIENCES				
144. GEOCHEMISTRY & GEOPHYSICS	32,728	0.5	7.6	12
145. GEOGRAPHY, PHYSICAL	10,440	0.16	6.9	11
146. GEOLOGY	9,447	0.15	6.1	10
147. ENGINEERING, GEOLOGICAL	5,253	0.08	2.7	4
148. PALEONTOLOGY	8,039	0.12	4.9	8
149. REMOTE SENSING	5,869	0.09	5.6	8
150. OCEANOGRAPHY	22,387	0.34	7.7	12
151. ENGINEERING, OCEAN	3,725	0.06	2.9	4
152. METEOROLOGY & ATMOSPH. SCS.	33,043	0.51	8.2	12
153 ENGINEERING, AEROSPACE	12,910	0.2	1.8	3
154. MINERALOGY	9,038	0.14	5.5	9
155. MINING & MINERAL PROCESSING	7,333	0.11	3.1	5
XV. AGRICULT. & ENVIRONMENT				
156. AGRICULTURAL ENGINEERING	4,880	0.07	3.3	5
157. AGRICULTURE, MULTIDISCIPLINARY	15,859	0.24	4.8	8
158. AGRONOMY	26,490	0.41	4.5	7
159. LIMNOLOGY	6,362	0.1	7.2	11
160. SOIL SCIENCE	15,683	0.24	5.1	8
161. BIODIVERSITY CONSERVATION	7,186	0.11	6.5	10
162. ENVIRONMENTAL SCIENCES	78,593	1.21	6.7	10
163. ENVIRONMENTAL STUDIES	10,681	0.16	3.6	6
164. FOOD SCIENCE & TECHNOLOGY	46,497	0.71	5.1	8

165. NUTRITION & DIETETICS	23,879	0.37	8.5	13
166. AGRIC., DAIRY & ANIMAL SCIENCE	23,741	0.36	3.8	6
167. HORTICULTURE	11,415	0.18	4.8	7
XVI. BIOLOGY				
168. ORNITHOLOGY	4,902	0.08	4.2	6
169. ZOOLOGY	38,570	0.59	5.6	9
170. ENTOMOLOGY	21,639	0.33	4.0	7
171. WATER RESOURCES	28,222	0.43	4.4	7
172. FISHERIES	17,207	0.26	5.3	8
173. MARINE & FRESHWATER BIOLOGY	37,027	0.57	6.1	10
174. MICROBIOLOGY	63,814	0.98	11.2	17
175. PARASITOLOGY	13,268	0.2	6.2	10
176. VIROLOGY	24,543	0.38	15.1	23
177. FORESTRY	12,289	0.19	5.4	8
178. MYCOLOGY	6,973	0.11	5.3	8
179. PLANT SCIENCES	73,854	1.13	7.5	11
180. PURE AND APPLIED ECOLOGY	46,672	0.72	8.6	13
181. VETERINARY SCIENCES	54,380	0.84	3.8	6
XVII. MULTIDISCIPLINARY				
182. MULTIDISCIPLINARY SCIENCES	27,961	0.43	3.2	4
XVIII. RESIDUAL SUB-FIELDS				
183. MATERIALS SCIENCE, MULT.	153,666	2.36	4.9	7
184. CRYSTALLOGRAPHY	32,344	0.5	4.4	6
185. GEOSCIENCES, MULTIDISCIPLINARY	54,564	0.84	5.6	9
186. MEDICAL, RES. & EXPERIMENTAL	48,413	0.74	14.7	18

D.SOCIAL SCIENCES

XIX. SOCIAL SCIENCES, GENERAL				
187. CRIMINOLOGY & PENOLOGY	3,259	0.05	3.5	6
188. LAW	9,714	0.15	3.4	5
189. POLITICAL SCIENCE	12,582	0.19	2.4	4
190. PUBLIC ADMINISTRATION	3,595	0.06	2.5	4
191. ETHNIC STUDIES	817	0.01	1.9	3
192. FAMILY STUDIES	5,268	0.08	4.2	7
193. SOCIAL ISSUES	4,257	0.07	2.6	4
194. SOCIAL WORK	4,956	0.08	2.7	4
195. SOCIOLOGY	12,668	0.19	3	5
196. WOMEN'S STUDIES	3,757	0.06	2.8	5

197. EDUCATION & EDUCATIONAL RES.	15,755	0.24	2.4	4
198. EDUCATION, SPECIAL	3,055	0.05	3.7	6
199. AREA STUDIES	3,491	0.05	1.4	2
200. GEOGRAPHY	5,876	0.09	4.3	6
201. PLANNING & DEVELOPMENT	6,403	0.1	3.1	5
202. TRANSPORTATION	2,100	0.03	3.5	6
203 URBAN STUDIES	4,856	0.07	3.1	5
204. ETHICS	3,667	0.06	2.4	4
205. MEDICAL ETHICS	972	0.01	3.8	6
206. ANTHROPOLOGY	6,884	0.11	3.2	5
207. COMMUNICATION	5,052	0.08	3.0	5
208. DEMOGRAPHY	2,364	0.04	4.2	6
209. HISTORY OF SOCIAL SCIENCES	1,346	0.02	1.4	2
210. INFORMATION SC. & LIBRARY SC.	9,167	0.14	2.9	4
211. INTERNATIONAL RELATIONS	6,460	0.1	2.3	3
212. LINGUISTICS	6,031	0.09	4.3	7
213. SOCIAL SCIENCES, INTERD.	8,996	0.14	2.4	4
XX. ECONOMICS & BUSINESS				
214. AGRICULTURAL ECONOMICS & POLICY	2,034	0.03	2.6	4
215. ECONOMICS	40,420	0.62	3.6	5
216. INDUSTRIAL RELATIONS & LABOR	2,197	0.03	3.3	5
217. BUSINESS	10,516	0.16	5.1	8
218. BUSINESS, FINANCE	6,982	0.11	4.9	7
219. MANAGEMENT	14,854	0.23	4.7	7
ALL CATEGORIES	**6,512,031**	**100**	**8**	11
Mean Values	29,735	-	6.1	8.8
Standard Deviation	33,826	-	3.4	5.0

Table B. Number of Articles, Mean Citation Rates, and Critical Citation Lines In the Double Extended Discipline and Field Counts, As Well As the All Sciences Case In the Geographically Extended Count

	DISCIPLINES				FIELDS			
	Number Of Articles	%	MCR	CCL	Number Of Articles	%	MCR	CCL
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
I. BIOSCIENCES					*429,332*	*7.8*	*15.4*	*22*
D1. Multidisciplinary Biology	42,034	0.69	9.5	15				
D2. Biochemistry, Biophysics, Mol. Biology	287,797	4.71	16.0	23				
D3. Cell Biology	97,545	1.60	22.5	32				
D4. Genetics & Development Biology	91,943	1.51	16.7	24				
II. BIOMEDICAL RESEARCH					*317,909*	*5.7*	*8.8*	*13*
D5. Anatomy & Pathology	39,021	0.64	8.9	13				
D6. Biomaterials & Bioengineering	91,185	1.49	8.9	13				
D7. Experimental & Laboratory Medicine	15,423	0.25	6.4	10				
D8 Pharmacology & Toxicology	136,684	2.24	8.1	12				
D9 = Physiology	49,225	0.81	10.7	17				
III. CLINICAL MEDICINE I (INTERNAL)					*509,541*	*9.2*	*13.2*	*18*
D10. Cardiovascular & Respiratory Medicine	79,780	1.31	12.2	18				
D11 = 21. **Endocrinology & Metabolism**	55,583	0.91	13.3	20				
D12. General & Internal Medicine	149,527	2.45	11.9	13				
D13. Hematology & Oncology	131,133	2.15	16.1	23				
D14. Immunology	115,554	1.89	13.8	20				
IV. CLIN. MED. II (NON-INTERNAL)					*549,174*	*9.9*	*8.3*	*12*
D15. Age & Gender Related Medicine	59,716	0.98	7.4	12				
D16 = Dentistry, Oral Surgery	23,294	0.38	5.5	8				
D17. Dermatology & Urogenital System	59,102	0.97	8.3	13				
D18. Ophthalmology & Otorhinolaryngology	47,410	0.78	6.1	9				
D19 = Integrative & Complementary Medicine	2,633	0.04	4.4	7				
D20. Psychiatry & Neurology	110,370	1.81	10.1	15				
D21 = 46. **Radiology, Nuclear Med. & Imaging**	58,950	0.97	7.9	12				
D22. Rheumatology & Orthopedics	55,519	0.91	7.1	11				
D23. Surgery	155,182	2.54	9.1	13				
D24 = Pediatrics	45,506	0.75	5.9	9				

V. CL. MED. III (HEALTH & OTHER SCS.)					*114,753*	*2.1*	*5.9*	*9*
D25. Health Sciences	105,469	1.73	6.2	9				
D26. Other Clinical Medicine	15,378	0.25	3.5	5				
VI. NEUROSCIENCE & BEHAVIOR					*231,219*	*4.2*	*10.2*	*15*
D27. Neurosciences & Psychopharmacology	129,562	2.12	13.4	20				
D28. Psychology & Behavioral Sciences	113,029	1.85	6.5	10				
VII. CHEMISTRY					*580,050*	*10.5*	*7.3*	*11*
D29 = Chemistry, Multidisciplinary	107,816	1.77	8.9	13				
D30. Analytical, Inorganic & Nuclear Chemistry	125,780	2.06	7.3	11				
D31. Applied Chemistry & Chemical Engineering	95,175	1.56	4.7	8				
D32. Organic & Medicinal Chemistry ,	105,557	1.73	7.8	12				
D33. Physical Chemistry	165,622	2.71	7.8	12				
D34 = Polymer Science	61,649	1.01	6.2	9				
VIII. PHYSICS					*610,826*	*11.0*	*7.1*	*10*
D35. Multidisciplinary Physics	136,906	2.24	8.4	11				
D36. Applied Physics	208,980	3.42	5.7	8				
D37. Physics, Atomic, Molecular & Chemical	74,351	1.22	8.6	13				
D38. Thermodynamics (Classical Physics)	19,276	0.32	3.5	5				
D39. Physics, Mathematical	41,061	0.67	5.9	9				
D40. Particle & Nuclear Physics	74,155	1.21	8.8	12				
D41. Physics of Solids, Fluids & Plasmas	160,097	2.62	6.0	9				
IX. SPACE SCIENCES					*82,073*	*1.5*	*12.5*	*18*
D42. Astronomy & Astrophysics ,	82,073	1.34	12.5	18				
X. MATHEMATICS					*163,098*	*2.9*	*3.0*	*4*
D43. Applied Mathematics	106,187	1.74	3.5	5				
D44. Pure Mathematics	76,078	1.25	2.1	3				
XI. COMPUTER SCIENCE					*132,264*	*2.4*	*3.5*	*5*
D45. Computer Science & Information Tech.	132,264	2.17	3.5	5				
XII. ENGINEERING					*392,455*	*7.1*	*3.5*	*5*
D46. Electrical & Electronic Engineering	135,308	2.22	3.6	5				

D47. Civil Engineering	49,282	0.81	4.2	6				
D48. Mechanical Engineering	99,768	1.63	3.1	5				
D49. Instruments & Instrumentation	48,605	0.80	4.1	6				
D50. Fuel & Energy	69,897	1.14	3.4	5				
D51. Other Engineering	60,713	0.99	3.0	5				
XIII. MATERIALS SCIENCE					*138,254*	*2.5*	*4.3*	*7*
D52. Materials Science	138,254	2.26	4.3	7				
XIV. GEOSCIENCES					*137,187*	*2.5*	*6.6*	*10*
D53. Geosciences & Technology	64,682	1.06	6.6	10				
D54. Hydrology & Oceanography	24,878	0.41	7.2	12				
D55 Meteo., Atmosph., Aero., Sc. & Tech.	42,560	0.70	6.7	10				
D56. Mineralogy & Petrology	14,782	0.24	4.7	7				
XV. AGRICULT. & ENVIRONMENT					*235,573*	*4.3*	*5.6*	*9*
D57. Agricultural Science & Technology	46,943	0.77	4.5	7				
D58. Plant & Soil Science & Tech,	22,045	0.36	5.7	9				
D59. Environmental Science & Technology	91,032	1.49	6.2	9				
D60. Food & Animal Science & Technology	98,654	1.62	5.6	9				
XVI. BIOLOGY					*404,113*	*7.3*	*7.3*	*11*
(ORGANISMIC AND SUPRAORG. LEVEL)								
D61. Animal Sciences	65,071	1.07	5.0	8				
D62. Aquatic Sciences ,	73,019	1.20	5.3	8				
D63. Microbiology	100,770	1.65	11.5	17				
D64. Plant Sciences	91,487	1.50	7.0	10				
D65 = 180. **Pure and Applied Ecology**	46,672	0.76	8.6	13				
D66 = 181. **VETERINARY SCIENCES**	54,380	0.89	3.8	6				
XVII. MULTIDISCIPLINARY					*27,961*	*0.5*	*3.2*	*4*
D67. MULTIDISCIPLINARY SCIENCES	27,961	0.46	3.2	4				
XVIII. RESIDUAL SUB-FIELDS					*288,618*	*5.2*	*6.6*	*8*
D68. MATERIALS SCIENCE, MULT.	153,666	2.52	4.9	7				
D69. CRYSTALLOGRAPHY	32,344	0.53	4.4	6				
D70. GEOSCIENCES, MULT.	54,564	0.89	5.6	9				
D71. MED., RES. & EXPERIMENTAL	48,413	0.79	14.7	18				

XIX. SOCIAL SCIENCES, GENERAL					*129,000*	*2.3*	*3.0*	*5*
D72. Law & Criminology	12,480	0.20	3.5	5				
D73. Political Science & Public Administration	15,769	0.26	2.4	4				
D74. Sociology & Other Social Studies	28,575	0.47	3.0	5				
D75. Education	18,810	0.31	2.6	4				
D76. Geography, Planning & Urban	20,550	0.34	3.2	5				
D77. Ethics	3,948	0.06	2.5	4				
D78. Other Social Sciences	44,619	0.73	3.0	5				
XX. ECONOMICS & BUSINESS					*65,360*	*1.2*	*3.9*	*6*
D79. Economics	42,067	0.69	3.6	5				
D80. Business & Management	28,360	0.46	4.6	7				
ALL CATEGORIES	**6,107,509**	**100.0**	**7.0**	**-**	**5,538,760**	**100.0**	7.0	
ALL SCIENCES	**4,142,281**	**-**	**8.2**	**11**				